Sun wind water earth life living; legends for design

COLOFON

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Contents

Introduction

‘Building is cooperating with the Earth.’
Marguerite Yourcenar.

Motivation

Activating senses

Sun, wind, water, earth and life touch our living senses immediately, always, everywhere and without any intervention of reason. They simply *are* there in their unmatched variety, moving us, our moods, memories, imaginations, intentions and plans.

Mathematics next to senses

However, the designer transforming sun into light, air into space and water into life, touches pure mathematics next to senses. Mathematicians left alone destroy mathematics releasing it from senses, losing their unmatched beauty and relief, losing their sense for design. To restore that intimate relation, the most freeing part of our European cultural heritage my great examples are Feynman’s lectures on physics, D’Arcy Thomson’s ‘On Growth and Form’ and Minnaert’s ‘Natuurkunde van het vrije veld’ (‘Outdoor physics’). Minnaert elaborated the missing step from feeling to estimating.
I am sitting in the sun. How much energy do I receive, how much I send back into universe?
I am walking in wind. How much pressure do I receive and how much power my muscles have to overcome? It is the same pressure giving form to the sand I walk on or giving form and movement to the birds above me! I am swimming in the oldest landscape of all ages, the sea. How can I survive?

Re-constructing behaviours

No longer can I escape from reasoning, from looking for a formula, a behaviour that works. But this reasoning is next to senses and once I found a formula I can leave the reasoning behind going back into senses and sense. The formula takes its own path in my Excel sheet as a living thing. It ‘behaves’. Look! Does it take the same path as the sun, predicting my shadow? Put a pencil and a ruler in the sun. Measure, compare, lose or win your competition with the real sun as Copernicus did.
Mathematics have no longer much to do with boring calculations. Nowadays computers do the work, we do the learning. They sharpen our reasoning and senses. We see larger contexts and smaller details than ever before discovering scale. Discovering telescopic and microscopic scale we find the multiple universe we live in, freeing us from boredom forever, producing images no human can invent. We do not believe our eyes and ears, we discover them. It challenges our imagination in strange worlds no holiday can equal. Life math is a survival journey with excitement and suspense.

Science as design

But do we *understand* the sun? No, according to Kant (1976) we *design* a sun behaving like the sun we feel and see from our position and scale of time and space we live in. We never know for sure whether it will behave tomorrow in the same way as our sheet does now. But we have *made* something that works *here* and *now*.
‘Yes! It works.’ That is a designer’s joy.

How to use this book

This book is not a reader. It contains original texts by the authors from our school and one civil engineer to understand how specialists think, supporting our profession as urban designers.

Systematic encyclopaedia

It is ordered in an systematic encyclopaedic style. It is accessible by its table of contents (elaborated in more detail at the beginning of each chapter), and by a key word list containing some 6000 key words at the end of the book, including other authors we refer to. Full references to other authors are given in a reference list, also to be found via the key word list. Direct references into publications and websites to look up immediately as a result of reading are given as foot notes ([a]) indicated by letters in the text and listed at the bottom of the page. Questions for exercise are indicated as numbered end notes ([1]) by numbers in the text listed at the end of the book (see page 711). However, these questions don not yet cover the whole content of the book.

A conditional sequence: physics first

The chapter titles start as the title of the book indicates: Sun, Wind, Water, Earth, Life, Living and Legends for design. These subjects are ordered this way, because it is the conditional sequence we experience them directly outdoor and gradually can understand them best.

The sequence of the chapters follows the range of abiotic, biotic and conceptual phenomena with apparently increasing complexity. The simulation of these phenomena is firstly approached by supposing a causal sequence (effect follows cause: c $\Rightarrow$ e) usual in physics. Even life, living and legends for design obey the boundary conditions of physics. So, we firstly try to simulate these phenomena by purely causal simulation. After all, we can not imagine living systems (B) without an abiotic environment (A), as we can not imagine conceptual systems (C) without a living environment (B). Let us call that 'ABC-model' (see *Fig. 1*).

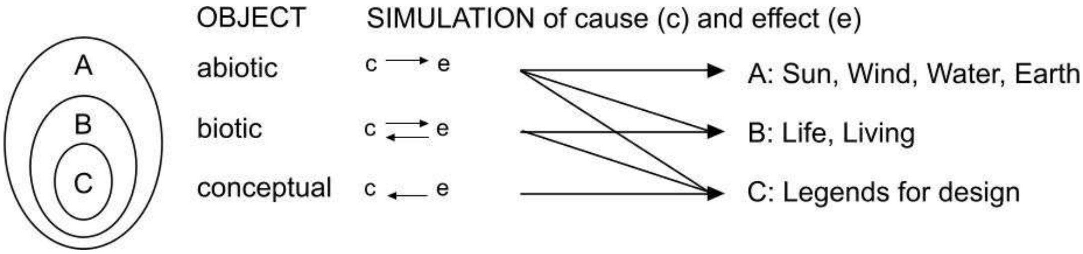

Fig. 1 Simulating reality by different approaches according to the 'ABC-model'

Biotic feed-backs included

However, biotic phenomena (including humans) and some human artifacts seem to take the effects of earlier behaviour into account, adapting next behaviour ('empirical cycle'[a]). A one way causal simulation of such a phenomenon should contain its history from second to second including the evolutionary history of its ancestors from the very beginning. It should not exclude details that might have been crucial. That long description to predict behaviour would require too many gradually changing cycles finally solving chicken-and-egg questions typical for biology. But you can understand the pattern and process of an egg in a shorter way if you suppose what will come out (for convenience, without additional teleological assumptions). In that approach the effect also 'precedes' the cause (see *Fig. 1*). The main 'experience' of a species is stored in its genes and in other chemical substancies steering action, completed by increasing 'experiences' of a specimen born in a specific context. We still do not understand much of all feed-back loops in any organism. But, we can simplify the description of its behaviour by drawing a black box and looking what is going in (input) and what is coming out (output) in a determined period. That is called 'systems approach'.[b] By a systems approach you design a model with the same input and output as observed to predict behaviour. In the algorithm of such a model many 'if … then …' statements will appear connecting the possible branches of causal behaviour in different circumstances. If the behaviour of the model is much the same as observed we are inclined to suppose the model represents reality, which is not the case.

Conceptual projection added

For our purpose, the most satisfying description of the difference between humans compared to other animals is their ability to represent a larger range of activities beforehand[c]. It is the very basis of making artifacts serving further purposes (if I will do this first, then I can do that later) and the very basis of task division (if you do this, I can do that). So, humans are supposed to simulate internally a longer range of 'causes' (actions) and 'effects' before they come into action ('look before you leap') than routinous animals. As soon as action and utilising its effect are connected by an intermediate (interfunctional) action, such as making an instrument, the whole range can be noted as an algorithm. Designing is such an intermediate activity in a range of activities 'planned' beforehand. That kind of 'conceptual' behaviour completes many unconscious components of behaviour stored in an organism as biotic routines. That is why in this paper we leave out the supposed 'cognitive' part of human

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[a] Groot, A.D. de (1970) Methodologie. Grondslagen van onderzoek en denken in de gedragswetenschappen ('s-Gravenhage) Mouton & Co)
[b] Emery, F.E. [ed.] (1969) *Systems thinking* (Hammondsworth) Penguin Books Ltd,
[c] Harrison, G.A. (1964) *Human biology* (Oxford) Clarendon Press

behaviour as long as we can simulate (understand) it sufficiently by a black box. But, there comes a time these biotic simulations do not fit reality any more. Then, we have to add new suppositions about the 'plan' humans have in mind before they act. Many 'plans' (earning a living, finding a partner, getting children) look the same. But the question is, if these are really 'plans' or simply the 'conceptualisation' of predictable biological inclinations afterwards to justify them socially. What we can simulate by less suppositions we will do ('razor of Ockham'). Interpreting humans as mere animals clarifies an increasing amount of behaviour[a]. But, there are still unpredictable behaviours apparently following a 'plan'. The question is, if we ever could predict that kind of behaviour. In that case we have to give up our supposition of free will (supposed in democracy) after all. In this paper we will not do so, because it is the core of design to find unexpected possibilities (necessary in an ecological crisis). If these possibilities could be expected it would be predictions, not designs. In *Fig. 1* is expressed that conceptual projection can not be used to simulate abiotic and biotic phenomena.

Levels of scale

A principle of ordering we aimed for in any separate chapter is the level of scale. So, you can choose the sub-chapter concerning the level of scale you focus on in your study. We have tried to start every chapter on the highest level of scale. There are arguments to start with the lowest level, most directly related to our senses, but we chose the other way round, because lower levels of scale are better understood knowing their context. This way, you may get a feeling for contextual factors determining a particular environment and its mathematical modelling with parameters stemming from that context. In design practice you can reason the reverse way or both ways. But, to know how to design 'throught the scales' you have to be aware of scales, the frame and grain of legend units, the scale specific inferences and the danger of using conclusions from an ather scale.

Design related use

So, you do not have to read everything before you can use it making inventories for design (like a local atlas of thematic maps), while designing or reflecting on your designs. Reflecting on your design work is what we ask in the assignments of the course accompanying this book: how did you apply Sun in your earlier design work, what could you have done, how do you apply Sun in your actual design work and what could you do with it in the future? The same is asked for Wind, Water and so on. A growing number of computer programs for experiments and calculations per section is downloadable from *http://team.bk.tudelft.nl* publications 2008.

Non-disciplinary combinations like Sun, energy and plants

The chapter 'Sun' contains sub-chapters on energy, entropy, temperature, light, the history of our territory dependent on solar fluctuations, man-made plantation (written by Prof.dr.ir.C.M. Steenbergen and Drs. M.J. Moens), shadow and vision as well. These subjects are often related in design or better comprehensible in the offered context. Perhaps in your design you can connect things in another way than the usual scientific and specialist's distinctions of disciplines suggest. For the same reason we did not aim for a distinction between natural and man-made phenomena in the sequence of chapters. It is rather a conditional sequence of growing complexity in cycles of inductive observing, deductive understanding and practical application. So, any chapter is better understood knowing something about the subject of the preceding chapter.

Wind, sound and noise

The chapter 'Wind' contains sound and noise as well, because both are movements of air. These flows are more complex than those of mere energy and light.

Water, networks and crossings

The chapter 'Water' is primarily based on the lecture notes Prof.dr.ir. C. van den Akker offered us for use when he retired from the Faculty of Civil engineering. Ir.D. de Bruin, drs. M.J. Moens and ir. M.W.M. van den Toorn added many subjects relevant for design. However, it contains traffic as well, based on the book of ir. B. Bach[b], because the combination of these different flows on the Earth's surface and their resulting networks are an important part of urban and regional design. So, we did not primarily make a distinction between natural and man-made networks. The comparison of their characteristics is interesting, instructive, and may be a source of new design ideas.

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[a] De Waal …

[b] Bach, B. (2006) …

Earth and site preparation

The chapter ‘Earth’, primarily written by Drs. M.J. Moens and elaborated by ir. M.W.M. van den Toorn , is better understood if you know something about wind and water. The division of its sub-chapters starts strictly with levels of scale, but then sub-chapters follow about soil pollution and preparing a site for development.

Life, ecology and nature

The ecological chapter ‘Life’ supposes sun, wind, water and earth. These conditions are discussed earlier in the book, so the chapter can focus on the distribution and abundance of life itself. Biology is physics with numerous feed-back mechanisms, not te be modelled so easily in a mathematical sense. However, it introduces approaches of system-dynamics, demography, useful in human environments as well. Life contains human life. So, this chapter tries to consider man as a species between other species (syn-ecology), while the next chapter ‘Human Living’ concentrates on human species only (aut-ecology). However, there are sub-chapters on valuing and mananging nature by man in your plan, and on the role of an urban ecologist.

The subject of this chapter is not very familiar to designers. So, you can think it is not very relevant. But in my opinion ecology, the science of distribution and abundance of species, is the very core of urban and regional design. Design changes predictable distributions. Local vegetaton and wild life clarifies much about what designers feel as a mysterious ‘genius loci’. Ecology is a neglected source of local identity. Evolution of life has something in common with design thinking: its course of trial and error into diversity and order. The evolutionary taxonomy of plants and animals, types of life, their distribution and adapation into different environments, accommodating and modifying them, give examples of the same problems any design task stands for. Your typological repertoire of design solutions selects environments and the reverse different environments select different types of design.

Living, human density and environment

The chapter ‘Living’ shows the history of human occupation in general and in The Netherlands in particular. That piece of land in between France, Belgium, Germany and Great Britain contains both lower and higher grounds, combining many characteristics of its neighbours. Its delta gives an impression of a development known from many densely populated lowlands in the world, the spatial composition of ecological, technical, economic, cultural and administrative components. A sub-chapter is devoted to urban density on different levels of scale. The sub-chapter ‘Environment’ discusses some consequences of living in high densities like environmental problems, environmental norms, gains and losses.

Legends for design

The chapter ‘Legends for design’ stimulates to consider these phenomena of urban physics as innovative components, legend units, spatial types given form in a design composition. It raises philosophical questions on unusual types, their suppositions, combinations and consequences.

Simulators accompanying the book

Every chapter is accompanied by Excel sheets[a] programmed with Visual Basic Language to exercise mathematical relations described in this book. These simulators show the hidden suppositions of specialists in yellow sliders by which you can change the model and see the results without own calculations. By doing so, you can ask the right questions if specialists criticize your design with mathematical certainty. They often show counter-intuitive results. If you do not believe them, then Excel allows you to show the formulas en their relations to criticize their inference. That will make you less vulnerable in the company of many specialists you will meet in practice.

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[a] sun*.xls*, sound and noise *.xls* energy*.xls*, wind*.xls*, water*.xls*, precipitation *.xls*, traffic*.xls*, earth*.xls*, life*.xls*, living*.xls*, environment*.xls*, legends*.xls*, math functions*.xls* downloadable from *http://team.bk.tudelft.nl/* > Publications 2008

1 Sun, energy and plants

Contents

1.1 Energy

1.1.1 Physical measures

The internationally accepted SI system of units defines energy and power according to Newton by distance, time and mass as follows. As long as a force ‘f’ causes an acceleration ‘a’, a distance ‘d’ is covered in a time interval ‘t’. Multiplying f by d produces the yielded energy f · d, expressed in joules. Energy per time interval t produces the performed power f · d / t expressed in watts (see *Fig. 2*).[1]

Velocity ‘v’ and acceleration ‘a’ suppose distance d and time interval t:

d (distance) **t (time)**	$\frac{d}{t}$ **= v (velocity)**	$\frac{d}{t^2}$ **= a (acceleration)**

Linear momentum ‘i’ and force ‘f’ suppose mass m, velocity v and acceleration a:

m (mass)	$\frac{d}{t}$ **m = i (momentum)**[2]	$\frac{d}{t^2}$ **m = ma = f (force)**[3]

	times distance = energy ‘e’	divided by time = power ‘p’
	$\frac{d^2}{t^2}$ **m = e (energy)**[4]	$\frac{d^2}{t^3}$ **m = e/t = p (power)**[5]

Energy is expressed in joules (J), power (energy per second) in watts (W)[6]

	J=kg*m^2/sec^2	W = J/sec

Old measures should be replaced as follows:

k= kilo(*10^3)	kWh = 3.6 MJ	kWh/year = 0.1142W
M= mega(*10^6)	kcal = 4.186 kJ	kcal/day = 0.0485W
G= giga(*10^9)	pk.h = 2.648 MJ	pk = hp = 735.5 W
T= tera(*10^{12})	ton TNT = 4.2 GJ	PJ/year = 31.7 MW
P= peta(*10^{15})[7]	MTOE = 41.87 PJ	J/sec = 1 W
E= exa(*10^{18})	kgfm = 9.81 J	
	BTU = 1.055 kJ	W (watt) could be read as watt*year/year.
	watt*sec = 1 J	

The equivalent of 1 m^3 natural gas (aeq)[8], roughly 1 litre petrol[9], occasionally counts 1 watt*year:

Occasionally:	m^3 aeq = 31.6 MJ and Wa = watt*year = 31.6 MJ	aeq/year = 1 W, or 1 W = 1 watt*year/year
	1 MJ = 0.0316888 Wa 1 GJ = 31.7 Wa 1 TJ = 31.7 kWa 1 PJ = 31.7 MWa	‘a’ from latin ‘annum’ (year) Wa is watt during a year ‘k’ (kilo) means 1 000x ‘M’ (mega) means 1 000 000x

Fig. 2 Dimensions of energy

A happy coincidence

A year counts 365.24 · 24 · 60 · 60 = 31 556 926 seconds or 31.6 Msec, since M means '·million'.
So, the **power** of 1 watt *during* a year: 1 watt·year = 31.6 MW·sec = 31.6 MJ =
1 Wa ('a' derived from latin 'annum', year), which is **energy**. [10]
Occasionally the equivalent of 1 m^3 natural gas ('aeq') or 1 litre petrol or 1 kg coal energy counts for approximately 31.6 MJ = 1 Wa energy as well.[11]

So: m^3 natural gas ('aeq')	≈ watt·year = Wa (energy)
and m^3 natural gas *per year*	≈ watt = W (power).

So, read 'Wa' and think	'1 m^3 natural gas', '1 litre petrol' or '1 kg coal' (energy);
read 'W' and think	'1 m^3 natural gas *per year*' (power);
read 'kW' and think	'1000 m^3 natural gas *per year*' (power);
read 'kWh' and think	'1000 m^3 natural gas per year *during an hour*' (again energy).

Easy calculating kilowatthours (kWh) and joules (J) by heart

Since there are 365.24 · 24 = 8 766 hours in a year: 1 Wa (watt·year) = 8 766 watt·hour (Wh) or 8.766 kilowatt·hour (kWh), because 'k' means '·thousand'.
Since there are 31 556 926 seconds in a year: 1 Wa = 1watt·year = 31 556 926 Ws (J) or 31 557 kJ, 31.557 MJ or 0.031557 GJ, because k = ·1 000, M = ·1 000 000 and G = ·1 000 000 000.[12]
This Wa measure is not only immediately interpretable as energy content of roughly 1 m^3 natural gas, 1 litre petrol or 1 kg coal, but via the average amount of hours per year (8 766) it is also easily transferable by heart into electrical measures as kWh and then via the number of seconds per hour (3 600) into the standard energy measure W·s=J (joule).
Moreover, in building design and management the year average is important and *per year* we may write this unit simply as W (watt). So, in this chapter for *power* we will use the usual standard W, known from lamps and other electric devices while for *energy* we will use Wa. If we know the average use of power, energy *costs* depend on the *duration* of use. So, we do not pay *power* (in watts, joules per second), but we pay *energy* (in joules, kilowatthours or wattyears): power x time.

Watts in everyday life

A quiet person uses approximately 100 W, that is *during* a year the equivalent of 100 m^3 natural gas. That power of 100 W is the same as the power of a candle or pilot light or the amount of solar energy/m^2 at our latitude[a]. That is a lucky coincidence as well. The power of solar light varies from 0 (at night) to 1000 W (at full sunlight in summer) around an average of approximately 100 W.
Burning a lamp of 100 W *during a year* takes 100 Wa as well, but electric light is more expensive than a candle.[13] Crude oil is measured in barrels of 159 litres. So, if one barrel costs € 80, a litre costs € 0.50. However, a litre petrol (1 Wa) from the petrol station after refining and taxes costs more than € 1. Natural gas requires less expensive refinary.
In the Netherlands 2008, 1 m^3 natural gas (1Wa) costs approximately *€ 0,70*[b]. However, an electric Wa costs approximately *€ 1.80*. That is more than 2 times as much. Why?

Conversion of fuel into a useful kind of energy

Electric energy is usually expressed in 'kWh_e' ('e' = electrical), heat energy in 'kWh_{th}' ('th' = thermal).
A kWh_e electricity is more expensive than a kWh_{th} of heat by burning gas, petrol or coal, because a power station can convert only approximately 38% from the energy content of fossile fuels into electricity (efficiency η=0.38). The rest is necessarily produced as heat, mainly dumped in the environment 'cooling' the power station like any human at work also looses heat.[14] That heat content could be used for space heating, but the transport and distribution of heat is often too expensive. However, enterprises demanding both heat (Q) and work (W) at the same spot, could gain a profit by generating both locally (*cogeneration*, in Dutch 'warmte-kracht-koppeling' *WKK*).

Necessary heat loss

The necessary heat loss is described by two main laws of thermodynamics: no energy gets lost by conversion (first law of thermodynamics), but it always degrades (second law of thermodynamics).

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[a] It is slightly more, sometimes described as 1000 kWh/m^2 per year, which is 114 W/m^2. See *http://www.solaraccess.nl/content/page12.php*.
[b] Zie *http://consumenten.eneco.nl*

By any conversion only a part of the original energy can be utilised by *acculumation* and *direction* at one spot of application. The rest is *dispersed* as heat content Q (many particles moving in many directions), to concentrate a minor useful part W (work) on the spot where the work has to be done. The efficiency η of the conversion is W/(W+Q). In the case of electricity production it is $38kWh_e/100kWh$ or 38%. Once the work W is done, even the energy of that work is transformed into heat. However, according to the first law of thermodynamics both energy contents are not lost, they are degraded, dispersed, less useful. However it could still be useful for other purposes.
For example, the temperature of burning gas is ample 2000^oC, much too warm for space heating. If you would use the heat from burning fuels firstly for cooking, then for heating rooms demanding a high temperature and at last for heating rooms demaning a low temperature, the same heat content is used three times at the same cost in a 'cascade'. To organise that is a challenge of design.

Exergy

Theoretically any difference in temperature can be used to extract some work, but the efficiency of a small temperature difference ΔT is lower than that of a large temperature difference (see *Fig. 3*).

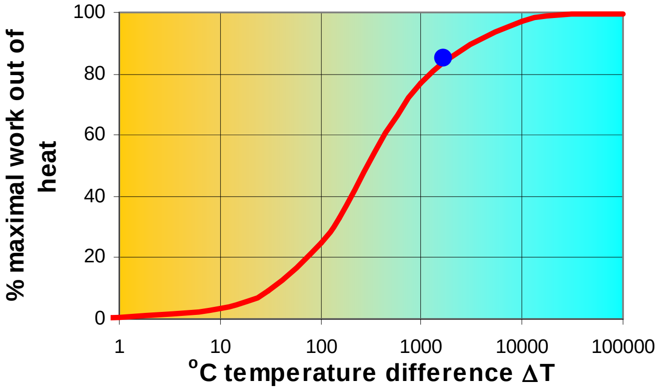

Fig. 3 The %maximum amount of work (W) retrievable from a temperature difference ΔT

The amount of work you can get out of heat (W/Q) per temperature difference available is called exergy. Apparently, chemical energy like fossile fuels do have a higher 'quality' than work; work has a higher quality than heat; high temperature heat has a higher quality than low temperature heat.
So, using high quality energy where low quality would be enough, leaves unused the opportunity to use the same energy several times in a cascade of uses.
The 'quality' of energy can be expressed in a single quantity. That quantity is called 'entropy'.

1.1.2 Entropy

The 'quality' of energy

The 'quality' of heat (Q) and work (W) is apparently different, though both are 'energy'.
In the same way high temperature (T) energy has a higher 'quality' than the same energy at low T. While converting fossile fuels into heat, the 'state' of energy changes. But how to describe that 'state' and its 'quality'? To introduce that 'state' in energy calculations the term 'entropy' S is invented by Clausius ca. 1855. In a preliminary approach one could think S = Q/T, but it concerns *change*, forcing us into differentials. It is often translated as 'disorder', but it is a special kind of disorder as Boltzmann showed in 1877. What we often perceive as 'order', a *regular* dispersion in space, is 'disorder' in thermodynamics. Let us try to understand that kind of thermodynamic disorder to avoid confusion of both kinds of 'order'.

'Disorder' in thermodynamics

In *Fig. 4* all possible distributions of n = {1,2,3,4} particles in two rooms are represented.
If you mark every individual particle by A, B, C, D, you can count the possible combinations producing the same distribution k over the rooms numbered as k = {0,1 …n}.

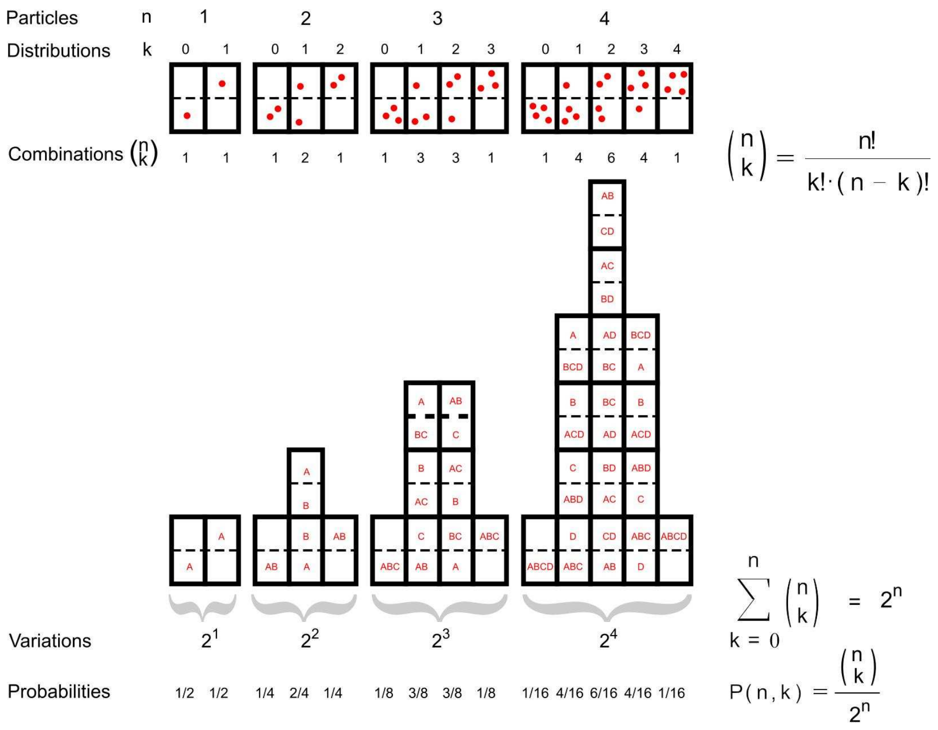

Fig. 4 k Distributions of n particles in two rooms

The numbers n and k determine the probability P(n,k) that this combination will occur[a].
Minimum and maximum values of k represent the extreme concentrations in one room or the other.

The more particles there are, the more combinations are possible and the more improbable will be the two extreme cases of accumulation in one room. For example, if there are 10 particles, the probability of total sprawl is 252 possible combinations from 1024 (25%), but the probability of total accumulation in one room is 1 case from 1024 (0.1% see *Fig. 5*, left).

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[a] Here is a tacid supposition, that the particles have an equal probability of entering and leaving a room without an selection at the doors between them like Maxwells Demon (remark of Van Bilsen 2007).

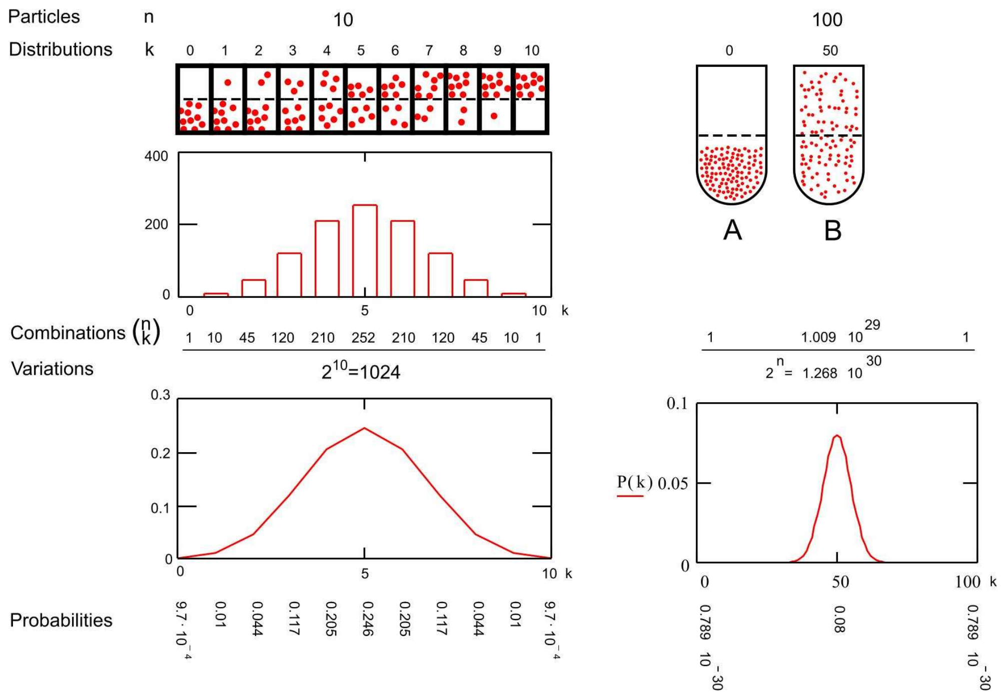

Fig. 5 The decreasing probability of concentration with a growing number of particles

Fig. 5 (A) shows the least probable distribution of 100 particles in a cylinder, but state B is very probable. These probabilities can be calculated as approximately $1/13 \cdot 10^{29}$ (A) and 1/13 (B).
So, if anything changes it will most probably change from A into B instead of from B into A.
That asymmetry of process is the core of thermodynamics.

From *Fig. 5* you also can learn that by an increasing number of particles most combinations accumulate around the middle of $k=0.5 \cdot n$. If you would calculate the possible combinations of 1000 particles the probability of sprawl (B) between k=495 and 505 (1% of n) would be practically 1 (100%). The graph would show a vertical line rather than a gaussian ‘bell’.

Difference of entropy

Suppose now the content of the cylinder is a mole of gas (that is approximately $6 \cdot 10^{23}$ particles, Avogadro’s number n). Then the probability of state B approximates 1 (100%). The probability of state A is again $1/2^n$. That is nearly zero, because the number 2^n is extraordinary large: a 1 with more than 10^{23} zeros. An ordinary computer can not calculate all combinations of that number as done in *Fig. 4*. However, to determine the entropy of state A we need the natural logarithm (the exponent to ‘e’ or 2.718) of that probability: $\ln 1/2^n$ or $\ln(2^{-n})$. And $\ln(2^{-n})$ is easily written as $-n \cdot \ln(2)$. That will save a lot of calculation, because n will disappear in the definition of entropy by Boltzmann using that probability:

$$S = \text{moles} \cdot \frac{R}{n} \cdot \ln(\text{probability})$$

Fig. 6 The statistical definition of entropy by Boltzmann in 1877

In state A and B with $n = 6 \cdot 10^{23}$ particles, the number of moles is 1; n is Avogadro’s number.
R is a constant (gas constant) we will explain later.[a] So, entropy is related to probability by a constant! However, Boltzmann chose the logarithm of probability, because if you want to know the entropy of two sub systems (for example two moles), you would have to multiply the combination of each sub system. If you take the logarithm first, than you can simply add both[b].

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[a] R/n, the gas constant divided by Avogadro’s number is mainly written as Boltzmann’s constant k.

[b] Remark by Van Bilsen(2007).

In this case we can write the increase of entropy from stage A into B as S_B-S_A:

$$\Delta S = \frac{R}{n}\cdot\ln(1) - \frac{R}{n}\cdot\ln\left(\frac{1}{2^n}\right)$$

Fig. 7 The increase of entropy from accumulation in one room into sprawl in two rooms

The probability of state B is very near 1, and the logarithm of 1 is zero, so we can write:

$$\Delta S = -\frac{R}{n}\cdot\ln\left(\frac{1}{2^n}\right) = -\frac{R}{n}\cdot\ln\left(2^{-n}\right) = -\frac{R}{n}\cdot -n\cdot\ln(2) = R\cdot\ln(2)$$

Fig. 8 Simplifying the formula of Fig. 7

So, the entropy of stage B is R·ln(2). The natural logarithm of 2 is 0.693, but what is R?

R is the gas constant per mole of gas:

$$\frac{P_A\cdot V_A}{T_A} = \frac{P_B\cdot V_B}{T_B} = \frac{P\cdot V}{T} = 8.31472\,\frac{\text{joule}}{K\cdot\text{mole}} = R$$

Fig. 9 Defining the gas constant R

In *Fig. 9* P is the pressure (force/m^2) and V is the volume (m^3). So, on balance P·V is ‘force times distance’: energy (expressed in newton·m: joule). T is the temperature in degrees of Kelvin (K).

In a mole of gas the proportion between that energy and temperature in normal conditions appears to be the same[a]: 8.31472 joule/K. That constant is named ‘gas constant’ R. So, that is also valid for both stage A and B. Now we could calculate the increase of entropy as R.ln(2) = 5.8 joule/K·mole. However, in thermodynamics the ‘probability’ of a state contains more than the distribution over two rooms. For example the reduced freedom of movements of particles in liquids and solids. That is why we limit ourselves here to complete freedom of movement (gas) to describe the states A and B. Moreover, gas plays a dominant role in energy conversion any engineer is occupied with.

Change of entropy

If a mole of gas expands from A to B, the heat content Q disperses over a doubled volume. So, the temperature tends to drop and the system immediately starts to adapt to the temperature of the environment. That causes an influx of extra heat energy ΔQ. So, in a slow process T could be considered as constant and the pressure will halve to keep also P·V constant at R·T (see *Fig. 10*).

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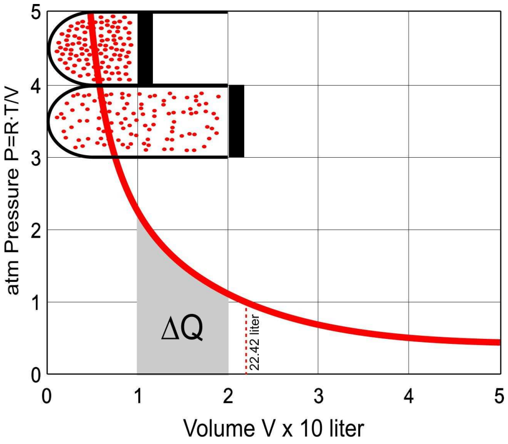
[a] the Boyle-Gay-Lussac law.



P·V = R·T (see *Fig. 9*), so P = R·T/V (see the graph left). If at any moment Q := P·V, any small change dQ equals P·dV and a larger change ΔQ from stage 1 into 2 is the sum of these small changes:

$$\Delta Q = \int_1^2 P\, dV = \int_1^2 \frac{R\cdot T}{V}\, dV = R\cdot T\cdot \ln(2)^{a}$$

so, $\frac{\Delta Q}{T} = R\cdot \ln(2)$. Remember now Fig. 8: $R\cdot \ln(2) = \Delta S$

if $\Delta S = \frac{\Delta Q}{T}$, then also $dS = \frac{dQ}{T}$. So, $\boxed{S = \int \frac{1}{T}\, dQ}$

Fig. 10 Extending 1 mole of gas (22.42 liter at 1 atmosphere) from 10 to 20 liter keeping T at 0^{o}C or 273.26K.

The heat energy Q is equal to P·V, but if it increases P itself is dependent on V.
So, every infinitely little increase of V (dV) has to be multiplied by a smaller P. Summing these products P·dV between V = 1 and V = 2 is symbolised by the first 'definite integral' sign in *Fig. 10*. However, that formula can not be solved if we do not substitute P by R·T/V (see *Fig. 9*) in the next formula. In that case the mathematicians found out that definite integral is equal to R·T·ln(2).
Now we have a real quantity for ΔQ, because R·T·ln(2) = 1574 joule.

So, ΔQ/T = R·ln(2), and R·ln(2) reminds us of *Fig. 8*: it is ΔS, the change of entropy!
A few steps according to *Fig. 7* takes us back to the statistical definition of Boltzmann in *Fig. 6*, but now it is related to heat content Q and temperature T, the variables used in any engineering.
If ΔS = ΔQ/T, then also dS = dQ/T and now we can write the famous integral of Clausius:

$$S = \int \frac{1}{T}\, dQ$$

Fig. 11 The thermodynamic definition of entropy

This formula shows that an increasing heat content increases entropy, but a higher temperature decreases it. If we now keep the heat content the same (closed system) and increase volume, then accumulation, pressure and temperature decrease (Boyle-Gay Lussac, see *Fig. 9*), so entropy will increase.
So, accumulation (storage, difference between filled and empty) decreases entropy, increases order.

Design and the conception of order, specialists' conceptions

The explanantion of entropy above is extended, because of two reasons.
Firstly, while defending a concept of order, arrangement in design, designers often refer to low entropy and that is not always correct. Perceptual order could refer to a regular dispersion of objects in space and just that means sprawl, entropy. In thermodynamics an irregular dispersion with local accumulations has a lower entropy (disorder) than complete sprawl. However, in fluids and solids rectangular or hexagonal patterns with low entropy appear, due to molecular forces. But in general, if the particles have freedom of movement, sprawl is much more probable than accumulation.
It reminds us of the avoidance of urban sprawl. Thermodynamically accumulation is possible, but very improbable. So, *if* thermodynamics has any lessons for designers: sprawl is not the task of design, if there is freedom of movement, than it very probably happens without intention.

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[a] A little math: $\int_1^2 \frac{1}{V}\, dV = \ln(2) = 0.693$; $\int_1^3 \frac{1}{V}\, dV = \ln(3) = 1.099$; $\int_2^3 \frac{1}{V}\, dV = \ln(3) - \ln(2) = 0.405$

Secondly, energy and entropy are basic concepts in any engineering. To understand specialists in their reasoning and to be able to criticise them demands some insight by designers. The impact of the industrial revolution, the accumulation of population in cities can not be understood without understanding the manipulation of sprawl on another level of scale as has happened in the development of the internal-combustion engine. The internal-combustion engine is extensively used in industry and traffic. So, I would like to proceed with some explanation of that engine, the main application of sunlight stored in fossile fuels in human society.

Forced concentration

The (change of) force by which a piston is pushed out of a cylinder is equal to the proportion of (change of) energy and entropy *Fig. 12*. In a cylinder engine, alternating states of dispersion are used to convert imported disordered energy (heat) partly into directed movement. It is only possible by exporting part of the heat in an even more dispersed form (cooling).

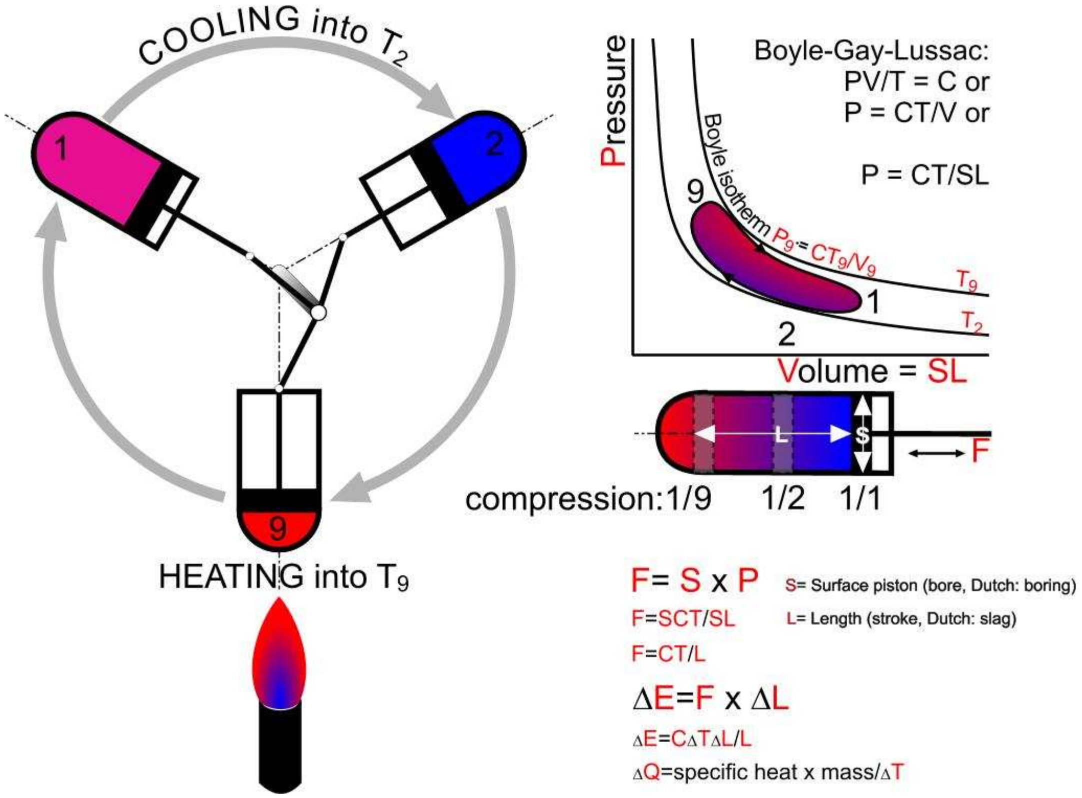

Fig. 12 Carnot-engine

The necessary event of cooling makes an efficiency of 100% impossible and increases entropy in a larger environmental system. The reverse, adding rotating energy to this engine the principle that can be used for heating (heat pump) and cooling (refrigerator).

1.1.3 Energetic efficiency

The proportion of the applicable part from total energy content of a primary source is the efficiency of the conversion.[15] In *Fig. 13* some conversion efficiencies are represented.

Device or process	chemical->thermic	thermic->mechanisal	mechanical->electric	electric->mechanical	electric->radiation	electric->chemical	chemical->electric	radiation->electric	thermic->electric	efficiency
										100%
electric dynamo			■							
electric motor				■						
										90%
steam boiler	■									
HR-boiler	■									
										80%
c.v.-boiler	■									
electric battery						■	■			
										70%
fuel cell							■			
										60%
										50%
steam turbine		■								
										40%
electric power station	■	■	■							
gas turbine	■	■								
										30%
car engine	■	■								
neon lamp					■					20%
solar cell								■		
										10%
thermocouple									■	
										0%

Fig. 13 Energy conversion efficiencies[a]

Producing electric power

An electric power station converts primary fuel (mostly coal) into electricity with approximately 38% efficiency. *Fig. 13* shows that such a power station combines 3 conversions with respecitive efficiencies of 90, 45 and 95%. Multiplication of these efficiencies produces 38% indeed.[16] The step from chemical into electrical power could also be made directly by a fuel cell (*brandstofcel*)[b], but the profit of a higher efficiency (60%) does not yet counterbalance the costs.

The table shows the solar cell as well. The efficiency is between 10 and 20% (theoretical maximum 30%). Assuming 100W sunlight per m^2 Earth's surface average per year in The Netherlands (40 000 km^2 land surface) we can yield at least 10W/m^2.

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[a] Gool e.a. (1986)

[b] Zie *http://mediatheek.thinkquest.nl/~lla091/fuelcell_nl.html*

Domestic use of solar energy

The average Dutch household uses approximately 375 wattyear/year or 375W electricity.
In a first approach a household would need 37.5 m2 solar cells. However, a washing machine needs also in periods without sunshine now and then 5000W. So, for an autonomous system solar electricity has to be accumulated in batteries. According to *Fig. 13* such batteries have 70% efficiency for charging and discharging or 0.7 x 0.7 = 50% for total use. The needed surface for solar cells doubles in a second approach to at least 75 m^2 (37.5 m^2 / (0.7 x 0.7)).

Changing into alternating current

However, most domestic devices do not work on direct current (D.C.) from solar cells or batteries, but on alternating current (A.C.). The efficiency of conversion into alternating current may increase the needed surface of solar cells into 100 m^2 or 1000 W installed power. Suppose solar cells cost € 3,- per installed W, the investment to harvest your own electricity will be € 3 000,-. In the tropics it will be approximately a half.

Peak loads

Suppose, electricity from the grid amounts about *€ 0.70* per Wa. So, an average use of approximately 375 W electricity approximately amounts to € 250 per year. In this example the solar energy earn to repay time exclusive interest is already approximately 3000/250 per year = 12 year. Concerning peak loads it is better to cover only a part of the needed domestic electricity by solar energy and deliver back the rest to the electricity grid avoiding efficiency losses by charging and discharging batteries. It decreases the earn to repay time.

The costs of solar cells compared to fossile fuel

The costs of solar cells decreased since 1972 a factor of approximately 100. Their efficiency and the costs of fossile fuels will increase. To pass the economic efficiency of fossile fuels as well the price of solar cells has to come down relatively little (*Fig. 14*). 'Solar power cost about $4 a watt in the early 2000s, but silicon shortages, which began in 2005, have pushed up prices to more than $4.80 per watt, according to Solarbuzz … In a recent presentation, Bradford said that prices for solar panels could drop by as much as 50 percent from 2006 to 2010.'[a]

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[a] *http://www.technologyreview.com/Biztech/20702/?a=f*

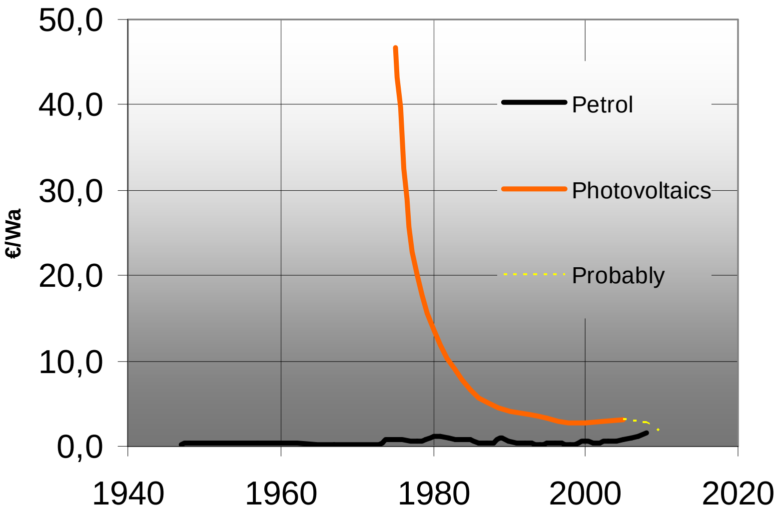

Fig. 14 Decreasing costs of solar cells and petrol[a]*, possibly developing according to* [a]*.*

The efficiency of solar cells compared to plants

The efficiency of solar cells is rather high compared with the performance of nature. Plants convert approximately 0.5 % of sunlight in temporary biomass (sometimes 2%, but overall 0.02%), from which ony a little part is converted for a longer time in fossile fuels. Biomass production on land delivers maximally 1 W/m^2 being an ecological disaster by necessary homogeneity of species. In a first approach a human of 100 W would need minimally 100 m^2 land surface to stay alive. However, by all efficiency losses and more ecologically responsible farming one could better depart from 5 000 m^2 (half a hectare).

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[a] http://www.wtrg.com/prices.htm and Maycock cited by Brown, Kane et al. (1993)

1.1.4 Global energy

Available solar power

There is more than 6 000 times as much solar power available as mankind and other organisms use. The Earth after all has a radius of 6Mm (6 378 km at the equator, 6 357 km at the poles) and therefore a profile with approximately 128 Mm^2 (π x 6 378 km x 6 378 km = 127 796 483 000 000 m^2) capturing sunlight. The solar constant outside atmosphere measures 1 353 W/m^2, on the Earth's surface reduced to approximately 47% by premature reflection (-30%) or conversion in heat by watercycle (-21%) or wind (-2%). The remainder (636 W x 127 796 483 000 000 m^2 of profile surface unequally distributed over the spherical surface) is available for profitable retardation by life or man. However, 99.98% is directly converted into heat and radiated back to the universe as useless infrared light. Only a small part (-0.02%) is converted by other organisms in carbohydrates and since about a billion years a very small part of that is stored more than a year as fossile fuel.

		Earth	The Netherlands	
radius	Mm	6		
profile	Mm^2 [a]	128		
spherical surface	Mm^2	510	0,10	0,02%
solar constant	TW/Mm^2	1353	832,99	61,57%[b]
solar influx	TW	172259	33,83	0,02%
from which available				
sun 47% or 100W/m2	TW	80962	10,00[c]	0,01%
wind 2%	TW	3445	0,68	0,02%
fotosynthesis 0,02%	TW	34	0,01	0,02%

Fig. 15 Globally and nationally received solar power

The human use of energy

The actual energy use is negligible compared to the available solar energy (*Fig. 15* and *Fig. 16*).

		Earth	The Netherlands	
coal	TW	3	0,02	0,45%
oil	TW	4	0,03	0,77%
gas	TW	2	0,05	2,14%
electricity	TW	2	included in fossile	
traditional biomass	TW	1		
total	TW	13[d]	0,10	0,73%

Fig. 16 Gobal and national energy use[e]

Biological storage

The biological process of storage produced an atmosphere livable for much more organisms than the palaeozoic pioneers. Without life on earth the temperature would be $290^{o}C$ average instead of $13^{o}C$. Instead of nitrogen (78%) and oxigen (21%) there would be a warm blanket of 98% carbon dioxide (now within a century increasing from 0.03% into 0.04%). By fastly oxidating the stored carbon into atmospheric CO_2 we bring the climate of Mars and heat death closer, unless increased growth of algas in the oceans keep up with us.

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[a] $Mm^2 = (1\ 000\ 000\ m)^2$

[b] Cosine of latitude.

[c] Here $100W/m^2$ is assumed. See also http://www.solaraccess.nl/content/page12.php

[d] rounding off difference

[e] Dutch figures are more recent than global ones.

Wind and biomass

Concerning *Fig. 14*, *Fig. 15* and *Fig. 16* making a plea for using wind or biomass is strange. Calculations of an ecological footprint based on surfaces of biomass necessary to cover our energy use have ecologically dangerous suppositions. Large surfaces of monocultures for energy supply like production forests (efficiency 1%) or special crops (efficiency 2%) are ecological disasters.
Without concerning further efficiency losses Dutch ecological footprint of 0.10 TW (*Fig. 16*) covered by biomass would amount 10 times the surface of The Netherlands yielding 0.01 TW (*Fig. 15*). However, covered by wind or solar energy it would amout 1/7 or 1/100. However, efficiency losses change these facors substantially (see 1.1.5).

How much fossil fuel is left

To compare energy stocks of fossile fuels with powers (fluxes) expressed in terawatt in *Fig. 15* and *Fig. 16*, *Fig. 17* expresses them in power available when burned up in one year (a = annum).

		Earth	The Netherlands	
coal	TWa	1137	0,65	0,06%
oil	TWa	169	0,03	0,02%
gas	TWa	133	1,60	1,20%
total	TWa	1439	2,28	0,16%

Fig. 17 Energy stock

By this estimated energy stock the world community can keep up its energy use 110 years.[17] However, the ecological consequence is ongoing extinction of species that can not keep pace with climate change. Forests can not move into the direction of the poles in time because they need thousands of years to settle while others 'jump from the earth' flying for heat.

Fission of uranium

Fig. 16 shows an actual global energy use of 13 TWa. One TWa is 1 000 GWa. One GWa$_e$ can also be generated in a nuclear power station. Instead of 2 000 000 000 kg coal, that requires 800 kg enriched uranium (U) only[a]. Dependent on the density in the rock, substantial extraction marks can be left in the landscape. Storage and transport of the raw material with uranium has to be protected against possible misuse.

The conversion ino electricity occurs best in a fast breeder reactor. Older fission cycles with and without retracing of plutonium (Pu) use so much more uranium that the stocks will not be sufficient until 2050. The fast breeder reactor recycles the used uranium with a little surplus of plutonium (see *Fig. 18*). However, that requires higher temperatures than without recycling.

With non-braked 'fast' neutrons from the core of the reactor in the 'casing' or 'mantle' of fissionable material non-fissionable heavy uranium (U238) is converted in fissionable plutonium (Pu239), suitable for fuel in the same reactor.

Uranium stocks

Because the uranium stocks are estimated to be approximately 5 000 000 000kg, approximately 6 million GWa electricity could be extracted (plus approximately two times as much rest heat). If you estimate the world electricty use to be 1000 Gw$_e$ per year, then that use can be sustained some 6 000 years with fast breeder reactors. Supposing an all-electric society and a world energy use of 10 000 GWa, then the uranium stocks are enough for 600 year.

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[a] AER (1979) Kolen en uraan ('s-Gravenhage) Staatsuitgeverij

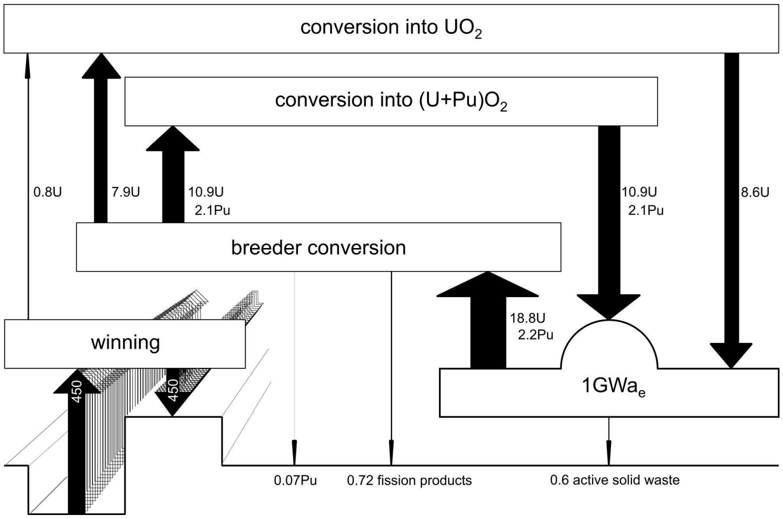

Fig. 18 Nuclear fuel cycle of a fast breeder reactor in 1000kg, producing 1 GWa_e [a]

Impacts of radio activity on the human body

The released radio-active material radiates different kinds of ionizing particles. Dependent on their energy (expressed in electronvolt, eV) they can penetrate until different depths in the soft body tissues where they can cause damage (see *Fig. 19*).

in millimetres	charged particles		non-charged particles		
	alfa	proton	beta	neutron	gamma
on 1 MeV	0.005	0.025	5	25	100
on 10 MeV	0.2	1.4	50	ca 100	310

Fig. 19 Halving depth of ionizing radiation in body tissue[b]

In the air similar distances apply. That means that approaching radio active waste until some metres does not have to be dangereous. The real danger starts by dispersion of radio-active particles in the air, water, soil and food. Through that dispersion the sources of radiation can enter the body and cause damage on a short distance of vulnerable organs.

The damage is determined by the quantity of the particles of *Fig. 19*, but also by the composition of the intake and the time they remain in the body (biological halving time). The composition determines the radio active halving time and the energy of different particles. The damage is different for sex cells, lungs, bone forming tissue and/or red bone marrow.

Objections against nuclear enery conversion

Against nuclear energy social and political objections are raised concerning:[18]

1. possible misuse of plutonium (proliferation of nuclear weapons)
2. risks in different parts of the cycle
3. the long lasting dangers of dispersion of radio-active waste.

Possible misuse

In *Fig. 18* some moments exist where ample 2 000kg of plutonium have to be transported into the next production phase. At these moments the plutonium can be stolen. If in the breeder conversion plant 12

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[a] after AER 1979 Kolen en uraan blz. 116
[b] Hermans & Hoff 1982, blz. 46

kg PuO_2 is stolen, then 10 kg pure metal can be produced, the 'critical mass' for an nuclear bomb. However, it is not easy to produce a nuclear bomb from this material without very large investments.[19]

Risks during operation

In different parts of the cycle risky moments occur. Though the formation of a 'critical mass' where enough neutrons are confined to cause a spontaneous explosion is very improbable, non-nuclear causes like a failing coolingsystem or 'natrium burning' can get a 'nuclear tail' if they cause a concentration of fissionable material. Both can be caused by terrorist attacks or war.

Liquid natrium is used as cooling medium in breeder reactors because water would brake the necessary fast neutrons. Natrium reacts violently with water and air (eventually with the fission material as well). So, the cooling system sould not have any leakage. If the cooling system fails, then the fisson material can melt forming a critical mass somewhere. A breeder reactor can contain 5 000 000 kg of natrium and by its breeding mantle a relatively large amount of fission material.

Waste

The danger of dispersion of radio-active material does not only occur by accidents. Radio active waste has to be isolated from the biosphere for centuries to prevent entering the food chains. For any GWa electricity produced the wastes are approximately:

1 000 kg of fission products
10 000 kg of highly active solid waste (in Dutch: HAVA)
20 000 kg of medium active solid waste (MAVA)
300 000 kg of low active solid waste (LAVA)
2 GWa of heat

Besides that, once in the 20 years dismantling of the plant has to be taken into account. Many components will have become radio active, so they have to be stored or reused for new plants.

Dispersion of radio-active material

If concentration of these wastes on a few places could be guaranteed for many centuries, this relatively small stream of waste would be no problem. The distance of impact of these radiations is so small, that you can live safely in the neigbourhood of wastes from many centuries.
However, you cannot guarantee concentration for centuries. Even salt domes can be affected by geological or climatic proceses. Blocks of concrete can leake, storage places can be blown up by terrorist or military operations.

Dispersion through the air, water, soil, the food chain or the human body is dangerous and impredictable. Comparison with other environmental risks is difficult. If you take the accepted maximum concentrations in the air as a starting point, you can calculate how much of air you need to reach an acceptible concentration of the dispersed wastes. To make a volume like that imaginable, you can express it as the radius of an imaginagy air dome reaching the accepted concentration by complete dispersion. In that case very roughly calculated recent nuclear waste of 1 GWa requires 50km radius. One year old waste requires 40km, 10 years old waste 15km and 100 years old waste 7km. However, from calculations like this you cannot conclude that you are safe at any distance. In reality dust is not dispersed in the form of a dome, but depending on the wind in an elongated area remaining above the standards over very long distances.

Fission and fusion

If you would have a box with free neutrons and protons at your disposal, you could put together atoms of increasing atomic weight. However, you would have to press very hard to overcome the repelling forces between the nuclear particles. Once you would have forced them together the attracting forces with a shorther reach would take over the effort and press the particles together in such a way that they have to loose mass producing energy[a]. Until 56 particles (iron, Fe56) you would make energy profit. Adding more particles increases the average distance between the particles mobilising the repelling forces again. If you would like to build furter than iron, then you would have to *add* energy.

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[a] A billion watt during a year with 31 560 000 seconds (GWa) is $3.156*10^{16}$ joule and the speed of light c = 299 792 458 m/sec. So, according to the famous Einstein formula $E=mc^2$, if E = 1 GWa, then the loss of mass is 0.351 kg.

However, that also means that heavier atoms like uranium can produce fission energy as discussed above.

Bond energy

The added or released energy are called bond energy. The amount of available bond energy is dependent from the number of particles in the atomic nucleus (zie *Fig. 20*). For example, if you split the nuclei of 1000 kg of uranium (U235) or even better plutonium (Pu239) into strontium (Sr96) and cesium (Cs137), *Fig. 20* shows that you can yield several GWa's. However, it is also clear that if you put together 1000 kg of the hydrogen isotopes deuterium (D2) and tritium (T3) into helium (He4), approximately ten times more GWa can be released.

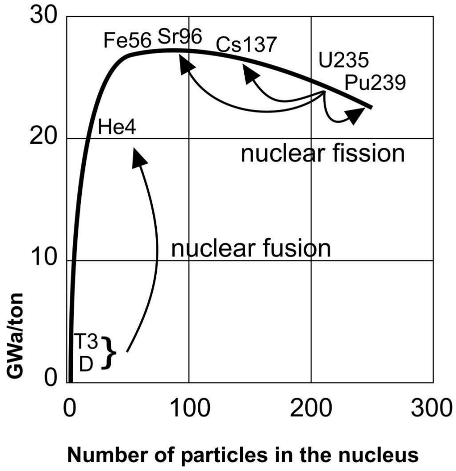

Fig. 20 Bond energy of nuclei as a function of the number of particles[a]

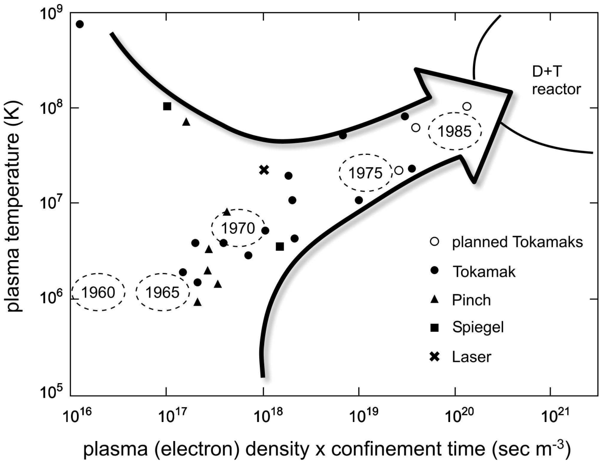

Fig. 21 Progress of nuclear fusion as expected in 1982[b]

Nuclear fusion, the Sun on Earth

This 'putting together' is called nuclear fusion. That is more difficult than it seems, because you could overcome the repelling forces only on 100 000 000 degrees kelvin if in the same time you could keep the hydrogen together in sufficient density long enough (criterion of Lawson). The Sun does so by its mass, isolated by vacuum, delivering its energy by radiation only. On Earth until now, that only has succeeded in experiments with hydrogen bombs, each ignited with a limited fission of uranium. Since long, the temperature under controlled laboratory circumstances is no problem anymore. Already in 1960 higher temperatures have been reached. The real problem is, to reach the Lawson-criterion together with these high temperatures. In that respect impressive progress is made at the end of the 20th century recapitulated in the "Lawson-diagram" of *Fig. 21*.

Thermonuclear power conversion

In 1982 it seemed probable that the first thermonuclear reactor (a converter based on fusion) could deliver electricity before the end of the century. But that fell short year after year. Immense budgets were and still are spent to reach that phase. However, after reaching fusion in controlled circumstances many technical problems have to be solved, but in the end thermonuclear reactors will play an important role in energy supply. In the initial phase of this technology lithium (to be bred from the very volatile and radio active heavy isotope of hydrogen tritium) will be necessary (D+T reactor). However, exclusive use of abundantly available and harmless deuterium will be possible at last.

The stock of deuterium

One of 7000 hydrogen nuclei is a deuterium nucleus. If you estimate the total amount of water on Earth at one billion km^3, the stock of deuterium is 30 000 Pg (1Pg is 1000 000 000 000 kg). This amount is practically spoken inexhaustible. The end product is non radio active inert helium. The radio

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[a] *Lysen 1980 eindeloze energie p42*

[b] *Braams in Hermans en Hoff 1982 p.273*

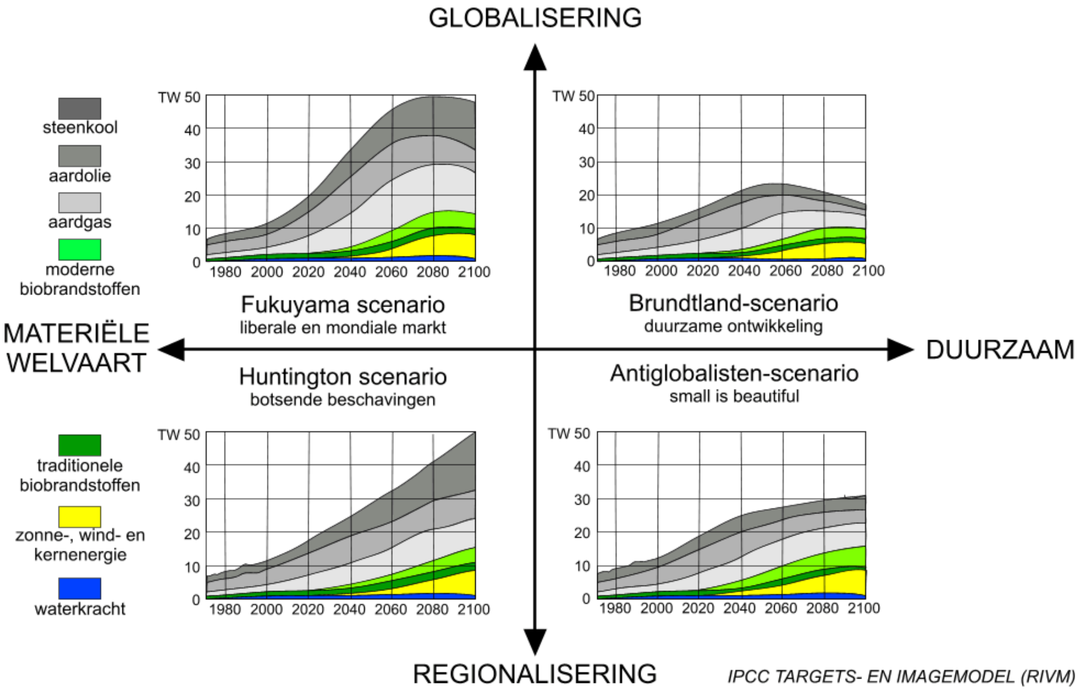
active waste of a thermonuclear reactor merely consists of the activated reactor wall after dismantlement. At average that will be approximately 100 000 000 kg construction material. In the right composition it will loose its radio activity in 10 years. Instead of storing it, you can better use it to construct a new plant immediately. Connected to that, thermonuclear plants can be built best in units of 1.5 GW_e regularly renewed by robots. So, we would need approximately 9000 plants to meet our current global needs or 7 for the Dutch.

Risks of thermonuclear power

The risks of fission power plants like for example the proliferation of plutonium, a "melting down" with dispersion of radio active material are not present in thermonuclear processes based on deuterium. Any attack will stop the process by a fall-down of temperature. However, the use of the extremely volatile radio active tritium in the initial phase is very dagerous. Plutonium is not a necessary by-product as in any fission cycle, but you can use a fusion reactor to breed plutonium if you really want to do so. Perhaps it is possible to make existing radio active wastes from earlier fission harmless in the periphery of the 'fusion sun'.[20]

Energy scenarios

For the contribution of different kinds of energy supply scenarios are made (*Fig. 22*).



IPCC TARGETS- EN IMAGEMODEL (RIVM)

Fig. 22 Energy scenarios[a]

The small contribution solar energy (even combined with nuclear power) and the great confidence in fossile fuels and biomass are remarkable.

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[a] *After RIVM (2000)*

1.1.5 National energy

Use

According to CBS (2009) Dutch energy use (see *Fig. 23*) approaches 100 GW (0,1 TW)[a] from which approximately 10% finally electric: 10Gw$_e$ (0.01TW$_e$)[b] [21].

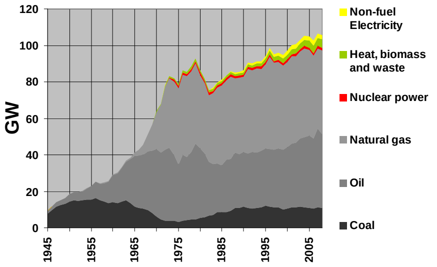

Fig. 23 Development of Dutch energy use 1945-2008 ..

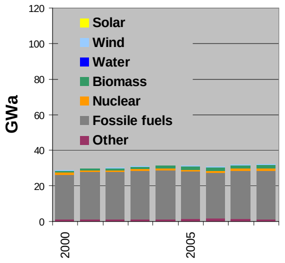

Fig. 24 .. of which used by power stations 2000-2008

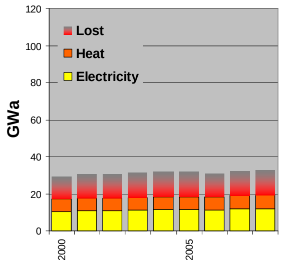

Fig. 25 .. of which used as electricity, heat and lost

Sun and wind energy

An ecological footprint of 1/7 of our surface on the basis of nearly 7 times as much wind as we need looks favourable, but how efficiently can wind be harvested? How useful is the power of 680 GW blowing over The Netherlands? The technical efficiency of wind turbines is maximally 40%, practically 20%. The energy from wind principally cannot be harvested fully because the wind then would stand still behind the turbine. At least 60% of the energy is necessary to remove the air behind the turbine fast enough. Technical efficiency alone (R1) increases the windbased footprint of 1/7 into more than ½. But there are other efficiencies (see *Fig. 26*) together reducing the available wind energy from 680 GW available into maximally 20 GW useful.

The Netherlands full of windturbines only can afford 1/5 of the energy demand

Putting the Dutch coast from Vlaanderen to Dollard full with a screen of turbines and behind it a second one and so on until Zuid Limburg, these screens could not be filled by more than 80% with circular rotors (R2). In the surface of the screen some space has to be left open between the rotors to avoid nonproductive turbulence of counteracting rotors (R3). In a landscape of increasing roughness by wind turbines the wind will choose a higher route. So, in proportion to the height the screens need some distance to eachother (R4). The higher the wind turbine, the higher the yield, but we will not harvest wind on heights where costs outrun profits too much (R5). Decreasing height could be compensated partly by increasing horizontal density (R6) though local objections difficult to be estimated here can force to decrease horizontal density (R7).

R1 technical efficiency	0,20	R5 vertical limits	0,30
R2 filling reduction	0,80	R6 horizontal compensation	2,50
R3 side distance	0,25	R7 horizontal limits	P.M.
R4 foreland distance	0,85	PRODUCT TOTAL	0,03

Fig. 26 Reductions on theoretical wind potential.

By these efficiency reductions the ecological footprint on basis of wind appears not to be 1/7, but at least 5. For an ecological footprint on the basis of solar energy there are only technical and horizontal limits. A comparable ecological footprint then is 1/10. In both cases efficiency losses should be added caused by storage, conversion and transport, but these are equal for both within an all-electric society.

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[a] http://statline.cbs.nl/StatWeb/publication/default.aspx?DM=SLNL&PA=37281&D1=6-7%2c16-18%2c25&D2=1%2c4%2c7-10&D3=0-52%2c57%2c62%2c67%2c72%2c77%2c82%2c87%2c92%2c97%2cl&HDR=G2&STB=G1%2cT&VW=D

[b] TW$_e$ is the electrical part. To convert 1 PJ/year (10^{15} joule per year) as usual in CBS figures into MW (10^6 joule per second) one should multiply by 31,7 (amongst others dividing by the number of seconds per year: $10^{15}/(10^6*365*24*60*60)$).

Sun, wind or biomass?

The ecological footprint based on biomass depends on location-bound soil characteristics and efficiency losses for instance by conversion into electricity. A total efficiency of 1% applied in the comparance of *Fig. 27* is optimistic.[22]

			W/m^2
rounded off total Dutch energy use	100	GW	1.00
rounded off Dutch electricity use	10	GW	0.10
SUN			
The Nederlands receives	10000	GW	100
after reduction by 0.1	1000	GW	10
required surface	10%		
BIOMASS			
The Nederlands receives	10000	GW	100
after reduction by 0.01	100	GW	1
required surface	100%		
WIND			W/m2
over The Nederlands blows at least	680	GW	6.80
after reduction by 0.03	17	GW	0.17
required surface	577%		

Fig. 27 Comparing the yield of sun, biomass and wind

Costs

What are the costs? In *Fig. 28* for wind, sun and biomass the required surface is represented only. The environmental costs are not yet stable. Environmental costs of new technologies are in the beginning always higher than later on. For coal, uranium and heavy hydrogen the environmental costs are calculated, the required surface is negligible.[a]

	total		**per inh.**	
Current Dutch energy use	**96**	**GW**	**5993**	**W**
yielded by				
solar cells	10	x 1000 km2	0,06	ha
wind	564	x 1000 km2	3,53	ha
biomass	96	x 1000 km2	0,60	ha
surface of The Nederlands inclusive Continental Plat	100	x 1000 km2	0,63	ha
Actual use electric	**10**	**GW**	**652**	**W**
remaining heat	26	GW	1630	W
yielded by				
coal	20864	mln kg coal	1304	kg coal
waste	62592	mln kg CO2	3912	kg CO2
waste	835	mln kg SO2	52	kg SO2
waste	209	mln kg NOx	13	kg NOx
waste	1043	mln kg as	65	kg as
uranium	0.01	mln kg uranium	0,001	kg uranium
waste	3.45	mln kg radio-active	0,216	kg radio-active
heavy hydrogen (fusion)	0.01	mln kg h.hydrogen	0,001	kg h.hydrogen
waste	0.01	mln kg helium	0,001	kg helium

Fig. 28 Environmental costs of energy use

The environmental costs of oil and gas are less than those of coal, but concerning CO_2-production comparable: the total production is approximately 30kg per person per day! That makes clear we have to avoid the use of fossile fuels.

The contribution of alternative sources

The contribution of non fossile fuels is increased substantially (*Fig. 29*), but it is not yet 1 from the yearly used 100 GW. The growth of 0,5% into 0,8% is mainly due to the use of waste including biomass unused otherwise.

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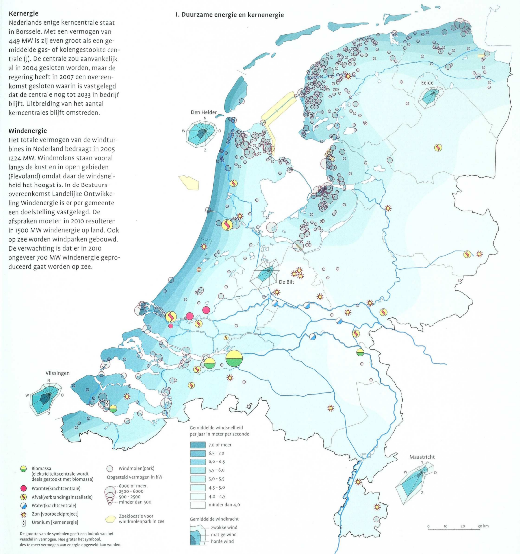
[a] Jong, Moens et al. (1996)



Kernergie

Nederlands enige kerncentrale staat in Borssele. Met een vermogen van 449 MW is zij even groot als een gemiddelde gas- of kolengestookte centrale (J). De centrale zou aanvankelijk al in 2004 gesloten worden, maar de regering heeft in 2007 een overeenkomst gesloten waarin is vastgelegd dat de centrale nog tot 2033 in bedrijf blijft. Uitbreiding van het aantal kerncentrales blijft omstreden.

Windenergie

Het totale vermogen van de windturbines in Nederland bedraagt in 2005 1224 MW. Windmolens staan vooral langs de kust en in open gebieden (Flevoland) omdat daar de windsnelheid het hoogst is. In de Bestuursovereenkomst Landelijke Ontwikkeling Windenergie is er per gemeente een doelstelling vastgelegd. De afspraken moeten in 2010 resulteren in 1500 MW windenergie op land. Ook op zee worden windparken gebouwd. De verwachting is dat er in 2010 ongeveer 700 MW windenergie geproduceerd gaat worden op zee.

De grootte van de symbolen geeft een indruk van het verschil in vermogen. Hoe groter het symbool, des te meer vermogen aan energie opgewekt kan worden.

Fig. 29 Sustainable energy sources and nuclear power in the Netherlands 2007[a]

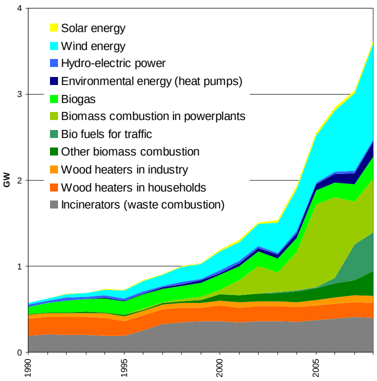


Fig. 30 GW sustainable energy sources between 1990 en 2008[a]

The growth of the contribution of wind, heat pumps and sun (*Fig. 30*) is impressive on itself, but responsible for approximately 0.1% of total energy use.

Stagnating decrease of solar cell costs

Why does solar energy develop so slowly while so much energy can be gained? Solar cells are 100 times as cheap as 40 years ago. The stagnating decrease in price of *Fig. 14* would be due to increasing silicium prices and efficiency improvements in peripheral equipment. Just before passing the economic efficiency of fossile fuels these barriers loom up. The oil industry has collected solar patents and studies that question, in the mean time developing the technology to exploit the still large stocks in oil sands (an ecological disaster). Scenarios still depart from a small contribution of solar energy in 2030. The development of the steam engine lasted 40 years. Are the technological barriers now larger? Any way, the consequences are larger than those of the industrial revolution. Many people will loose their jobs or investments, but use of energy, depletion of resources and mobility would no longer be environmental problems. Only basic ecological problems remain: from the 1.5 mln known species 100 000 are lost, 80% of the human population is not healthy.

Power supply

The capacity of electric power stations in The Netherlands is approximately 15 GW_e (15 000 MW_e), from which at average 10 GW_e is used (the rest is necessary to receive peak loads). These plants produce in the same time approximately 15 GW_{th}. From that heat only a part is used by cogeneration.[b] Electric power stations can not be switched off immediately. Temporary overproduction is sold cheaper at night or into foreign countries (for example to pump up water in storage reservoirs). Approximately 2% is generated by nuclear power, 1% sustainable, the rest by fossile fuels (see *Fig. 24*).

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[a] Bosatlas(2007)Bosatlas van Nederland(Groningen)Wolters-Noordhoff

[b] http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=7516&D1=0&D2=0-2,5,14-15,26-30,34,37,42&D3=a&HDR=G2,T&STB=G1&VW=T

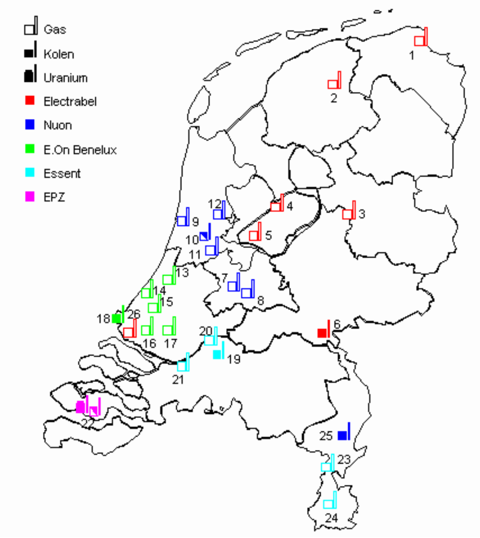

Fig. 31 Power stations in The Netherlands[a]

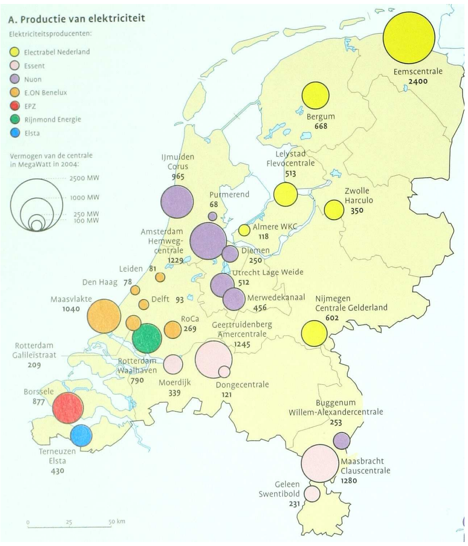

Fig. 32 MW capacity per power station of Fig. 31[b]

The use of electricity takes up only a small part of our total consumption of primary energy sources. The Dutch energy balance as a whole is represented in the flow diagram[c] of *Fig. 33*.

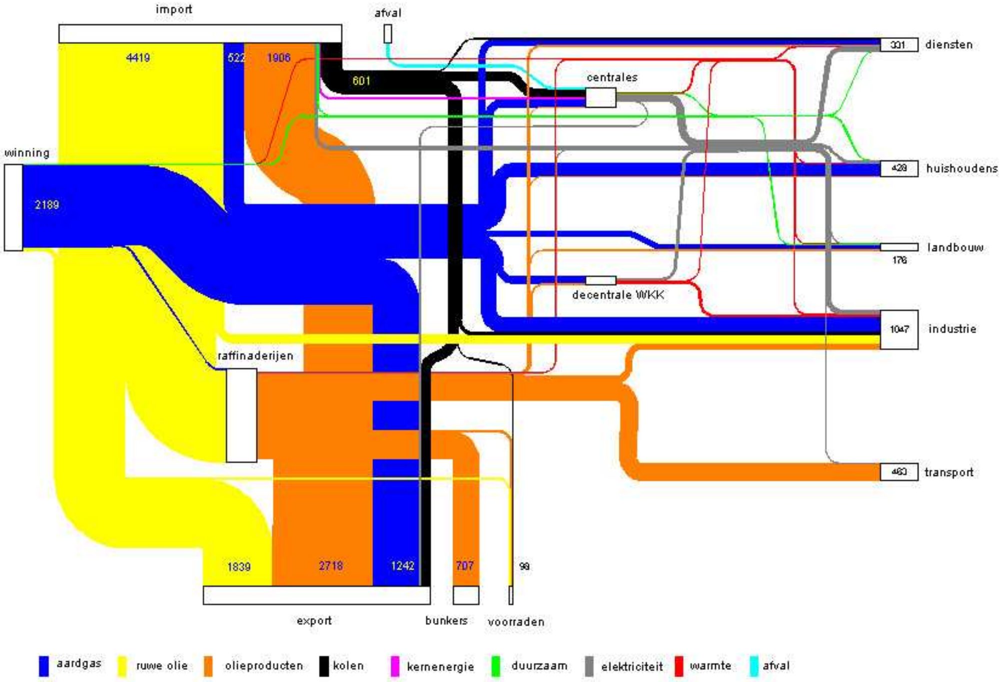

Fig. 33 Energy flows through The Netherlands, 2000 (x PJ equalling 31.7 MWa)[d]

Comment [T.M.1]: Pagina: 29
Op basis van de energiestatistieken van het CBS voor 2000 is dit Sankey diagram gemaakt, dat de herkomst en bestemming van energiestromen in Nederland aangeeft. De verschillende energiedragers (aardgas, ruwe olie, olieproducten, kolen, kernenergie, duurzaam, elektriciteit, warmte en afval) zijn alle in PJ's, maar in verschillende kleuren weergegeven. Herkomst van energiedragers is winning dan wel import, of een conversie vanuit andere energiedragers (raffinaderijen, elektriciteitscentrales en WKK). Energieverliezen bij conversie zijn ook in het Sankey diagram verwerkt. Dat is vooral goed te zien bij elektriciteitscentrales: de ingaande stroom gas, kolen, kernergie en afval is groter dan de uitgaande stroom elektriciteit. Bestemming van energiedragers is export of het verbruikssaldo van één van de eindverbruikerssectoren (diensten, huishoudens, landbouw, industrie of transport). De dikte van de lijnen wordt bepaald door de omvang van de energiestromen. Hiermee is in één oogopslag te zien wat de onderliggende verhoudingen zijn. Opvallend is de omvangrijke doorvoer van olie en olieproducten. Ook is het belang van de raffinaderijensector in Nederland te zien. De daar geproduceerde olieproducten worden slechts beperkt in eigen land gebruikt, ze zijn vooral voor de export bestemd. In het binnenlands verbruik speelt aardgas een belangrijke rol.

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[a] http://www.energie.nl/
[b] Bosatlas(2007)Bosatlas van Nederland(Groningen)Wolters-Noordhoff
[c] http://www.sdraw.com/
[d] http://www.energie.nl/

A summary like *Fig. 33* is made every year[a]. Adding "winning" (extraction) and import while subtracting export, "bunkers" (stocks) and "verliezen en verschillen" (losses and differences), one has left "verbruikerssaldo" (balance of use). Subtracting from that balance of use what power companies need themselves, one has left the quantity customers can use. Losses on the way to the customer have to be subtracted to find what really lands to the customer, the 'finaal gebruik' (final use).[23]

Energy slaves

Calculating back these figures per inhabitant, expressing them into the individual human power during a year (100 Wa), one gets a figure like the number of 'energy slaves' people have to their disposal. The balance of use comes down to about 60 energy slaves per Dutch (wo)man. Power companies need 11 of them to produce the rest. So, 46 remain for final use. From these 46 energy slaves industry takes 19, transport 8 and 19 are needed for offices and dwellings. From these 19 natural gas delivers 13, oil 3 and electricity 3 as well.

In 1982 the average inhabitant had 11 energy slaves in his own home, 10 of them needed for heating. At that time there were 2.8 inhabitants per dwelling. So, at average approximately 3000 m3 natural gas per year was needed for heating a house.

1.1.6 Local energy storage

The importance of storage for alternative sources

Sustainable energy sources fluctuate per season or per 24 hour. That is why their supply does not stay in line with demand. Therefore, energy storage is of overriding importance for succes of these sources, but also for mobile applications like cars.[24]

Different kinds of storage

In *Fig. 34* some kinds of storage are summed up with their use of space and efficiency. If you lift up 1000 kg water (1m^3) 1 meter against Earth's gravity (9.81 m/sec^2), you need 1000 kgf or 9810 newton during 1 m and 9810 newton·meter is 9810 joule or 0.0003109 watt during a year (Wa, see *Fig. 2*, page 12). Now you have got potential energy you can partly gain back as electricity any time you want by letting the water flow down via a water turbine and a dynamo. The efficiency is approximately 30%. So, you can gain back maximally some 0.000095 Wa/m^3 electricity. If you have a basin of 1km^2 where you can change the waterlevel 1m you can deliver 95 W_e[b] during a year, 190 W_e during half a year or 34722 W_e (0.00003472 GW_e) during a day. To deliver 1 GW_e you need 1/ 0.00003472 km^2 = 28800 km^2 (see *Fig. 34*). That is nearly three-quarter of the Netherlands! A larger fall (of 10m for example) improves both storage and efficiency of the turbine by increased speed of falling water.

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[a] See *http://statline.cbs.nl/StatWeb/start.asp?LA=nl&lp=Search/Search*

[b] 1 GW_e means "1 000 000 000 watt electric", the heat part is lost in efficiency reduction.

	Storage[25]	Efficiency		Surface for 1 GW_e during	
	gross	(max.)	net	24 hours	half a year
	Wa/m3	%	Wa/m3	km^2	km^2
Potential energy					
water (fall = 1 m)	0,0003	x30%	=0,0001	28800	5259600
water (fall = 10 m)	0,003	x75%	=0,002	1152	210384
water (100 m)	0,03	x90%	=0,03	96	17532
50 atm. pressed air	1,3	x50%	=0,6	4	789
Kinetic energy					
fly weel	32	x85%	=26,9	0,10	18,56
Chemical energy					
natural gas	1	x80%	=0,8	3,42	625,00
lead battery	8	x80%	=6,3	0,43	78,89
hydrogen (liquid)	274	x40%	=109,5	0,03	4,57
petrol	1109	x40%	=443,6	0,01	1,13
Heat					
water (70°C)	6	x40%	=2,5	1,08	197,24
rock (500°C)	32	x40%	=12,7	0,22	39,45
rock salts(850°C)	95	x40%	=38,0	0,07	13,15

Fig. 34 Storage capacity (for conversion into electricity) from some systems[a]

Land use

From the row '50 atm. pressed air' on, the last column of *Fig. 34* simply departs from a surface with a built height of 1m needed to deliver 1 GWe (1 000 MWe) during 24 hours or half a year continuously. By doubling the height of course you can halve the needed surface. Space for turbines and dynamos is not yet included. Fossile fuel like petrol still stores energy most efficiently.

However, in normal storage circumstances this surface is estimated too large for two reasons. Firstly energy production by some differentiation of sources never falls out completely. So you can partly avoid storage. Secondly, the average time difference between production and consumption is smaller than half a year or 24 hours. So, you need a smaller capacity. However, you have to tune the capacity to peak loads and calculate a margin dependent on the risks of non-delivery you want to take. These impacts can be calculated as separate reductions of the required storage

The actual Dutch energy use amounts nearly 100 GW, partly converted into electricity. So, you do not need 100x the given surface per GW to cover this use from stock. After all, in the total figure losses of conversion from fuel into electricity are already calculated in, and these are calculated in *Fig. 34* as well.

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[a] After Lysen (1980) and Hermans and Hoff (1982)

1.2 Sun, light and shadow

1.2.1 Looking from the universe (α, β and latitude λ)

The different axes of the Earth's rotation and orbit α=23,46^o

The earth orbits around the sun in 365.25 days[a] at a distance of 147 to 152 million km. The radius of the earth is only maximally 6 378 km. So, the sunlight reaches any spot on earth by practically parallel rays. The surface covering that practically circular orbit is called the ecliptic surface. The polar axis of the Earth has always an angle α = 23,46^o with any perpendicular on that ecliptic surface.

The angle β between polar axis and sunrays varies around 90^o at average

On December 22nd (Fig. 35) the angle β between polar axis and the line from Sun into Earth within the ecliptic surface equals 90^o + α. On March 21st β = 90^o, on June 21st β = 90^o - α and on September 23rd again β = 90^o. Arrows a in Fig. 35 show the only latitudes where sunrays hit the Earth's surface perpendicular at December 22nd and June 21st. So, the sunlight reaches the earth perpendicular only between plus or minus 23,46^o latitude from the equator (tropics). Anywhere else they hit the Earth's surface slanting. At December 22nd the sunlight (sunray b in Fig. 35) does not even reach the northpole inside the arctic circle at 90^o – 23,46^o = 66, 54^o latitude (arctic night).

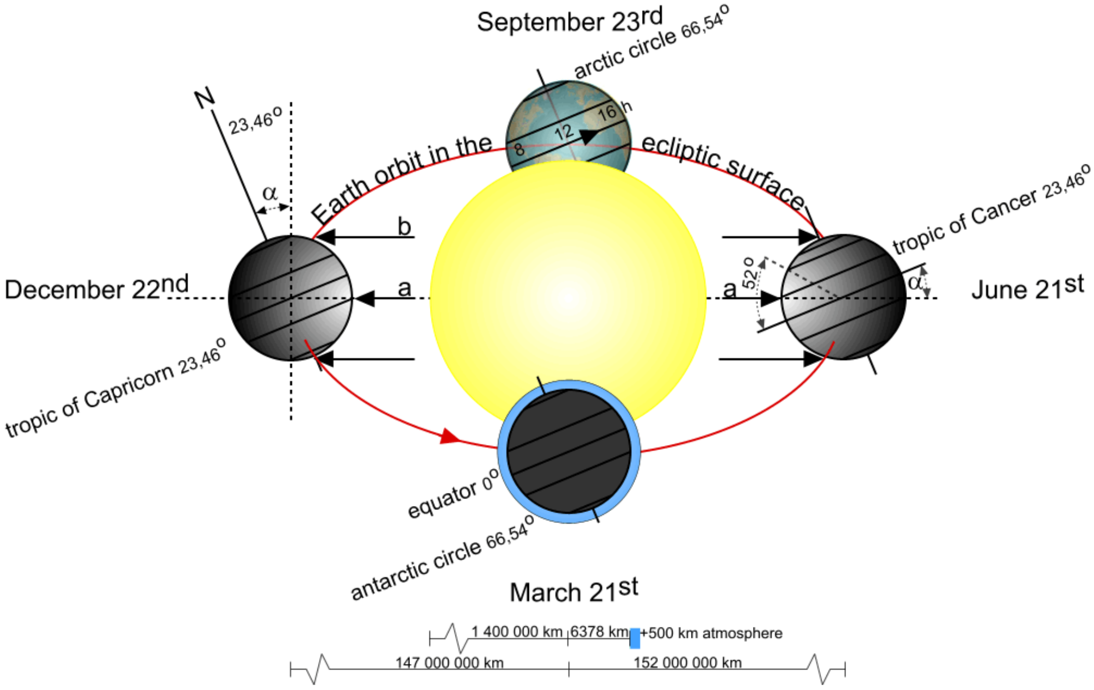

Fig. 35 *The orbit of the earth around the sun*

Sunlight reaching the earth's surface

The sunlight reaching the earth's atmosphere has a capacity of 1353 W/m^2 (solar constant). Some 500 km atmosphere reduces it by approximately 50%. So, any m^2 of sunrays reaching the surface of the Earth distributes say 677 W over its slanting projection on the earth's surface. Let us restrict ourselves

---

[a] These days are 'sun-days'. However, the Earth turns around its axis in 23 hours, 56 minutes and 4 seconds ('star days'). Related to the sun that period is completed into 24 hours by travelling around the sun approximately 1^o per day. So, if we look at distant stars they turn around us in 366.25 days ('star-year'). That is slower than the sun. That is why we see the sun and its other planets travelling against the background of distant stars passing the same 12 constellations in the ecliptic surface called Zodiac in a year: Ram, Bull, Twins, Crab, Lion, Virgin, Scales, Scorpion, Archer, Sea-goat, Water-bearer, Fishes.

in the next section to the two moments per year the sunrays are perpendicular to the Earth's axis of rotation ($\beta = 90^o$ on March 21st and on September 23rd).

Culmination γ, the maximum angle of sunrays to the local Earth's SN surface

In Fig. 36 (left) the solar capacity of $1m^2$ (677W) is distributed that way over the larger surface SN (South-North). That $1\ m^2$ capacity, divided by hypotenuse surface SN, equals $\sin(\gamma) = \cos(\lambda)$.
So, $1m^2$ Earth's surface in P (maximally turned to the Sun at solar noon) receives $\cos(\lambda)$ x 677W.

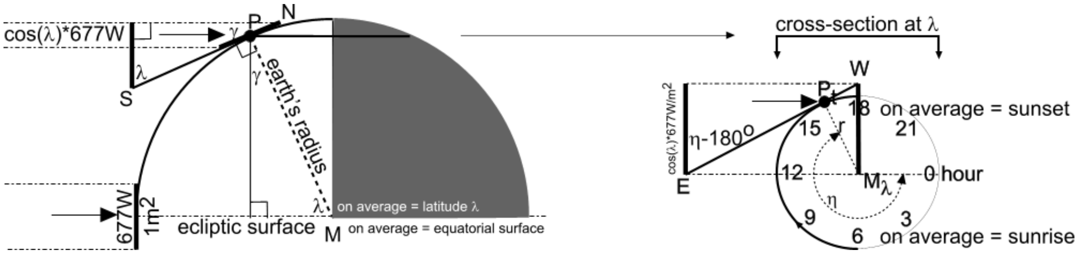

Fig. 36 *The maximally received solar capacity at latitude λ;daily fluctuations with the hour angle η.*

Hour angle η reducing solar capacity turning away from noon

However, by rotation of the Earth noon-point P travels around our latitude in 24 hours. At any other point of the cross-section the maximum capacity $\cos(\lambda)$ x 677W at noon is reduced again by turning away from the sun (see Fig. 36 right). At solar midnight our location is turned away as much as possible from the sun (hour angle $\eta = 0^o$). At noon our location is exposed to the sun as much as possible (hour angle $\eta = 180^o$). So, at 6 o'clock solar time the hour angle is 90^o, at 18 o'clock 270^o. Between these hours the maximum capacity $\cos(\lambda)$ x 677W at noon is reduced again by $\cos(\eta\text{-}180)$ according to the hour of the day.

The average solar capacity given latitude λ

The University of Technology in Delft is positioned around 52^o latitude, a global parallel crossing the building for Electrotechnical and Civil Engineering on its campus. The cosine of 52^o is 0.616. So, there the year average solar capacity *at noon* is 417 W per square meter earth surface. Averaged again per 24 hours it is $417/\pi = 133$ W (not concerning Dutch weather conditions). This value is reached only as daily average on March 21st or September 23rd. At other dates it varies symmetrically around that average.

Average sunlight per day

On March 21st or September 23rd it happens 24 hours on the whole latitude λ circle because these days polar axis is perpendicular to the sunrays. That circle with radius r of latitude λ ('parallel'), seen from the Sun is a straight line with **2r** length. On both days the Sun continuously delivers $\cos(\lambda)\cdot 677$W distributed over any m^2 of that line. In 24 hours that capacity is distributed over a larger circular surface length **2πr** of the whole latitude circle. So, the 24hour average is that capacity divided by π. We do not yet have to calculate more cosinuses for every hour (Fig. 36 right) to conclude that 24hour average. And March 21st or September 23rd offer useful averages for the whole year as well.

1.2.2 Looking from the Sun (declination δ)

The day period between sunrise and sunset varies and throughout the year the sunlight reaches the earth's surface at noon by a varying maximum angle γ ('culmination' related to the Earth' surface, not to be confused by declination δ related to its polar axis, see Fig. 38). After all, seen from the sun the earth nods 'yes' (Fig. 37). Bending to left and right does not matter for locally received sunrays.

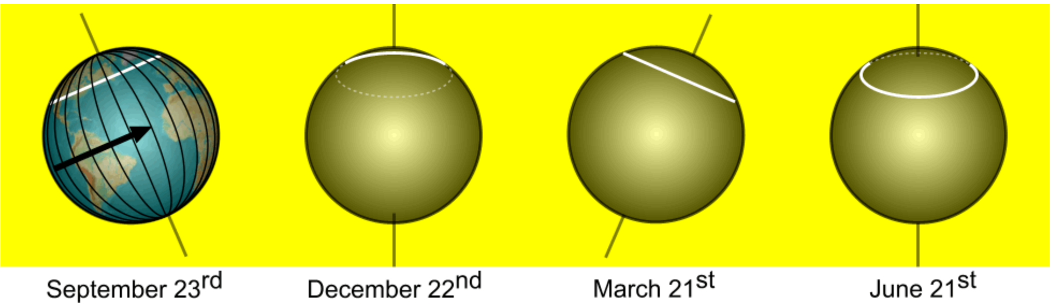

Fig. 37 *The yearly nodding earth with a parallel λ=52^o seen from the sun*

December 22nd the earth is maximally canted $\alpha = 23.46^o$ backwards related to the sunrays. At noon we receive: $677 \cdot \cos(52^o \mathbf{+ \alpha}) = 170$ W/m^2. Canting forward on June 21st we have to subtract α: $677 \cdot \cos(52^o \mathbf{- \alpha}) = 595$ W/m^2. Inbetween we need a variable 'declination' $\{\delta \mid +23.46^o \leq \delta \leq -23.46^o\}$ instead of α. In Fig. 38 declination δ is positive in June, so now we can write $677 \cdot \cos(\lambda - \delta)$ W/m^2 for any day at noon at any latitude. From Fig. 38 we can derive visually: $\gamma + \lambda - \delta = 90^o$ or $\lambda - \delta = 90^o - \gamma$.

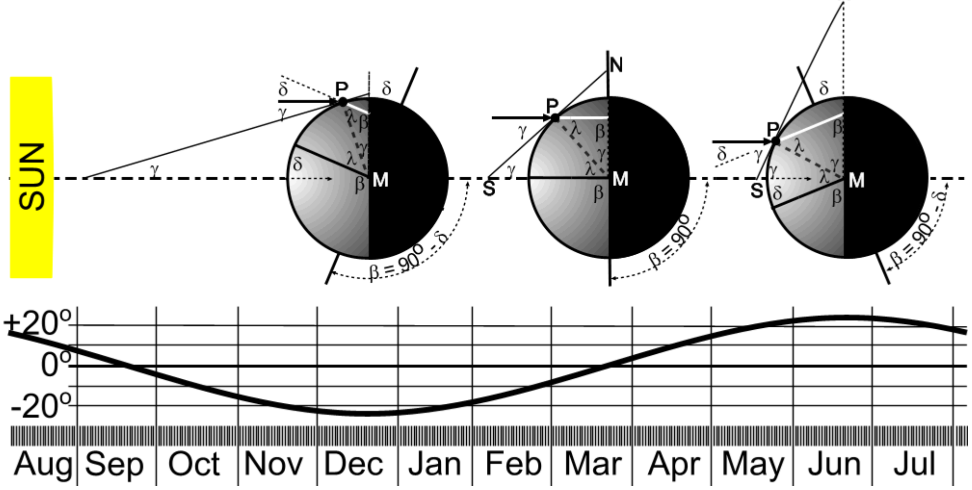

Fig. 38 *Declination δ*

Declination δ could be read from Fig. 38 or calculated according to Voorden (1979) by $\delta = 23.44 \sin(360^o \times (284 + \text{Day}) / 365)$. As 'Day' we fill in the number of days from January 1st, for instance:

Mar21 = 31 + 28.25 + 21 = 80.25
Jun21 = 31 + 28.25 + 31 + 30 + 31 + 21 = 172.25
Sep21 = 31 + 28.25 + 31 + 30 + 31 + 30 + 31 + 31 + 21 = 264.25
Dec22 = 31 + 28.25 + 31 + 30 + 31 + 30 + 31 + 31 + 21 + 31 + 30 + 22 = 356.25

1.2.3 Looking back from Earth (azimuth and sunheight)

The turning earth

But how is that capacity distributed per hour? The earth turns 360^o in 24 hours ousting the Old World by the New Word all the time. That is 15^o per hour, drawn in Fig. 37 (left) by 12 visible meridians of 15^o.

The distribution on a constant latitude λ is not only affected by a declination δ varying day by day but also by the hour angle η visibly varying every minute. From Fig. 39 we derive the hour angle of sunset and sunrise: $\cos(\eta_{sunset}) = h \times \cot(\beta)/r \times \cos(\lambda)$, while $h = r \cdot \sin(\lambda)$.

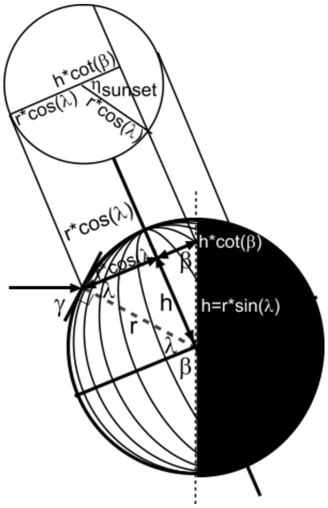

Fig. 39 *Sunset and sunheight at noon varying with β and hour angle η on one parallel circle.*

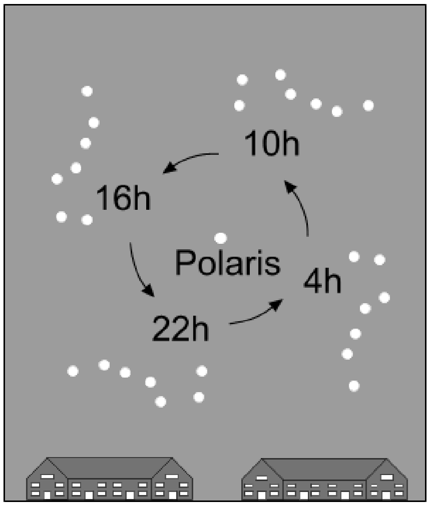

Fig. 40 *Looking back to the universe in the Autumn.*

Within that formula, r plays no rôle and $\cot(\beta) = \tan(90^o - \beta) = \tan(\delta)$, see Fig. 38.
So, we can write:

$$\text{sunrise} = \text{acos}(\sin(\lambda) \times \tan(\delta) / \cos(\lambda)) / 15^o \text{ and sunset} = 24 \text{ hour - sunrise.}$$

The turning sky

Now we can move our field of vision down to earth looking back to the universe as Copernicus saw it, reconstructing the preceding model from what he saw. Then we see any star moving daily in perfect circles around, the Pole Star (Polaris) practically standing still. So, we see the Great Bear and some 'circumpolar' constellations througout the year turning around Polaris (Fig. 40). Other constellations disappear daily behind the horizon, be it seasonly at an other moment of the day and therefore in some seasons by day not visible behind the brightness of the Sun. Polaris is a star 1600 times more powerful than the Sun, but on a distance of 300 light years. Occasionally it stands in our polar axis apparently standing still that way, moving too little (1 degree) to take into account.

The sun against the background of stellar constellations

The Sun makes its daily circles shifting approximately 1 degree per day (the year circle of 360^o is called eclipse) against a more stable remote background of 12 constellations (the Zodiac[a]), according to its yearly wave seen by a nodding Earth.

Turning ourselves 360^o we see a lamp on our desk describing a circle around us as well. Bowing our head backward 23.46^o while turning around we see the lamp low in our field of vision. When we stay turning around and in the same time walk around the lamp keeping our head in the same polar direction (slowly nodding forward until we are half way and than again backward) we experience how

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[a] Aries (The Ram), Taurus (The Bull), Gemini (The Twins), Cancer (The Crab), Leo (The Lion), Virgo (The Virgin), Libra (The Scales), Scorpius (The Scorpion), Sagittarius (The Archer), Capricornus (The Sea-goat), Aquarius (The Water-bearer), Pisces (The Fishes).

we see the sun during the year starting from December 22st. When we had a third eye in our mouth we would have a complementary view from the southern hemisphere as well.

Sun bows in a sky dome

Such circles we can draw as sun bows in a sky dome using β as deviation from the polar axis (Fig. 41).

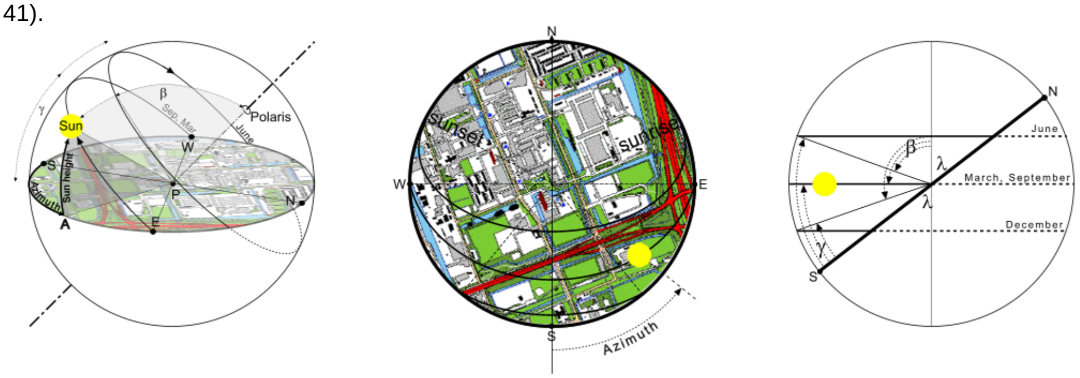
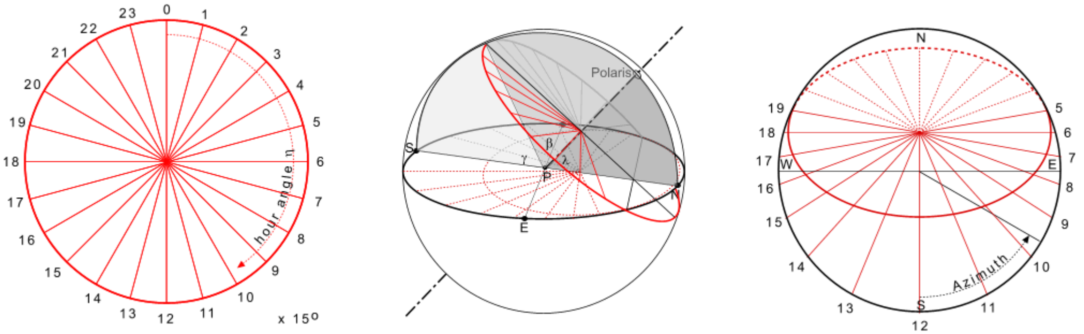


Fig. 41 *Sun bows 3D in a sky dome, map and cross section.*

Projecting the sun bow on the earth's surface

The circular parallel sun bow divided in hours has to be projected as an ellipse on the Earth's surface (see Fig. 42). The hours in the Azimuth angle then decrease in the direction of sunrise and sunset.

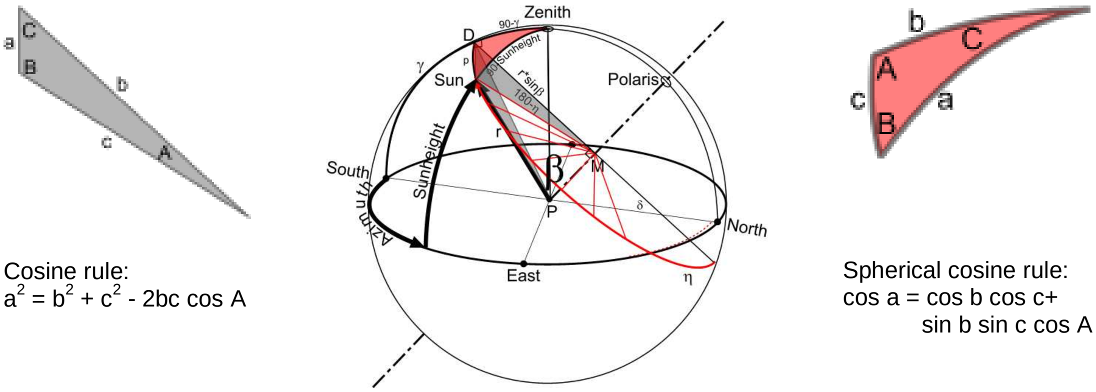


The hour angle η in the parallel surface projected on the Earth's surface.

Fig. 42 *The hour angle transformed into Azimuth.*

Some formulas

To transform the hours of the parallel surface into hours on the Earth's surface we can observe two triangles perpendicular to the surface SouthZenithNorth (see Fig. 43) the first with two equal sides SunM and MD (r sin β), the second with two equal sides SunP and PD (r) as well, and a common third side. The first triangle has an angle SunMD=180^o-η. So, we can use the cosine rule two times to calculate the square of the third side SunD in both triangles and angle SunPD = arc p. Spherical cosine rules applied on the spherical triangle SunZenithD produce Sunheight and Azimuth as angles.



Cosine rule:
$a^2 = b^2 + c^2 - 2bc \cos A$

Spherical cosine rule:
$\cos a = \cos b \cos c + \sin b \sin c \cos A$

Fig. 43 *Two isosceles triangles and a spherical one*

However, Voorden (1979) in his Appendix A and C (see Enclosure 2) derives by more difficult transformation rules the usual and easier formulas:

Declination = 23.44^o x sin(360^o x (284+Day)/365))

Sunheight=
asin(sin(Latitude) sin(Declination(Day)) – cos(Latitude) cos(Declination(Day) cos(Hour x 15^o)

Azimuth= asin(cos(Declination(Day) sin(Hour x 15^o))/cos(Sunheight(Latitude, Day, Hour))

1.2.4 Appointments about time on Earth

On a meridian 1° East of us (68 km on our latitude) local solar time is already 4 minutes later. If we used the solar time of our own location we could only make appointments with persons living on the same meridian. So, we agreed to make zones East from Greenwich of ± 7.5° around multiples of 15° (1026 km on our latitude), using the solar time of that meridian. However, between the weekends closest to April 1st an November 1st we save daylight in the evening by using summertime. By adding an hour around April 1st in the summer, 21.00h seems 22.00h on our watch and it is unexpectedly light in the evening. So, to find the solar time from our watch we have to subtract one hour in the summer and the number of degrees of longitude x 4 minutes West of the agreed meridian. In the Netherlands we use the solar time of 15° East of Greenwich (time zone 1), but live between 3° and 8°.

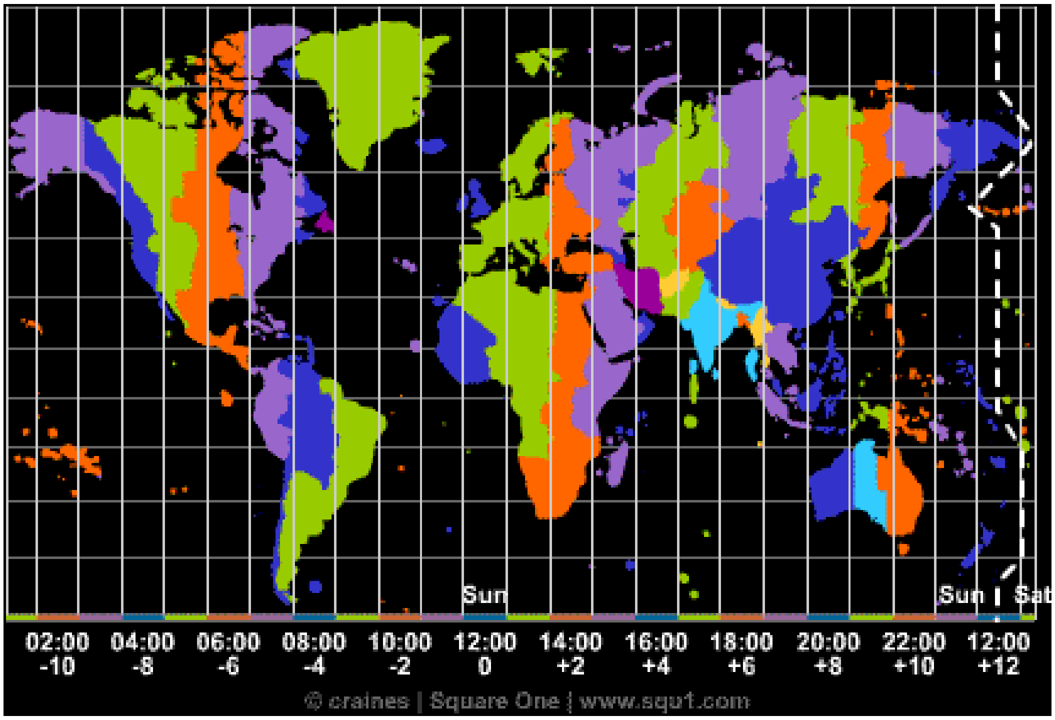


Fig. 44 Time zones[a]

So, on the Faculty of Architecture in Delft (4° 22.5' easter longitude = 4.38°) in winter we have to subtract 15 x 4 minutes from our watch time and add 4.38 x 4 minutes (-10.62° x 4 minutes = -48.48 minutes) to find an approximate solar time. In summertime we have to subtract an extra hour.

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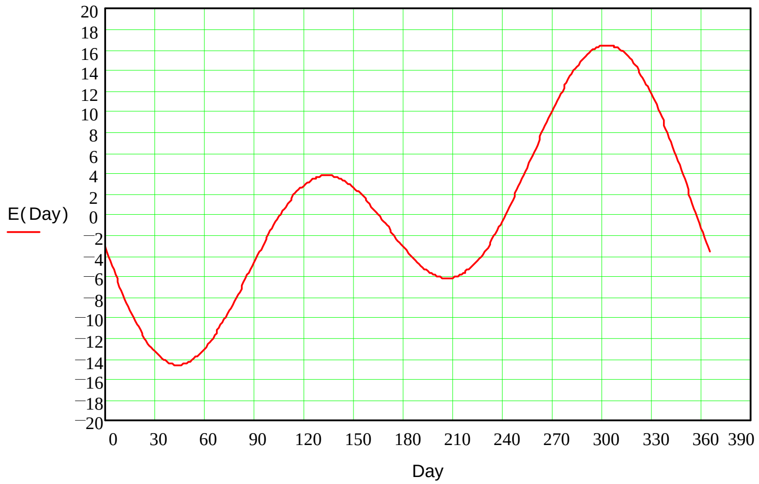
[a] http://www.squ1.com

Slowing down traveling around the sun

In addition to these corrections we have to add or subtract some minutes (time equalization E) amongst others due to differences in travel speed (29.3 km/s in summer, 30.3 km/s in winter) around the Sun according to *Fig. 45*.



$$\mathrm{Day} := 0..365$$

$$E(\mathrm{Day}) := 9.87\cdot\sin\left[\frac{4\cdot\pi}{364}\cdot(\mathrm{Day}-81)\right] - 7.53\cdot\cos\left[\frac{2\cdot\pi}{364}\cdot(\mathrm{Day}-81)\right] - 1.5\cdot\sin\left[\frac{2\cdot\pi}{364}\cdot(\mathrm{Day}-81)\right]$$

Fig. 45 Time equalization per day of the year

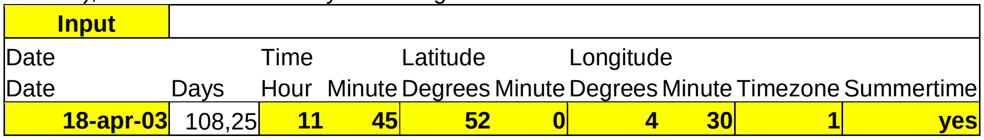
So, instead of the Hour we read on our watch (WHour with minutes decimally added) in the formulas for Sunheight and Azimuth we should fill in Sun Hour (SHour) from:

SHour(WHour,Timezone,Longitude,Summertime,Day) = WHour - Timezone + Longitude/15^o – Summertime + E(Day)/60

As Timezone we fill in 1, 2, 3 and so on with a maximum of 23. As Summertime we fill in daylight saving yes=1, no=0 and E(Day) we read or calculate from *Fig. 45*.
Finally, atmospheric refraction of 34’ and sun radius of 16’ (together nearly 1^o) shows us sunrise nearly 4 minutes earlier and sunset 4 minutes later, but by day this effect approaches to zero at noon.

1.2.5 Calculating sunlight periods

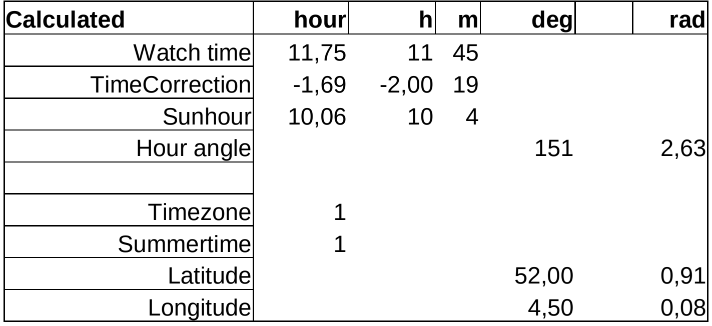
Putting the formulas we found in an Excel Sheet (download *http://team.bk.tudelft.nl*, publications 2007 Sun.xls), we can check them by observing shadows.



Input									
Date		Time		Latitude		Longitude			
Date	Days	Hour	Minute	Degrees	Minute	Degrees	Minute	Timezone	Summertime
18-apr-03	108,25	**11**	**45**	**52**	**0**	**4**	**30**	**1**	**yes**

Fig. 46 Data needed for solar calcuations

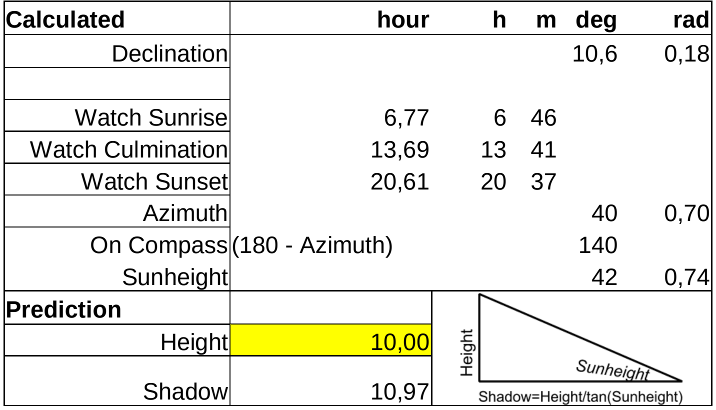
We need date, time, geographical coordinates, the time zone and wether or not we have to take summer time into account. The Sheet brings them into a decimal form and adds a time correction to calculate the hour angle in radians. Excel needs radians to calculate sine, cosine and tangent.



Calculated	**hour**	**h**	**m**	**deg**		**rad**
Watch time	11,75	11	45			
TimeCorrection	-1,69	-2,00	19			
Sunhour	10,06	10	4			
Hour angle				151		2,63
Timezone	1					
Summertime	1					
Latitude				52,00		0,91
Longitude				4,50		0,08

Fig. 47 Restating data in dimensions needed

The sheet then calculates the declination of the day and at what time on our watch we can expect sunrise, culmination and sunset neglecting atmospheric influence from –4 to + 4 minutes. Finally the sheet calculates Azimuth and Sunheight. Azimuth is calculated from South, but a compass gives the number of degrees from North (180 – Azimuth).



Calculated	**hour**	**h**	**m**	**deg**	**rad**
Declination				10,6	0,18
Watch Sunrise	6,77	6	46		
Watch Culmination	13,69	13	41		
Watch Sunset	20,61	20	37		
Azimuth				40	0,70
On Compass	(180 - Azimuth)			140	
Sunheight				42	0,74
Prediction					
Height	10,00				
Shadow	10,97				

Fig. 48 Solar calculations

The height of an object on the Earth's surface given, the sheet calculates the length of its shadow.

Measuring sunheight

Now we can check these results by putting a pencil in the sun. Measure its height, the length of its shadow and Azimuth as the angle of its shadow with a North-South line (using a map or reliable compass, not disrupted by iron in the neighbourhood!) (*Fig. 49*).

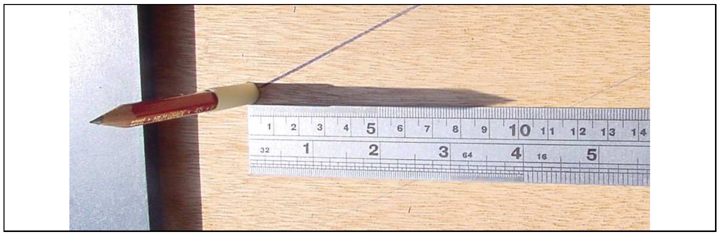


Fig. 49 Fast indoor check of shadow.

Outdoors you can measure angles copying, folding and cutting the paper instrument of *Fig. 50* to get the sunheight and the height of buildings. To measure height of buildings you need a mirror or mirroring piece of glass. Measuring Azimuth you need a compass or map as well.

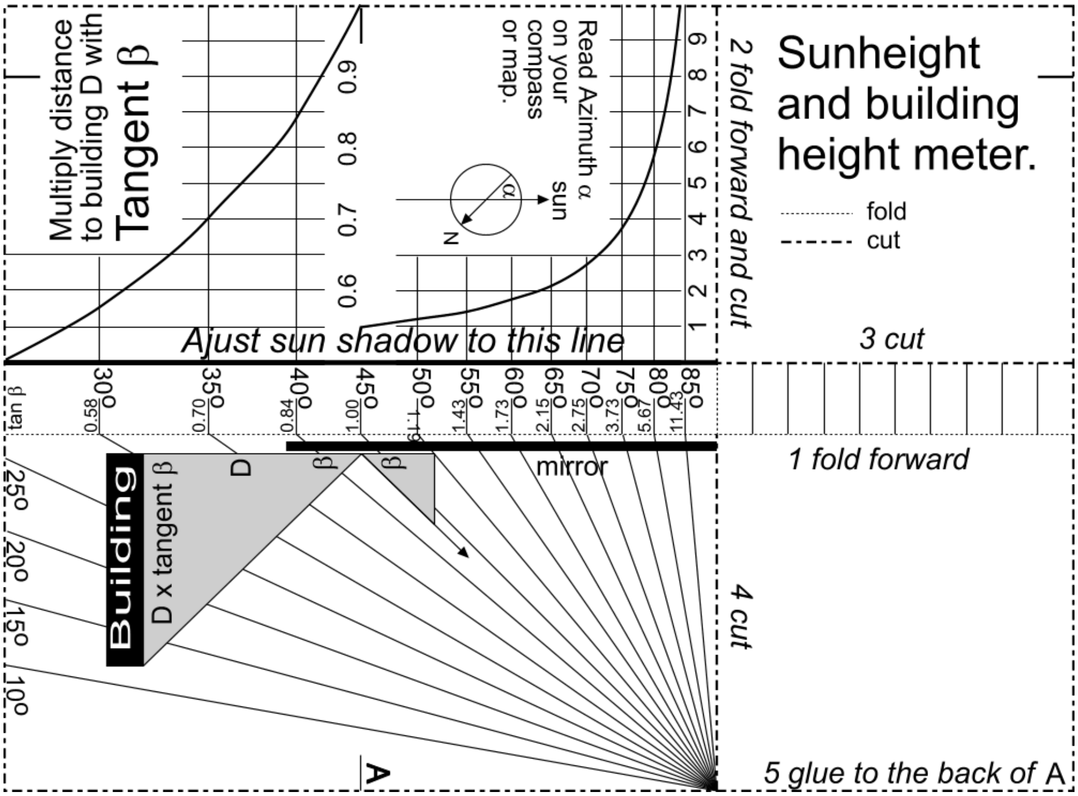


Fig. 50 Cut and fold this paper instrument

Using the paper instrument

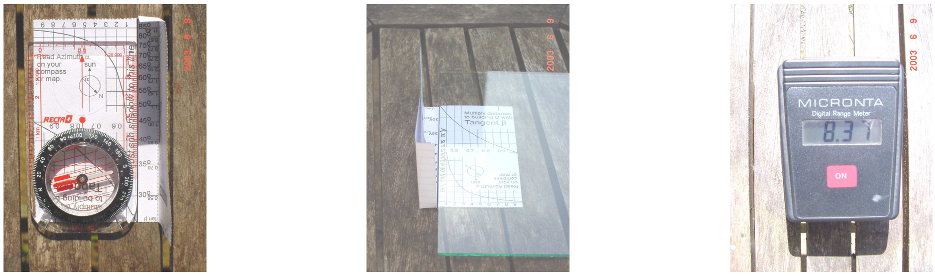


Fig. 51 Measuring Azimuth, sunheight and building height outdoors

Fig. 51 shows a compass directed to the sun by adjustment to the shadow line of a vertical object. It indicates 106^{o} from North, which is 74^{o} from South (azimuth). Sunheight appears to be 39^{o} on the paper instrument. Turning the instrument 180^{o} partly covered by a piece of glass we read an angle of 40^{o} (tangent 0.84) to the upper edge of the mirrored building. According to our distance meter that building is at 8.37m distance. However, when we measure it by tape measure it appears to be 10.30m, occasionally just like the shadow . So, we do not trust the electronic divice. It apparently has measured the tree closer by. The height of the building must be 10.30 x 0.84 = 8.65m above the table surface from which we took the measurement (35cm above ground level). So, the building should be 9m high. That could be right, because the building has 2 storeys (3 layers).

Check your measurement by calculation

Now we can fill in the measurements (Fig. 52) and check its prediction.

date	09-06-03	dd-mm-yy
Watch time	10.15	hour.minute
Building height	9	metres
Shadow	10.30	metres
Azimuth	74	degrees
Sun height	39	degrees

Building height and Shadow would indicate (calculated):

Azimuth	74	1.29
	degrees	radians
Sunheight	41	0.79

Fig. 52 Checking shadows[a]

The sun height may be measured a quarter earlier. Then it was calculated as 39^{o} indeed. The shadow was predicted to be 10.27m elsewhere in the sheet So, the measurement agrees with the calculation rather well.

1.2.6 Shadow

Around your house

Fig. 53 shows a plot division of 19 dwellings taking shadow into account (download *http://team.bk.tudelft.nl* publications 2003 standaardverkaveling.exe). All of them have the same plot area of 120m^{2}, but the Southern dwellings have narrow and deep plots to make front gardens possible and make the back gardens accessible for sunlight at some distance of the buiding. However, the Northern dwellings with South gardens have shorter and wider plots and parking lots instead of front gardens and public green. Eastern and western buiding blocks have no sun in the street in the morning or evening but at noon they have. But at the back they have a different character. Western

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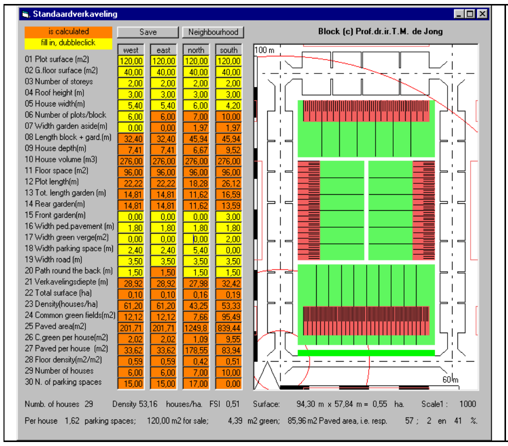
[a] sun.*xls*, downloadable from *http://team.bk.tudelft.nl/* > Publications 2008

blocks do have sun in the garden and living room in the morning, Eastern blocks in the evening. Having breakfast or dinner in the sun attract (or create) people with different life styles.



	west	east	north	south
01 Plot surface (m2)	120,00	120,00	120,00	120,00
02 G.floor surface (m2)	40,00	40,00	40,00	40,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,40	5,40	6,00	4,20
06 Number of plots/block	6,00	6,00	7,00	10,00
07 Width garden aside(m)	0,00	0,00	1,97	1,97
08 Length block + gard.(m)	32,40	32,40	45,94	45,94
09 House depth(m)	7,41	7,41	6,67	9,52
10 House volume (m3)	276,00	276,00	276,00	276,00
11 Floor space (m2)	96,00	96,00	96,00	96,00
12 Plot length(m)	22,22	22,22	18,28	26,12
13 Tot. length garden (m)	14,81	14,81	11,62	16,59
14 Rear garden(m)	14,81	14,81	11,62	13,59
15 Front garden(m)	0,00	0,00	0,00	3,00
16 Width ped.pavement (m)	1,80	1,80	1,80	1,80
17 Width green verge(m2)	0,00	0,00	0,00	2,00
18 Width parking space (m)	2,40	2,40	5,40	0,00
19 Width road (m)	3,50	3,50	3,50	3,50
20 Path round the back (m)	1,50	1,50	1,50	1,50
21 Verkavelingsdiepte (m)	28,92	28,92	27,98	32,42
22 Total surface (ha)	0,10	0,10	0,16	0,19
23 Density(houses/ha)	61,20	61,20	43,25	53,33
24 Common green fields(m2)	12,12	12,12	7,66	95,49
25 Paved area(m2)	201,71	201,71	1249,8	839,44
26 C.green per house(m2)	2,02	2,02	1,09	9,55
27 Paved per house (m2)	33,62	33,62	178,55	83,94
28 Floor density(m2/m2)	0,59	0,59	0,42	0,51
29 Number of houses	6,00	6,00	7,00	10,00
30 N. of parking spaces	15,00	15,00	17,00	0,00

Numb. of houses 29 Density 53,16 houses/ha. FSI 0,51 Surface: 94,30 m x 57,84 m = 0,55 ha. Scale1 : 1000

Per house 1,62 parking spaces; 120,00 m2 for sale; 4,39 m2 green; 85,96 m2 Paved area, i.e. resp. 57 ; 2 en 41 %.

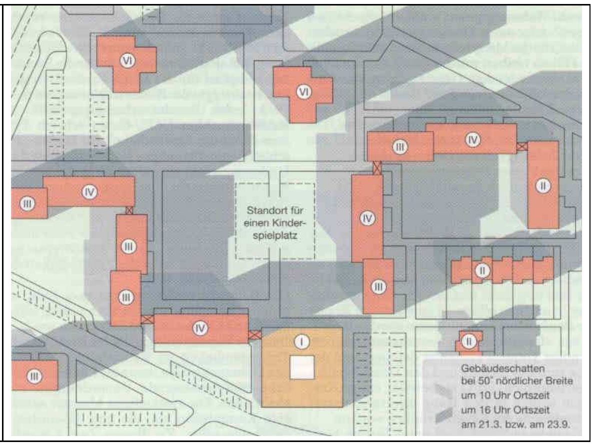


Fig. 53 Plot division taking shadow into account[a]

Fig. 54 Avoiding shadow by neigbours according to German regulations[b]

The value of dwellings can decrease when neigbours are not limited in building on their plots by regulation removing sun from other gardens. So, many urban plans regulate building on private plots.

In the garden

Fig. 55 shows the length of shadows on June 2nd from an object of 10m height for every hour. Try other dates.[c]

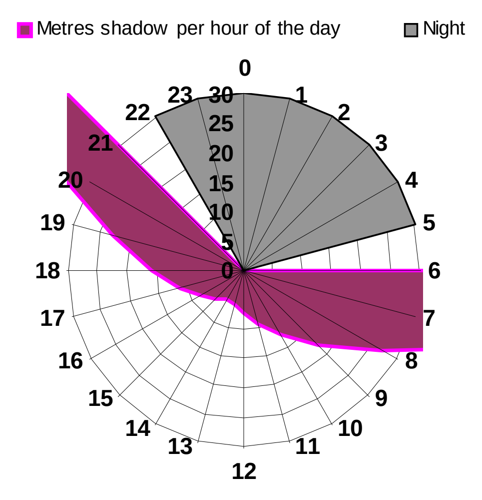


Fig. 55 *Shadows throughout the day June 2nd* [d]

Fig. 56 *A garden on June 2nd at 12 o'clock*

At noon - 13h40min. - shadows are smallest. Turning the figure with that point North we got some idea (not precise, see Fig. 42!) of the shadows to be expected throughout the day. The figure is symmetrical around that point and the centre. It does not seem so because the graph rounds off on full hours, sunrise is at 5h31min., sunset at 21h50min. and noon inbetween. So, we can put the figure on

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[a] Jong (2001)
[b] Hotzan (1994)
[c] Download sun.*xls*, from *http://team.bk.tudelft.nl/* > Publications 2008
[d] sun.*xls*, downloadable from *http://team.bk.tudelft.nl/* > Publications 2008

a map of same scale with that orientaton and shift it on a line with given height to get som idea of the shadow caused by a building block, a line of trees and so on. East~ and westward shadows are symmetrical.[26]

Diversity of life

From an urbanistic point of view shadow is important for climate and lightning of outdoor space, gardens and public spaces. Fig. 56 shows a South garden with two small trees at the southern border (above) throwing shadow. The Northern part has sunlight all day and ants clearly undermine the pavement there. There is a substantial damage on pavements by ants in towns. However, the continuously shadowed Southern part of the garden is more moisty and the pavement is filled by rough moss. At the Eastern and Western part of the circle inbetween the tiles (20x20cm) grass and flatter kinds of moss find their optimum.

North and South parts

In the sunny Northern side sun loving plants like grape (Fig. 57 left) find their optimum, in the Southern shadowed borders you find shadow loving plants like ferns (Fig. 57 middle).

grapes ferns cars

Fig. 57 *Full sun to grow grapes, filtered shadow for ferns and full shadow for parking cars*

On the other side of the building (Fig. 57 right) there is full shadow all day with high trees catching light in their crowns only and slow growing compact shrubby vegetation in a little front garden. Such fully shadowed spaces are suitable for parking lots. “Keep pavements in the shadow” may be a sound rule.

The roof of public space

Trees filter sunlight by small openings projecting images of the sun on the ground as Minnaert noted in the first article of his marvellous book in three volumes on physics of the open air. You can see it best when an eclipse of the sun is projected thousendfold on the ground (Fig. 58). Most solar images are connected to vague spots and sometimes the openings in the foliage are too large to get clear images. Leaves of a tree are composed differently into a so called leaf mozaic (Fig. 59).

Fig. 58 *Eclipse of the sun August 11th 1999*

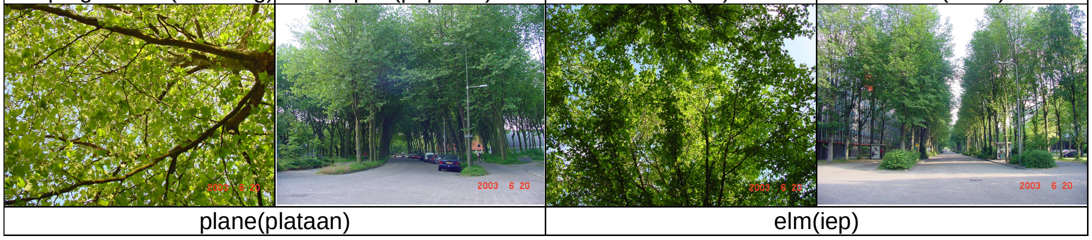
Fig. 59 *Leaf mozaic*

That roof of public space is worth more attention. People love the clairobscur of filtered light with local possibilities of choice for full sun and full shadow meeting their moods. It challenges their eyes more than one of the extremes continuously. Urban designers should be aware of the importance of light and its diversity in cities. None of them ever makes a shadow plan, though any painter knows that shadow makes the picture. The same goes for artificial city light in the evening and at night. Dry engineers calculate the minimum required amount of light for safety to disperse streetlamps as equally (economically) as possible over public space.

Fight for light

Nature’s diversity is primarily based on competition for light. Some plants grow as high as possible to outrun neighbours. Others are satisfied by less light growing slower, using more years to reproduce. By very closed foliage some trees do not leave any light to plants on the ground like spruces and beeches. They are the trees of dark forests. Trees of light forests are not stingy with light for plants growing below, like birches. They need helpers there to get the right minerals from soil. So, trees are different in light permeability (Fig. 60).

weeping willow (treurwilg) | poplar(populier) | alder(els) | lime(linde)



plane(plataan) | elm(iep)

Fig. 60 *Light permeability of trees*

Light

How do we measure such differences? The power of visible radiation (the part of radiation we call ‘light’) produced by a 1/60 cm^2 black body with the temperature of melting platina (2047^{o}K) under specified pressure in a specified angle (‘sr’, 8% of a sphere, see *Fig. 61*) is 1 candela (cd).[27] That equals 1/683 watt/sr. It is a measure characterising the power of a source of light in its point of departure, not its dispersed impact elsewhere, at any distance or surface. To quantify *that* amount of light we need an other unit, the lux. To calculate the number of lux you receive at your desk, you have to take the distance to the source into account, because that determines the dispersion of light power per m^2 of your desk. If you want 1 lux covering 1m^2, you need a power of 1 candela at 1m distance and that is called 1 lumen. The surface increases with the square of the distance, so at 2 m distance you need 4 lumen and 14 candela (produced by a light bulb of less than 0.1 watt). To be able to read you need much more.

The Sun produces $2\cdot10^{28}$ candela, but the amount of light reaching the Earth is small. To calculate that amount we have to divide the number of candelas of the Sun by some angle covered by the Earth to get the number of lumens at that distance. What we subsequently receive per m^2 is lux (lumen/m^2). The Earth receives $7\cdot10^{17}$ lumen. Devided by its cross (see Fig. 35) section that would be approximately 5000 lux. That is too much to read a book.

Now, let us take a closer look.

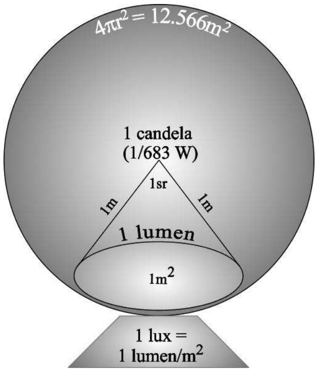
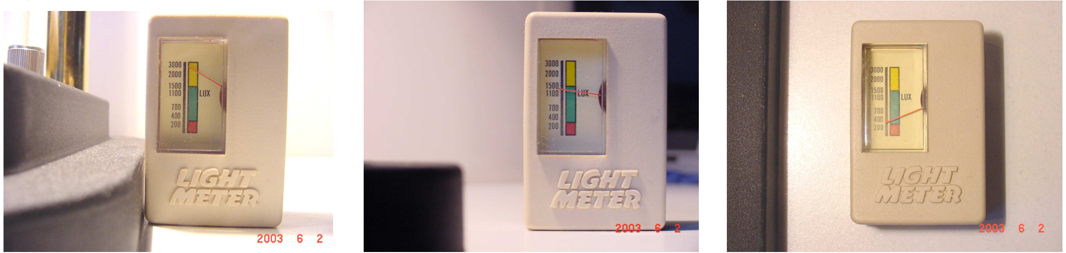


Fig. 61 Candela, lumen, lux

An angle covering 1 spherical m^2 at 1m distance (radius) around the source[a] is called a 'spherical radius' ('sr', ample 8% of a sphere, a rotated angle of 65.541^{o}). A candela (cd) produces per sr a power of 1 lumen (lm), at 0.5 sr 0.5 lm, dispersing that power according to the distance to source. So, cd = lm/sr and lm = cd·sr.[28]

But how much power actually reaches your book? The lightning power of 1 lm *per m^2* on a specific location is 1 lux (lx). So, lx = cd·sr /m^2.[29] And you need 300 – 1500 lux to read a book. Lux is something we can measure easily by a lux meter. Fig. 62 shows how shifting the lux meter 10cm can decrease lightning power from 2500 to 1100 lux.

Light on your desk



directly under the lamp   at a small distance 90^{o} turned laying flat

Fig. 62 *Impacts of distance to source and direction of surface on local lightning power*

Turning the lux meter 90^{o} (Fig. 62) diminishes the available power/m^2 further to 300 lux. So, distance to source and orientation of surface to light in the neighbourhood of the source (here approximately 30cm) make much difference. On larger distance the impact is less dramatic. Besides to this, the colour differences between the photographs show the differences a camera can not compensate like our eyes do by perception with brains near by.

To calculate which lamp you need at a given distance to read a book, you can avoid candelas if you know the lumen/watt efficiency of a lamp. A light bulb has 12 lm/W, low voltage halogen 20, a LED nowadays reaches 150. If you need 300 lux, that is 300 lm/m^2 at 1m, but lumens are dispersered over a larger surface by the square of the distance to the source, so you should divide the available lumens by the square of the distance. So, at 2m you need 1200 lm. That is a light bulb of 100W, a low voltage halogen of 60W or LEDs totalling 8W.

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[a] Or in 100 spherical m^2 at 10m distance (radius). Surface or distance do not matter, only their proportion called 'spherical radius' or 'sr' matters

1.3 Temperature, geography and and history

1.3.1 Spatial variation

The Earth

Latitudinal differences account for the largest global variations (from approx. -40℃ to 30℃) in average monthly temperatures (*Fig. 63* and *Fig. 64*).

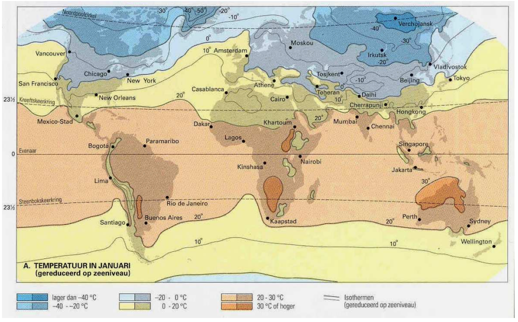

Fig. 63 Global winter temperatures

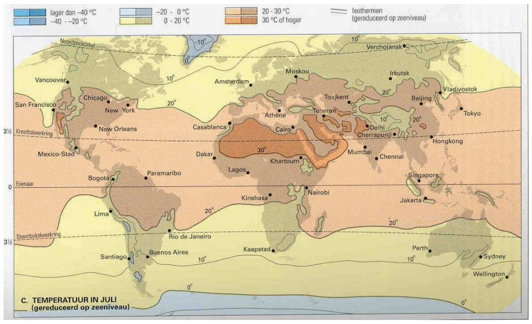

Fig. 64 Global summer temperatures[a]

Europe

Latitudinal differences account for most of the average monthly temperature variations in Europe, but these are moderated by the sea from approx. -15℃ to 25℃ (*Fig. 65* and *Fig. 66*).

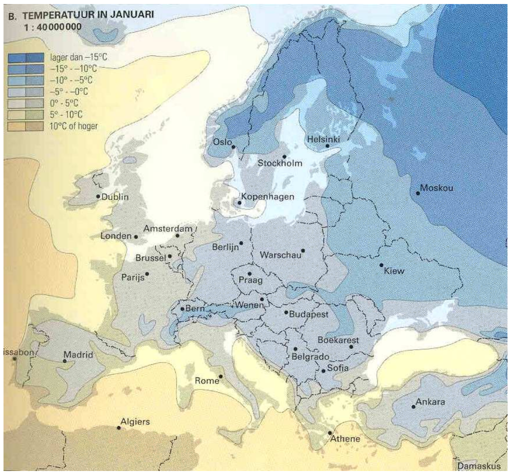

Fig. 65 Winter temperatures in Europe

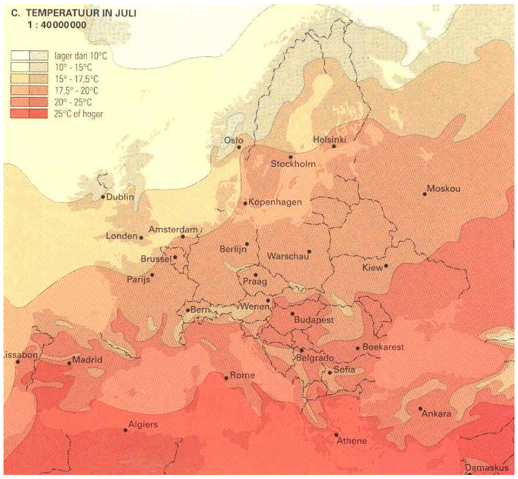

Fig. 66 Summer temperatures in Europe[b]

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[a] Wolters-Noordhof (2001) page 180

[b] Wolters-Noordhof (2001) page 71

The Netherlands

Latitudinal differences account for most of the average monthly temperature variation in the Netherlands, but they are moderated by the sea, especially in winter, from approx. 3℃ to 17℃ (*Fig. 67* and *Fig. 68*).

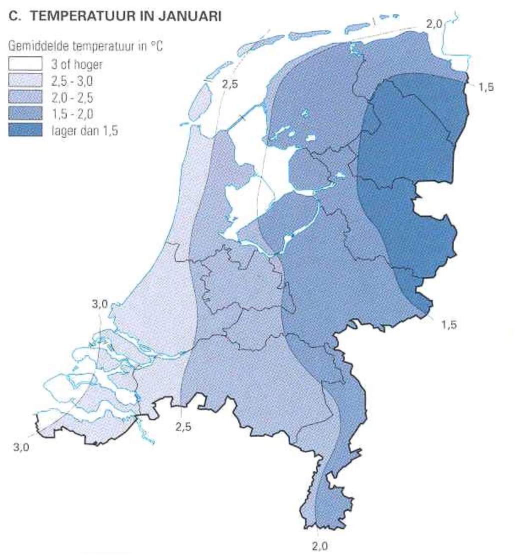

Fig. 67 Winter temperatures in the Netherlands

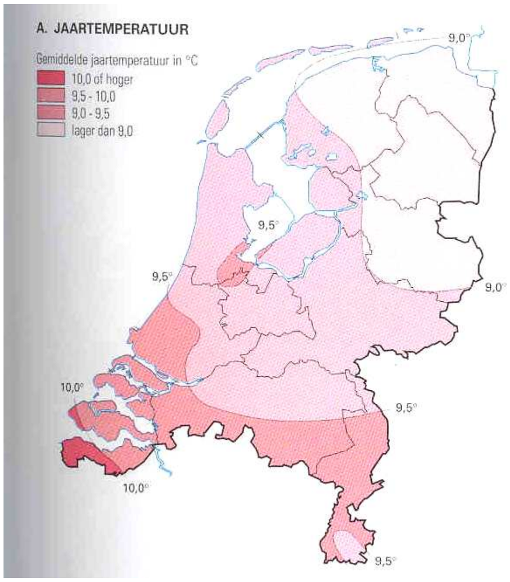

Fig. 68 Year temperatures in the Netherlands[a]

Heat islands

The study of urban heat islands (see *Fig. 69*) has become synonymous with the study of urban climate. Since the increased urbanization and industrialization of the middle of the twentieth century the intensity and the extent of the thermal anomalies has grown. The urban heat island influences physiological comfort, cooling and heating requirements, air circulation and precipitation.

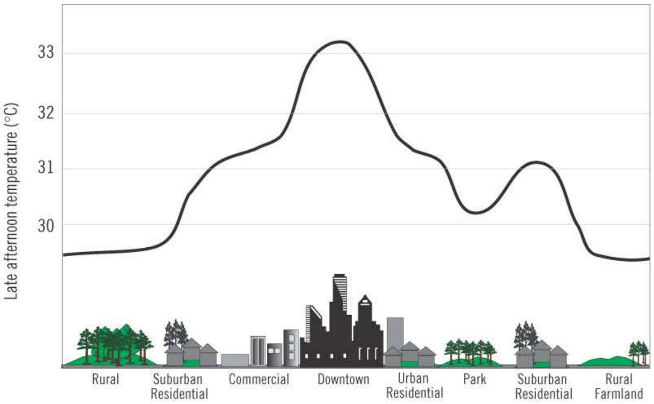

Fig. 69 The urban heat island[b]

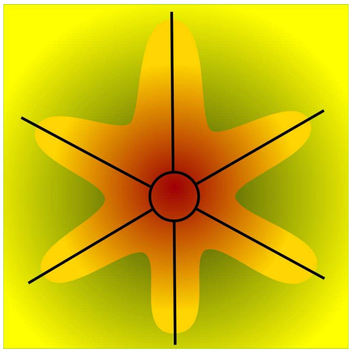

Fig. 70 "Green finger parks" as a contra form of radials in the city

The structure of the city itself influences also the climatic conditions of the city through the density of the buildings, the urban open space, the width of the streets, the crookedness of the streets, the

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[a] Wolters-Noordhof (2001) page 43

[b] *http://adaptation.nrcan.gc.ca/perspective/health_3_e.php*

squares and the occurrence of parks and trees aligning streets or squares. Wind velocity will not be discussed in this section.

What causes the urban heat island?

What causes the differences in climatic conditions between an urban area and the surrounding rural areas? The urban heat island is caused by the large heat capacity and the high heat conductivity of urban building material. These facts prevent also a rapid cooling of the urban environment after sunset. This balance causes all kind of movements from the surroundings of a city to the city. The heat island is also equally influenced by other factors such as: rapid runoff of precipitation and as a result a lower amount of evapotranspiration. Through all the buildings and metalled surface the city does not have left over a lot of space where rain can infiltrate the soil. The rain will stream in the sewers and will be discharged immediately. The extra heat in the form of waste heat from urban and industrial buildings the year round together with the heat from the air conditioning in the summer deliver an equally important amount of heat to the city.

Contrast with rural areas

This is in great contrast with the situation in rural areas, where the heat capacity is substantially lower. The heat conductivity is also lower in the rural area. The extra heat delivery by buildings and industry is also nearly negligible.

The differences between urban and rural areas concerning heat capacity and conductivity and the other above mentioned factors make it possible to draft an energy balance between these two areas. This balance alters dependent on the situation such as summer-winter, sunshine or rainfall.

The differences are responsible for pressure differences in the atmosphere and cause equalization by a streaming of air from an area with high air pressure towards an area with a low air pressure. This means a streaming of air from the colder rural area towards the warmer city or a wind blowing towards the city. The wind is relatively cooler then the temperature in the city. The wind will have the Buys Ballot deviation so it will have a deviation to the right on the northern hemisphere and to the left on the southern hemisphere.

Differences in the built up area

Of course there are heat differences in the built up area. It will be obvious that the heat capacity and the heat conductivity will be different for the various urban fabrics. They will be influenced strongly by the cover and the shape of roofs i.e. tiles or bitumen and flat or with inclination, metalled surfaces and parks in combination with water bodies like lakes and canals. Especially the parks with water bodies can have a positive influence on temperature. The temperature there is lower than in the surrounding urban area. If a wind blowing in the city from the rural area outside the built up area passes a large enough park the temperature of the air will cool down. The form of the parks in the built up area plays an important role. Since the air does not flow directly in a straight stream from outside to the centre of a city but with a curve, a belt of parks around the city will not be so effective as “green finger parks” in the form of radials in the city (see *Fig. 70*).

Local variation

In the Netherlands, on 3rd March 1976, the differences in local temperatures, within metres of each other, ranged from -2℃ to 62℃ (Fig.34)!
The air temperature at a height of 1 metre (*Fig. 71*) was 11.8℃.

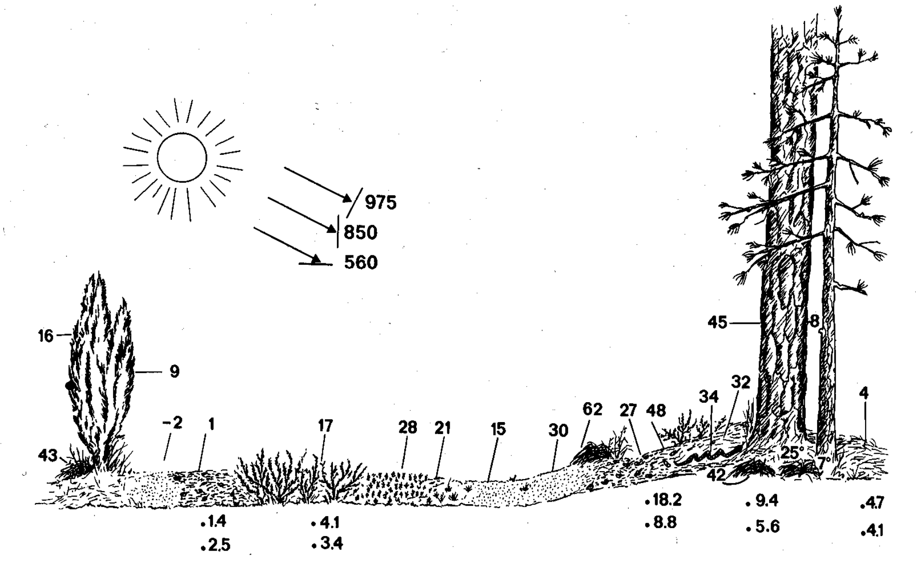

Fig. 71 Surface temperatures along a line perpendicular to edge of a forest[a]

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[a] Barkman and Stoutjesdijk (1987) citing Stoutjesdijk (1977)

Individual variation

Plants are long term indicators of local climate and environment (sun, wind, water, soil) while occasional measurements give a random indication of moments.
Plants receiving shadow throughout the day in the growing seasons grow larger and narrower (etoilement) than the same species receiving more sunlight. They look for light rising as high they can (see *Fig. 72*A).

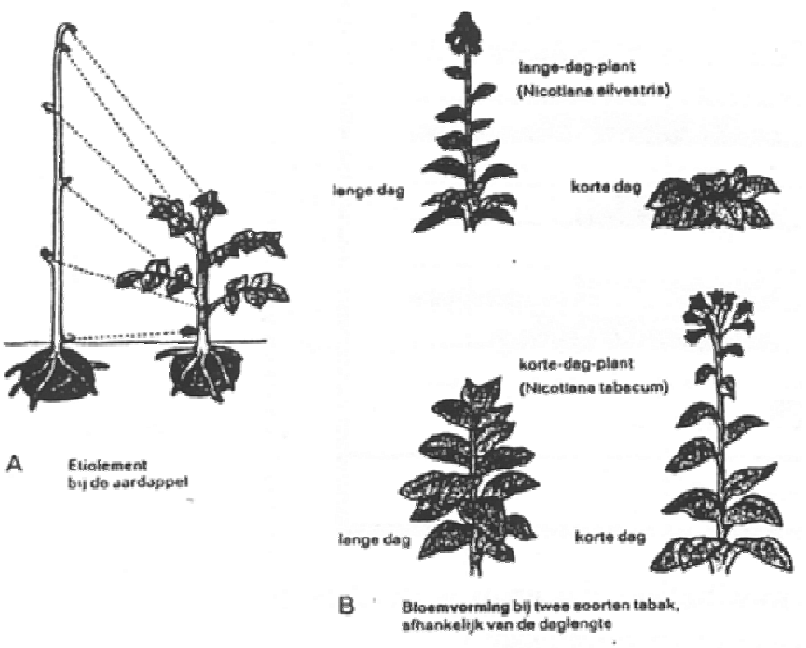

Fig. 72 The influence of variations in light[a]

A plant can not grow if the day is too short (see *Fig. 72*B above).
However, some species are adapted in a way they grow better if the day is short (see *Fig. 72*B below).

The plant species listed below occur so widely that it is well worth while getting to know them.
In the tables below, a number of plants are mentioned in the month in which they can first be encountered in the Netherlands.

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[a] Vogel, Günter et al. (1970) page 198, 199

1.3.2 Long term temporal variation

The distance to the sun ‘vibrates’ in periods of 100 000 years or less, causing ice ages and great differences in wind, water, earth and life stored and named in layers of soil (*Fig. 73*).

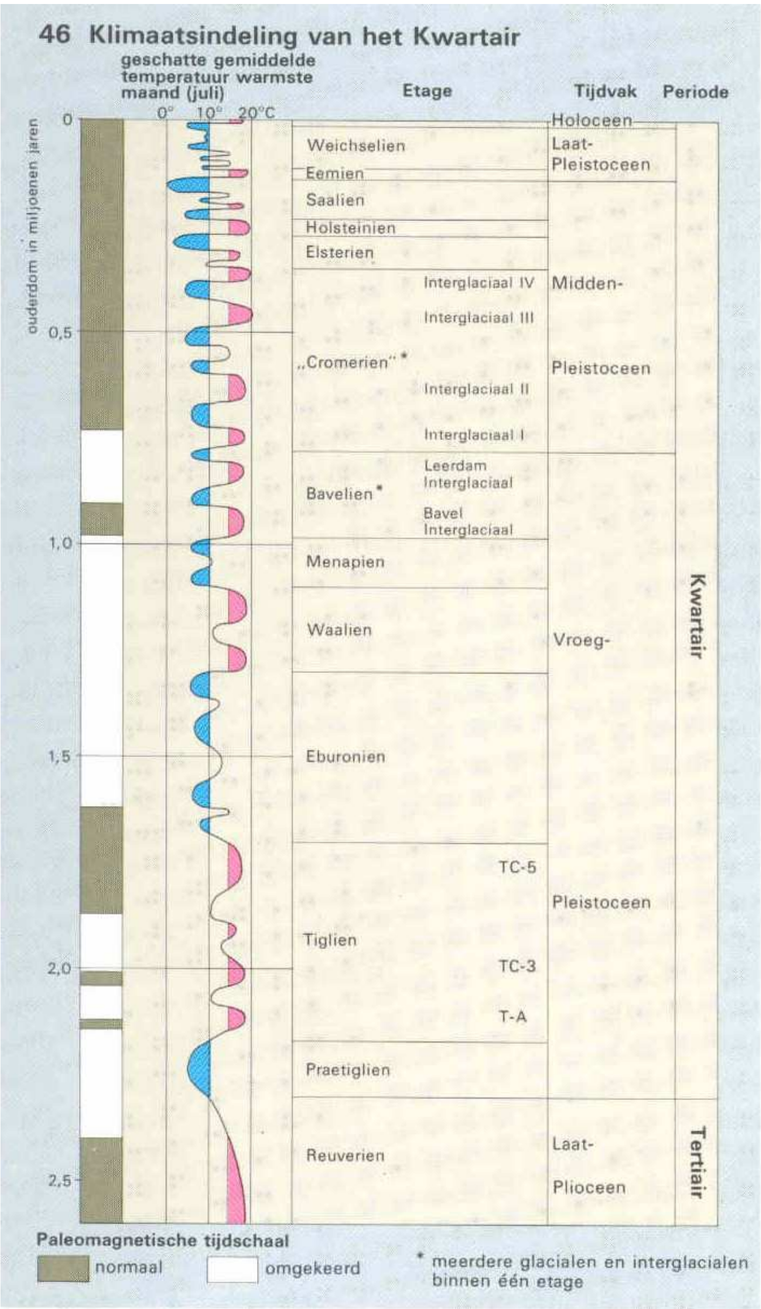

Fig. 73 Temperature fluctuations in The Netherlands in the past 3 million years[a]

These impacts are readable from the topographic history of The Netherlands (Fig. 74).[30]

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[a] Sticht.Wetensch.Atlas_v.Nederland (1985)page 13

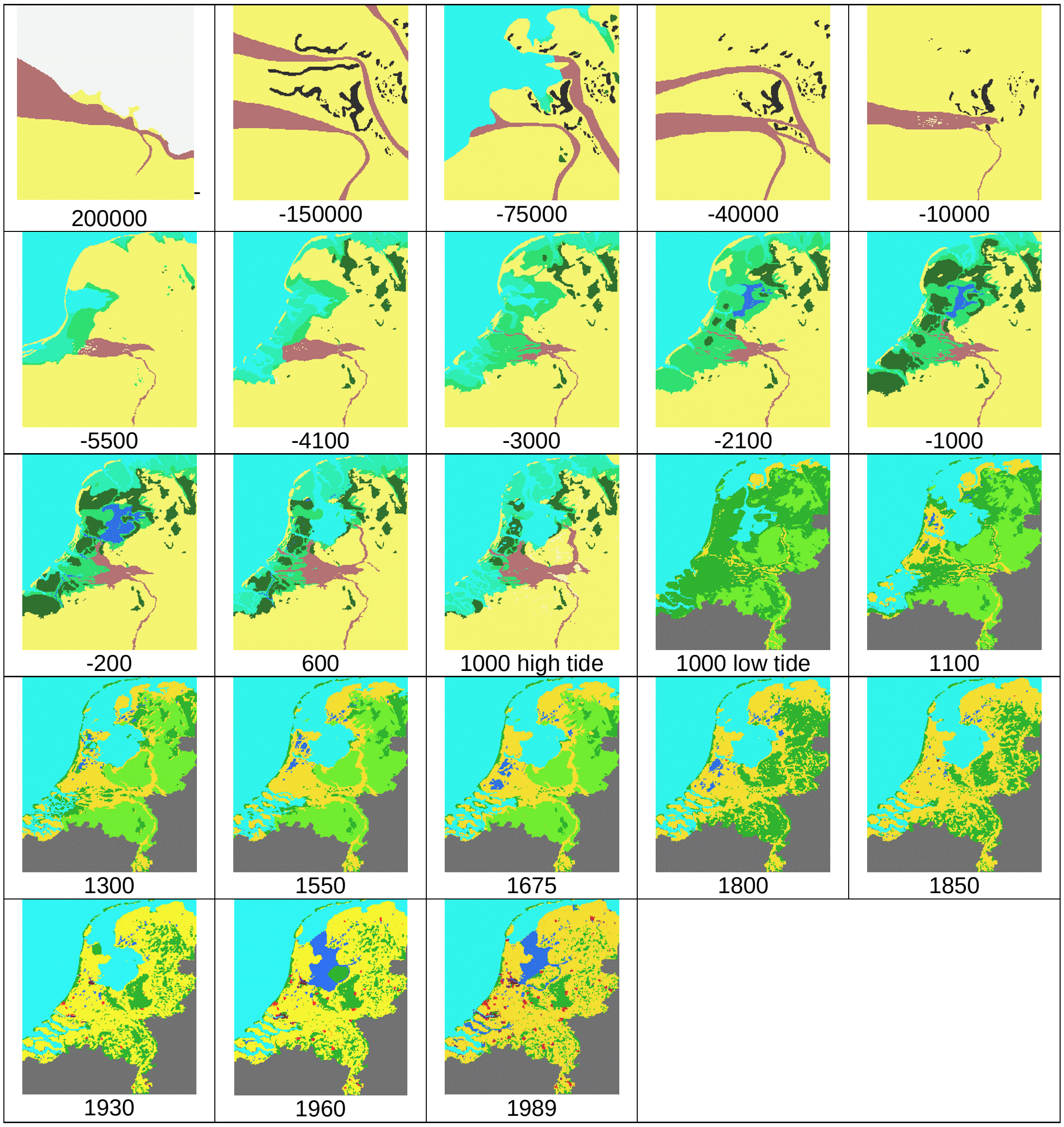

Fig. 74 *De topographic history of The Netherlands*[a]

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[a] Universiteit van Utrecht 1987 commisioned by Nederland Nu Als Ontwerp

The Dryas and Alleröd Periods (from 10,000 years BC)

In the famous Lascaux caves, people have made images of mammoths and long haired rhinos. These animals became extinct during the last Ice Age. In Scandinavian countries this period is known as Weichsel and in the Alpine countries as Würm. A tundra plant '*dryas octopetala'* grew in our part of Europe at that time and gave its name to the last cold period of the Weichsel.

Fig. 75 The end of the Weichsel ice age, the Dryas period[a]

15 000 – 10 000 b.C. Older Dryas period

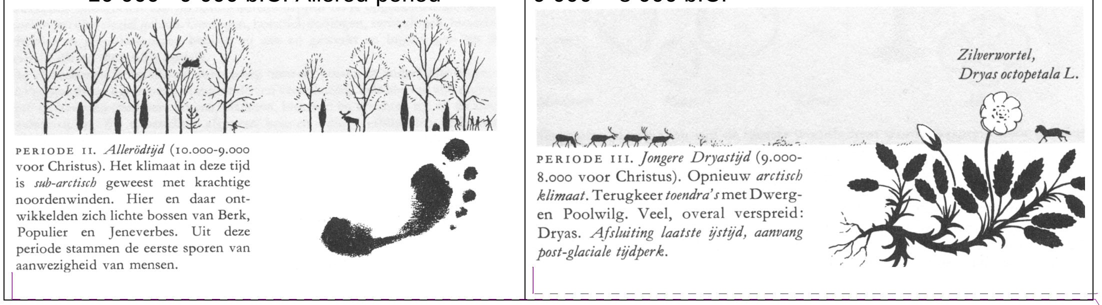
PERIODE I. *Oudere Dryastijd* (15.000-10.000 voor Christus). Genoemd naar de alpine plant Zilverwortel (afb. bij III). *Arctisch klimaat.* Grote oppervlakten zonder vegetatie. Schijngrassen, grassen, mossen, Dwergberk, Jeneverbes.

Fig. 76 Vegetation during the Dryas period[b]

Comment [T.M. de2]: Pagina : 57

10 000– 9 000 b.C. Alleröd period

9 000 – 8 000 b.C.



PERIODE II. *Allerödtijd* (10.000-9.000 voor Christus). Het klimaat in deze tijd is *sub-arctisch* geweest met krachtige noordenwinden. Hier en daar ontwikkelden zich lichte bossen van Berk, Populier en Jeneverbes. Uit deze periode stammen de eerste sporen van aanwezigheid van mensen.

PERIODE III. *Jongere Dryastijd* (9.000-8.000 voor Christus). Opnieuw *arctisch klimaat*. Terugkeer *toendra's* met Dwerg- en Poolwilg. Veel, overal verspreid: Dryas. *Afsluiting laatste ijstijd, aanvang post-glaciale tijdperk.*

Fig. 77 Sub-divisions of the Dryas [c]

Comment [T.M. de4]: Pagina : 57

Comment [T.M. de3]: Pagina : 57

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[a] University of Utrecht 1987

[b] Vedel and Lange (1974)

[c] *Vedel and Lange (1974) p 216*

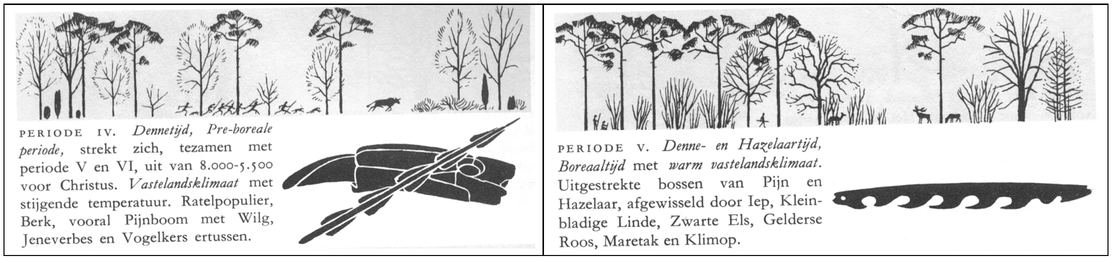
The PreBoreal and Boreal Periods (from 8,000 BC)

In the warmer periods that followed the Dryas, people learnt how to hunt smaller animals using correspondingly smaller stone tools. The Mesolithicum, the Middle Stone Age, had already started, and peat was also beginning to form due to the warmer climate.

About 8,000 BC the oceans began to rise again, because of the melting ice, and the North Sea filled with water again.In the Netherlands, peat formation began late in the Boreal Period, after the cold extensions of the Dryas and Pre-Boreal, and this continued into the warm and humid Atlanticum. The rising sea levels flooded western parts of the country.

Pre-Boreal (8,000 BC)

Early Boreal (7,000 BC)

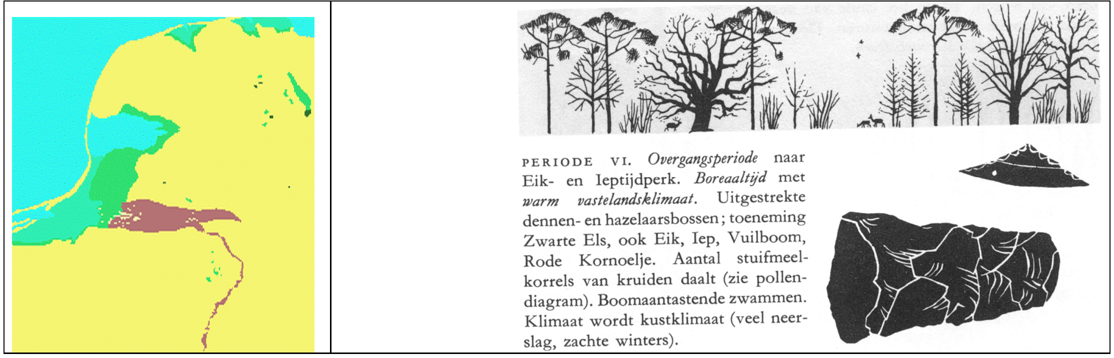


PERIODE IV. *Dennetijd, Pre-boreale periode,* strekt zich, tezamen met periode V en VI, uit van 8.000-5.500 voor Christus. *Vastelandsklimaat* met stijgende temperatuur. Ratelpopulier, Berk, vooral Pijnboom met Wilg, Jeneverbes en Vogelkers ertussen.

PERIODE V. *Denne- en Hazelaartijd, Boreaaltijd* met *warm vastelandsklimaat*. Uitgestrekte bossen van Pijn en Hazelaar, afgewisseld door Iep, Kleinbladige Linde, Zwarte Els, Gelderse Roos, Maretak en Klimop.

Fig. 78 The landscape of the Pre-Boreal and Early Boreal [a]

Approximately 5,500 BC the sea formed off-shore bars that during the ebb tide were blown higher, forming dunes. In the Waddenzee, behind the dunes, fine sand and silt were deposited, successively, on top of the peat base. The silt became the ‘old’ or ‘blue’ marine clay of (the provinces of) Holland.



PERIODE VI. *Overgangsperiode* naar Eik- en Ieptijdperk. *Boreaaltijd* met *warm vastelandsklimaat*. Uitgestrekte dennen- en hazelaarsbossen; toeneming Zwarte Els, ook Eik, Iep, Vuilboom, Rode Kornoelje. Aantal stuifmeelkorrels van kruiden daalt (zie pollendiagram). Boomaantastende zwammen. Klimaat wordt kustklimaat (veel neerslag, zachte winters).

Fig. 79 The Boreal landscape. (from 5,500 BC)[b]

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[a] Vedel and Lange (1974)

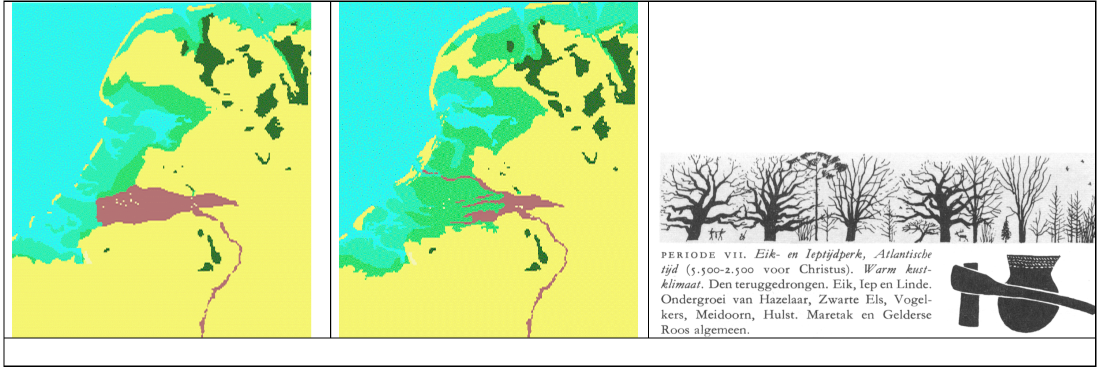
[b] University of Utrecht(1987), Vedel and Lange (1974)

Atlanticum (from approx. 4,000 BC)

While ever the sea continues to rise, the coast and the peat advance. Approx. 3,000 BC the rise in sea level began to slow down; the off-shore bars remained intact and these broadened out seawards to form a strong coast.

A new row of dunes was laid down in front of the old ones and the peat that had grown on top of the blue marine clay, in so far as the sea had not washed it away, was dug out later. Peat streams first became estuaries and then reverted back to peat streams again. The sea cut into the Sub-Boreal peat leaving channels in which fine sand was deposited. Subsequent drainage caused a reversal in relief.

Atlanticum (4,100 BC).   Atlanticum (3,000 BC)

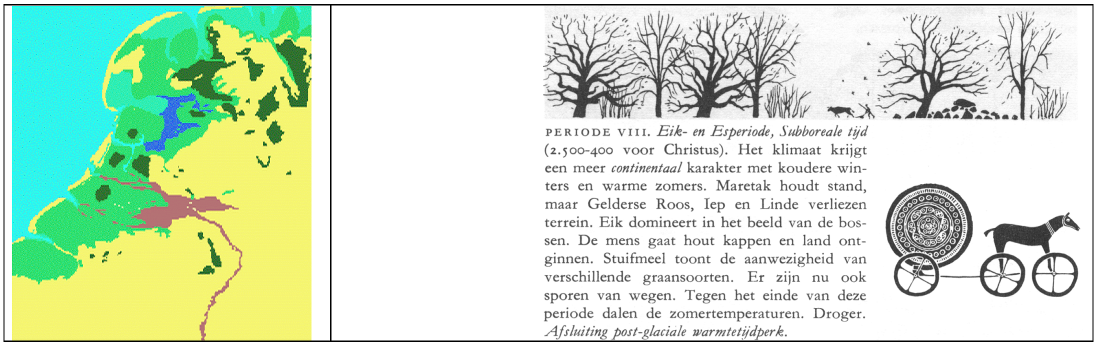


PERIODE VII. *Eik- en Ieptijdperk, Atlantische tijd* (5.500-2.500 voor Christus). *Warm kustklimaat*. Den teruggedrongen. Eik, Iep en Linde. Ondergroei van Hazelaar, Zwarte Els, Vogelkers, Meidoorn, Hulst. Maretak en Gelderse Roos algemeen.

Fig. 80 The landscape of the Atlanticum[a]

The Sub-Boreal (from approx. 2,000 BC)

Approx. 2,100 BC, rivers carred fresh water into the lagoon behind the off-shore bars, causing widespread peat formation



PERIODE VIII. *Eik- en Esperiode, Subboreale tijd* (2.500-400 voor Christus). Het klimaat krijgt een meer *continentaal* karakter met koudere winters en warme zomers. Maretak houdt stand, maar Gelderse Roos, Iep en Linde verliezen terrein. Eik domineert in het beeld van de bossen. De mens gaat hout kappen en land ontginnen. Stuifmeel toont de aanwezigheid van verschillende graansoorten. Er zijn nu ook sporen van wegen. Tegen het einde van deze periode dalen de zomertemperaturen. Droger. *Afsluiting post-glaciale warmtetijdperk*.

Fig. 81 The Sub-Boreal landscape[b]

Late Boreal and Sub-Atlanticum, from 1000 BC.

Approx. 1,000 BC: The stagnation of water from streams also causes *hoogveen* (i.e. peat formations above the water table) to develop on the lower parts of sandy ground (e.g., the Peel and Drente).

Approx. 200 BC: peat erosion also occurs along the shores of the Almere lake (Zuiderzee area), thereby extending the lake.

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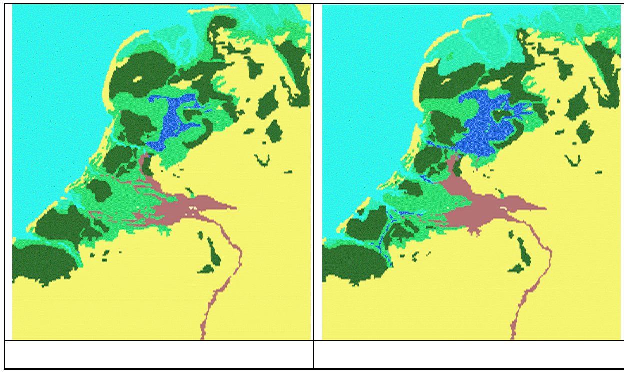
[a] University of Utrecht(1987), Vedel and Lange (1974)

[b] University of Utrecht(1987), Vedel and Lange (1974)

Late Sub-Boreal, 1000 BC

Sub-Atlantikum, 200 BC



PERIODE IX. *Beukperiode, Subatlantische tijd* (vanaf ongeveer 400 voor Christus). In deze tijd neemt de neerslag toe en de zomertemperaturen dalen nog verder, waardoor voor Nederland een normaal, *koel kustklimaat* ontstaat. Beuk en Haagbeuk gaan domineren, Berk, Populier en Jeneverbes zijn algemeen geworden; het voorkomen van de Eik wordt minder.

Fig. 82 The Sub-Boreal landscape and Subatlanticum[a]

The Roman period and early Middle Ages, from 100 BC.

Approx. 100 BC: The sea attacked again and large areas of the *laagveen* (i.e. peat formations below the water table) were washed away: this continued for centuries. Bloemers, Kooijmans et al. (1981) and Klok and Brenders (1981) describe Roman relics from this period in The Netherlands like Corbulogracht (*Fig. 84*).

Approx. 600 AD: The sea first broke through in the North to create the Waddenzee and the Zuiderzee.

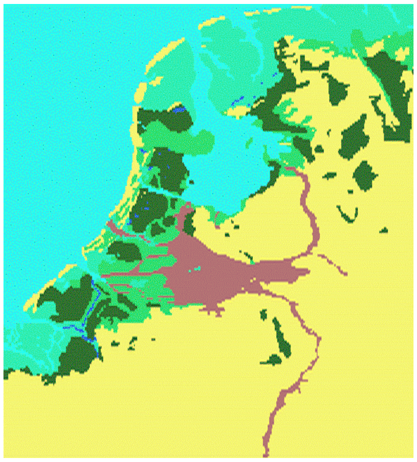


Fig. 83 The landscape of the Early Middle Ages, 600 AD[b]

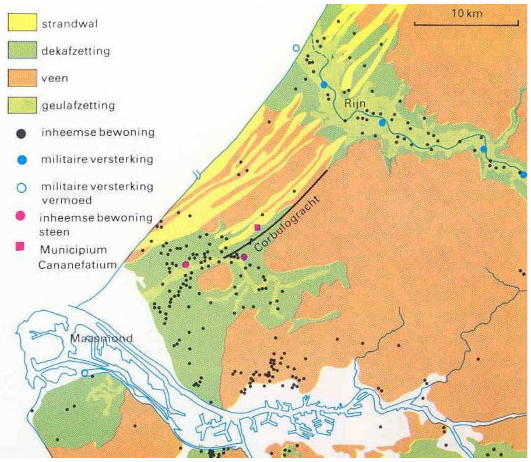


Fig. 84 Roman sites[c]

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[a] University of Utrecht(1987), Vedel and Lange (1974)

[b] University of Utrecht

[c] Bloemers, Kooijmans et al. (1981) page 99

1.3.3 Seasons and common plants

Wetland and water

Few shoreline and water plants flower before may.

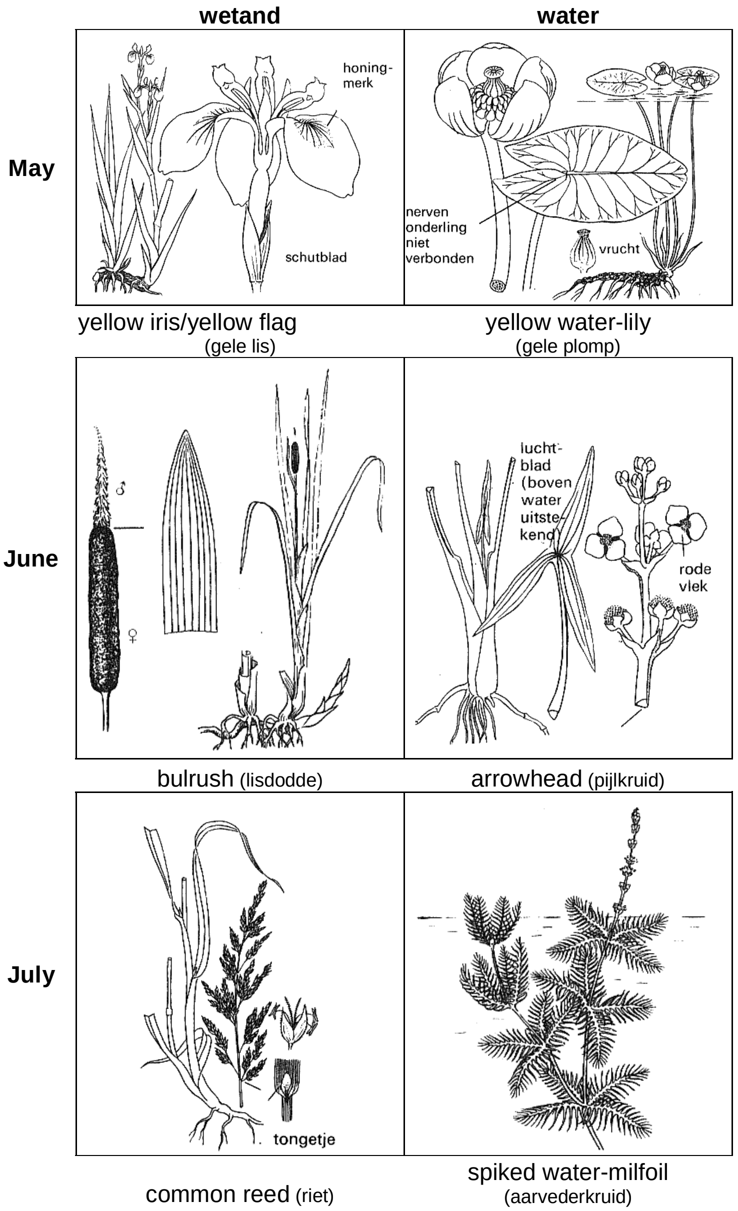

Fig. 85 Flowering periods wetland and water[a]

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[a] Kelle and Sturm (1980)

Disturbed and ruderal grounds

If one comes across pioneer vegetation in a certain season, then one can assume that the ground has been recently disturbed. If one comes across plants that grow on rough ground (ruderals), then one can assume that the soil was disturbed one or more years previously.
There are few plants growing on rough ground that flower before March.

pioneering-plant **ruderal**

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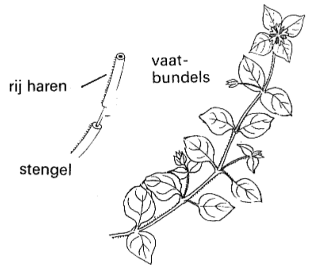
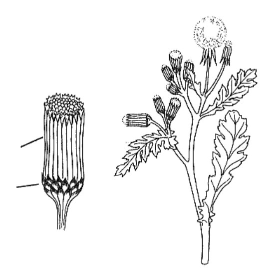
Bouwkundestudenten zijn niet geïnteresseerd in de op blz. 45 t/m 51 genoemde plantensoorten.

Jan

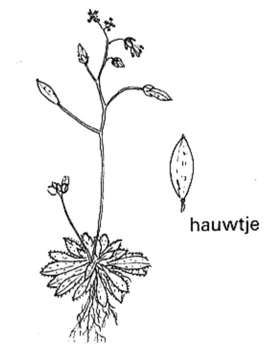


chickweed (vogelmuur)

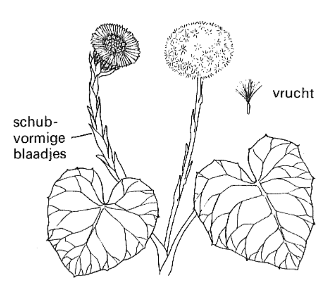


groundsel (klein kruiskruid)

Feb

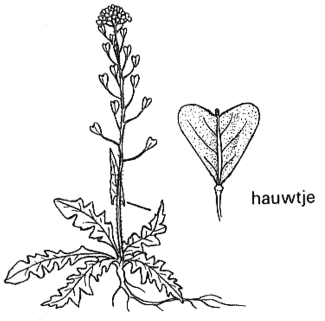


common whitlowgrass (vroegeling)

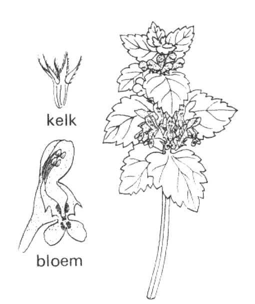


coltsfoot (klein hoefblad)

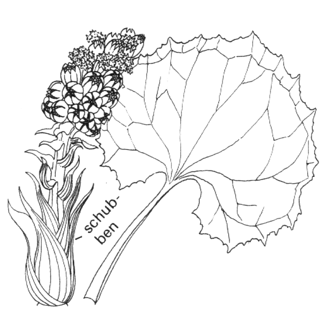
March



shepherd's-purse (herdertasje)

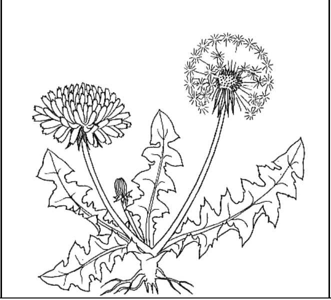


purple dead-nettle (paarse dovenetel)

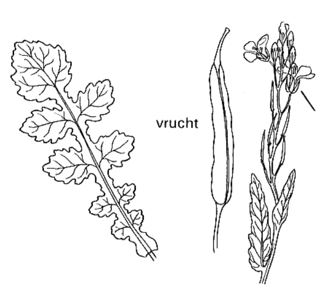


giant butterbur (groot hoefblad)

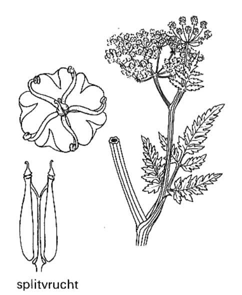
April



dandelion (paardebloem)



rape (koolzaad)



cow parsley (fluitekruid)

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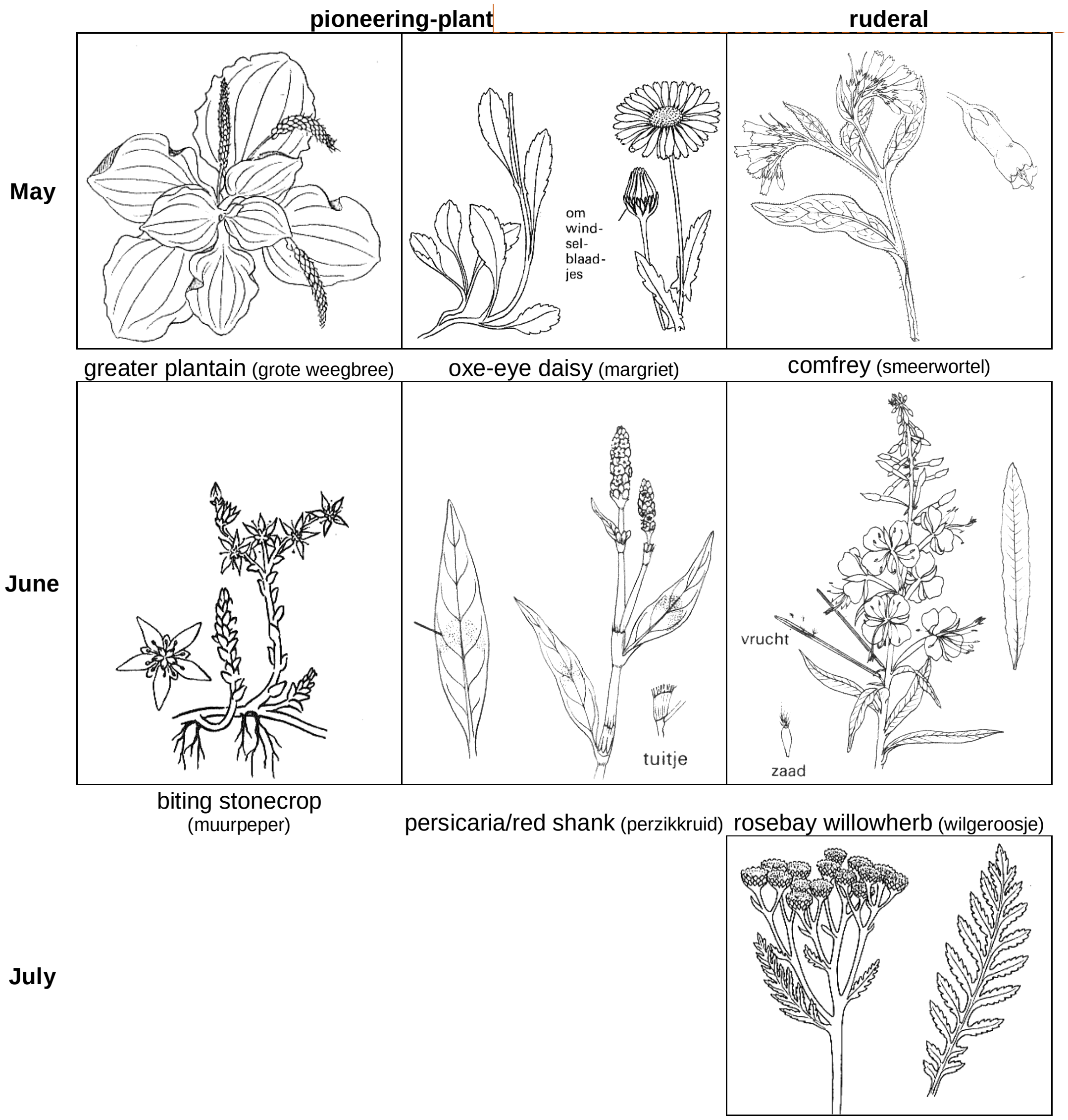

greater plantain (grote weegbree)

oxe-eye daisy (margriet)

comfrey (smeerwortel)

biting stonecrop (muurpeper)

persicaria/red shank (perzikkruid)

rosebay willowherb (wilgeroosje)

tansy (boerenwormkruid)

Fig. 86 Flowering times pioneers and ruderals[a]

There are few pioneering plants that begin to flower after June.

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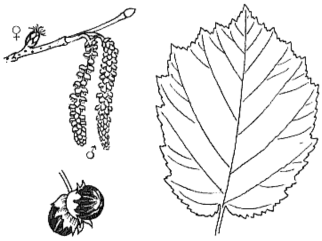
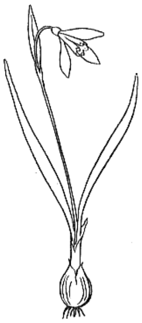
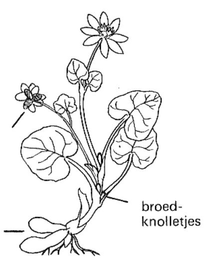
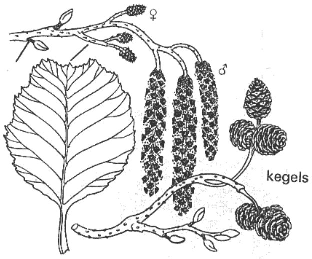
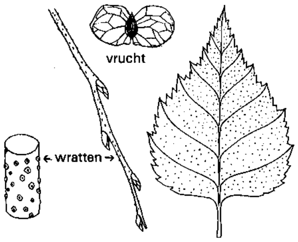
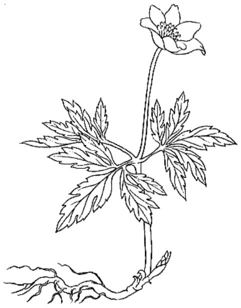
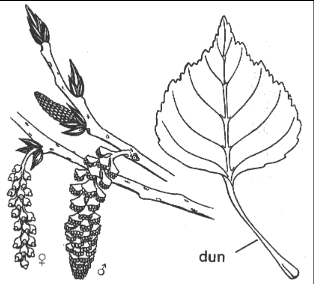
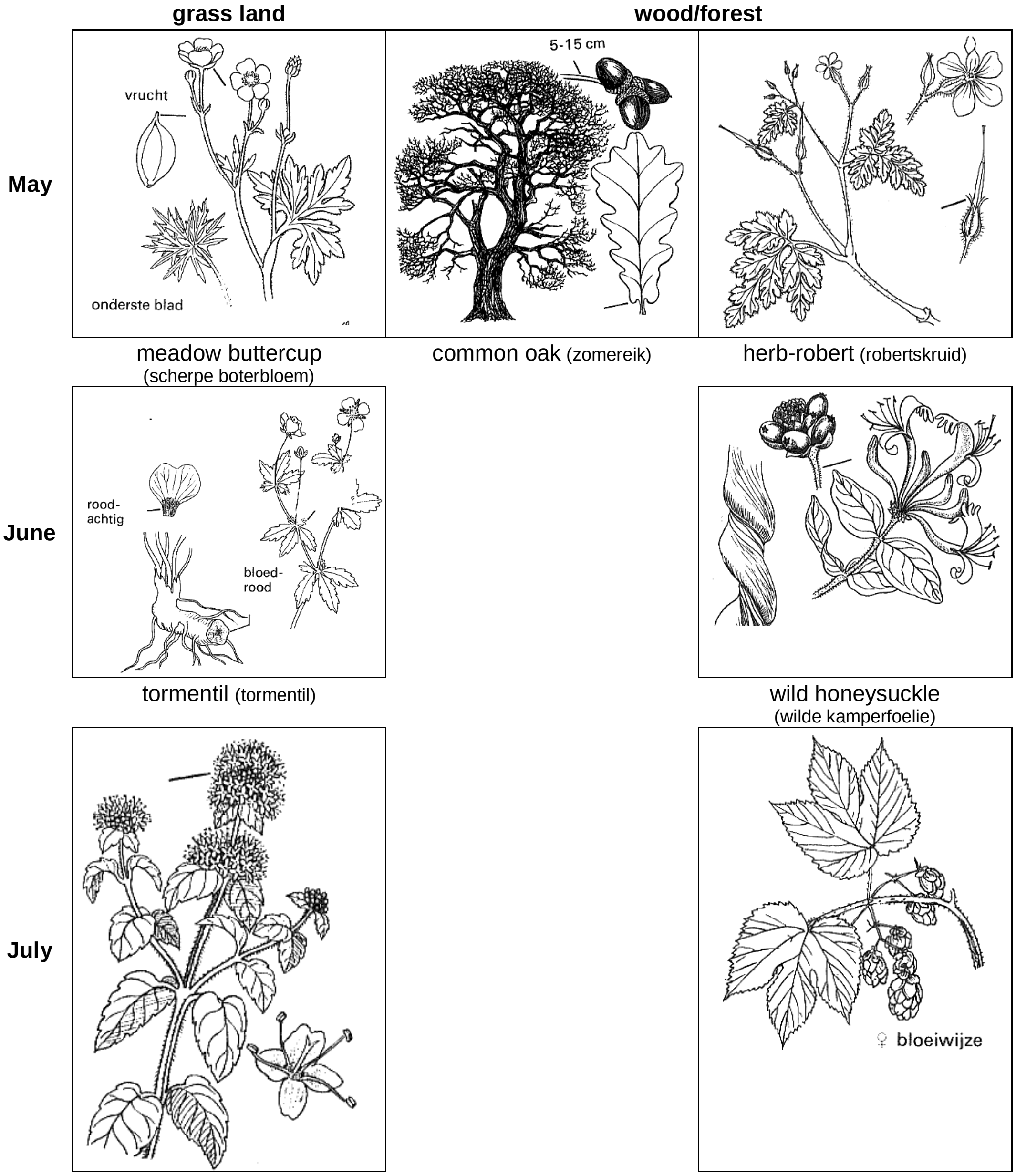
[a] Kelle and Sturm (1980)

Grassland and forest

If one encounters woodland vegetation, then the soil has remained undisturbed for a longer time.

	grass land	**wood/forest**	
Jan			
	daisy (madeliefje)	hazel (hazelaar)	snow drop (sneeuwklokje)
Feb			
	lesser celandine (speenkruid)	alder (zwarte els)	cornelian cherry (gele kornoelje)
March			
	ground ivy (hondsdraf)	silver birch (ruwe berk)	wood anenome (bosanemoon)
April			
	lady's smock/ cuckooflower (pinksterbloem)	poplar (populier)	broom (brem)



meadow buttercup (scherpe boterbloem)

common oak (zomereik)

herb-robert (robertskruid)

tormentil (tormentil)

wild honeysuckle (wilde kamperfoelie)

water mint (watermunt)

hop (hop)

Fig. 87 Flowering times on grass land and in forest[a]

Few trees flower after May.[31] [32]

---

[a] Kelle and Sturm (1980)

Mowing Grasslands

Grassland plants indicate frequent mowing, however, from the nature of grassland vegetation and on the basis of the above table, one should be cautious to mow in flowering periods if you do not want to disturb animals like butterflies.[33]

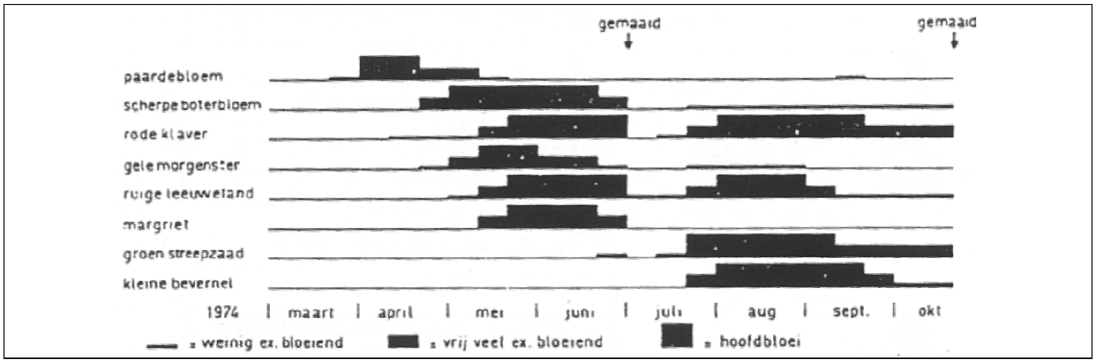


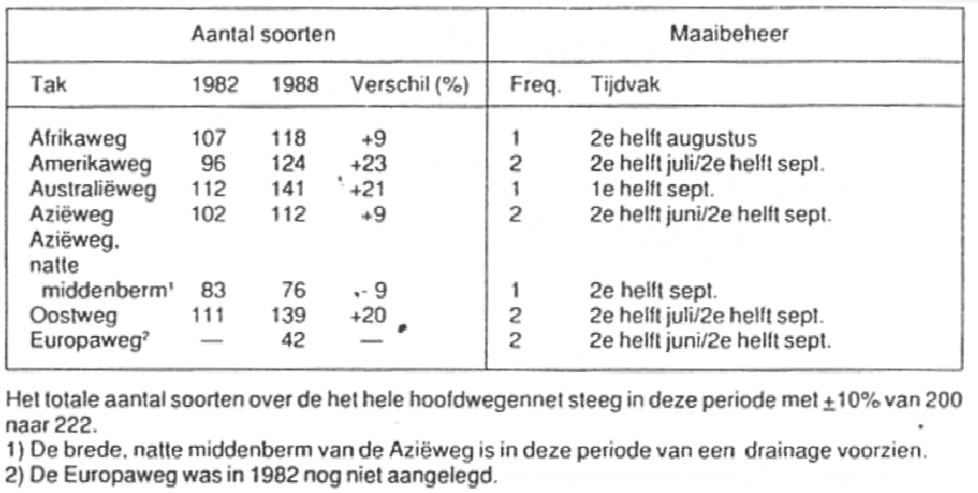
Fig. 88 The effect of mowing on various species[a]

Some species show a second flowering period after mowing.

Mowing to remove minerals

On poor soils one encounters special plants in greater diversity than on rich soils. There, they are pushed aside by very common species like stinging nettle (brandnetel).

For more than 10 years already there has been a mowing policy in Zoetermeer that is directed towards ensuring that the food content of roadside vegetation is drastically reduced by regularly removing biomass:



Aantal soorten				Maaibeheer	
Tak	1982	1988	Verschil (%)	Freq.	Tijdvak
Afrikaweg	107	118	+9	1	2e helft augustus
Amerikaweg	96	124	+23	2	2e helft juli/2e helft sept.
Australiëweg	112	141	+21	1	1e helft sept.
Aziëweg	102	112	+9	2	2e helft juni/2e helft sept.
Aziëweg, natte middenberm¹	83	76	- 9	1	2e helft sept.
Oostweg	111	139	+20	2	2e helft juli/2e helft sept.
Europaweg²	—	42	—	2	2e helft juni/2e helft sept.

Het totale aantal soorten over de het hele hoofdwegennet steeg in deze periode met ±10% van 200 naar 222.

1) De brede, natte middenberm van de Aziëweg is in deze periode van een drainage voorzien.

2) De Europaweg was in 1982 nog niet aangelegd.

Fig. 89 Mowing management in Zoetermeer[b]

Over a period of 10 years, impoverishing the soil does not appear to lead to a large increase in the number of species growing there. Obviously, more time is needed for this to happen.

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[a] Londo (1987) page 103

[b] Vos (1990)

1.4 Planting by man

1.4.1 Introduction

The key thing to remember when designing and using planting elements is that you are dealing with living material.[34] Architects work with dead material; buildings are not living organisms. Trees grow, and young trees have a form, different from mature trees. They look different in winter and change under the influence of climatic conditions. A plane tree, for example, has a pyramidal form when young and then 'sags' when older. Trees attain their typical growth form when they are 15 to 20 years old and keep it until they are 80, but by then they will have acquired an individual 'character'. Shrubs usually achieve their mature form after about 10 years. Perennials and roses reach maturity in just 2 to 3 years.

Planting effects

The following illustrations give an impression of the wealth of effects that can be achieved with planting.

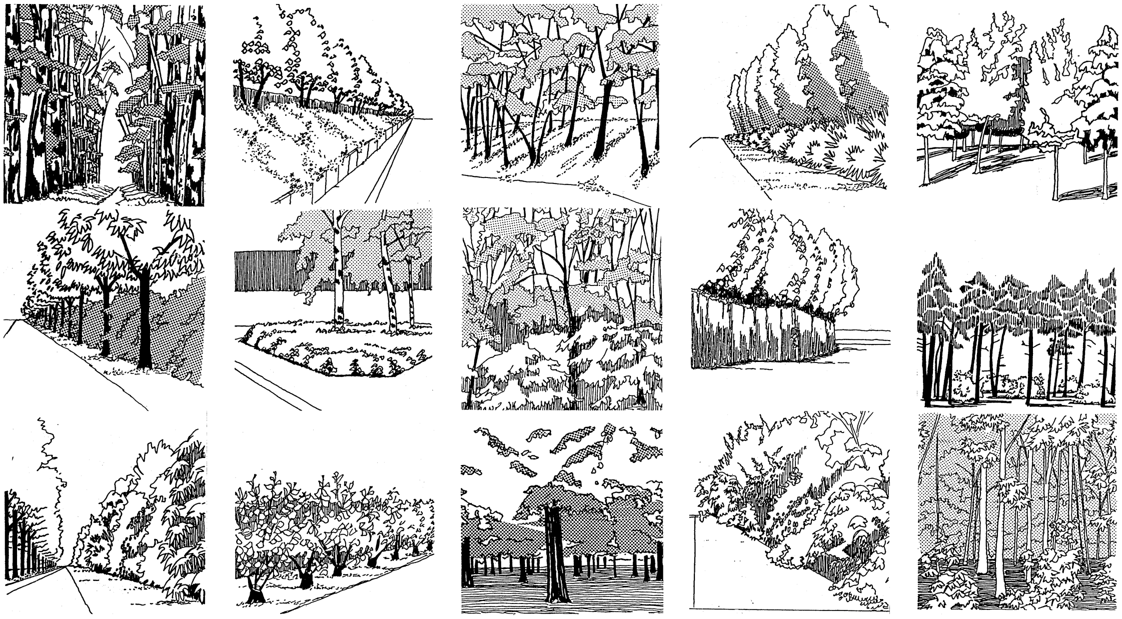

Fig. 90 *Visual effects of planting*

Conceptual framework

Introduction

The conceptual framework is a language to express and convey planting effects. To describe a particular effect we can draw from the themes and related visual forms described below. The overall effect. Depends on the role of each theme.

Themes

The degree of screening[35]
Height is an important consideration when deciding on planting elements. Their height determines how much of the objects behind the planting can be seen. The degree to which they are hidden is called the degree of screening.

The degree of transparency
The visibility of objects behind the planting also depends on how much can be seen through the planting. This is referred to as the degree of transparency.

The degree of uniformity
When looking at a planting element we can examine the diversity of species in relation to the height of the composition to determine vertical variation in texture.

The degree of continuity
In the same way, the diversity of species along the length of the planting element can be examined. The horizontal variation in texture is important.

Structure[36]
The manner in which trees and shrubs are placed to create a unified composition has a strong influence on the other themes. Structure plays a major role in creating the overall effect.

Edge profile
In urban areas planting elements are usually narrow and consist, essentially, of two edges. The profile of these edges has a major influence on the appearance of planting elements.

The degree of naturalness
The mood or atmosphere created depends to an important extent on whether the composition has a formal, artificial appearance or an informal, ‘natural’ feel.

Characteristic Forms

Each theme can manifest itself in different ways characteristic forms. These can be clearly indicated by introducing terms for all the possible forms.

The degree of screening

Fig. 91 *Edge: maximum planting height 0.5m*

Fig. 92 *Articulation: planting height between 0.5 and 1.5 m*

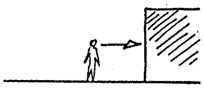

Fig. 93 *Partition: planting height between 2 and 5 m*

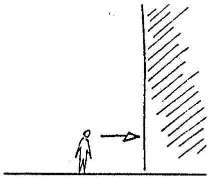

Fig. 94 *Screening: planting is higher than 5 m*

The degree of transparency

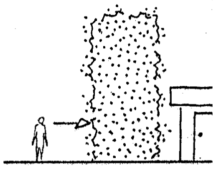

Fig. 95 *Wall: the planting blocks all vision*

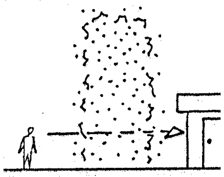

Fig. 96 *Curtain: even, partial visibility through the planting*

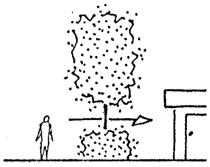

Fig. 97 *Window: opening in the planting*

The degree of uniformity

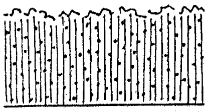

Fig. 98 *Even: no clear vertical variation in texture*

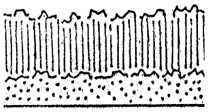

Fig. 99 *Layered: clear vertical variation in texture*

The degree of continuity

Fig. 100 *Constant: no horizontal differences in texture*

Fig. 101 *Rhythm: differences in texture at regular intervals*

Fig. 102 *Accentuation: random striking differences in texture*

Edge profile

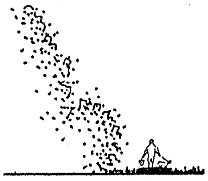

Fig. 103 *Receding*

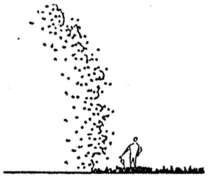

Fig. 104 *Upright*

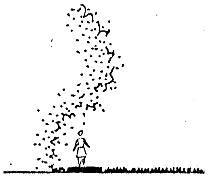

Fig. 105 *Overhanging*

Degree of naturalness

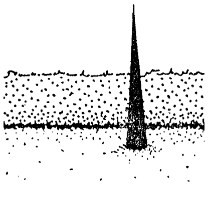

Fig. 106 *Straight and 'hard': the planting has straight contours and 'hard' boundaries*

Fig. 107 *Ragged and 'soft': the planting has irregular contours and vague edges*

Structure

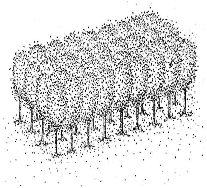
Fig. 108 *Trees*

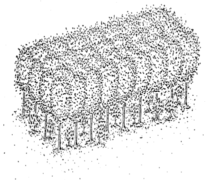
Fig. 109 *Trees with occasional shrubs*

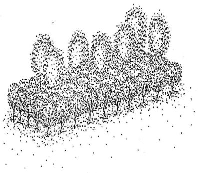
Fig. 110 *Shrubs with occasional trees*

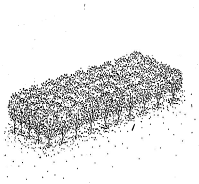
Fig. 111 *Shrubs*

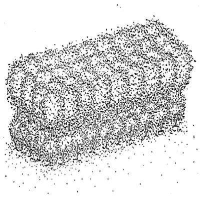
Fig. 112 *Trees with a shrub margin*

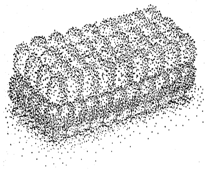
Fig. 113 *Trees with a shrub layer*

Design tools

Comment [B6]: Page: 73
Blz. 59, 60 Section)???

Each of the characteristic forms described above can be created using different design tools:

Edge
- Native stock trimmed to form a hedge
- Low-growing non-native plants

Articulation
- Native stock trimmed to form a hedge
- Smaller, non-native shrubs

Partition
- Native shrubs with or without trimmed edges
- Larger non-native shrubs

Screening
- Tree planting, no crown raising
- Tree planting with shrub layer; the trees and shrubs must intertwine

Wall
- Native species with a dense, compact habit
- Non-native evergreen species
- Wide spacing and sufficient thinning to allow full growth and the development of complete foliage cover
- No crown thinning, branch reduction or crown raising
- Broad plant bed

Curtain
- Species with an open and loose habit
- Small distances between plants, which encourages them to grow upwards
- Crown thinning, branch reduction and crown raising is possible
- Narrow plant bed

Window
- Native shrubs pruned to the right height
- Low, non-native shrubs
- Widely spaced shrubs for full growth and good foliage cover
- Trees with upright crowns
- Trees with raised crowns

Even
- Large number of species, individually mixed
- Small number of species with very similar textures
- One species

Layered
- A few layers with very different textures
- Each layer consists of one species or a few species with very similar textures

Constant
- In species-rich planting the length of the planting element must be many times its height (minimum 100 m)

Rhythm
- Striking individual trees or shrubs planted at regular intervals

Accentuation
- Striking individual trees or shrubs at irregular intervals

Receding
- Free growth along the edge
- Shrub margin in front of tree planting

Upright
- Use of woodland planting as hedge
- Tree planting with low branching crowns

Overhanging
- Edge pruning in a margin of trees and shrubs
- Crown raising in an margin containing only trees

Straight and hard
- Pruning for shape
- Straight, clearly defined edges
- Rhythmic or striking accentuation along the edge
- A sharp silhouette
- Layered

Ragged and soft
- Vague, ill-defined edges; abundant herbs in the edge
- Individual mixing of striking species
- Ragged silhouette

The effect over time

Planting schemes can be grouped according to the way they develop from the time of planting until they reach full maturity.

The first group consists of planting schemes with a pronounced static character. Stated simply, the effect of such planting schemes changes little over time, they just become higher and fuller. These planting schemes are simple, containing just a few species which each have a clear place and contribute to the overall long-term effect.
In contrast, the second group consists of planting schemes with a distinctly dynamic character. A typical example is traditional woodland planting schemes: species-rich, individually mixed planting. The roles of the individual species constantly change, creating a succession of visual effects over time.[37]

The final group of planting schemes are those with a cyclical development. The visual effect is obtained by periodic rigorous pruning back to restore the same visual effect.

Design techniques

Each of the planting groups described above can be linked to a number of specific design techniques to choose from.

Static planting

- The structure of the planting and the role played by each species in the visual effect is determined beforehand.
- The way the visual effect will develop is clear from the start; specific maintenance work will need at certain times to achieve this effect.
- When the planting has reached maturity the purpose of maintenance work is to maintain vitality and a tidy appearance.
- Radical rejuvenation measures are delayed as long as possible.
- The ‘nurse crop’ system cannot be used.[a]
- Use of long-lived species.
- Rows of different species.

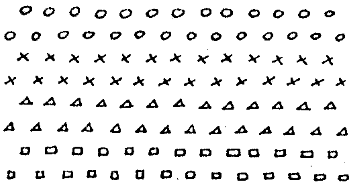

Fig. 114 *Static planting technique*

Dynamic planting

- Indicate the characteristic forms that will determine the appearance of the planting (e.g. transparency)The structure of the planting and the role of each species in creating the visual effect are not fixed in advance. During the growth of the planting there are certain moments when the designer and technical maintenance staff have to decide how the planting scheme will continue to develop. The choice is influenced by the previous visual forms.
- The ‘nurse crop’ system can be used.
- Plants may be individually mixed.
- Species with different life cycles may be mixed together, although this makes maintenance more complex and expensive. The most manageable system is to keep to the life cycle of the main plants.
- The plant bed must be at least 50 m wide; any narrower and it is extremely difficult to manage the visual effect. The planting will acquire a ragged appearance with, in places, considerable differences in height, texture and transparency.

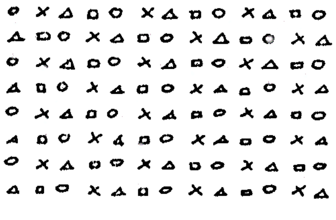

Fig. 115 *Dynamic planting technique*

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[a] In this system the planting mixture contains a number of species which grow faster than the permanent species. Their function is to protect the main planting during the initial years of growth and are removed after a number of years (see § 0)

Cyclical planting

- The appearance of the planting is fixed beforehand.
- The desired appearance develops too quickly but is repeated; the effect is dominated by periodically cutting back to just above ground level.
- The timing of pruning is based on the fastest growers – depending on their rate of growth, once every three to seven years.
- The 'nurse crop' system cannot be used.
- Only species amenable to hard pruning can be used.
- A wide range of species can be used because species do not have the chance to suppress other species.

Restrictions on the choice of plant material

Both the nature of the plant material and the environment in which it is planted impose a number of limitations. If these limitations are not properly taken into account in the design, the desired visual effect will not be achieved.

The range of influential factors can be divided into two groups:[38]
- The characteristics of the plant material itself, called 'iron laws'.
- Environmental influences, in this case the urban environment.

Iron laws

Introduction

The native species available for planting differ widely in two respects:
- Light requirement
- Rate of growth

These differences drive two processes that are always at work in woodland planting schemes:
- The natural process of forming open spaces in woodland
- Process of species supressing other species

Because these processes always occur they are often called referred to as 'iron laws'.

The natural process of forming open spaces in woodland

Under natural conditions, herbs are in time overgrown by shrubs, which in turn are eventually shaded out by trees. The planting 'hollows out', as it were, from the middle. Eventually, the middle of the planting area will consist mainly of trees; shrubs can maintain themselves only along the edges. What develops is, in effect, a natural woodland profile. This process repeats itself when trees die and fall. In the open spaces where sunlight reaches the ground, herbs spring up again, only to be overgrown by shrubs, etc.

This profile does not develop in artificial urban environments because the plant beds are usually far too narrow. This means that in urban areas 'woodland planting' based on this natural process can only contain a segment of the natural profile of the woodland edge. There are a number of possibilities:

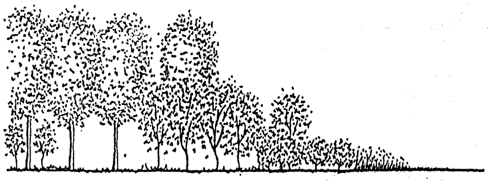


Fig. 116 *Woodland profile*

These are called ‘planting forms’ – in effect, no more than combinations of trees and shrubs derived from the natural woodland edge.

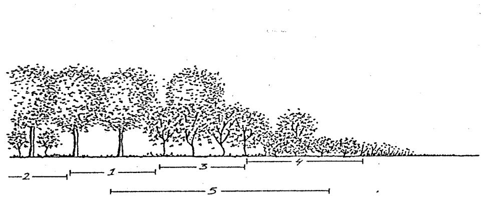


Fig. 117 *Planting forms*

If the process is not the basis of the design, a further option can be added to the list:

In such a planting scheme the process must be continually checked, which requires intensive maintenance. The appearance easily degrades if maintenance work is not carried out on time.

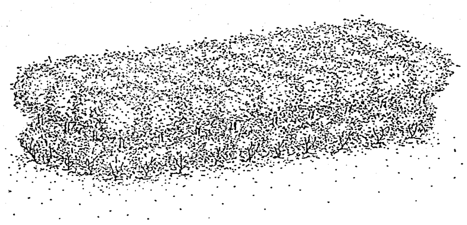


Fig. 118 *Tree layer with a shrub layer*

Each of the planting forms has specific planting and maintenance requirements. These are listed below.

Tree layer

Dimensions:

- minimum width of the plant bed: 15 metres
- in narrower compartments one or two rows of nursery-grown standard trees

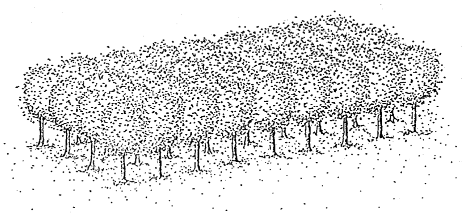


Fig. 119 *Tree layer*

Tree layer with occasional shrubs

In addition to the recommendations for the tree layer above:

- the shrubs must tolerate shade
- the trees must cast as little shade as possible

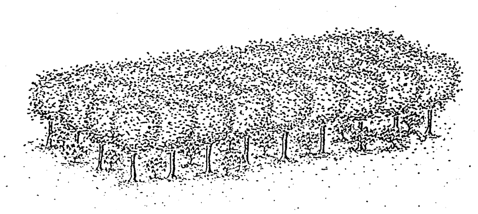


Fig. 120 *the tree layer with occasional shrubs*

Shrub planting

Giving each shrub less space encourages rapid vertical growth. Constraining horizontal growth, though, usually reduces the robustness of each individual shrub.

Fig. 121 *Shrub planting*

Shrub planting with occasional trees

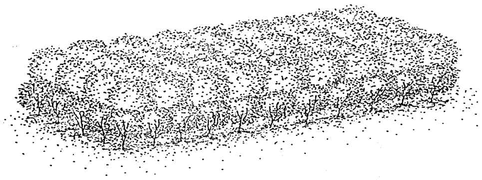
- the trees should cast little shade
- trees should be nursery-grown standards planted at least 20 metres or more apart

the shrubs must grow more slowly than the trees

Fig. 122 *Shrub planting with occasional trees*

Tree planting with a shrub margin

The recommendations made for the tree layer and for shrub planting apply here; tree planting with a shrub margin is actually these two forms joined together. Again, some additional recommendations can be made:



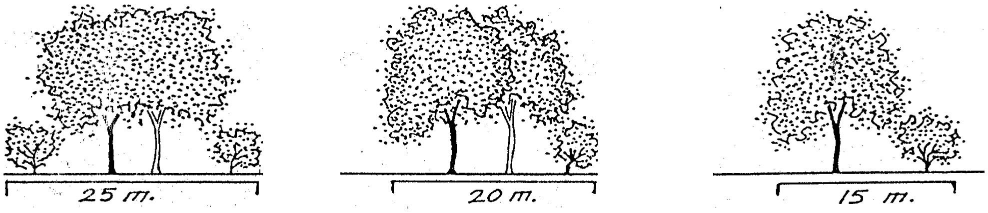


Fig. 123 *Tree planting with a shrub margin*

Dimensions
- minimum width of the plant bed for a symmetrical profile: 25 metres
- minimum width of the plant bed for an asymmetrical profile: 20 metres
- 15 metres is sufficient width for a row of nursery-grown standard trees and a row of nursery-grown shrubs

Plant selection and situation
- sun-loving shrubs can only be planted on open south-facing sites
- a continuous strip of shrubs on north-facing edges is not possible: only a few dispersed shade-tolerant shrubs will be able to survive
- eastern and western edges should be planted with shade-tolerant shrubs

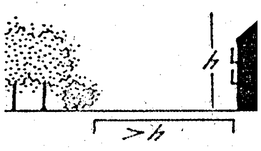


Fig. 124 *This is necessary to ensure sufficient daylight penetration*

Process of species suppression by other species

The environment into which new plants are put (bare soil) is ideal for pioneer species[a] However, planting schemes often involve planting pioneer species and climax species[a] in the same bed. The pioneer species thrive in this environment and soon outgrow the climax species.

We can deal with this in different ways:

- accept the suppression of species
- prevent the suppression of species

Working against the suppression of species is not really possible. Maintaining a rich mixture of pioneer and climax species 'whatever the cost' involves a considerable amount of work. The visual effect is highly vulnerable to any delays in maintenance work.

Accepting the suppression of species

When some slow-growing species have only a temporary role to play in the visual effect, the suppression of species presents no problems. When the planting is still young these species can maintain themselves without difficulty and enhance the appearance of the planting for a while. When the plants grow up they are eventually suppressed and the fast growing species dominate.

This means that:

- the appearance of the planting changes quite a lot during its development, in a sequence of intermediary forms
- this planting type requires relatively little maintenance

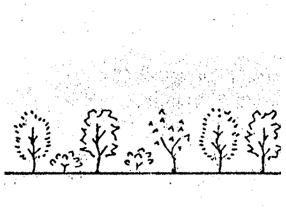


Fig. 125 *Intitial species*

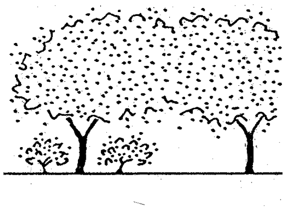


Fig. 126 *suppressed later*

Preventing the suppression of species

If a limited number (1 to 3) of species with the same growth rate are planted none of them will be suppressed.

This means that:

- the appearance of the planting changes little over time
- such planting schemes require relatively little maintenance During its development each species plays the same role in the overall effect.

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[a] These are terms from plant ecology and relate to the changes a natural vegetation goes through in the course of time, the succession.

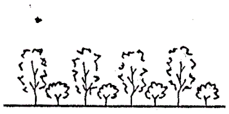

Fig. 127 *Small number of species*

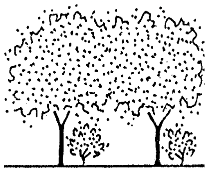

Fig. 128 *not suppressed later*

Artificial succession

A totally different way of dealing with different growth rates is to use the nurse crop system. Pioneer and climax species are planted together, the pioneers (the nurse crop) protect the climax species when they are young. Once the pioneers have fulfilled their function they are cut, allowing the climax species to develop further.

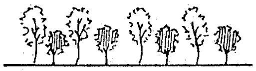

Fig. 129 Nurse crop

Fig. 130 removed

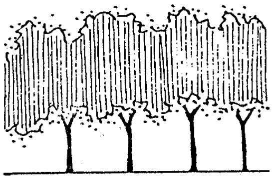

Fig. 131 leaves climax species

This approach means:

- the appearance of the planting changes considerably and suddenly over time; in effect there are two stages, each with its own appearance
- this type of planting requires a relatively high level of maintenance
- the appearance degrades if maintenance falls behind schedule

Urban areas

Introduction

Besides the influences of the plants themselves, the influences of the physical environment surrounding the planting also play a role: in this case, the urban environment.

Data on a number of these factors are available, for example on:

- the soil (profile, mineral composition, organic matter content)
- water management regime
- traffic engineering requirements (sightlines)
- mains services, cables and pipes
- building control (distance to outer wall)
- pollution (exhaust gases, road salt)
- gusts and downdraughts

A few important aspects are discussed below. These are:

- the limited space
- the limited amount of daylight
- informal use (wear and tear)

Limited space

It is only really the width of a plant bed that sets firm limitations on the use of woodland planting in urban areas. The plots in urban areas are often too narrow. Native species in particular need plenty of horizontal space to grow freely. Shrubs can easily achieve a diameter of 5 meters and the crowns of the biggest trees can be as much as 10 metres across or more, given time.

The minimum width of a pant bed must be greater than the width of a spreading shrub because after woodland planting has been thinned the margin will never consist of a straight row of plants.

Minimum width of the plant bed
- Shrubs in woodland planting require a plot at least 6 metres wide.
- A woodland planting that includes trees requires a plot at least 15 metres wide.

Plant beds narrower than 6 metres wide
- Only suitable for woodland planting if at a later stage the margins are continually cut back or pruned.
- Straight row of nursery-grown shrubs or trees.
- The required width can then be reduced to 5 metres. If the margins are also cut back the plot may be even narrower.
- Non-native species with a narrower growth form.

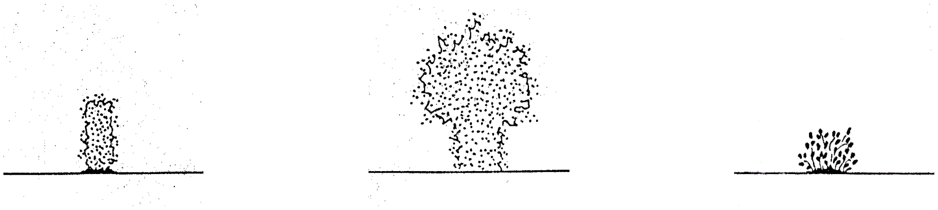

Fig. 132 *Plant beds narrower than 6 metres wide*

Besides a sufficiently wide plant bed, a generous margin is needed if plants are to grow freely and reach their full width.

Edges

On edges you should leave space for later development.

Fig. 133 *Leaving space*

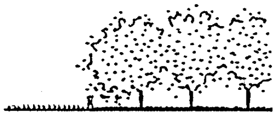

Fig. 134 *for later*

Another possibility is to plant up the whole plot and remove the outside row at the first thinning.

An unplanted strip should be left along the margin of the plant bed. This can be temporarily filled with grass, herbs or ground cover plants.

Fig. 135 *Initial planting*

Fig. 136 *thinning*

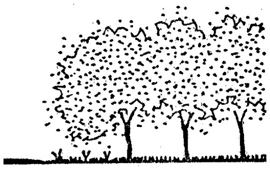

Fig. 137 *for growth*

The stems of the shrubs in the outside row should be no less than 2.5 metres from the edge of the plant bed

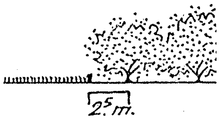

Fig. 138 *Shrub distance*

When trees are included in the planting they should be at least 5 metres from the edge of the plant bed.

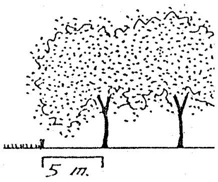

Fig. 139 *Tree distance*

Planting patterns

A regular pattern of rows is the most preferred option for the long narrow plots usually found in urban areas; it permits mechanised planting and hoeing and systematic thinning.

An irregular pattern requires more complex maintenance and makes the visual effect more difficult to control; in narrow plots the planting can easily take on a patchy appearance.

Rows can either be planted to form a square or triangular grid; an important feature of the triangular pattern is that after the first systematic thinning the remaining plants are equal distances apart, which is highly beneficial for their subsequent development.

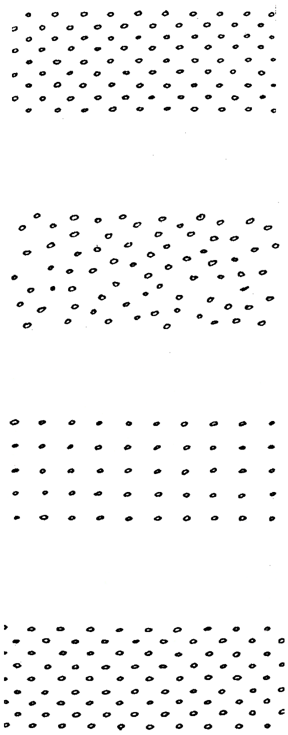

Fig. 140 *Planting patterns*

Limited daylight penetration

The way the edges of the planting develop is heavily influenced by the amount of light. Two aspects play a role here:

The orientation of the edge in relation to the sun.
The location of any nearby objects; other planting and buildings often cut out a lot of light.

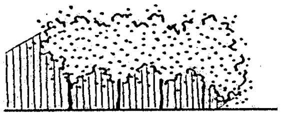

Fig. 141 *Sunlight orientation*

We can deal with these effects in various ways:

- Appreciate the positive aspects of the differences between margins resulting from differences in daylight penetration.
  For example, the differences between a north-facing edge and a south-facing edge can be seen as a special feature. On the shaded side you can look between the stems into the planting; in the background the sunlight filters through the foliage on the other side in a soft green haze. On the sunny side you look at a dense mat of foliage; a few small patches of the darkness beyond are occasionally visible.

- Give all edges the same profile through the careful choice of species.
  If the aim is to ensure a good edging with shrubs, species will have to be planted along the eastern and western edges different from those along the southern or northern edges.

- Careful siting of plants in relation to nearby objects[39].

Fig. 142 *Siting of plants*

  - Trees and shrubs can become straggly and thin if the distance between the plant bed and a nearby object is less than the height of that object.
  - Spreading, well formed trees and shrubs and a dense margin can develop where the distance between the plant bed and a nearby object is greater than the height of that object.

Informal use (wear and tear)

Plants in urban areas are exposed to heavy use. Paths may be worn by people walking through planting elements and children may play in them.

Such wear and tear can be resisted. This is often desirable for planting elements in semi-public spaces, such as residential courts, where residents can exert informal social control to prevent damage to planted areas. Narrower strips of planting are particularly vulnerable and the survival of the whole planting element could be at risk.

- Preventing informal use
  - The first step is to locate the planting element with sufficient care: study the walking routes and level of use in general; maybe even cancel the planting altogether.
  - Plant species that are hard to walk through, such as thorny bushes, but do not forget that these can severely hamper maintenance work and are not suitable near schools or playgrounds.
  - Another option is to add exotic species to the woodland mix. These give the planting a more graceful appearance which can evoke greater respect from the public, particularly if they feel attached to the area.

Instead of preventing informal use there may be opportunities to make use of it. This may be possible in planting with a clear public function in a more anonymous location. In such places, informal use of planting elements can enrich the functional value of the public domain. Moreover, planting areas in public spaces are usually larger and so informal use is no threat to the survival of the planting element as a whole. Plots accessible to the public must be at least 25 to 30 metres wide (deep).

- Accepting informal use
  - When managing a *fait accompli*, e.g. surfacing a short cut worn through regular use, the special qualities (e.g. a certain sense of secrecy) of cutting through the vegetation is destroyed.
  - Not replanting open spots in the planting.
  - Use species that are resilient to wear and tear.
  - Opportunities can be created, for example by tipping a pile of sand in the planting area so that children can make a mountain bike arena.

1.4.2 Planting and Habitat

Factors

The suitability of planting depends on climatological conditions (wind, light, seasons)[40] and physical conditions (soil, groundwater level, air and the space available above and below ground). A different selection of plants is needed behind the dunes along the coast than on a site in a fenland polder or on the sandy soils of Noord-Brabant.
As a designer, you will at first be tempted to base your choice of plants on spatial qualities to do with dimension, form (habit), colour and structure. A further consideration is whether the site is in a rural or an urban environment, where there are special restrictions.

Whatever the scale at which you are working, the final detailing is crucial. Financial resources will often be an important consideration (particularly if planting or transplanting older trees is involved).

Climatological conditions

Wind

Wind, usually from the sea, is an important factor in the west and north of the Netherlands; frost in the east and south. The effects of wind must be fully considered as it exerts considerable pressure on twigs and branches (in leaf). In rural areas, the direction of the prevailing wind can often be read from the shape of the trees.

Poplars grow rapidly and quickly make a spatial impact, but are ‘not solid enough’. At about 40, branches tend to split and so many trees are felled at around this age. Poplars are not the trees to plant if you want them to be around in 100 years time, although they can live for a long time. As solitaires, it may be worth the extra work, but not for an avenue.

Unfortunately, many a good tree succumbs to our autumn storms; the poorest specimens have by then lost their leaves, but those that still have a good leaf cover are exposed to the full force of the wind.

But wind is not restricted to rural areas. The taller buildings built in recent years create considerable ‘downdraughts’. In front of the Robeco building in Rotterdam some trees have been planted to absorb these downward gusts so that passing cyclists are not literally blown through the air! Climatological conditions, therefore, do play a role in urban planting.

Light

Light pollution (albeit only at high levels) and salt (road salting in winter, fish stalls on the market) are disastrous for trees. Light requirement and ‘drip damage’ are more important factors affecting shrubs, and trees with dense crowns permit only a very little undergrowth. The so-called ‘woodland planting’ (plots with trees and shrubs) dating from the 1970s often cause problems now. The trees are large and the undergrowth is dying off purely due to insufficient light. Of the original large plots full of trees and shrubs, only the edges will eventually remain, the planting being hollow under the tree canopy in the middle. If you want the shrubs top remain, plant the trees far apart or choose trees with open crowns that let a lot of light through. ‘Drip damage’ can be a significant problem; some hedges (e.g. Yew) are very susceptible to drip damage, other, like Beech or Sycamore, are unaffected.

Seasons

Planting should look attractive the whole year round. Some trees and plants bloom in winter. Autumn colouration can also add variety.

Spring (flowering)[41]

- trees: alder and willow (March); cherry and magnolia (april); apple, horse chestnut, hawthorn (may)
- Shrubs: hamamelis, forsythia (March); currant, rhododendron (April); azalea (May)
- bulbs/tubers:
- early: (February/March): snowdrop, crocus
- late: (April/May): narcissus, tulip

Summer[42]

- trees: horse chestnut, catalpa (july); golden rain (June)
- shrubs: hibiscus, hydrangea, roses and perennials

Autumn (colours)[43]

- trees: sycamore, birch, hornbeam, sweet chestnut, hawthorn, honey-locust, oak
- shrubs: whitebeam, currant, spindle

Winter

- berries: hawthorn, privet, ornamental apple
- evergreen shrubs: rhododendron, holly, viburnum
- shrubs with berries: currant, whitebeam, ivy, privet, rose

Winter (flowering)[44]

- tree: *prunus subhirtella* ‘autumnalis’ (flowers November/December and again in April)

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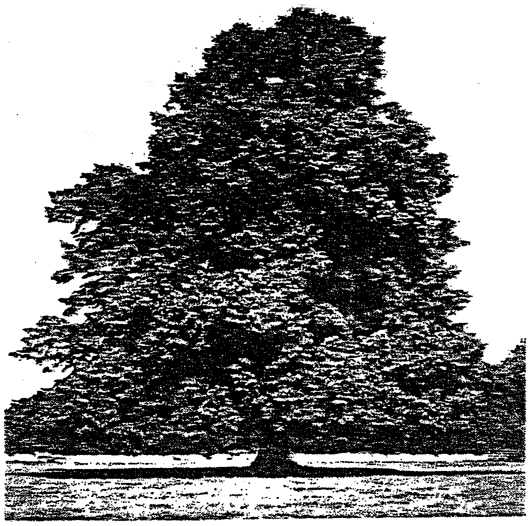


Fig. 143 *Lime (summer)*

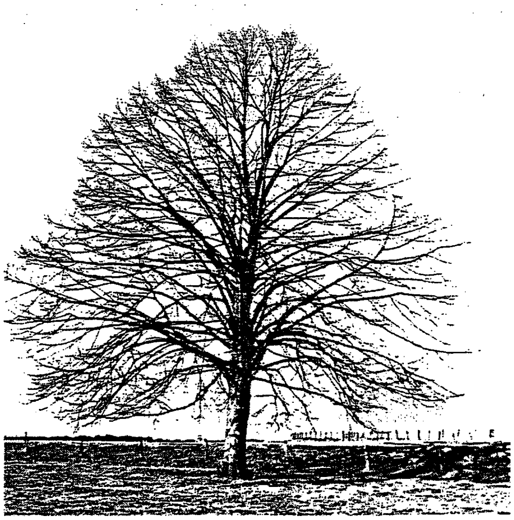


Fig. 144 *Lime (winter)*

Physical conditions

Pysical conditions concern soil, groundwater, air and space for roots.[45]

Soil

Roughly speaking, soil in the Netherlands can be classified into clay, peat and sandy soils (and all the intermediary forms). Plants on sandy soils – often in windy locations – have adapted by reducing the size of their leaves (e.g. sea buckthorn, juniper), by growing hairs on their leaves (mullein) or by taking on light or greyish colours.

Examples of coastal trees:[46]

- alder
- poplar
- oak
- willow
- rowan

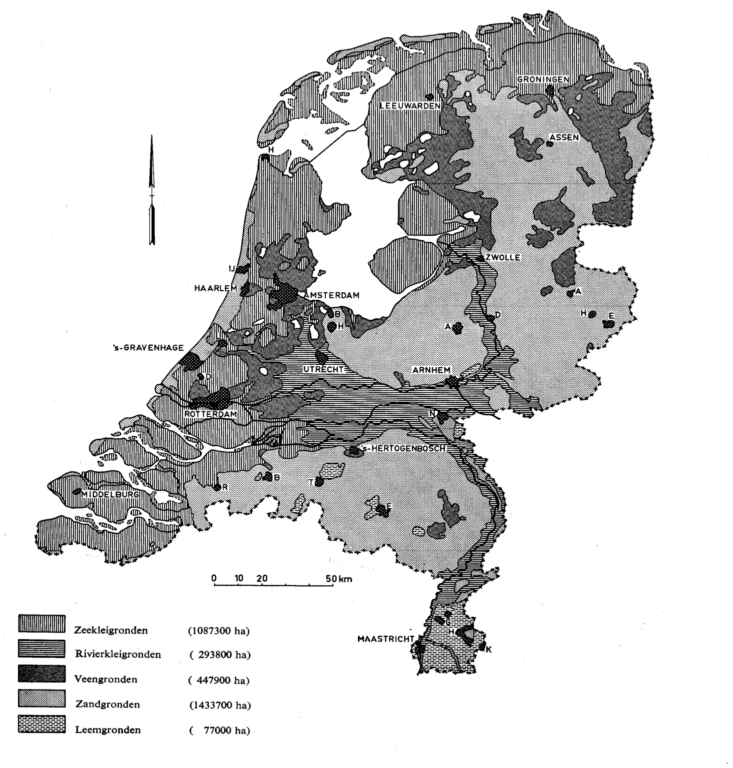
Because of their structure, clay and loamy soils retain water for a long time. They are often cold in spring, and less oxygen is available than in sandy soils.

Examples of trees on clay/loam soils:[47]

- alder
- horse chestnut
- birch
- cherry

Another important factor is the presence of calcium, which supports a different type of vegetation; a base-poor dune vegetation contains different plants to calcareous dune valley vegetation. Peaty areas are acid and always moist; nutrient levels are a crucial factor. alder and rowan do well in nutrient-rich peat, birch in nutrient-poor peat. Well-known shrubs suitable for acid soils are rhododendron and azalea. If they are planted in other soil types, peat will always have to be added to the soil.[48]

The above also applies, in principle, in rural areas, where plants still have a ‘feel’ for the soil. Clearly, in purely urban environments the original soil is less important for plants, particularly trees.



Sea clay
River clay
Peat
Sandy soils
Loamy soils

Fig. 145 *Soils of The Netherlands*

Groundwater

If the water table is too high, few trees and shrubs will be able to survive. Tree roots will develop poorly and not anchor the tree well in the ground; as a result they are easily blown over. Of course, too little groundwater is not good, either; the plants wilt.

Trees which can grow in wet conditions are: Alder, Birch, Poplar and Willow. [49]
Trees that can grow in dry conditions are a few Maple species, Birch, Hornbeam, Acacia and a few Poplar species. During the growing season (May to August) tress take up large quantities of water from the soil.

In an urban environment, trees depend on a number of sources of water:

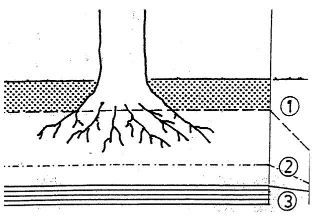
- Groundwater

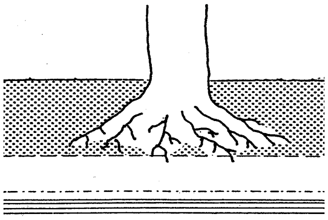
- Capillary water (‘sucked’ up from the groundwater through the soil)
- Pendular water (precipitation that clings to the surface of particles in the aerated zone)

The demand for water in summer is greater than the amount of pendular water. The extra is drawn from the groundwater; the water table falls in summer, but it is replenished again in winter from rain and snow.

Much water in the city goes straight into the sewer; the more ‘porous’ the paving is the better this is for the trees. But the water must remain for as long as possible in the pendular water zone. Humus is a valuable component in the soil because it retains a lot of water.

The best situation is a water table that fluctuates around 1.25 m under the soil surface (1.50 m in the summer and 1 m in the winter).[50] Under these conditions trees can become well established and firmly anchored. If a tree cannot take up enough water, the roots go in search of more. The root ball of a healthy tree reflects the size of the crown.





1. Soil containing humus
2. Capillary zone
3. Water table

Fig. 146 Spring

Fig. 147 Autumn

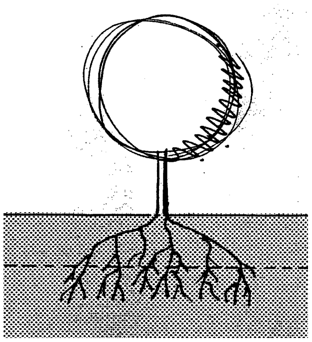


Fig. 148 *Groundwater level approx. 1.25 m:Roots and branches: above ground = below ground*

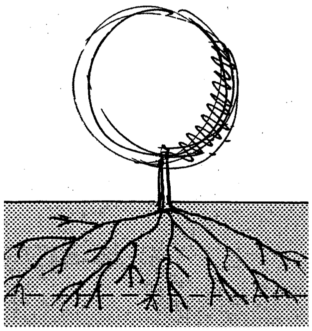


Fig. 149 *Deep groundwater level: roots ‘search out’ water*

Air

Trees in built-up areas – except trees in parks and gardens – grow in a habitat that simply cannot be compared with a site in a wood or open landscape. The soil in the country is open (to air and water) and fallen leaves provide a supply of nutrients. Conditions in urban areas are very different. Paving requires well compacted soil; but trees need open soils. Air is kept out by the closed road surface and compacted soil, which leaves almost no pore volume for air to penetrate.

In open soils, about 50% of the volume is air; below 15% oxygen, roots become stunted, at 11% oxygen they start to die. All paving seals the surface of the soil and so open spaces – slotted flags or widely spaced paving bricks – are essential. Trees cannot develop roots under asphalt surfaces (0% oxygen). The pressure and vibration caused by heavy traffic further compacts the soil.

In ‘sinking’ areas (peat soils) in the West of the Netherlands the paving has to be raised every so often, even up to 30 or more centimetres at a time. As a result, many trees receive too little oxygen and die. Oak and Beech always die, Lime trees grow a new layer of roots if the additional soil layer is no deeper than 25 to 30 cm. Elms and Planes tolerate these conditions quite well.[51]

A. Sinkhole
B. Sawn kerb, min. length 500
C. Kerb type Cru 80
D. Tree grille Cruquius concrete blue limestone colour 1200 x 1200 x 120
E. Air grate
F. Dark paving brick (size, 20x6.6x6)
G. Dark paving brick (Waal size, 20x5x7)

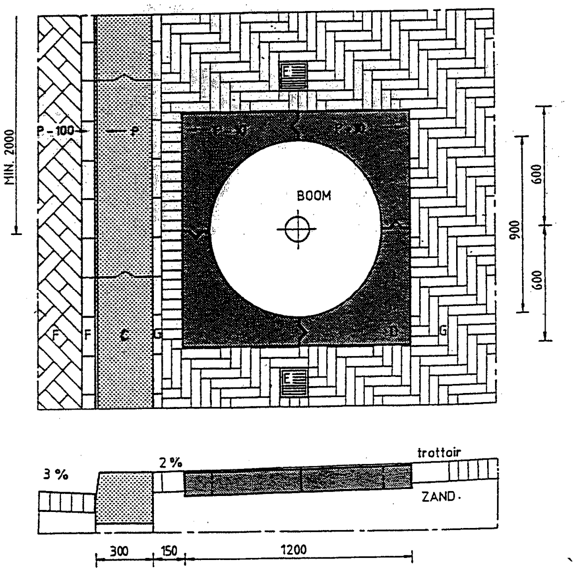


Fig. 150 *Tree pit*

Root corridor and tree pit

Urban trees cannot be viewed in isolation from their environment; they are one of the factors that define the public domain in the city. Street trees add to the quality of public spaces and have a different effect in each place. When planting trees in urban areas it is wise to design a strip for trees only, with no cars, cables and pipes or street furniture: a ‘corridor’. This ‘plantpit’ can be finished with a 10 cm layer of sand, with paving on top (with no risk that the paving will sink any faster than the surrounding area).[52]

If this is not possible, a tree pit of 2 x 2 x 1 m should be made and filled with suitable tree soil. Tree soil is light soil, contains approx. 4% humus, is well aerated and well drained, retains water well and contains sufficient nutrients. Where more air is required in the soil, perforated drainage pipes can be used as ‘air pipes’ to ensure better aeration of the soil.

In many places, though, hard road surfacing and numerous mains services and cables leave no room for planting. In these situations the minimum area required for a tree is 7.5 m on both sides (i.e. 15 m apart) because otherwise they will have an even greater struggle for survival. The more open the structure of the topsoil, the better this is for the tree.

It is important to choose a good tree grille. Square tree grilles are often used in paved areas because these fit well into the pattern of most paving materials. Cast iron or metal tree grilles are attractive, but expensive. Accumulation of dirt and rubbish in the space between the grille and the soil (approx. 10 cm) can be prevented by filling this space with Argex pellets until right under the grille. These are light, expanded clay granules (reddish brown) which considerably improve aeration. Another attractive solution is to use gravel. A cheaper option is 30 x 30 cm slotted flags. In parking areas always ensure that the tree trunk is protected.

Cross-section
Pavement
Tree corridor
Road / main sewer
Pavement / cables
and pipes

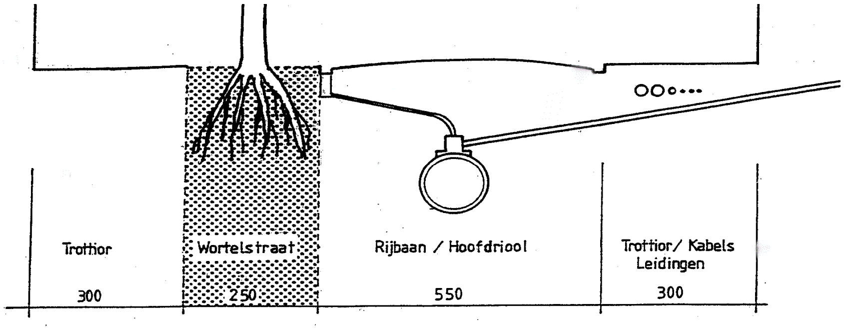


Fig. 151 *Cross-section*

Types of trees

Size, form, structure, colour

Size and form not only depend on climatological and physical factors, but also have a major impact on the streetscape. In spatial terms, they may or may not provide structure or accentuate the spatial composition (see Tree Structure Plan Amsterdam). Texture relates to the shape, size and arrangement of the leaves and it is very important when detailing to ensure compatibility with the materials used. Colour speaks for itself. A significant fact is that light green tints have the effect of expanding spaces, dark green and red-brown make spaces seem smaller and can create a sombre atmosphere. Copper-leaved trees are striking, particularly as solitaires, such as copper beeches on farms (also sycamore/maple, apple, cherry, oak).

Choosing a tree

When choosing trees, consider the amount of space above ground. If you meet the conditions discussed above (tree pit, soil, etc.) there is a chance that the trees will grow to maturity and attain their full size. Plane trees can easily have branches 10 m long, and so they should be planted 12 m from buildings. If the pavement is not very wide, choose a tree a size or two smaller or a tree with a columnar crown. If not, the crown will soon grow up against wall and must either be pruned each year, or the tree felled and another species planted.

Size classes of trees:[53]

- Size class 1: 15 m and taller
- Size class 2: to about 10 m
- Size class 3: to about 5 m

Size 1 trees develop crowns at least 15 metres across. Large dense crowns must be avoided in small streets, where trees with light open crowns are to be preferred (e.g. Gleditsia/Honey Locust). For most residents the minimum acceptable distance between crown and wall is about 2 metres. Obviously, planting distances will bear some relation to the location of the doorways, drives and passages along street frontages.

Planting distances

If trees are planted very close to buildings, drastic measures are repeatedly needed to ensure enough daylight penetration. Sometimes these measures can be so drastic that the resulting remnant of the tree may no longer make a positive contribution to the streetscape.

To plant trees that can develop freely with the minimum number of complaints, you need to weigh up the following considerations:

- The nature of the building facade
- The distance between the trees and the building
- The distance between the trees
- The tree species
- The pruning method

In real terms, this means that when planting new trees, *minimum distances* must be adhered to. Greater distances should be used when planting trees with a broad, dense crown, such as plane and horse chestnut.

Trees may only be planted at shorter distances than given in the table:
- When planting trees with a columnar or thin crown
- Along ‘blind’ walls
- When special pruning methods are used, such as espalier, pyramid pruning and pollarding
- When only a few trees are planted along a street frontage

Rows of trees let through very different amounts of daylight, depending on whether the crowns of the trees join together (closed) or are spaced apart. This makes it important to note the relevant planting distances for the various size classes.

Planting

As a rule trees are planted between 1 November and 15 April. They are then resting and have the best chance of becoming established.

Standard sizes of trees for planting are:
- 14–16 cm girth (approx. 5 cm diameter)
- 16–18 cm girth (approx. 6 cm diameter)
- 18–20 cm girth (approx. 6.5 cm diameter)

The price ratio for these sizes is 1:1.5:2.

Planting distances for rows of trees:

Size class	open row (spaces between crowns)	closed row (crowns touching)
size class 1	> 18 m	5–10 m
size class 2	> 12 m	5–8 m
size class 3	> 9 m	< 5 m

Minimum distance between the buildings and the centre of the stem[54]

size class	min. distance stem to building
size class 1	6 m
size class 2	4 m
size class 3	3 m

In urban renewal areas where high levels of vandalism are expected it is better to plant fewer larger trees rather than a larger number of thinner trees.

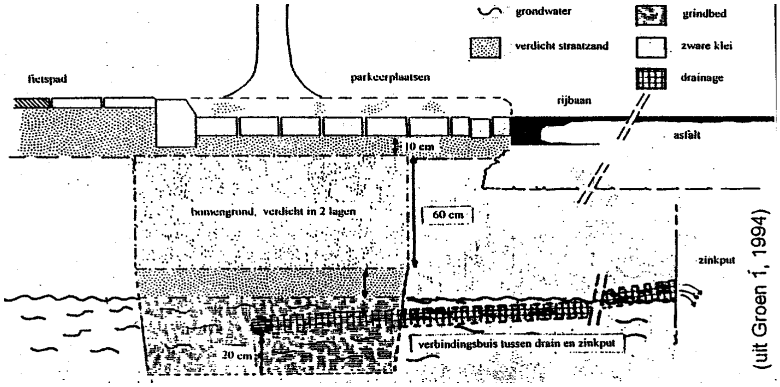
Transplanting

Trees with stems about 30 cm diameter can be transplanted; the larger the tree, the more expensive the operation. Trees with bigger stems can be transplanted, but their chances of survival are much smaller. Ensure that the root ball is as large as possible (min. 3 m across and 1–1.5 m deep). If you know well in advance that a tree will be transplanted the roots can be cut when the tree is still standing, and new hair roots will grow to form a neat compact root ball. This can be done is summer or winter.

The latest method is to soak the root ball in winter. This then freezes to create a solid ball of soil and roots. The tree can then be lifted out with a crane and transported by trailer to its new site. After planting (good pit and tree soil, etc.) the tree should be pruned to restore the balance between the root system and the crown. Prices depend on size, transport options (disconnecting the overhead tram lines, transplanting at night, etc.) and financing. Transporting a Horse Chestnut with a stem diameter of 45 cm over a distance of 1 km (difficult journey, disconnection of tramlines and transport by night) costs about € 10,000 per tree.

groundwater (grondwater)
compacted street sand (verdicht straatzand)
gravelbed (grindbed)
heavy clay (zware klei)
drainage (drainage)

Bicycle path (fietspad)
Parking places. (parkeerplaats)
Tree soil, compacted in two layers (bomengrond verdicht in twee lagen)
Road (rijbaan)
Asphalt (asfalt)
Soakaway (zinkput)
Pipe between drain and soakaway (verbindingsdrain tussen drain en zinkput)



(Source: *Groen* 1, 1994)

Fig. 152 *Modern tree pit design for the trees in the Plantagemiddenlaan, Amsterdam*

1.4.3 Tree planting and the urban space

Visual effects

Different visual effects can be reached applying loose groups and solitaires, rows, rhythm, screens, walls or diferent canopies.[55]

Loose groups and solitaires

The plants are allowed to grow in their natural form and are often used to create a contrast between a 'hard' architectural element and a loosely structured planting scheme. A 'loose' planting scheme can only be used when there is sufficient space available. Solitary trees are, in effect, 'green monuments'; they often stand in special locations and have a striking form (e.g. a Lime tree in the village square).

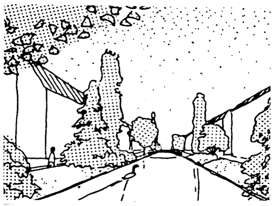


Fig. 153 Loose groups

Rows

A planting scheme in which the distance between trees is so great that the crowns cannot meet. Rows are often used for long, regular street frontages. The free-standing trees provide some visual articulation along the length of the street. In rows the specific characteristics of the tree species are the key visual features: each crown is clearly set off against the buildings.

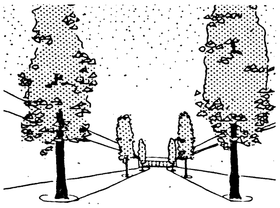


Fig. 154 Rows

Rhythm

Comparable with a row, but in this case the trees are planted in such a way that the visual articulation they provide is integrated into the design structure of the built environment. A rhythm may consist of solitaires. This planting pattern can be a good solution for situations where there is not enough space for continuous planting schemes. Instead, many trees can be planted on corners or other regularly occurring sites where there is more room.

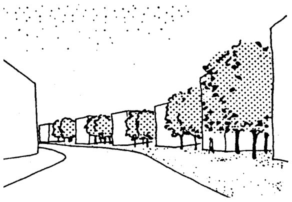


Fig. 155 Rythm

Screen

A screen is a transparent wall of trees through which the facades of the buildings are more or less visible, depending on the viewpoint. A screen is best created using species with an open crown in which the branches do not grow in one main direction so that they easily flow together to form a visual whole. Elms are good trees for creating a screen. Some other species, if planted close together and with some extra pruning, can also be used to create a screen effect. A problem, though, is that if the trees are planted close together the transparent effect can easily be lost.

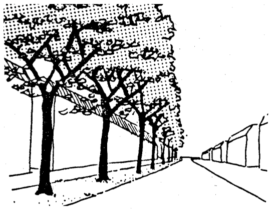


Fig. 156 Screen

Wall

A wall consists of multiple rows of trees planted short distances apart so that the crowns grow into each other. If tree species that develop dense crowns are used (e.g. Lime) it may even be possible to plant just one row; the trees must then be no more than 8 m apart. In the summer this planting scheme creates the effect of a ‘green wall’. It is important that the trees form a continuous whole. If the planting distances are too great or if too many trees are missing from the row, the wall effect is largely lost.

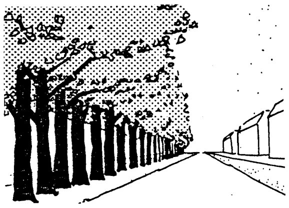


Fig. 157 Wall

Canopy

A canopy consists of multiple rows of trees short distances apart and with intertwining crowns. The most suitable trees species are those with a broad, fairly open crown. The canopy effect is largely lost if the trees are planted too far apart to form a unified mass.

Fig. 158 Canpy

Habitat

The choice of tree species, pruning method and intensity of the maintenance regime are determined partly by the street profile. The biggest problems arise in narrow streets with trees that are too large. In narrow streets with pavements between 3 and 5 metres wide, only trees with a narrow pyramidal or columnar crown should be planted. Trees with a broad pyramidal crown or a definite spreading habit must be planted at least 7 m from the nearest building.

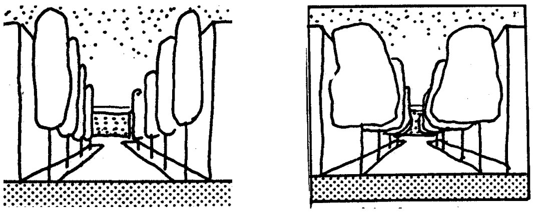


Fig. 159. Columnar or pyramidal crowns in narrow streets

Trees in size classes 2 and 3 are also suitable for planting in these situations. Fig. 160 shows a cross-section through a narrow pyramidal tree in a narrow street. This tree requires a lot of pruning:
Crown thinning: pruning branches back to allow daylight penetration to the buildings
Possibly crown reduction: shortening lateral branches to prevent them touching the buildings
In wider streets with pavements at least 6 m wide it is possible to plant trees that have a more spreading habit. The maintenance work required is comparable with that in example *A*.

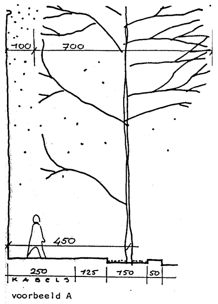


Fig. 160 *Narrow columnar habit*

Fig. 161 shows a tree with a columnar crown has been used. These require less pruning: only crown raising and possibly a little thinning. Unfortunately, few species have this habit. The well-known *Populus nigra* 'Italia' cannot be planted in narrow streets because its very shallow roots push up the hard surfacing (heave). This species requires a zone about 5 m across free of hard surfacing.

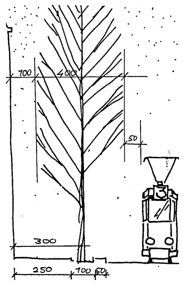


Fig. 161 *Pyramidal habit*

Fig. 162 shows a tree planted near a private garden. In these cases, medium-sized trees should be planted no less than 5 m away from the edge of the garden. For trees with a spreading habit, like Plane and Horse Chestnut, this distance may need to be as much as 15 m. This distance must be adhered to prevent:

- the tree blocking out all light to the garden;
- undue sucker growth in the garden;
- spreading branches.

In special cases, meetings can be held with local residents/users about planting trees in or near private gardens, but firm maintenance agreements will have to be made.

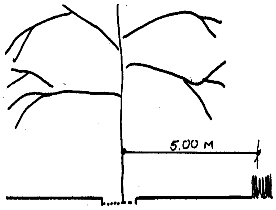


Fig. 162 *Tree close to private garden*

The sensitivity of certain species to climatological influences, particularly when they get older, can pose considerable problems. The most striking example is vulnerability to wind. Large, spreading branches are highly dangerous and may lead to liability problems for the party responsible for maintenance (usually the municipal council).

Achieving the desired visual effect

Besides the habitat of the trees, other essential factors in achieving the desired visual effect are the choice of species and planting scheme. If, for example, a screen of trees is to be planted in a street, the designer will have to decide whether to use a slow-growing species at short distances apart or a fast-growing species planted further apart. In narrow streets, however, fast-growing species will soon cause problems and it is better not to use them.

There are three methods for achieving a reasonably good planting(visual effect(time)) in a relatively short time:

- plant slower growing trees at short intervals;
- plant a mix of fast and slow growing species;
- plant semi-mature trees (more than 10 years old).

Re 1: Planting at short intervals quickly yields a reasonably good visual effect. Short distances between trees are often necessary to obtain a screen or wall effect. An advantage of planting trees close together is that the trees compete for light and quickly grow upwards, giving an upright habit with straight stems. A disadvantage is the extra pruning that is often required.

Re 2: Mixing species with different growth rates requires intensive maintenance work which must be carried out promptly. It is only recommended for planting in broad strips of vegetation (woodland planting). The advantage here is that slow growers are ‘forced up’ by faster growing species. This only works with some species: elms can be combined with poplars; oaks grow too slowly and are eventually shaded out.

Re 3: Another option is to plant semi-mature trees at their final distances apart. Semi-mature trees, however, find it hard to adapt to their new habitat and it takes a few years before they grow at their normal rate again. Moreover, transplanting is an expensive business. An advantage of container trees is that they can be planted easily and successfully at any time, even outside the planting season. This makes these trees highly suitable for use in special situations: rapid restoration of planting schemes in squares or along an important road, or after accidents, etc. However, container trees are often slow to become established and can be ‘overtaken’ by smaller, root-balled trees.

Planting distances

When deciding on the planting distances needed to achieve the desired visual effect the following points should be considered:

- the final diameter of the crown of the tree
- height of the tree
- the habit of the tree (tree shape, height/width ratio, openness of the crown)
- the root system
- shading of nearby buildings
- width of the road and path (for canopy effect)
- the relation between the final height of the tree and nearby buildings
- the period needed to achieve the desired visual effect

A number of examples are presented to explain points 1, 2 and 3.

Road and street planting, seen from the carriageway

Seen from the carriageway, rows, screens, walls and canopies create increasingly enclosed effects.

Visual contact with the wider environment. Trees planted at 20 to 30 m intervals form an open row which permits a good view of the wider environment (trees of size class 1) (See Fig. 163).

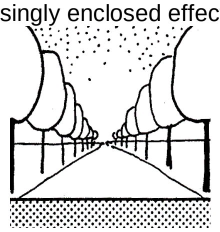


Fig. 163 *Screen/row*

Greater delineation of the road; a wall gives a stronger effect than a screen. Planting intervals should be no greater than 10 m to allow the crowns to grow together. A careful choice of species is necessary because not every species grows well in this configuration (See Fig. 164).

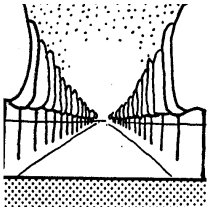


Fig. 164 *Wall*

The vault: the trees have an upright habit (with branches at an angle of 45 to 60 degrees). The crowns just meet to form a very high ‘roof’. A narrow road planted with Elms creates this effect well (See Fig. 165).

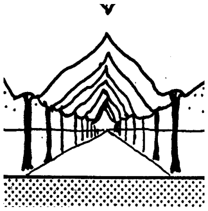


Fig. 165 *Canopy, vault*

The flat canopy: mature broad pyramidal trees or trees with overhanging branches give a flat, broad canopy. The branches grow at an angle of 0 to 45 degrees. Trees that can be used to create this effect are Oak, Horse Chestnut and Lime (See Fig. 166).

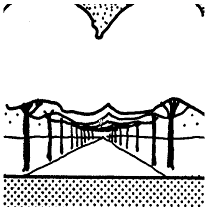


Fig. 166 *Flat canopy*

The cathedral effect: two rows on either side of the road, the crowns of the inner rows are lifted higher than the outer rows(See Fig. 167).

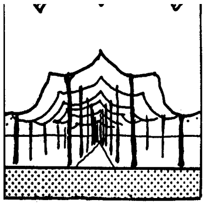


Fig. 167 *rows are lifted higher than the outer rows*

Planting distances

Planting distances have a considerable effect on the urban environment according to the applied size class.[56]

Closed screen or wall

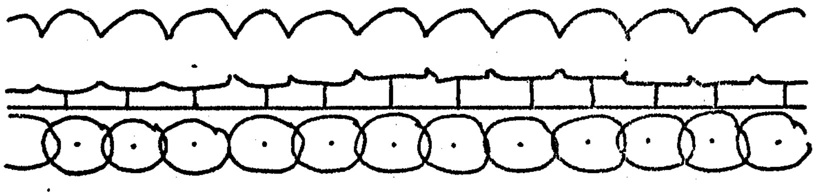


Fig. 168 *Trees of size class 1; planting distance 5–12 m; open under the crowns*

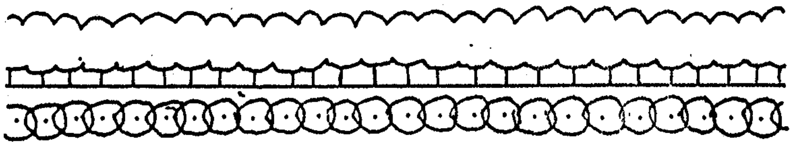


Fig. 169 *Trees of size class 2; planting distance 3–8 m*

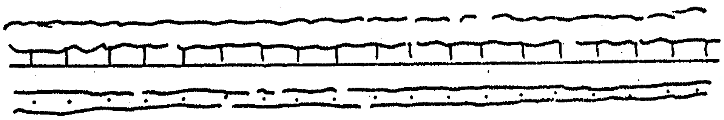


Fig. 170 *Trees of size class 3; planting distance 2–4 m*

Row

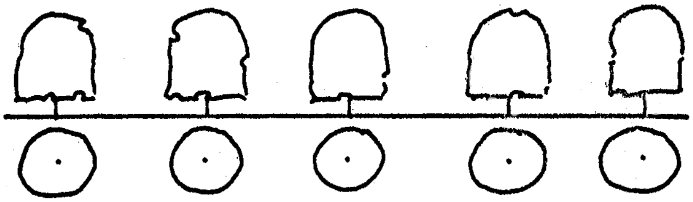


Fig. 171 *Trees of size class 1; planting distance 20–30 m*

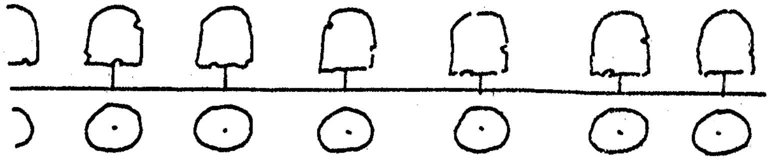


Fig. 172 *Trees of size class 2; planting distance 15–30 m*

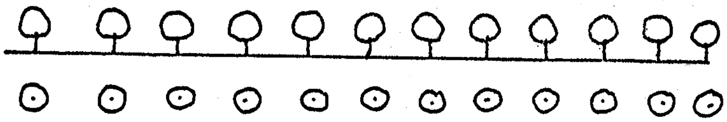


Fig. 173 *Trees of size class 3; planting distance 10–20 m*

Silhouettes of the different trees

Fig. 174 *Alder (els)*

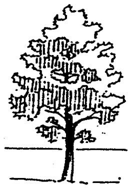


Fig. 175 *Black Poplar (populier)*

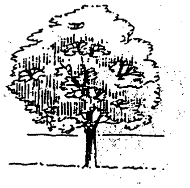


Fig. 176 *Ash (es)*

Fig. 177 *London Plane (plataan)*

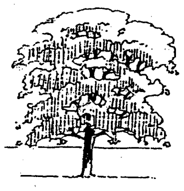


Fig. 178 *Elm (iep)*

Fig. 179 *Common Oak / Pedunculate Oak (eik)*

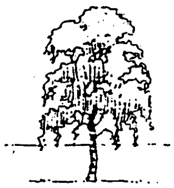


Fig. 180 *Downy/White Birch (witte berk)*

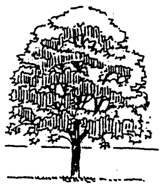


Fig. 181 *Sycamore / Great Maple (esdoorn)*

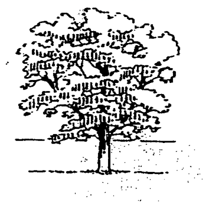


Fig. 182 *Locust Tree / False Acacia (acacia)*

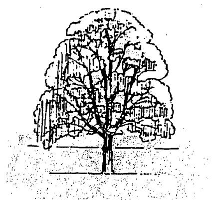


Fig. 183 *Common Lime (linde)*

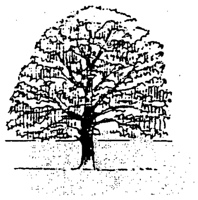


Fig. 184 *Common Beech (beuk)*

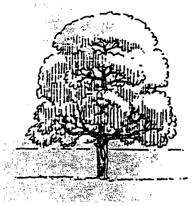


Fig. 185 *Horse Chestnut (kastanje)*

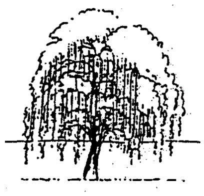


Fig. 186 *Weeping Willow (treurwilg)*

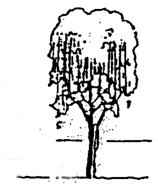


Fig. 187 *White Willow (schietwilg)*

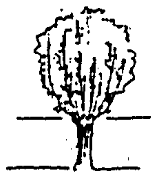


Fig. 188 *Pollarded Willow (knotwilg)*

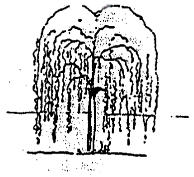


Fig. 189 *Weeping Ash (treures)*

Pruning

There is a balance between the amount of leaves and roots a tree has. If too much growth (above ground) is cut away the tree will compensate for its shortage of leaves by throwing up many new shoots. Pollarded trees such as Poplar and Willow must be pruned each year. Trained trees/espaliers are grown for their architectural form. Examples are:

- Lime
- Plane
- Hornbeam

A nursery grown tree has been pruned in the nursery to obtain a clear stem height of 2 m while its natural form is maintined. During the first 5 to 10 years the crown of the tree will require some light pruning. Trees close to the edges of a road must have their lower branches remove to ensure sufficient clearance for passing traffic.

Trees do not last forever, so do not hesitate to remove old specimens with a limited life expectancy and plant younger trees!

Crown raising

Trees planted along roads and paths should have their lower branches removed. This crown raising (to a height of about 2.5 m) is started when the trees are still young. Depending on the situation, a street tree will have to undergo further crown raising over the years. In some cases up to as much as 7 m above ground level (species with hanging branches).

When raising a tree crown thought should be given to obtaining the right balance between the length of the stem and the crown (2:3 or 1:2). It is an unattractive sight for a tree of 14 m to have a clear stem height of 7 m. In these cases it is better to go for an asymmetrical crown. In the example above the tree may have its crown raised to 4 m on the pavement side, but up to 7 m. on the side above the road. This gives the streetscape a much better appearance. The rows of elms planted along canals are a good example of asymmetrical crown raising. In some cases, pruning will still be necessary on the side facing the buildings to ensure sufficient daylight penetration.

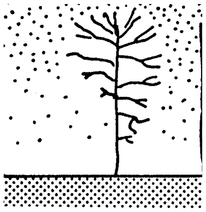


Fig. 190 *crown raising near building*

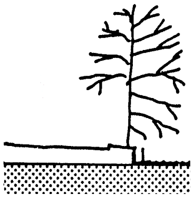


Fig. 191 *crown raising along a canal*

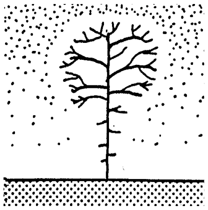


Fig. 192 *partial crown lifting*

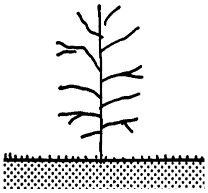


Fig. 193 *crown raising in grass*

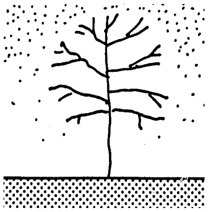


Fig. 194 *crown raising in a street*

Crown raising heights

planting stock	2.5 m
residential streets	3 m
main roads	4.5 m
tram lanes	4.5 m
trees with hanging branches	to 7 m
asymmetrical: housing side	2.5 m
asymmetrical: canal + quayside	2.5 m
asymmetrical: canal + grass	0–2.5 m
in grass	0–2.5 m
in ground cover	0–2.5 m
in low shrubs (to 1.5 m)	0–2.5 m
in medium-sized shrubs (to 2 m)	2.5 m
in tall shrubs (from 2 m)	2–7 m

Summary

The choice of plants depends on:
1. The site and growing conditions
2. Growth characteristics and habit of the planting material
3. The appearance of the planting and the atmosphere it creates
4. Practical aspects (function and goal)
5. Cost and available funds

1. Site and growing conditions
- natural landscape
- cultivated landscape
- urban area
- nature and character of the buildings (tall buildings create windy conditions)

Growing conditions

Soil type
- Sand nutrient rich
- Peat nutrient poor
- Clay
  - calcareous / lime rich
  - non-calcareous / base poor
  - acid
  - good/poor structure
  - humus content

Groundwater levels
- high – wet
- low – dry
- water retaining capacity of the soil

Climatological conditions
- sheltered
- exposed
- coastal
- urban area
- industrial site
- wind
- frost

Light requirement
- open site / full sun
- semi-shade
- full shade

2. Growth characteristics and habit

Tree dimensions
- Size class 1
- Size class 2
- Size class 3

Shrub dimensions
- Evergreen – taller than 4 m
- Deciduous 2–4 m
- 0.5–2 m
- less than 0.5 m

Crown shape and habit of trees
- spherical
- spreading
- broad pyramidal
- narrow pyramidal
- columnar
- weeping

Crown shape and habit of shrubs
- groundcover
- spreading
- upright
- compact
- overhanging

Texture
- leaf shape
- leaf size
  - large
  - medium
  - small
- leaf arrangement

Leaf colour
- light green – dark blue-green
- light to dark brown
- yellow
- variegated

Blossom
- flower colour
- flowering season early spring
- spring
- summer
- autumn
- fruit
- autumn colour
- bark

3. Appearance

Visual effect
- ankle height
- knee height
- waist height
- breast height
- eye level
- above eye level

Mutual relation between elements
- harmony
- contrast
- rhythm
- decorative value

4. Practical aspects
- winter hardness
- vitality
- disease resistance
- abundant and/or long-lasting blossom
- function in the plan
- spatial layout
- relation to buildings
- relation to existing planting
- client's wishes
- wind protection
- shade
- traffic guidance
- noise reduction
- enclosure
- ground cover

5. Costs
- purchase costs and required dimensions
- intensity of maintenance
- length of implementation period
- available financial resources

1.4.4 Hedges

Hedges divide the space where a fence or wall is undesirable. The primary function of a hedge is always separation, most obviously to divide two uses, for example to divide a private space (garden) from the public space. Hedges provide a natural background for other plants; thorny hedges form an impenetrable barrier. Hedges have an important spatial effect. They can be classified into those which divide up the space in which they stand ('free-standing') and those that form part of a larger mass immediately behind them.[57]

When the spatial impacts of hedges are examined more closely, it seems obvious to classify them by height. According to their application, we can then distinguish: edges (to approx 0.5 m high), partitions (0.5–1.5 m) and full screens (more than 2 m high). Their respective applications are: as an edge when used to mark out patterns or a composition of lines, as partitions when their function is to resist or direct movement, and as a full screen to visually seal off a space.

One spatial effect of hedges is to facilitate comprehension of the scale of the space and the elements in it, because the hedge has a consistent size (height) which serves as a reference on a human scale. Another spatial effect is created if the hedge is quite long and forms a connecting element that provides continuity. For this purpose hedges do not have to be trimmed; a row of shrubs (a 'loose hedge') can also create this effect. Besides their spatial effects, hedges may also, possess a number of intrinsic characteristics.

Natural (loose) habits of shrubs can be tightened up by pruning to form a hedge. These neater forms give hedges a more cultivated appearance, and the hedge is a symbol of continuous human intervention in the natural process of growth. A trimmed hedge can be used in two ways:
As a contrast with 'looser' forms in the surrounding area, or with a less cultivated environment (e.g. a neat hedge around a farm, set in an agricultural or quasi-natural landscape).
As a harmonising element; the regular 'architectural' shape of the hedge harmonises with an architectural, usually urban, environment.

Hedges may have an *ornamental value*, which cannot be seen in isolation from the above – the contribution the hedge makes to the appearance of the wider environment. The characteristics of hedges discussed above make them an ideal means to accentuate a prominent location.

Hedges have two major disadvantages. First, they have to be pruned regularly, in some cases two or three times a year. Second, they take up considerable quantities of nutrients, which are then not available for any plants near the hedge, making regular fertilisation necessary.

Hedges for marking out spaces

Hedges between the main road and bicycle lane or footpath

These hedges are planted for traffic safety reasons: they make crossing impossible and at night they prevent glare from the headlights of oncoming traffic. These street profiles are only found in post-war urban areas and non-urban areas. Trimmed hedges require a lot of maintenance, though, and in these situations can easily be replaced by untrimmed hedge/shrub planting if there is sufficient space, or, in places where the safety function is not essential, by a normal verge.

Hedges along watercourses

(See Fig. 195)These are also planted for safety reasons, to keep children away from the water. *The hedge is a friendlier type of fence*. The need for and value of hedges in the neighbourhood should be determined. Such hedges do not remove the danger altogether, but keep it at a distance and make it less threatening, but, because of this very effect, can make the (unknown) danger much greater.

In addition to the functions mentioned above, these uses of hedges can enhance appreciation of the scale of the space in which they stand.

Hedges as a visual screen to hide (mainly) parked cars

(See Fig. 198)This use of hedges is particularly dependent on the environment. They are suitable for this purpose in an urban environment, but in other environments they can easily be replaced by an untrimmed hedge or shrubs. It may even be worth considering removing some taller plants; owners often want to see their parked cars from the house.

Hedges as space-shaping elements

Hedges can create their own separate (sub)rhythm different in character from the larger space they are part of. An example is a garden surrounded by a hedge, possibly in a park, the regular form providing a contrast that sets off the space. In this case the trimmed hedge is an essential element. Should the situation within the hedges ‘not work’, it is better first to see if another use of the space can improve the situation before deciding to grub up any hedges. Hedges are planted around playgrounds and seating areas mainly for safety reasons because they stop children running onto the road. Besides this strictly functional aspect, hedges also provide ‘shelter’ and ‘security’ for the play area. In other words, the hedge marks out a territory.

The same quality of ‘security’ or ‘cover’ is provided by hedges surrounding a sitting area with benches. A trimmed edge is justified around such areas if they form a contrast with the loose forms in the area and so create their own place, or if the site is located within a paved area where the use of hedges adds an architectural dimension and has a practical effect of saving space (the ‘paved character’ relates to walls as well as horizontal surfaces).

Hedges as edging for a mass

The hedge as linear element

A tall or medium-sized hedge can provide a background for roses, for example, or a border. Removing such a hedge often destroys the appearance of the border and is only advisable if the border is of a sufficient size.

Hedges that form a pattern or composition of lines

Very low hedges, which are essentially an edging, are found around borders of roses or perennials. Often they are laid to give the border a less dreary look when there is little to see in the border itself. This situation has value only if two conditions are met:

The height of the hedge is in proportion with the planting material in the border
The hedges themselves form a particular pattern that is interesting enough when the roses of perennials have been pruned or cut down.

Use of these types of hedge is only justified in prominent places or in situations where there is very little green. Moreover, their maintenance is time-consuming in proportion to their length. Sometimes a compromise solution is acceptable to reduce the length of such hedges.

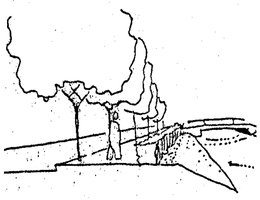


Fig. 195 *Hedge along watercourse*

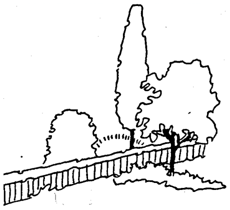


Fig. 196 *Contrast*

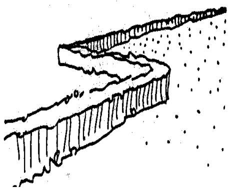


Fig. 197 *Hedge in open space*

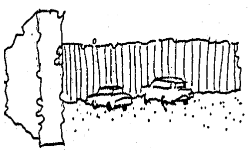


Fig. 198 *Hedge bordering car park*

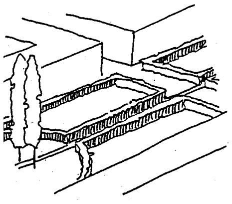


Fig. 199 *Harmony*

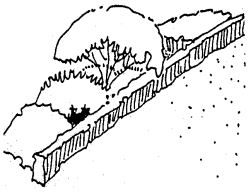


Fig. 200 *Hedge as part of a mass*

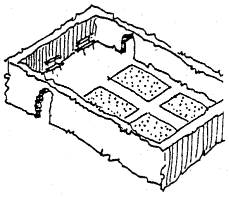


Fig. 201 *Hedge enclosing a garden*

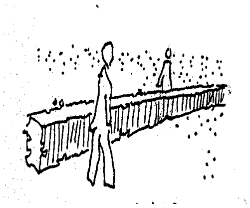


Fig. 202 *Partition*

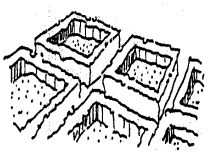


Fig. 203 *Edges*

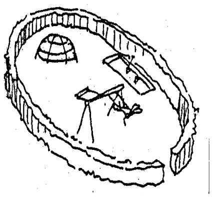


Fig. 204 *Hedge round a ‘place’*

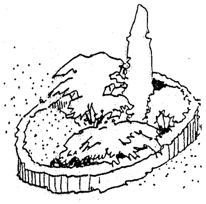


Fig. 205 *Hedge bordering shrub bed*

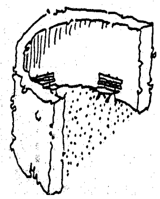


Fig. 206 *Complete screen*

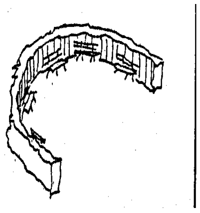


Fig. 207 *Shelter for seating*

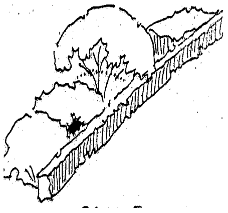


Fig. 208 *Edge*

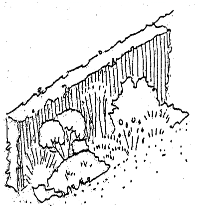


Fig. 209 *Background to border*

	Planting distance	Loose/regular	Growth rate
Evergreen hedges			
box (*buxus sempervirens*)	$5/m^1$	regular	
holly (*ilex aquifolium*)	3 à $4/m^1$	regular	
common yew (*taxus baccata*)	$3/m^1$	regular	
holly (*ilex aquifolium*)		loose	
privet (*ligustrum ovalifolium*)	3 à $4/m^1$	regular	
size 40–60			
deciduous hedges			
hornbeam (*carpinus betulus*)	$4/m^1$	regular	
beech (*fagus silvatica*)	3 à $4/m^1$	regular	
hawthorn (*crategus monogyna*)		loose	
blackthorn (*prunus spinose*)		loose	
rose – botanical roses		loose	

Growth rate: number of years until the plant reaches a height of 1.5 metres (depending on habitat, soil type and maintenance)

Pruning hedges

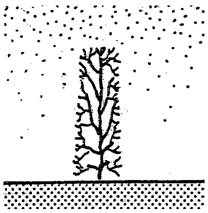


Fig. 210 *vertical*

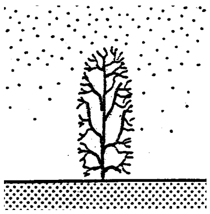


Fig. 211 *rounded*

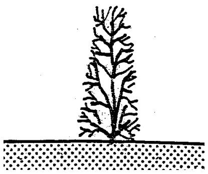


Fig. 212 *tapered*

2 Wind, sound and noise

Contents

2.1 Global atmosphere

2.1.1 Air, its mass and density

Pull the closed end of a garden hose out of a bucket filled with water and take it with you upstairs to the fifth floor. Above 10m, water is replaced by vacuum like vapour (mercury has vacuum above 76cm). Apparently, atmospheric air pressure on the bucket (1 bar, 100 000Pa, 100 000N/m^2 or old fashioned: 0.987 atm, 10 197.162 kgf/m^2)[58] can not push it higher. So, the mass of approximately 500km air above 1m^2 Earth's surface should equal approximately 10m^3 water or 10 000kg. Because the surface of the Earth is ample half a billion km^2 there is ample 5 x 10^{18} kg air, less than a millionth of the Earth's mass (6 x 10^{24}kg). At sea level density ρ of air is 1 290g/m^3 [59] which equals 3 x 10^{25} particles (*Fig. 215*).

2.1.2 Wind, its force and power

So, if your own cross section is 1m^2, then in one second at a wind velocity of 1m/sec (3.6km/hr), 1m·1m^2= 1m^3 air (1.29kg) would hit you. Fortunately much of this mass immediately starts flowing sideward around you (see chapter 2.6.4). Otherwise it would not 'pass by' and a train of many m^3 (many times 1¼ kg) moving air in front of you had to be resisted. But you are only changing its direction and velocity, braking it by 'negative acceleration', which is felt as a force, because force=mass·acceleration as we learned from Newton.

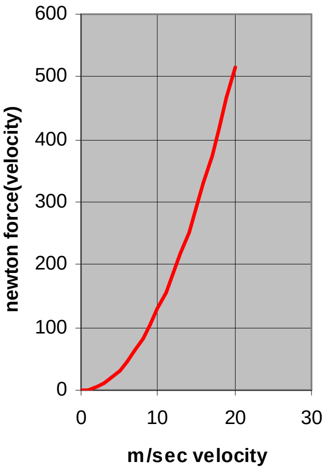
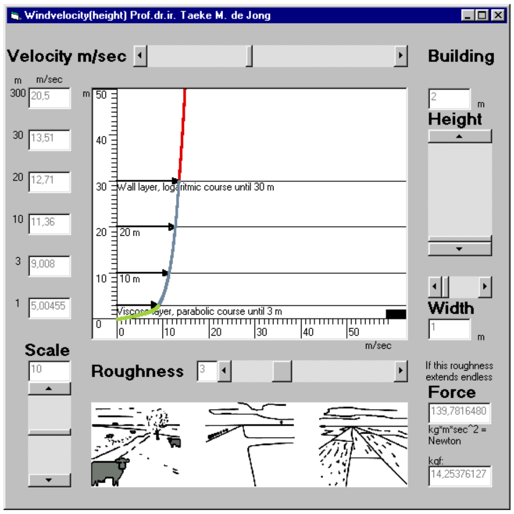


Fig. 213 *Wind force (= air mass x velocity/sec) Air mass = density x volume and air volume = height x width x length. Because air length = velocity x sec, velocity occurs two times in the formula for wind force, so force increases parabolically by square of velocity.*



Windvelocity(height) Prof.dr.ir. Taeke M. de Jong

m	m/sec
300	20,5
30	13,51
20	12,71
10	11,36
3	9,008
1	5,00455

Building: 2 m

Width: 1 m

Scale: 10

Roughness: 3

If this roughness extends endless

Force: 139,7816480 kg*m*sec^2 = Newton

kgf: 14,25376127

Wall layer, logaritmic course until 30 m

Viscose layer, parabolic course until 3 m

Fig. 214 *Wind velocity increasing by height depending on roughness of foreland. Wind load on a building has to be calculated on every layer of height and summed up to total height. Sideward flow is neglected here*[a]

But, to keep calculations simple we suppose you have to resist 1m^3 of air per second, that is 1.29kg/s at 1m/s, which is a force of 1.29kg·m/s^2 or 1.29N. It is per m^2, so you can also say a 'pressure' of 1.29N/m^2 or 1.29 pascal (1.29Pa). In storm (10m/sec) it will increase to 129N/m^2 (Fig. 213), because now 10m^3 air or 12.9kg hits you in one second also with ten times higher velocity! To get an impression: that force corresponds to the force produced by a child+bike (30kg) hitting you cycling at 15km/hour.

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[a] Jong (2001) *http://team.bk.tudelft.nl > Publications 2006 > Windvelocity(height) .zip*

So, to calculate the force or pressure (force/m^2), you have to take velocity *two times* into account. One time you need velocity to calculate the air *mass* hitting you in one second and the second time you need velocity to calculate *acceleration* (velocity per second) to determine force because force=*mass·acceleration*. So, wind force increases parabollically by *square* of wind velocity (see Fig. 213)[60]. However, these figures are valid on 1m height average, where ‘storm’ in grass land corresponds to 10m/sec (36km/hr) , but at 10m and 20m height it corresponds to 24 and 26m/sec at the same time. The velocity increases with the altitude first like a parabole, then logaritmically and at last exponentially in the ‘boundary layer’ influenced by the ‘roughness’ of the Earth (see Fig. 214).

Buildings are wider and heigher than you are, taking up much more m^2 surface. But you can not simply multiply the surface by the force you have to resist on ground level to get the force a building has to resist, firstly because the velocity increases by height. You have to calculate the wind load on an building on every level and sum all these force contributions up to total altitude (see Fig. 214). Download the Windvelocity(height) program with 8 pictures in the same directory and it will estimate the force in layers of 1cm be it neglecting sideward effects. The environment on the ground (roughness) has great influence, determining differing parameters you have to use. Get a feeling how it works by changing wind velocity and roughness in the program. It is a fast and rough approximation. To be more precise you should calculate it at any spot by vector integration in 3 dimensions, including sideward movements, decelerations and accelerations depending on the shape of the building[61].

2.1.3 The atmosphere

However, air density also decreases from 1290g/m^3 at ground level into 1g/m^3 at 50km height (see *Fig. 215*)[62]. So, aeroplanes meet less resistance the higher they fly (until 20km), but propellers and wings will work less effective as well. That is why jet engines are used at higher altitudes with higher velocities.

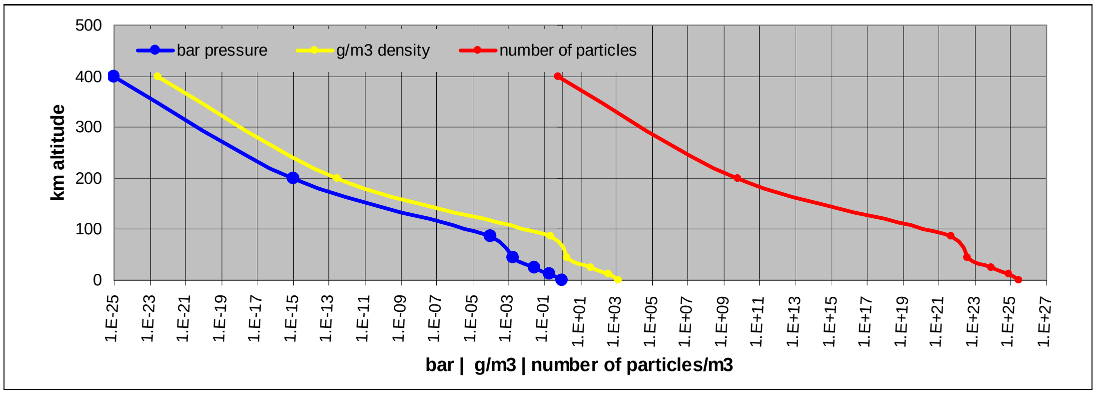
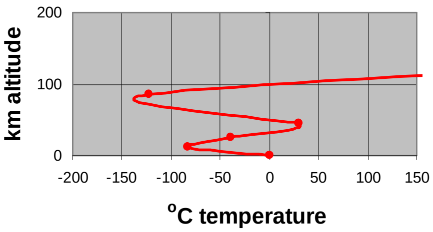


Fig. 215 Pressure, Density, Particles/m^3(height)
A bar is 100000N/m^2 or 100000Pa or approximately 1 atmosphere
1.E+03 in Excel means 10^3

The air temperature has three turningpoints according to the altitude (see Fig. 216)[63].The smallest wave lengths of ultraviolet sunlight entering the atmosphere from 500km altitude are directly absorbed heating the thin air more than 1000°C until it equals heat loss by own radiation. That influence reaches until approximately 100km altitude. Around 50km (mesosphere) the rest of UV light is nearly fully captured by ozone heating the air until 20°C at 50km with decreasing influence between 50 and 10km (stratosphere). On 10km the atmosphere measures - 50°C. However, the main stream of visible and infrared light is not captured and heats up the Earth’s surface, on its turn heating up the atmosphere by convection from below until 10km (troposphere) or radiating it back to universe as invisible infrared light, only captured by CO_2.



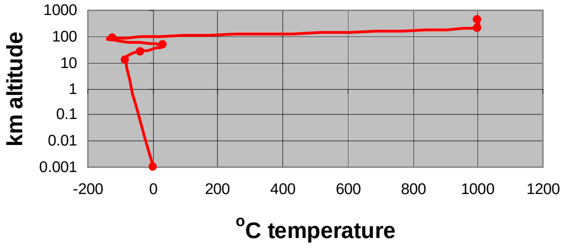


Fig. 216 Air temperature(altitude)

Fig. 217 Air temperature(log(altitude))

An air bubble heated by the Earth's surface climbs up in the troposphere expanding by decreasing environmental pressure. The aquired heat content is dispersed in a larger volume. So, its temperature decreases until it matches the environmental slower decreasing main temperature and rising stops. Meanwhile from a specific temperature onward damp could condensate to steam and ice resulting in cumulus clouds rising with drying air. They show a flat bottom indicating a temperature boundary for condensation is passed[64]. By condensation solar heat is released, giving the steaming air bubble an extra push upward.

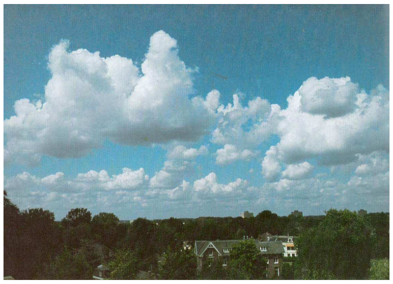


Fig. 218 Cumulus clouds with flat bottom[a]

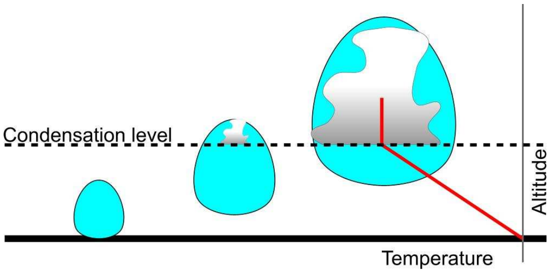


Fig. 219 Air bubble condensating

2.1.4 Climate

The Earth turns Eastward 360° in 24 hours. The equator is 40 000km long[65], as Napoleon ordered to determine the length of a metre. So, at the equator we have a velocity of 1 670km/hour and we are 3g lighter than at the poles by centripetal force. That force has stretched the Earth's radius 22km outward compared with the radius toward poles when Earth was yet a turning droplet from a sneezing sun. The same still happens to equatorial atmosphere: it is thicker there than at the poles[66].

Equatorial air heated and saturated from moist by tropical temperatures climbs fast and high (see Fig. 220). Shortages on the ground are supplied by 'trade winds' from South East and North East[67]. Coming from North and South they are not used to equatorial high speed Eastward. Seen from the ground their inertia give them a Westward drift. But they are pulled along with rough grounds. Then, once heated they climb higher than everywhere else on Earth, because of centripetal forces. Moreover, environmental density and temperature decrease slower here with so much competing air bubbles around, stimulated by an extra push from condensation causing tropical showers below.

But they continue to loose heat by expansion and radiation into the universe and reach the point they can not rise anymore because their temperature matches the environment. Where to go? Pressed by their upward pursuers they fly back high Northward and Southward getting colder and colder by radiation as an outburned balloon. They land in a subtropic latitude slower Eastward turning as if they came from South East causing subtropical high pressure and cyclones in struggle with winds departing direction South West into tropics as they did themselves in their youth. They join them at last causing a horizontally rolling spiral movement at larger scale between tropics and subtropical regions

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[a] Bont, G.W.Th.M. de; Zwart, B.; KNMI (1985) *De wolken en het weer* (Zutphen) Terra

or they travel direction pole participating in a second rolling movement as South-Western winds we know so well in The Netherlands.

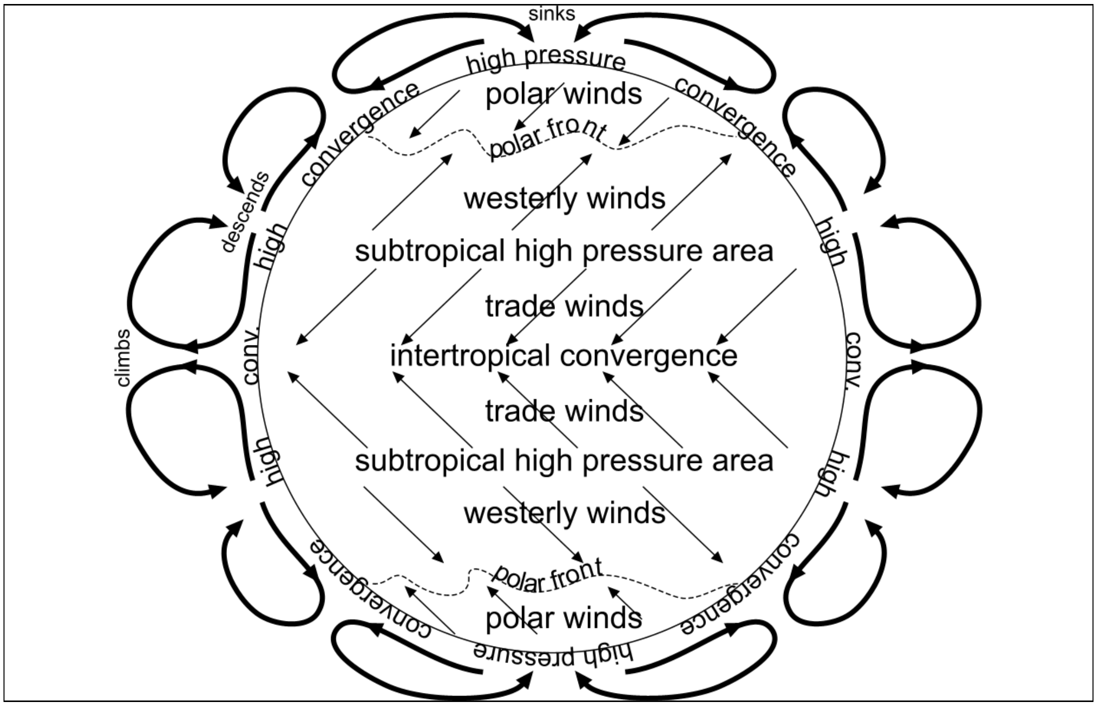

Fig. 220 *Gobal wind circulations*[a]

From the poles cold, heavy sinking air is swung by a turning Earth in all directions as polar winds. Parallel whirlings drag eachother like gearwheels in turning cells. Nobel prize winner and founder of chaos theory Prigogine (1977) boiled water in a very regular and stable pan like Bénard did in 1904 and saw regular cells emerging as structured 'order' out of chaos. Something like that could happen on a very stable, regularly heated Earth. But the Earth is turning and nodding (see Fig. 37), shaking its atmosphere like busdrivers their passengers. And it has continents heating up faster than oceans, having less water to evaporate. Disturbed by so much global and local causes meteorologists never can predict the weather of next week because little events have great consequences in the world of chaos like the proverbial butterfly causing a tornado some years later elsewhere. What is cause? However, in the long term we find some regularities (three 'rolling' cells from equator to pole) in the sum of turbulences called wind.

2.1.5 The urban impacts of wind

Local velocity of wind affects:

1. wind loads on buildings, plantation and objects in streets and gardens.
2. the energy use of buildings;
3. the potential profit of wind turbines;
4. the dispersion of air pollution;
5. the comfort of outdoor space;

In Fig. 213 we already showed the parabolic course of impact 1.
In Fig. 221 up to Fig. 224 on the vertical axis estimates of the other impacts are represented as a working of average wind velocity classes from 0,5 (0-1) up to 19,5 (19-20) m/sec on the horizontal axis.

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[a] After Bucknell (1967)

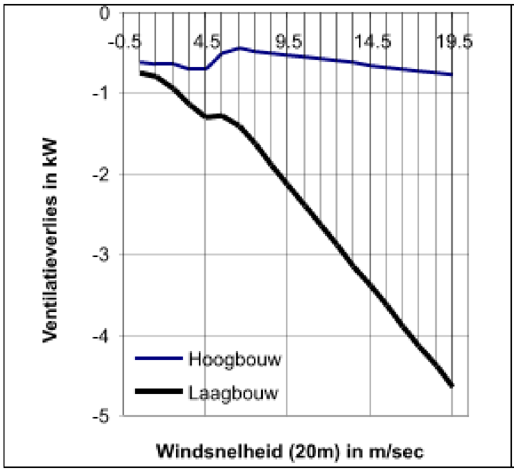


Fig. 221 *Ventilation characteristic*
Ventilation losses from dwellings increase according to the velocity of wind particulary in non airtight houses[68]. However, from 4 m/sec people close their windows. So, in this interval more wind *decreases* ventilation losses.

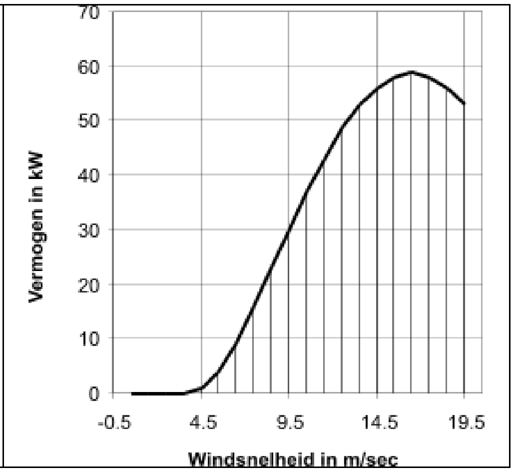


Fig. 222 *Powercharacteristic*
The produced power of this standard wind turbine increases up to 60 kW on a wind velocity of 16 m/sec. Most wind turbines brake on higher velocities to avoid damage[69].

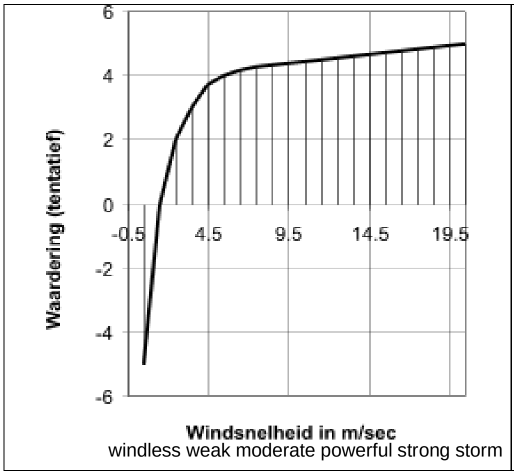


Fig. 223 *Air dispersion characteristic*
This tentative diagram represents air pollution disperses best by storm, but that impact is already reached on moderate wind.

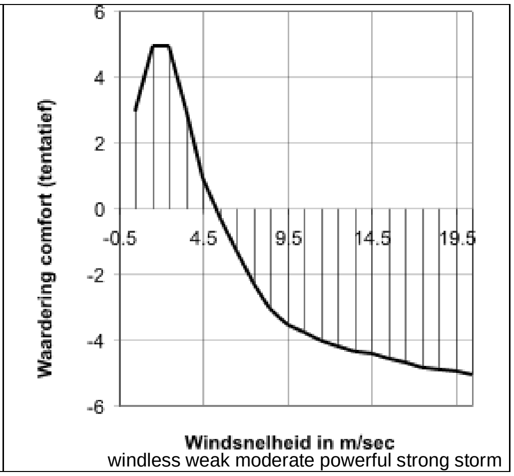


Fig. 224 *Comfort characteristic*
In this tentative diagram is supposed that a weak wind with an average velocity of 1-3m/sec is appreciated most.

Fig. 221 is used by Vermeulen (1986), point of departure in this chapter. In that time, high rise buildings were much more airtight than low rise buildings. That difference will be less today, but to show the impact of wind on energy use of buildings the 1985 span is most illustrative and still relevant. When after all, convection losses, losses by precipitation (drying up of buildings) neglected by Vermeulen and Jong (1985) would be calculated as well, an equivalent and even stronger positive relation than for former low rise buildings could be actual. An actual total energy loss characteristic then, could have an other form, but the line of reasoning remains the same. Minimisation of energy losses desires minimisation of wind velocity anyway. The fourth impact requires rather optimisation (not too much, but not too little as well). For higher velocities the aim is also minimisation of wind velocity. However, the second an third impact on the contrary require maximisation of local wind velocity. So, their aim is contrary to the first and last impact. In this representation temperature influences (relevant for Fig. 221 and Fig. 224) are still neglected.

Local average wind velocity can be influenced by environmental planning and design on national (r=100km), regional (r=30km) and different local levels (r= {10, 3, 1, 0.3 en 0.1}km). Measures on these levels are discussed in this chapter. They are not all equally applicable. Sometimes they have a theoretical of experimental character with little profit. Then they have a didactic value useful discussing next values. If that occurs, the measures and their impacts are discussed in a conditional sequence: any measure should be seen within boundary conditions of preceding measures. So, one can not miss a paragraph: measures on a local level could be understood only within boundary conditions of regional scale and these for their part from those on national level.

Here sometimes fades the boundary between ‘measure’ and ‘given circumstances’. Is the current Dutch coast the consequence of human measures or should one speak of ‘given circumstances’? A once performed measure then is a given circumstance, a condition for subsequent measures. To keep this chapter clear and readable anything deviating from a reference situation will be concerned als ‘measure’. Every time two states wil be compared: the reference and its deviation by application of the ‘measure’ concerned. The impacts of that measure are assessed. Though we wil try to formulate the ‘measures’ as context independent as possible the impact assessment remain context sensitive.To be able to apply such measures in other circumstances succesively added theoretical insights are necessary.

The choice of reference in such a method of ‘experimental impact assessment’ is important. Choosing ‘the average Dutch outskirt, filled with low-rise dwellings’ as a reference produces a rather practical image of measures, be it not well applicable for inner cities and high-rise areas. However, we are attached to raise some theoretical insight in aerodynamics. So, we will change references to show impacts that can not be assessed in a standard reference. So, the reference sometimes will have a theoretical character like ‘a city in the sea’ or ‘a sea in the city’ to clarify impacts by extremes. In practice after all, a measure lies between these extremes. By attention for extremes not only one specific measure is discussed, but a range of measures with gradually changing impacts.

2.1.6 Measures, targeted impacts per level of scale

The measures discussed in this chapter can be taken on the level of

- national choice of location (100km radius, page 107)
- regional choice of location (30 km radius, page 113)
- arrangement of rural areas, form of conurbations (10 km radius, page 125)
- local choice of location (10 km radius, page 122)
- form of town and town edge (3 km radius, page 131)
- lay-out of districts and district quarters (1 km radius, page 129)
- allotment of neighbourhoods and neighbourhood quarters (300 m radius, page 146)
- allotment and urban details and ensembles divided in 4 hectares (100 m radius, page 141)
- buildings (radius 30m), and
- the micro climate, important for humans, plants and animals (radius 10m).

The conditionality into two directions is self evident. To be able to compare variants on one level a reference on any other level is presupposed. That creates difficulties in comparing measures on different levels of scale, because references have to change to reach more general insight in impacts. Morover, for every several impact (on energy saving, energy production, air pollution and comfort) other characteristics of wind are relevant. For instance for energy saving windstatistics of the winter season are relevant, for other impacts those of the whole year, eventually specified per season. If not otherwise mentioned this chapter counts on wind statistics of the whole year.

2.2 National choice of location

2.2.1 National distribution of wind velocity

What kind of difference does it make choosing a new housing estate near Amsterdan or Eindhoven concerning energy use, the possibility to extract energy from wind, the dispersion of air pollution and the comfort of outdoor space?
To weigh different building locations concerning these impacts on a national level a simple calculation of wind statistics per location is needed. Here we give a description of such calculations.

On more than 50 locations in The Netherlands wind velocity is regularly measured (Fig. 225).

Selection from Wieringa, Rijkoort et al. (1983) page 28

Fig. 225 *Wind stations in the period 1945-1980*

Selection from Wieringa, Rijkoort et al. (1983) page 84

Fig. 226 *Year average potential wind velocity*[70]

Wind stations register gusts of more than 5 seconds duration. All measurements are averaged for one hour resulting in the 'hour average wind velocity'[71]. From these hour averages a year average can be calculated, the 'year average wind velocity'[72]. Obstacles around the wind station introduce a deviation by which these data are not immediately applicable in neighbouring locations. The correction into a 'standard ground roughness 3' (grass land) and a standard height of 10 metre produces the 'year average potential wind velocity' given in Fig. 226. Using local ground data (roughness classes) from the year average potential wind velocity one can calculate back the year average wind velocity of neighbouring locations on different heights.

2.2.2 Closer specification of wind statistics

However, in the year average wind velocity some data are lost relevant for energy use, potential energy profit, dispersion of air pollution and comfort of outdoor space as impact of different wind velocities.
Firstly we miss a specification of wind direction and a statistical distribution into different wind velocities throughout the year. For that purpose we still have to go back to the sources the 'distributive frequency division of the hour average wind velocity per wind direction, reduced to 10 metre height above open ground' per wind station. In Fig. 227 this frequency division of wind station Schiphol in the years 1951 - 1976 is given in numbers per 10 000 observations.

Velocity Class* m/sec	Still or variable 0	1	2	E** 3	4	5	S 6	7	8	W 9	10	11	N 12	TOTAL
vk	w													
0,5	348	10	8	11	10	12	16	14	16	15	9	13	14	148
1,5	78	39	43	50	51	58	72	53	66	51	36	44	55	618
2,5	15	59	82	98	80	97	132	111	119	84	68	79	102	1111
3,5	2	88	118	133	94	118	155	160	125	106	84	94	107	1382
4,5		86	132	136	86	124	150	170	113	110	77	87	87	1358
5,5		82	110	101	55	86	121	157	113	112	74	76	71	1158
6,5		74	112	82	46	71	100	163	119	109	73	76	66	1091
7,5		46	88	52	22	47	73	113	123	98	58	62	42	824
8,5		38	59	29	8	27	51	92	90	77	48	37	26	582
9,5		21	44	17	5	17	32	68	84	59	40	29	15	431
10,5		13	29	14	3	10	21	52	70	45	30	17	7	311
11,5		8	14	6	1	4	13	32	53	32	19	10	4	196
12,5		4	8	3		2	8	25	45	26	14	7	3	145
13,5		1	3	1		1	4	15	30	17	7	4	2	85
14,5		1	2	1			1	8	20	9	4	3		49
15,5			1				1	6	12	6	3	1		30
16,5								3	8	4	3	1		19
17,5								2	8	4	2			16
18,5								2	5	3	1			11
19,5								1	2	1	1			5
20,5									2	1				3
21,5									1	1				2
22,5									1					1
TOTAL	443	570	853	734	461	674	950	1247	1225	970	651	640	601	10000

* Here the middle of the class ± 0,5 is mentioned only.

** Here the wind direction in 'hours of the clock' are given; 12 hour indicates North.
'12 hour' contains all wind directions between -10 en 10 degrees from North.

Vermeulen, Hoogeveen et al. (1983) Enclosure 4.27

Fig. 227 *Frequency division w of wind velocity per class vk Schiphol 1951 until 1976 per 10 000*.

Frequency divisions like Fig. 227 are available from every wind station mostly specified per summer (may – october) and winter (november – april) half year and sometimes even per month.
Calculating the average wind velocity in Schiphol from Fig. 227 as

$$vg = \frac{\sum w * vk}{\sum w} = \frac{54420}{10000} = 5.442 \frac{m}{sec}$$

fits in the velocity class 5 – 5.5 m/s of location Schiphol indicated in Fig. 226.

In the last row of Fig. 227 all observations are specified by wind direction (Fig. 228).

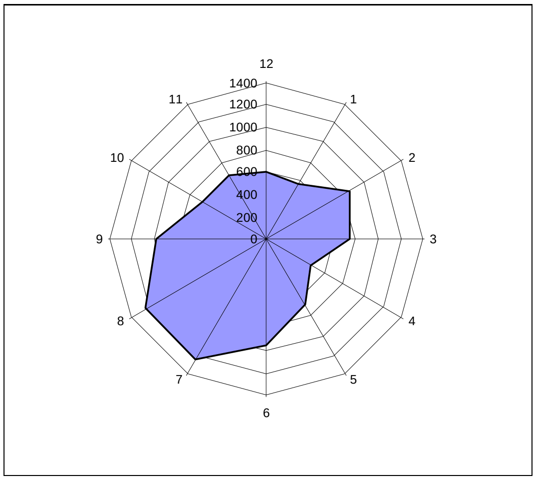
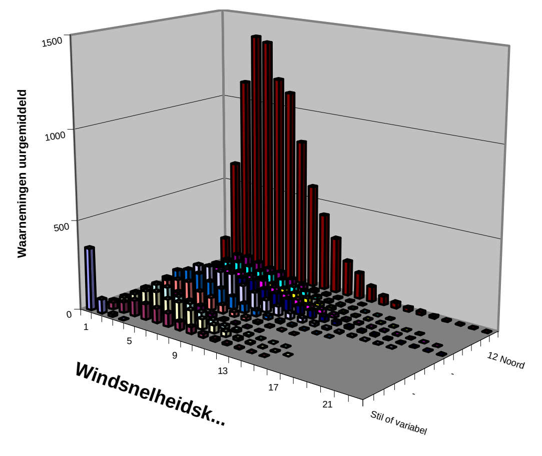


Fig. 228 C*ompass card, per 10 000 observations*

Because there are 10 000 observations, one can direcly read from Fig. 228 that 12% of the wind in Schiphol comes from directions 7 and 8. Together that is roughly 25% from South – West.

Fig. 229 shows Fig. 227 as a diagram of frequency divisions of wind velocity per class in total and per direction.



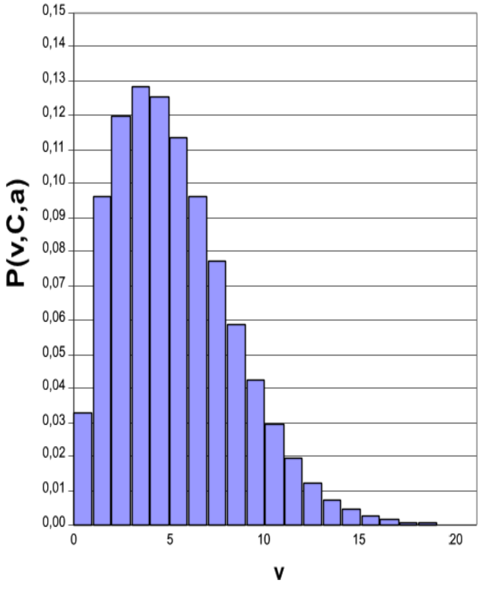


Fig. 229 *A diagram of* Fig. 227

Fig. 230 *Weibull-distribution*

The form of the graphs is higly similar to the mathematical graph of a *Weibull* probability distribution[73] like

$$P(v, C, a) := a \cdot C \cdot v^{C-1} \cdot e^{-a \cdot v^{C}}$$

represented in Fig. 230 with C and a as form and scale parameters specific for every location (Fig. 231).

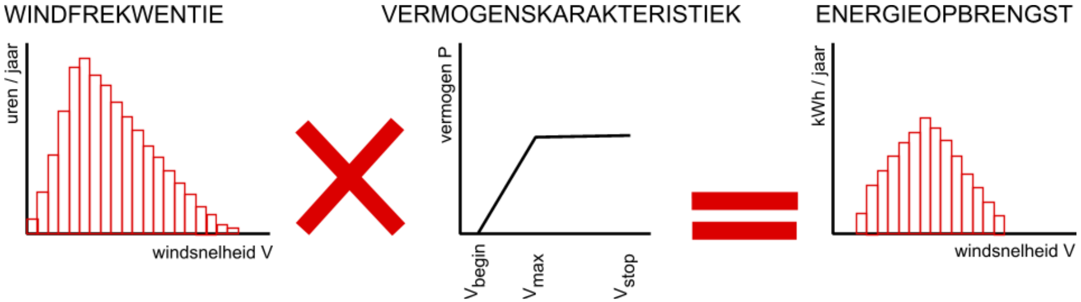
	form	schale	% from direction ('hours' from North, 0 is calm or variable):												
						E			**S**			**W**			**N**
	C	**a**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Beek	2,01	0,042	2	7	9	7	3	4	10	20	17	8	4	4	4
Den Helder	2,00	0,014	1	6	7	8	6	5	10	13	12	10	8	8	7
Eelde	1,74	0,059	3	6	8	8	7	5	9	14	14	10	7	5	4
Eindhoven	1,86	0,052	8	7	8	5	6	6	7	13	16	9	6	5	4
Schiphol	1,86	0,032	4	6	9	7	5	7	10	12	12	10	7	6	6
Vlissingen	1,95	0,025	1	9	9	6	4	5	9	13	13	11	6	7	7

Fig. 231 *Weibull parameters en contribution per wind direction for 6 stations.*

By this formula with tables like Fig. 231 we can avoid long tables like Fig. 227 and calculate back a stepless distribution of wind velocities in 12 directions on any location with the roughness of grassland. That represents local wind characteristics we need to connect to the impact characteristics from page 111. Later on we will show how per direction local landscape characteristics other than grassland are calculated in.

2.2.3 The energy profit of wind turbines

The number of observations of wind blowing with a given velocity and direction w(v,d) in Fig. 227 per number of observations 10 000 for many years in the past, is equivalent to its probability P(v,d) for the future. P(v,d) is proportional to the number of hours h(v,d) that kind of wind blowing from the total number of hours in a year. So h(v,d) = 8 766 x P(v,d). That number of hours determines the energy profit of wind turbines in an year. For example, if you know the power a wind turbine delivers on every velocity (power characteristic, see Fig. 222) you can find the profit by multiplying the number of expected hours that velocity will occur in an environment of grass land (Fig. 232).



Westra and Tossijn (1980), page 37

Fig. 232 *The way of calculating energy profit of a wind turbine*

Comparing national locations concerning the profit of wind turbines, direction of wind does not yet play the rôle it does concerning energy losses in buildings or comfort of outdoor space. The turbine after all can turn with the wind where buildings can not. On lower levels of scale we have to make this calculation for every direction seperately reduced by its specific roughness other than grass land.

However, this diagram of calculation can be used to estimate the impact of national choice of location on energy use of buildings, the comfort of outdoor space and the dispersion of air pollution as well. So, we will elaborate it for the difference in energy profit of wind turbines in the environment of Schiphol and Eindhoven.

In Fig. 233 left the velocity frequences per direction of wind from Fig. 227 and Fig. 229 are summarised into a total frequency division while the contribution of every separate direction remains (cumulatively) recognisable. Point of departure still is a standard height of 10 metres and a ground roughness comparable to open grass land. On lower levels of scale we will vary them as well.

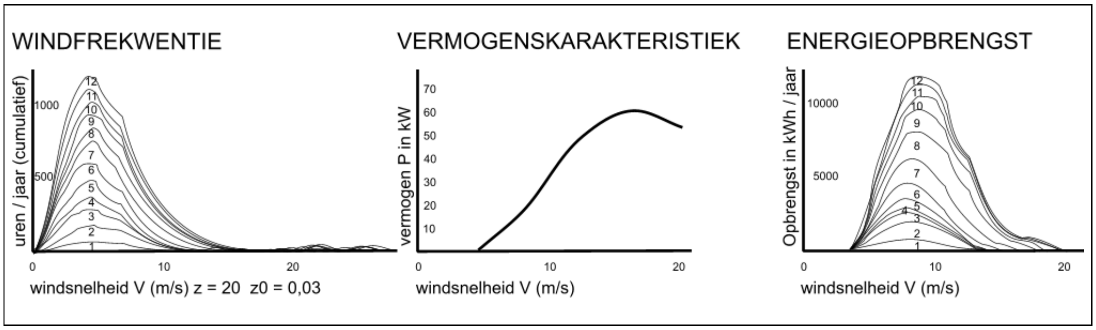


Fig. 233 *Calculating the energy profit of a specific wind turbine in the environment of Schiphol*

Left in Fig. 233 the expected number of hours per verlocity is given. The power characteristic of the wind turbine per velocity in the middle of Fig. 233 is equivalent to Fig. 222. Multiplying the number of hours of every subsequent velocity by the corresponding power produces the energy profit right in Fig. 233.
Apparently the wind turbine delivers most energy on directions 6, 7, 8 and 9 ‘hour’. So in that directions we have to keep the site open. However situating a wind turbine South East of town shields the turbine from an also considerable contribution from North West (1, 2 and 3 ‘hour’). So you can situate it better somewhat above West of town.

Comparing national locations can be done more simple by a rule of thumb for the energy profit of wind turbines with a height of 10m surrounded by open grass land[74]:

$$E = 2 \cdot vg^3 \cdot O$$

E = total yearly energy production in kWh/ m²·year
vg = year average wind velocity averaged per hour
O = surface of rotor

In Fig. 234 the energy profits presupposing a height of 10m in open grass land near Schiphol and Eindhoven are compared this way.

Schiphol:	$2 \cdot 5{,}4^3$ = 315 kWh/ m²	x 340 m² = 107 000 kWh
Eindhoven:	$2 \cdot 4{,}25^3$ = 154 kWh/ m²	x 340 m² = 522 000 kWh

Fig. 234 *The energy profit of wind turbines in Schiphol and Eindhoven by rule of thumb*

The total profit of a reference turbine of 340m2 of 10m height in all directions surrounded by grass land is in the environment of Schiphol approximately 100 000 kWh per year and in Eindhoven approximately 50 000 kWh.

We neglected amongst others height and wind direction differentiating velocity and local roughness. Wind supply is reduced from different directions, but most wind turbines are erected higher, reducing this impact. In Fig. 235 is indicated how wind velocity in open grass land (the international standard for local wind velocity measures) increases by height z. We will discuss this factor more precisely in paragraph 2.4.2.

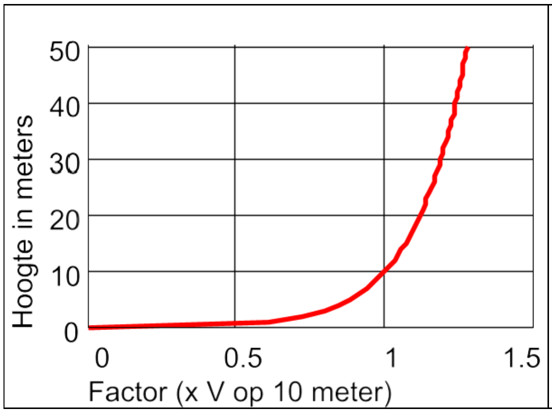


Fig. 235 *Wind velocity factor for height*

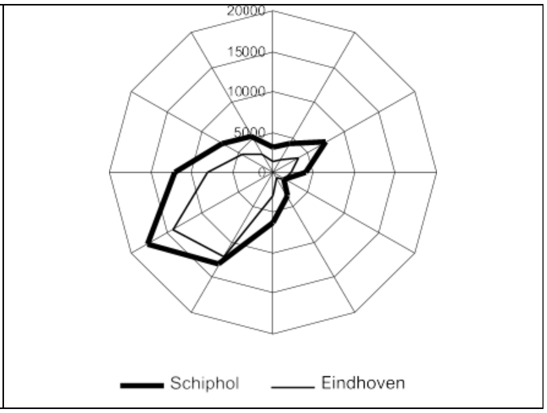


Fig. 236 *Contribution per wind direction 10m height*

Because the energy profit of wind turbines increases proportional to the third power of wind velocity (see rule of thumb on page 117) you can adapt the average wind velocity vg by this factor to the third power. The wind velocity on 20m according to Fig. 235 is x 1,13 higher than on 10m. To the third power this factor becomes 1,44. By this factor you can mulitply the profit on 10m to get the profit on 20m (for Schiphol and Eindhoven approximately 155 000 kWh and 75 000 kWh per year respectively). The absolute differences of both locations increase, as well as the contributions of different wind directions (Fig. 236).

2.2.4 Energy losses from buildings

The way of calculation in Fig. 232 can be applied to energy losses of buidings, the distribution of air pollution and the comfort of outdoor space as well. In that case you do not multiply the expected occurences of wind velocities by those in the power characteristic of wind turbines, but by those of the respective other characteristics mentioned on page 111.

Energy losses from buildings by wind not only consist of ventilation losses, but we will neglect other ones (convention, precitipation) as less important (see Vermeulen and Jong, 1985). For ventilation losses form dwellings we will restrict ourselves to wind data form the heating season, not importantly differing from better accessible data concerning the winter half year. The average wind velocity in a winter half year is approximately 10% higher than throughout the year (Fig. 237 and Fig. 238).

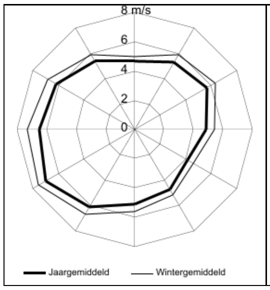


Fig. 237 *Winter half year velocities Schiphol*

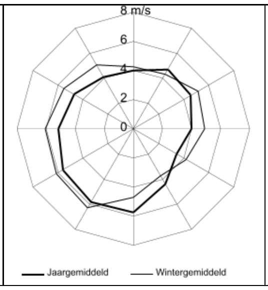


Fig. 238 *Winter half year velocities Eindhoven*

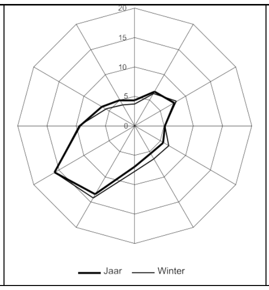


Fig. 239 Winter *probabilities Schiphol*

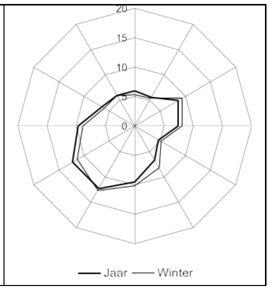


Fig. 240 *Winter probabilities Eindhoven*

The probability (number of hours) of wind from all directions is approximately the same in winter as throughout the year for all directions (Fig. 239 and Fig. 240).
In Fig. 241, Fig. 221 is repeated: the ventilation characteristic of an average one family low rise dwelling and an average more airtight one family high rise appartment. In this graph the average

occupant's behaviour to open windows at wind velocities lower than approximately 5 m/s is recognisable. This behaviour sometimes makes wind suppressing measures decreasing wind velocity less than 5 m/sec useless.

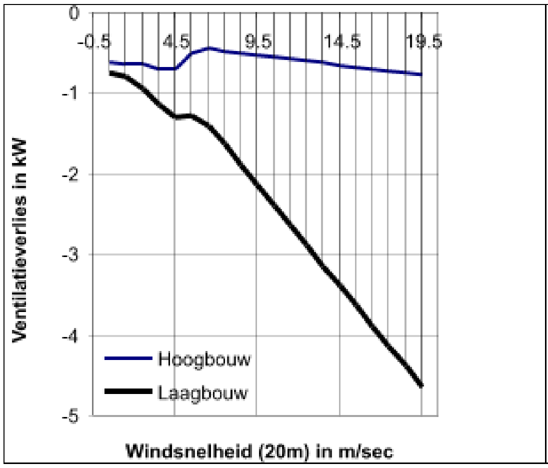


Fig. 241 *Ventilation characteristic*

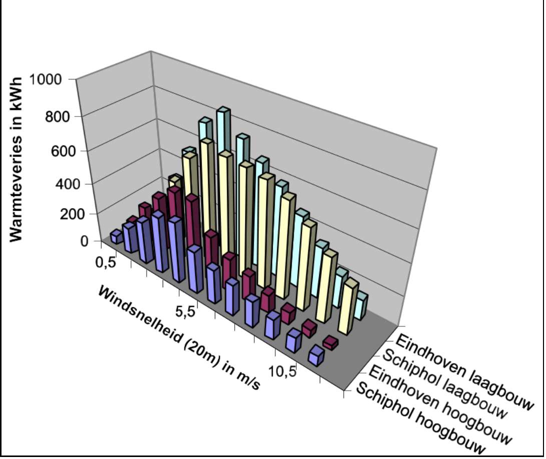


Fig. 242 *Ventilation losses per dwelling*

As expected Fig. 242 shows low rise familiy dwellings lose more in Schiphol (6861 kWh) than in Eindhoven (5557 kWh, 1300 kWh less). However, high rise dwellings lose *less* in Schiphol (2516 kWh) than in Eindhoven (2626 kWh, 110 kWh more). In Eindhoven with lower wind velocities people open up their windows more often and that counts negative in high rise buildings.

2.2.5 Temperature impacts

On which side you can shelter a dwelling best: the side of the coldest Easterly wind or the South-West side where most wind is coming from?
Answering this question requires input of temperature data. We choose an approach based on wind and temperature data Gids (1986) from wind station Eelde (with a wind characteristic between that of Schiphol and Eindhoven). We consider a period of the year between beginning December and the end of February. This approach gives a weight factor spreading heat losses by ventilation over 12 wind directions. Multiplied by the earlier mentioned figure for total energy losses of two dwellings in Schiphol en Eindhoven this produces contributions per wind direction as represented in Fig. 243 and Fig. 244.

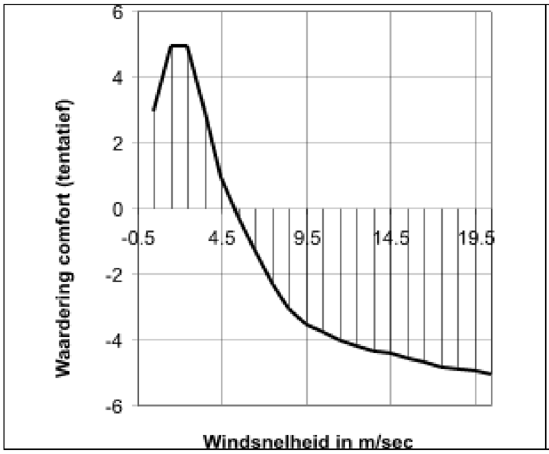
Fig. 243 *Ventilation losses weighting temperature per wind direction Schiphol*

Fig. 244 *Ventilation losses weighting temperature per wind direction Eindhoven*

Sheltering on East (3 "hour" or 90°) appears to be nearly as effective as sheltering West South West (8 "hour" or 240°), though highest velocities come from South West[75].

2.2.6 Comfort of outdoor space

The same approach without temperature impacts, this time using the tentative graph Fig. 224 reproduced in Fig. 245 would produce Fig. 246.



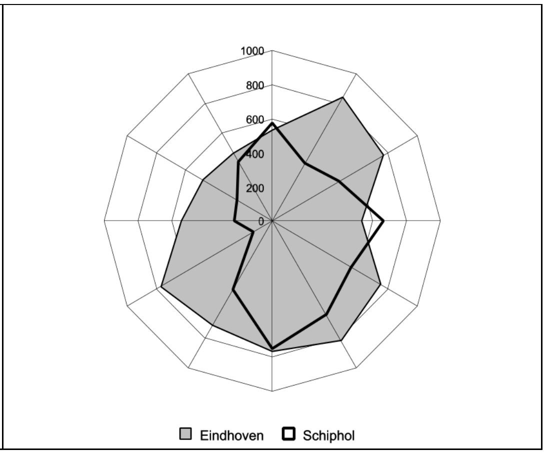


Fig. 245 *Tentative comfort characteristic*

Fig. 246 *Tentative appreciation comfort*

In Fig. 246 the appreciation of every velocity is multiplied again by the respective probable velocity per direction. For all directions together Schiphol would get 11 000, Eindhoven 16 000 points. Schiphol would probably like shelter in directions with a Westerly component. Eindhoven probably does not need any shelter but eventual complaints are most probably caused by wind from North West (10 or 11 'hour')[76].

2.2.7 Dispersion of air pollution

The higher the wind velocity the better air pollution is dispersed, though increasing velocities have diminishing returns. This impact is tentatively represented in Fig. 223 repeated in Fig. 245.

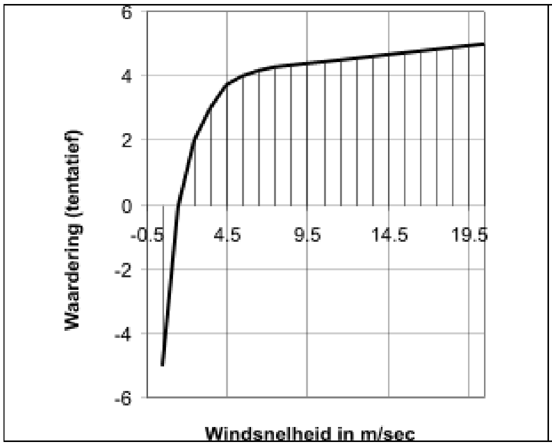


Fig. 247 *Tentative air pollution characteristic*

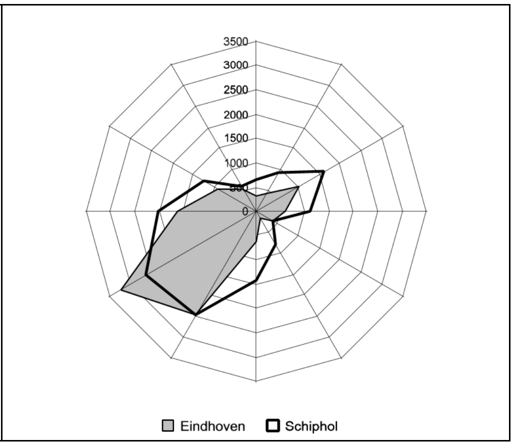


Fig. 248 *Tentative air pollution dispersion*

The impact having an overall positive relation to wind velocity, it shows pronounced similarity with the compass chard of Fig. 228. In Schiphol air pollution is better dispersed. The multiplication produces approximately 16 000 in Schiphol and 12 500 in Eindhoven.

2.2.8 Summary national comparison

Comparing Schiphol and Eindhoven on these criteria with most reservations concering the tentative ones, Fig. 249 shows which location scores best[77].

CRITERION	*WIND DIRECTION*	*1 2 3 4 5 6*	*7 8 9 10*	*11 12 TOT*
1 minimise	ventilation loss	E E E E E E	E E E E	E E E
2 maximise	wind energy	S S S S S S	S S S S	S S S
3 maximise	dispersion of air pollution	S S S S S S	X E S S	S S S
4 optimise	outdoor space comfort	E E E E E E	E E E E	E E E
S: Schiphol better E: Eindhoven better X: No difference				

Fig. 249 *Comparison Schiphol and Eindhoven on 4 criteria*

Temperature impacts are neglected. The evaluation of dispersion of air pollution is highly similar to the energy profit of wind turbines and the evaluation of outdoor space comfort is similar to that of ventilation losses from non airtight buildings. The difference for such buildings is substantial (1 300 kWh/year in favour of Eindhoven), but in the case of airtight buildings the much lower difference (110 kWh/year) is paradoxically in favour of Schiphol by the behaviour of inhabitants (more closed windows). In the next paragraphs we will restrict to energy profits of wind turbines and ventilation loss in airthigt and non airtight buildings. In case of non airtight buildings we can use the conclusions mostly for outdoor comfort as well and in case of energy profits of wind turbines in the same time we can think of dispersion of air pollution.

2.3 Regional choice of location

On a regional level you no longer can take grassland in all directions as a standard of comparison. Wind is hampered by vegetation and buildings. On a regional level we not yet see them individually, but roughly as 'roughness'. New buildings are sheltered by vegetation or existing (sometimes less air tight) buildings. However, they shelter other locations themselves. So, locating new buildings sheltered is not always obvious, especially when they are airtight. There are arguments to locate new buildings South West of town as well (sheltering old less airtight ones, comfort of existing outdoor space, dispersion of air pollution, possibilities to yield wind energy at location).

In this paragraph we restrict ourselves to regions comparable to Schiphol as far as wind statistics are concerned. We concentrate on roughness of surrounding grounds. Due to the Weibull approach (Fig. 230) we do not need tables with all occuring velocities like Fig. 227. We can use the average velocity (like Fig. 237) and its probability (Fig. 239) per direction, summarized again in Fig. 250.

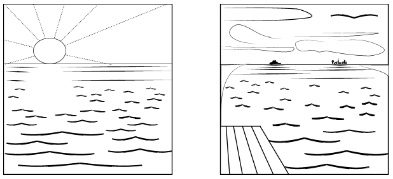
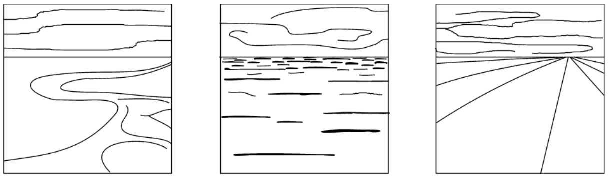
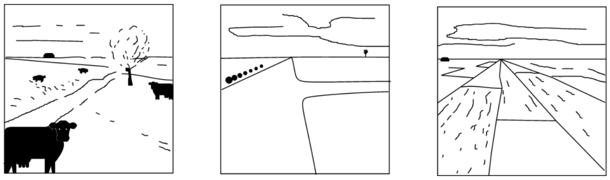
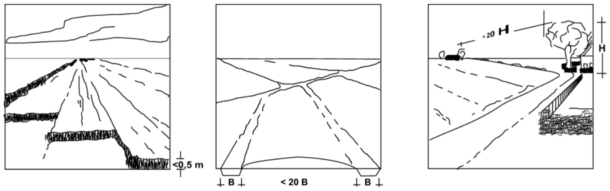
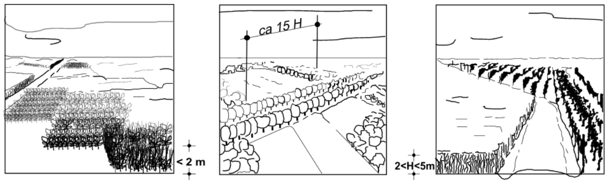
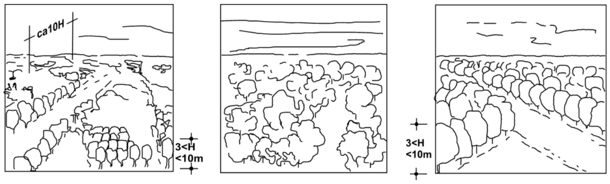
WIND DIRECTION :	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*TOT**
in degrees from North :	30	60	90	120	150	180	210	240	270	300	330	0	
			E			S			W			N	
whole year													
m/sec average	5,30	5,68	4,89	4,19	4,71	5,08	6,14	6,97	6,51	6,14	5,44	4,67	5,43
hours/ year	500	747	643	404	519	832	1074	1072	850	574	563	528	8766
*inclusive periods of calm or variable direction													

Fig. 250 *Potential wind velocities and their probabilities Schiphol*

In this paragraph we consider wind velocities in winter to be 10% the year average from Fig. 250 (important for calculating ventilation losses and comfort of outdoor space). The probability from a specific direction we take equal to half the values from Fig. 250.

2.3.1 Roughness of surrounding grounds

In wind surveys classes of roughness are distinguished (Fig. 251

Classes of roughness		
1		• open sea • pond with free brush length of at least 1km
2		• land surface without obstacles or vegetation o shallow o beach o ice plain o snow landscape without trees • pond with free brush length of approximately 1km
3		• flat land with shallow vegetation (grass) and isolated, rarefied obstacles: o air strip o grassland without trees o fallow fields
4		• farm land with regular low (<0,5 m) crops • grassland with ditches on mutual distance less than 20 x their width • dispersed obstacles on mutual distance of more that 20 x their own height: o low hedges o singuar row trees without leaves o singular farms
5		H < 2 m: • farm land with alternating high and low crops • vineyards, maize fields 2m < H < 5m: • low orchards • influential obstacles with mutual distance 15 x their own height: o rows of trees with leaves
6		3m < H < 10m: • groups of obstacles with a mutual distance of 10x their typical height: o large farmsteads o parcels of forest o dispersed shrubs o young densely planted woods o orchards

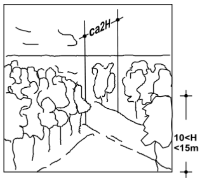
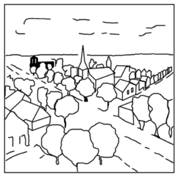
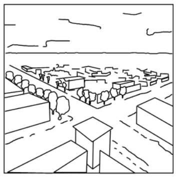
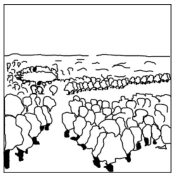
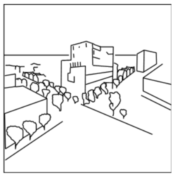
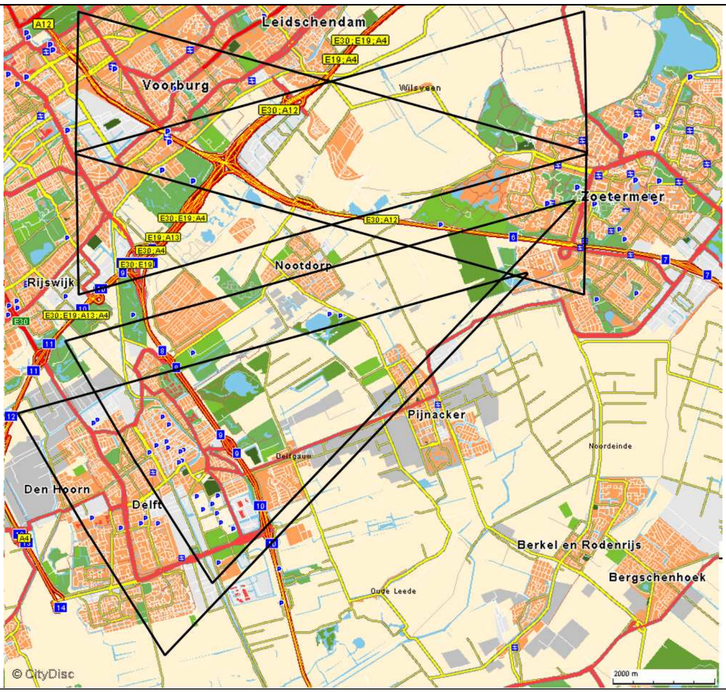
Classes of roughness		
7	  	10m < H < 15m: • bottom regularly and fully covered by rather large obstacles with mutual distance not larger than 2x their height: o regular forests o low rise buildings in villages o suburbs
8	 	H > 10m • centre of a large city with alternating high rise and low rise buildings • heavy forests with many irreguar open spaces

Fig. 251 *Classes of roughness*

The standard class supposed in wind data is class 3[78]. Wind characteristics on locations surrounded by other classes of roughness are derived mathematically from the data provided in class 3.
We wil now concentrate on a location of a residential area (class of roughness 7) Leidscheveen between Zoetermeer and Voorburg - Leidschendam[79]. The experimental question is, to compare wind climate without Leidscheveen, with Leidscheveen and when Leidscheveen would have been built adjacent to Zoetermeer ('VoZo'). In paragraph 2.3.5 we will compare several arrangements of green and buildings (roughness 6, 7 and 8) between Zoetermeer and Delft with or without a residential area Rokkeveen adjacent to Zoetermeer.



Citydisc/Top.Dienst

Fig. 252 Study area *Den Haag – Zoetermeer – Delft*

2.3.2 Impact of new urban area lose from or adjacent to town in case of Westerly wind

Fig. 253 shows a 30° cutout from 'zero point' in Zoetermeer direction West ('9 hour'). *Fig. 254* shows the calculated average wind velocity on 20m height in the reference. Below the graph the reference is styled as sequence of different roughnesses. The numbers refer to the classes of roughness in Fig. 251. Such calculations utilise the parameters from the last two columns of Fig. 251.

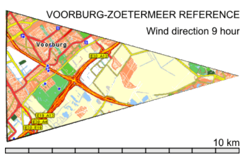


Fig. 253 Voorburg -> Zoetermeer reference

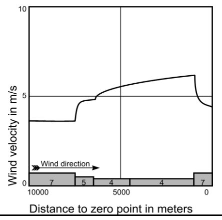


Fig. 254 Average wind velocity Fig. 253

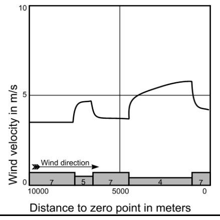


Fig. 255 Voorburg with Leidscheveen lose

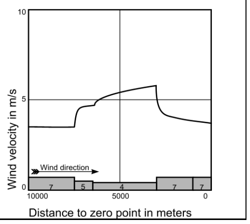


Fig. 256 Zoetermeer with VoZo adjacent

Fig. 255 shows Leidscheveen 1km lose from Voorburg. This urban area with approximately 8 500 dwellings slows down wind on 20m height roughly from 5 to 4 m/sec, but it has little impact on the built up area of Zoetermeer 3,5 km further on without obstacles inbetween. *Fig. 256* shows an imaginary variant with VoZo adjacent to Zoetermeer. In *Fig. 254* (reference) on zero point (right) an imaginary wind turbine has 10 530 kWh/year energy profit due to Westerly wind only; equivalent energy losses from a non airtight dwelling are 750 kWh/year. In *Fig. 255* they decrease by 760 and 20; in *Fig. 256* by 3 010 and 170 kWh/year.

2.3.3 Impact of new urban area lose or adjacent in case of Easterly wind

Fig. 257 to *Fig. 260* show reference and experiments to clarify the impact in case of Easterly wind on ‘zero point’ Voorburg. They are less realistic to remain comparable with the previous experiment.

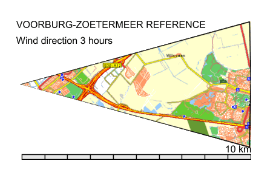


Fig. 257 Zoetermeer -> Voorburg reference

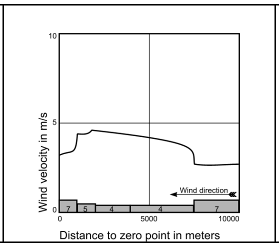


Fig. 258 Average wind velocity Fig. 257

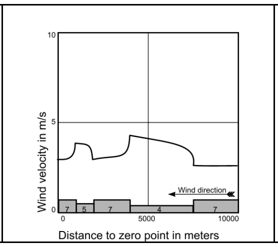


Fig. 259 Zoetermeer –> Voorburg with Leidscheveen

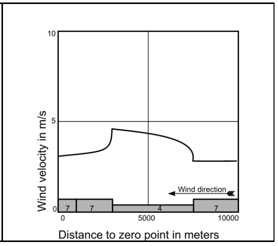


Fig. 260 Zoetermeer –> Voorburg variant

Fig. 258 immediately shows the lower average wind velocity from East compared with West. So, the impact is less as well. On the new zero point an imaginary wind turbine has 3070 kWh/year energy profit due to Easterly wind only; equivalent energy losses from a non airtight dwelling are 460. In *Fig. 259* they decrease by 1000 and 23 in *Fig. 260* by 710 and 60 kWh/year.

2.3.4 Impacts on energy losses by ventilation behind the edge in the interior of town

Fig. 261 shows the impacts of regional alternatives behind the Westerly edge of Zoetermeer. They decrease fast within 100m. Fig. 262 shows the same behind the Easterly edge of Voorburg. They are smaller because Westerly wind blows more often and stronger (see page 118) and the foreland of Voorburg already had a higher roughness than Zoetermeer, but lower temperatures neglected here could increase the impact.

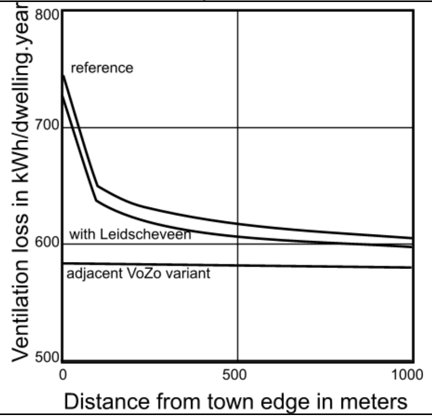


Fig. 261 *Impact Westerly wind on Zoetermeer*

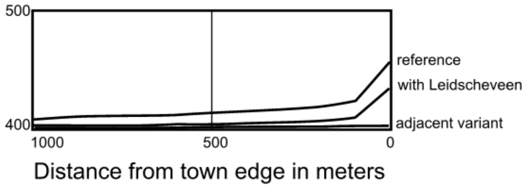


Fig. 262 *Impact Easterly wind Voorburg*

So, the total impact on ventilation losses is small, though they have some significance for comfort of outdoor space. That is why we pay not much intention to calculating these impacts more precise now, but they are point of departure and give insight for calculating measures on lower levels of scale. Not only temperature could affect the outcome, but also impacts perpendicular on the direction of wind. These 'lateral impacts' depend on the total form of the conurbation. They will be studied closer in 2.4.3 page 131. Furtermore we have to realise that these calculations are based on average roughnesses. Wide ways, open allotment and lay-out of the edge could increase wind loads inside of town locally substantially. We should conclude that in calculating the impact of measures on lower levels of scale the regional lay-out adjacent to towns are most important. So, we have to examine them in more detail.

2.3.5 Highways, railways, green areas and forests

Fig. 263 shows a 10km long cutout of 30^o this time seen from zero point Zoetermeer in wind direction '8 hour' to Delft. The largest zone is farm land (roughness 4) increasing wind velocity up to 6.67 m/sec on the edge of town Zoetermeer in Fig. 264.

Fig. 263 *Delft -> Zoetermeer reference*

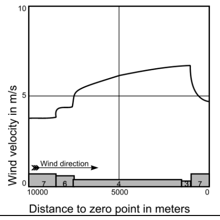


Fig. 264 *Average wind velocity in reference of* Fig. 263

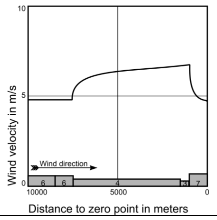


Fig. 265 *Delft -> Zoetermeer simplified reference*

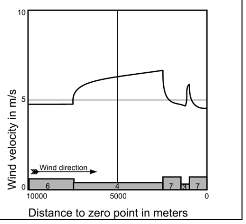


Fig. 266 *Delft -> Zoetermeer with Rokkeveen*

Fig. 265 simplifies Fig. 264 by gathering Delft and Delftse Hout as a zone with roughness 6. This simplification increases wind velocity at the edge of town Zoetermeer from 6,67 m/sec in Fig. 264 to

6,74 m/sec in Fig. 265. Such differences at more than 5km distance apparently do not matter much. So, Fig. 265 becomes our reference. In Fig. 266 Rokkeveen is added[80]. Though this residential area has a great impact on the wind velocity profile, for the town edge of Zoetermeer the impact is surprisingly less than we would expect because after slowing down above Rokkeveen the wind accelerates within 500m very fast above railways and highway A12 between Rokkeveen and existing Zoetermeer[81]. So, the impact of Rokkeveen reduces wind velocity from 6,74 to 5,92 m/s, reducing ventilation loss on the edge of town Zoetermeer by only 90 kWh/dwelling·year (1 m3 natural gas).

In Fig. 267 before Rokkeveen a green structure replaces farm land (roughness 6 see page 123).

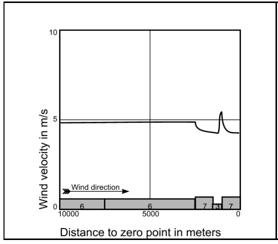


Fig. 267 *Delft -> Zoetermeer with green structure*

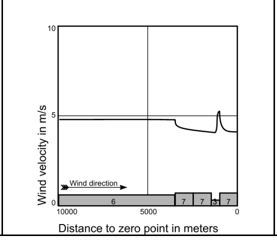


Fig. 268 *Delft -> Zoetermeer 1km regular forest added*

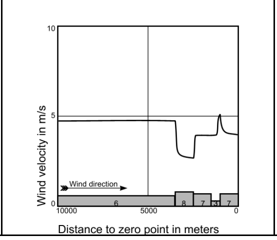


Fig. 269 *Delft -> Zoetmeer 1km heavy forest added*

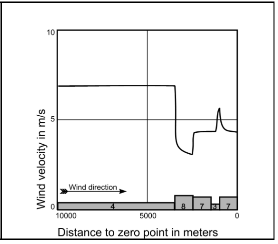


Fig. 270 *The same, with farm land instead of green structure*

In Fig. 268 except this green structure 1km forest (roughness 7) is added as well. Both cases do not make much difference on the old town edge. The impact is more than undone by railways and highway. Wind velocity is compared to the reference decreased from 6,74 to respectively 5,45 and 5,35 m/sec, but the largest amount was already caused by Rokkeveen. At the old town edge ventilation losses caused by this direction of wind are decreased by approximately 150 kWh/dwelling·year and for adjacent directions something comparable but smaller.
In Fig. 269 regular forest is replaced by heavy forest (roughness 8). Wind velocity at the old town edge then decreases somewhat (5,25 m/sec), but not significant though the wind profile changes substantially. The fast increase above Rokkeveen is remarkable.
In Fig. 270 the impact of a lower roughess on larger distance is studied by replacing Delft, Delftse Hout and green structure by farm land. By these measures wind velocity at the old town edge still increases from 5,25 to 5,71 m/sec.

2.4 Local measures

2.4.1 Local shelter of residential areas

From Chapter 2.2 we learned that the impact of relatively small linear open spaces as railways and highways perpendicular on wind is substantial. Wind sheltering action has to be taken as close to the residential area as possible. That is why we shift our attention some kilometres into a cutout with its zero point in Rokkeveen itself (8 ‘hour’ South West see Fig. 252). This residential area is not separated from its foreland by a highway or wide water. So, shelter can adjoin immediately to residential area.

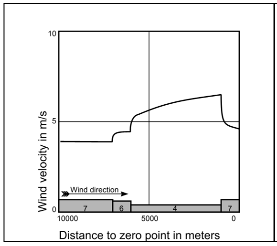


Fig. 271 *Reference windvelocity*

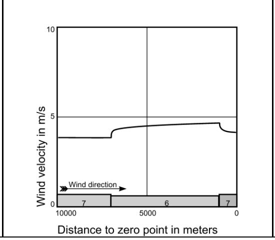


Fig. 272 *Delft -> Rokkeveen with 6km green structure*

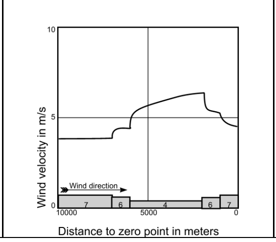


Fig. 273 *Delft -> Rokkeveen with 1km regular forest*

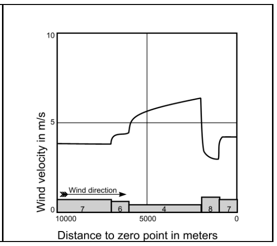


Fig. 274 *Delft -> Rokkeveen with 1km heavy forest*

In Fig. 271 we suppose above Delft a stable velocity of less than 4 m/sec. Above 1km Delftse Hout it climbs up and stabilises on 4.5 m/sec in a few hundred metres. Then above 5 km farmland it starts to climb up fast continuing to increase more slowly to 6,52 m/sec. Then above Rokkeveen it slows down fastly to 4,61 m/sec and outside the graph slowly to 4.2 km/sec above above suburban built up area.
In Fig. 272 farmland is replaced by green structure (rougness 6). Then wind velocity at the edge of Rokkeveen decreases substantially from 6.52 to 4.73 m/sec. Energy loss per non airtight dwelling per year as far as due to wind from this direction decreases 190 kWh only (from 987 kWh to 797 kWh).
If the last km before Rokkeveen would have been replaced by green structure only, velocity would reduce to 5.23 m/sec. Ventilation loss would still reduce by 141 kWh.
Would 1km roughness higher than 6 have more impact?

In Fig. 273 and Fig. 274 only the last km before Rokkeveen farmland (roughness 4) is replaced by regular forest (roughness 7) and heavy forest (roughness 8). From these thought experiments we conclude 1km regular forest has approximately the same impact as 6km green structure. However, 1km heavy forest with rather high trees (15m) reduces wind velocity substantially to 2.90 m/sec at the edge of town. Energy loss per non airtight dwelling per year as far as due to wind from this direction there decreases 324 kWh from 987 kWh to 663 kWh. However, above suburban built up area wind velocity increases again fastly stabelising on approximately 4.2 m/sec.

Fig. 275 and Fig. 276 compare regional remote (see 2.3.5) and locall adjacent (see above) impacts.

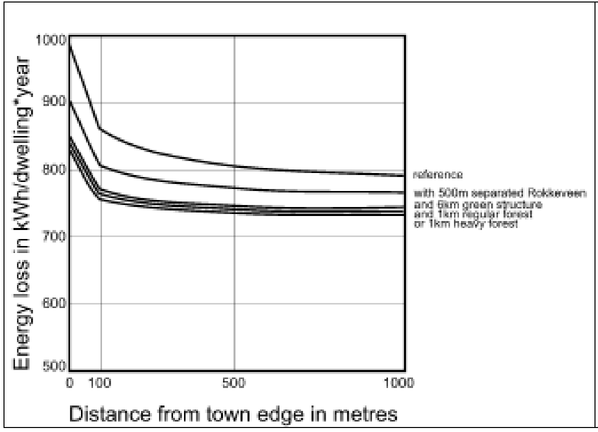


Fig. 275 *Impact regional layout on Zoetermeer separated by railways and highway*

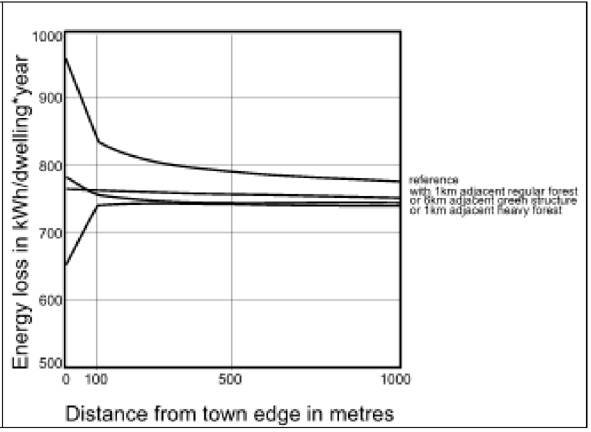


Fig. 276 *Impact locally adjacent shelter on Rokkeveen*

Representated impacts are restriced to 1 of 12 wind directions. Figures may be multiplied by a factor 3 to 5 if more directions are sheltered. The impact is decreasing fastly up to 100m in the urban area.

2.4.2 Increase of wind velocity by height

Preceding calculations are tacitly restricted to velocity differences in direction of wind itself (x-direction) and not perpendicular on x (in witdth y and height z). In Fig. 235 we casually mentioned the importance of velocity differences in height (z-direction), but then the view restricted to a height of 10m (international standard measuring wind) and passing chapter 2.2 to 20m (where wind is not disturbed substantially by single buildings).
On differences in wind velocity perpendicular to wind direction in witdh (lateral differences in wind velocity) we did not say more than mention them (2.3.4). Tacitly we supposed styled roughesses and velocities to be continued endlessly perpendicular to the surface of drawing.

However, on this level of scale we can not maintain these simplifications. A separated built up area (‘roughness island’) ondergoes substantial impacts from wind parallel to its edges. Wind survey yielded experimental results by which we can estimate these lateral impacts. However, that requires some insight in increase of wind velocity by heigth.

To calculate wind velocity v as a working of height z (v(z), wind profile, see Fig. 214, Fig. 278 and Fig. 279) we divide the atmosphere from the largest height $z=d_3$ where wind still is influenced by Earth’s surface to the ground in tree layers:
90% ‘boundary layer’ from d_3 to $0.1 \times d_3$;
9% ‘wall layer’ from $d_2 = 0.1 \times d_3$ to $d_1 = 0.01 \times d_3$;
1% ‘viscose layer’ from d_1 to ground level.

The wind velocity of these layers can be approximated by three different formulas (Voorden 1982, Appendix B):

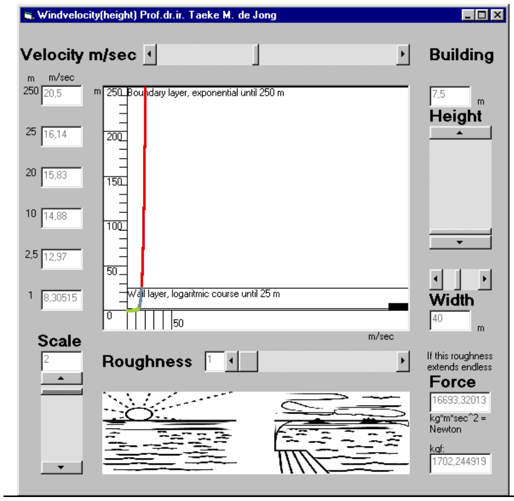
(1) where $d_3 > z > d_2$: $v_3(z) = v_{d3} \cdot (z/d_3)^{\alpha}$;
(2) where $d_2 \geq z \geq d_1$: $v_2(z) = (v_{d3} \cdot 0.4 / (\mathrm{Sqr}(25 + (\ln(d_3 / d_0))^2)) / 0.4) \cdot \ln(z / d_0)$;
(3) where $d_1 > z > 0$: $v_1(z) = v_2(d_1) \cdot ((2 \cdot z / d_1) - (z^2 / d_1^2))$.

If we know velocity v at d_3 (v_{d3}) the exponential formula (1) produces a velocity for every z in boundary layer below d_3 supposed we know d_3 and exponent α. Exponent α and d_3 are parameters dependent on roughness, we can take them from Fig. 277. For the wall layer the logaritmic formula (2) needs an other parameter d_0 different for every roughness as well (Fig. 277). In an urban environment with much local turbulence the lowest viscose layer has theoretical value only. But for roughesses lower than 5 we can approximate wind velocities by parabolic formula (3). Within formula (3), formula (2) is used to calculate $v_2(d_1)$.

Rough-ness class	α	d_3	d_2	d_1	d_0	parameters used elsewhere	
						D(h)	β
		m	m	m	m		
1	0.104	250	25.0	2.50	0.0002	0	0.07
2	0.144	275	27.5	2.75	0.005	0	0.08
3	0.181	300	30.0	3.00	0.03	0	0.09
4	0.213	350	35.0	3.50	0.1	0	0.11
5	0.245	400	40.0	4.00	0.25	0.3 0.7	0.14
6	0.273	450	45.0	4.50	0.5	0.7	0.16
7	0.313	475	47.5	4.75	1	0.8	0.18
8	0.363	500	50.0	5.00	2	0.8	0.20

Fig. 277 *parameters dependent from roughness in formulas used in wind surveys.*

If we do not know v_{d3}, but we know v_{10m} or v_{20m}, we can vary the upper scroll bar of the computer programme Windvelocity(height), - downloadable from *http://team.bk.tudelft.nl* publications 2003 - to get the right profile.


Windvelocity(height) Prof.dr.ir. Taeke M. de Jong

Velocity m/sec
m m/sec
250 20,5
25 16,14
20 15,83
10 14,88
2,5 12,97
1 8,30515

Boundary layer, exponential until 250 m
Wall layer, logaritmic course until 25 m

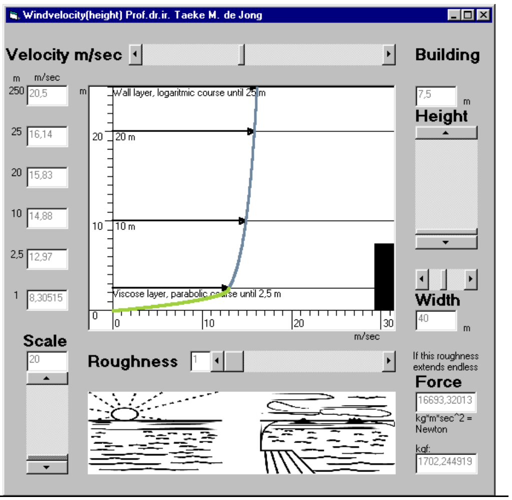
Building
7,5 m
Height
Width
40 m

Scale
2

Roughness 1

If this roughness extends endless
Force
16693,32013
kg*m*sec^2 = Newton
kgf:
1702,244919

Fig. 278 *Exponential $v_3(z)$ and Logaritmic $v_2(z)$ increase of wind velocity by height*


Windvelocity(height) Prof.dr.ir. Taeke M. de Jong

Velocity m/sec
m m/sec
250 20,5
25 16,14
20 15,83
10 14,88
2,5 12,97
1 8,30515

Wall layer, logaritmic course until 25 m
20 m
10 m
Viscose layer, parabolic course until 2,5 m

Building
7,5 m
Height
Width
40 m

Scale
20

Roughness 1

If this roughness extends endless
Force
16693,32013
kg*m*sec^2 = Newton
kgf:
1702,244919

Jong (2001)

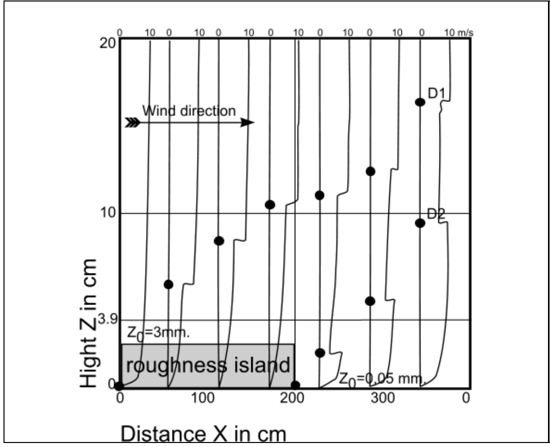
Fig. 279 *Logaritmic $v_2(z)$ and Parabolic $v_1(z)$ increase of wind velocity by height*

In the logaritmic formula (3) factor $v_{d3} \cdot 0.4 / (Sqr(25 + (\ln(d_3 / d_0))^2)$ is known as ‘wall shearing stress velocity’.

2.4.3 The form of a town

Fig. 280 shows the result of a wind tunnel experiment described in Vermeulen (1986). This experiment serves as a reference for thought experiments to follow.

Above a roughness island like a town or forest in a smooth environment discontinuities in wind velocity appear. The wind meets the edge of the roughness island for the first time (x = 0) still having a regular velocity profile like described on page 131. Above the roughness island a specific velocity profile is estabished with lower velocities than the surrounding smooth surface. However, on some height above the roughness island the old profile remains. The height up to where the new profile establishes its impact is called ‘internal boundary layer thickness (Δi). The development of this boundary layer is drawn by dots in Fig. 280. Behind the roughness isand the old profile recovers up to a second boundary layer height. In the used model x=300cm from the first change of roughness, the first boundary layer height (D_1) amounts 16,5 cm , the second (D_2) 9,5 cm.



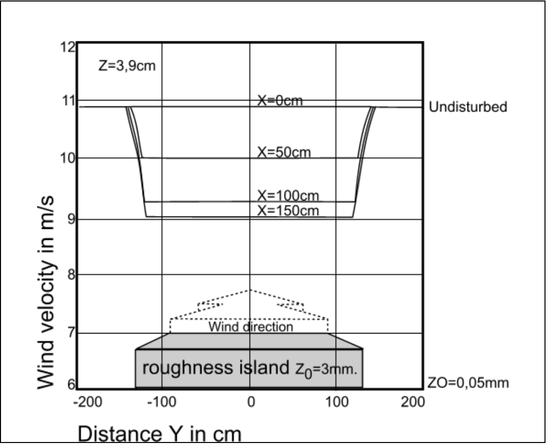


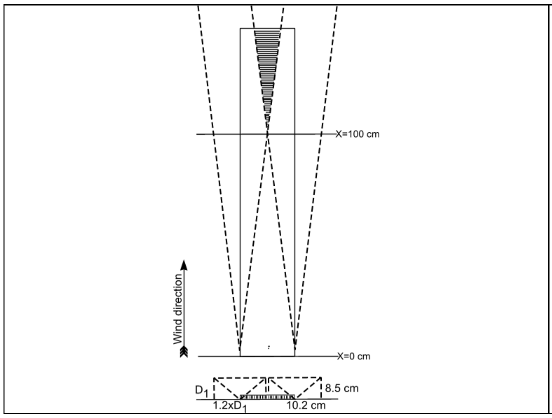
Fig. 280 *Wind velocity profiles in height*

Fig. 281 *Wind velocity profiles in width*

Fig. 280 shows wind profiles from the beginning (x=0) above and behind (up to x=300) the roughness island in cross section in case that island would extend endlessly perpendicular to the surface of drawing. Fig. 281 shows wind profiles 3.9cm above the roughness island in front view limited on two sides on a distance of x={0, 50, 100, 150cm) from the front edge. At x = 0 wind still behaves undisturbed like above a smooth surface. After 50cm above the rough surface wind velocity has slowed down, but on both sides the velocity of the smooth surface remains. Between both velocities a lateral transitional zone develops. In the experiment the width of the transitional zone appears to be 1.2 times the internal boundary layer thickness D_1.

Fig. 280 shows, the thickness of the internal boundary layer D_1 is approximately 1/10 times the distance to frontal edge x.
So, behind x=1000m (where D_1 is approximately 100m) a transitional zone can penetrate the air above the roughness island already 120m from the side edges. When the island is 240m width the transitional zones meet eachother. So, the wind velocity from this point on could increase by interacting lateral impacts to the back of the island in spite of the underlying roughness.
For example, above an elongated separated urban area with its narrow front to South, Southerly wind not only slows down in its own direction, but produces on the Westerly and Easterly edges a side effect. This increases wind velocity by interaction above the Northern part of the area.

To examine this interaction in more detail a windtunnel experiment on a narrow roughness island is carried out. Fig. 282 shows a map of the model with hypotheses concerning the transition zone, and Fig. 283 a front view with the result of measurements.



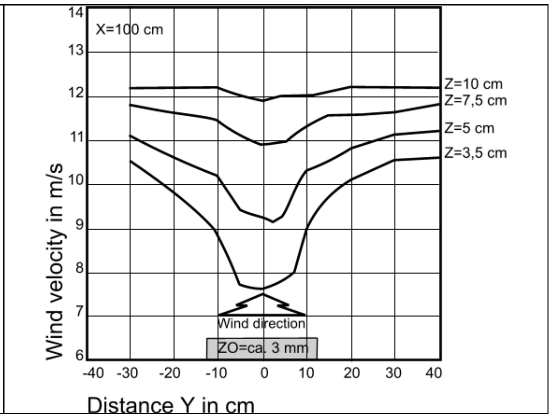


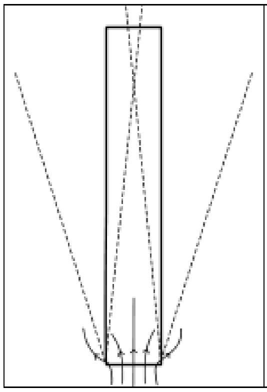
Fig. 282 *Hypothetical interaction above an elongated roughness island.*

Fig. 283 *Measurements above an elongated roughness island x=100cm.*

Fig. 283 shows results of measurement near the point where interaction hypothetically should begin (x=100cm). Behind this point (shaded area in Fig. 282) wind velocity should increase anew. Examining these results next deviantions draw attention:

1 wind velocity decreases more than expected (8,6 m/sec instead of 9,25 m/sec);
2 transition zone outside the roughness island is wider than 1,2 · D1 = 10,2 cm;
3 transition zone inside the roughness island is narrower than 10,2 cm.

We can explain these deviations concerning the possibility wind swerves out meeting a narrow roughness island (initial interaction). Fig. 284 represents this additional supposition. As a result of the crooked flow and the material used in the experiment in the very start wind meets a higher roughness than on perpendicular flow. That may explain the first effect. The other effects are caused by a slightly outward initial change of direction of the transition zone as a whole.



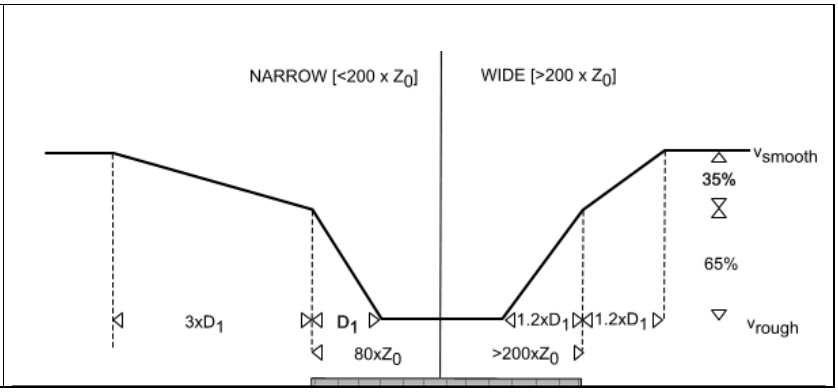


Fig. 284 *Supposed initial interaction*

Fig. 285 *Arithmatical approach of lateral interaction with and without initial interaction*

Fig. 285 shows how to calculate wind velocity in transition zones. Starting points are undisturbed velocities above smooth (v_{smooth}) and rough (v_{rough}) surfaces and their internal boundary layer thicknesses d_3. The difference between both velocities has to be bridged. Above the island already 65 % is bridged , the remaining 35 % is bridged above the smooth surface.
A wide roughness island has no initial interaction. The difference is bridged symmetrically in a distance of 1. 2·D_1. A roughness island narrower than 200 x Z0 (roughess length, not the length of the island) causes initial interaction. Wind velocity difference is bridged over a much larger distance outside the island and above the rough surface over a somewhat smaller distance. The island of Fig. 283 was

25 cm wide, 80 times the roughness length z_0 = 0,3 cm, much less than 200. By initial interaction 65 % was bridged above the island over a distance D_1 (8,5 cm), the remaining 35 % over a distance $2 \cdot D_1$ (17 cm).

Returning to the thought experiment of page 125 concerning Leidscheveen we can put *Fig. 255* on top of its background *Fig. 254* as shown in Fig. 286.

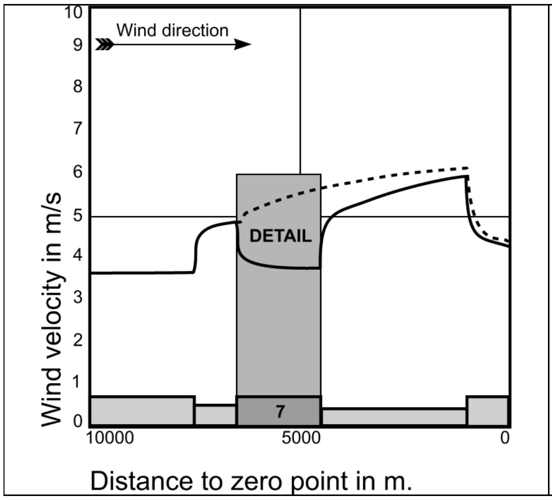


Fig. 286 *Westerly wind in and around Leidscheveen from Fig. 254 and Fig. 255*

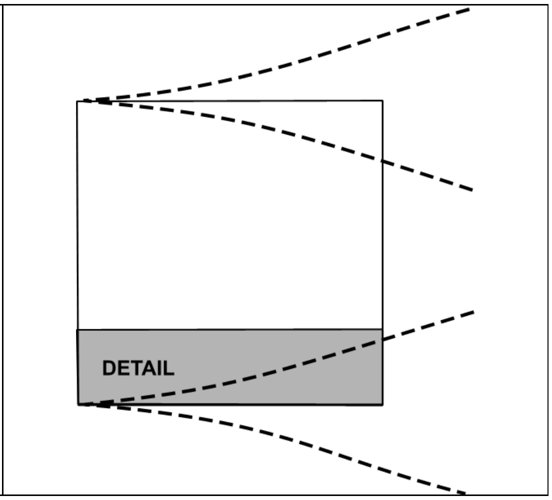


Fig. 287 *Leidscheveen as a rougness island*

Fig. 287 shows Leidscheveen styled as a square of 2x2km.It has no intial interaction because it is wider than 200 times the rougness length Z0 = 1 belonging to class 7. So, the transition zone will penetrate the built up area 1. $2 \cdot D_1$ m.

Fig. 288 and Fig. 289 are distorted details of Fig. 286 and Fig. 287.
Fig. 288 shows velocities outside and above Leidscheveen in more detail. Below their difference is represented. 65 % of the difference is bridged above rough urban area (Fig. 288). That is the way you find wind velocity on the edge inbetween the curves above. In the South East corner of Leidscheveen wind velocity is increased up to 5 m/sec by lateral impacts, while earlier calculations (Fig. 286) indicated there 3,7 m/sec. This velocity is not reached on the East edge until 300 meter (1. 2·D1) from the South edge (Fig. 289).

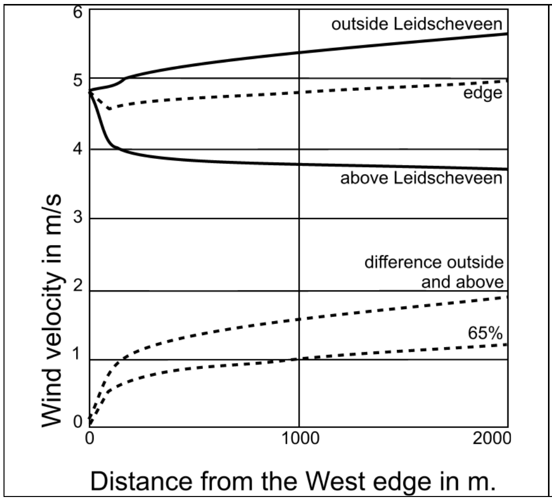


Fig. 288 *Given (continues lines) and calculated (dotted) wind velocities outside and above Leidscheveen as distorted detail from* Fig. 286

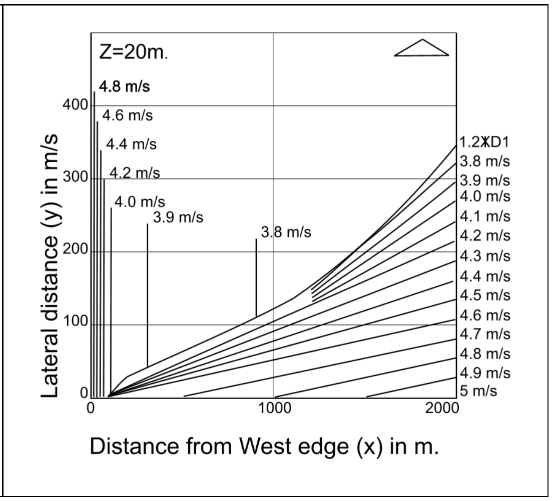


Fig. 289 *Transition zone penetrating from South in normal decrease of Westerly wind velocity above Leidscheveen as distorted detail from* Fig. 287

From Fig. 280 we learned D_1 (the height where the undisturbed wind velocity meets the disturbed one) is approximately 1/10 of x. So, we can approximate the distance from the South edge (Fig. 285) 1.2 x D_1 in Fig. 289 by drawing a straight line into the South West corner of the island, but here it is calculated according to a method by Vermeulen (1983). From Fig. 288 we know the velocity above Leidscheveen without lateral effect at the East edge (3.7m/sec) and the penetrating velocity in the South East corner (5m/sec). Inbetween the velocity increases proportional (Fig. 285) to the distance from the South edge. The velocities on the South edge we know from Fig. 288 as well. Connecting points of equal wind velocity at the East an South edge we get 'altitude' lines of equal wind velocity.

The below left quadrant of Fig. 290 is a copy from Fig. 289 mirrored 1km above and extrapolated 4km into the East. Width (1km) and length (4km) are not proportionally drawn. Now interaction appears behind the point where 1,2·D1-lines cross. According to Vermeulen (1986) the 'altitude' lines within the interaction area you can simply connect.

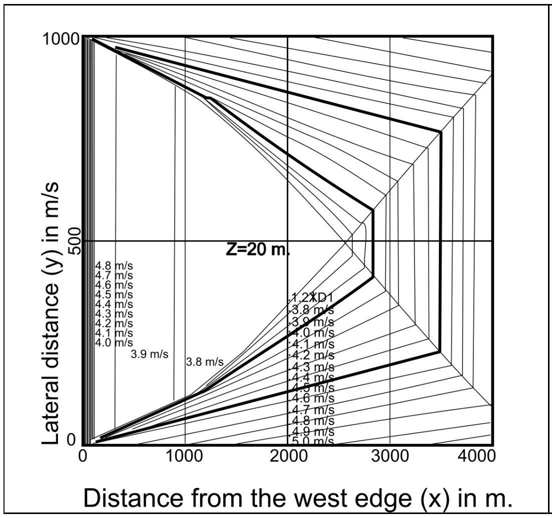


Fig. 290 *Elongated island head in wind (length drawn shortened)*

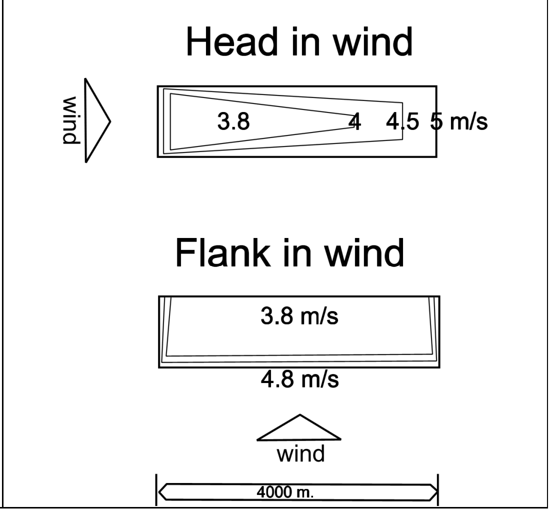


Fig. 291 *Head and flank in wind (proportionally drawn)*

Fig. 291 ‘head in wind’ shows the same model in true proportions: an elongated island with ‘altitude lines’ 4, 4,5 en 5m/sec adopted from Fig. 290. Wind velocity in heart line primarily drops from 4.8 to 3.8m/sec, but then increases up to 5m/sec on the East edge due to lateral impacts. Drawing the case ‘flank in wind’ the first left km from Fig. 290 is used only extrapolating the middle parts. In that case the urban area is surprisingly exposed to lower wind velocities because lateral impacts play practically no rôle. That conclusion is controversial to the usual intuition that elongated urban areas should be located with ‘head in wind’. ‘Flank in wind’ appears to be better from a viewpoint of shelter. However, the question is how much this measure yields. Fig. 292 compares them by a grid of hectares.

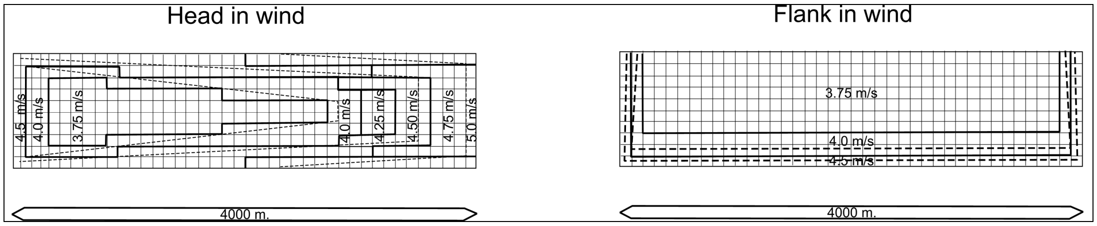


Fig. 292 *Windvelocities per hectare*

Suppose there are 40 dwelling per hectare. From ventilation losses of non airtight dwellings due to Westerly wind we now can calculate the total difference.

Windvelocity	head	flank	Ventilatilion loss in kWh due to Westerly wind			
m/sec	ha	ha	Per dwelling	Per ha.	Total head	Totaal flank
3,75	88	252	504	20160	1774080	5080320
4,00	98	90	521	20840	2042320	1875600
4,25	12		539	21560	258720	
4,50	120	58	557	22280	2673600	1292240
4,75	34		577	23080	784720	
5,00	48		597	23880	1146240	
Totaal	400	400			8679680	8248160

Fig. 293 *Difference in ventilatition loss head and flank in wind*

The difference due to western wind amounts 8679680 – 8248160 = 431 520 kWh per year (approximately 27 kWh average per dwelling). However, this amount can not be charged as profit by giving an elongated urban area a turn by 90^o. On every orientation after all, the impact of at least four wind directions have to be analysed. Then the profit is the difference in impact from two wind directions head and two flank.

2.4.4 Dispersion of urban area

Is a non elongated (‘compact’) town better than a whether or not favourably oriented elongated or dispersed one? This question can not be answered for all cases because elongatedness is substantially dependent from orientation. Anyway, for Westerly wind in case of Leidscheveen the following is valid. Fig. 294 and Fig. 295 show three classes of wind velocity on a hectare grid.

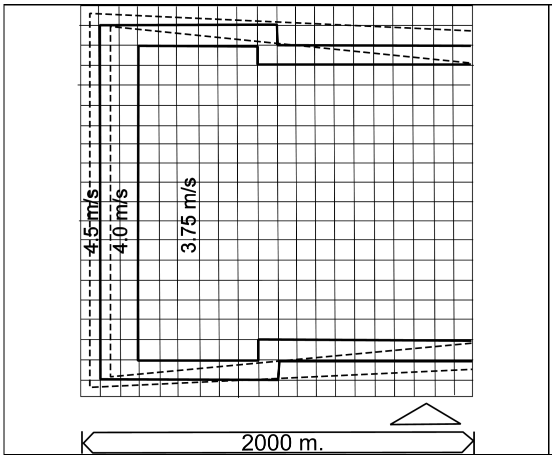


Fig. 294 *Compact town*

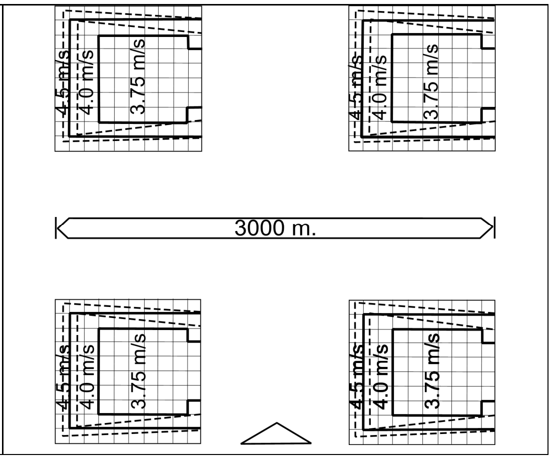


Fig. 295 *Dispersed town*

From the ventilation loss per dwelling due to Westerly wind of 3,75, 4 en 4,50 m/sec we can calculate a difference (Fig. 296).

Windvelocity	Compact	Spread	Ventilationloss in kWh due to westerly wind			
m/sec	ha	ha	per woning	per ha	totaal compact	totaal gespreid
3,75	250	160	504	20160	5040000	3225600
4,00	72	128	521	20840	1500480	2667520
4,50	78	112	557	22280	1737840	2495360
Totaal	400				8278320	8388480

Fig. 296 *Difference in ventilation loss in compact and dispersed towns*

The difference in favour of building compact towns amounts 8388480 – 8278320 = 110 160 kWh per year only (approximately 7 kWh average per dwelling). Velocity and probability of Western wind amounts a little above the average. So, you can multiply this figure by approximately 10 to estimate the total profit.
Comparison with elongated forms is more difficult by orientation sensitivity. A fast method of multiplying the profit of westerly wind does not make sense then. For every several case the calculation has to be repeated for all 12 wind directions. We will not elaborate that.
The intended profit of this paragraph to be used in next paragraphs is insight in the importance of lateral wind effects as such.

2.4.5 The form of town edge

The acquired insights make rough study of town edge design possible. By doing that in the same time we reach the lowest level of scale roughness based calculations can be useful. On lower levels of scale the average image of roughness is disturbed too much by local form variations essential for urban design. However, they remain indispensable as input for predictions on lower levels of scale. The next chapter will examine levels of district and neigbourhood further by carefully designed wind tunnel experiments. They will link up connections between urban design and wind behaviour in more detail.

However, on the level of town edge design the roughness approach (grain approximately 100m radius) still makes sense for rough conclusions. We restrict to the impacts of large gaps in the city edge. They occur by large access roads with noise zones or green lobes penetrating the city.
Fig. 297 shows a model of a small town (approximately 50 duizend inwoners) with lobes like that.

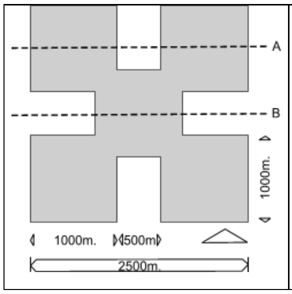


Fig. 297 *Small town with green lobes*

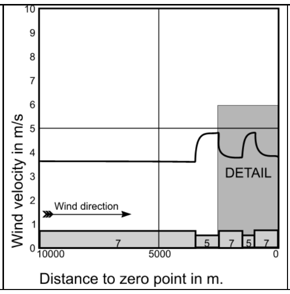


Fig. 298 *Wind velocity profile cross section A*

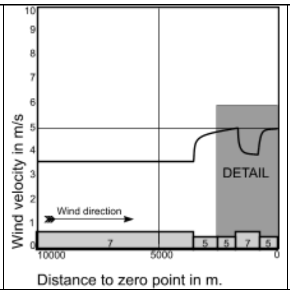


Fig. 299 *Windvelocity profiel doorsnede B*

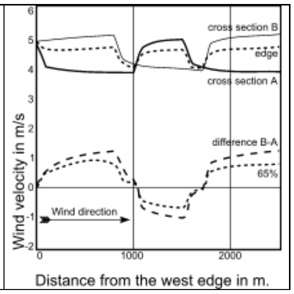


Fig. 300 *Difference profile A en B*

Fig. 298 and Fig. 299 show the windvelocity profiles of cross section A and B in case it would be Leidscheveen blown by Western wind. Fig. 300 shows above the last 3000m of both profiles projected on top of eachother. Below the difference between both profiles is represented; 65% has to be bridged laterally above urban area over a distance 1,2 · D_1. This determines wind velocity on the edge.

From these data we estimate again an average wind velocity per hectare.

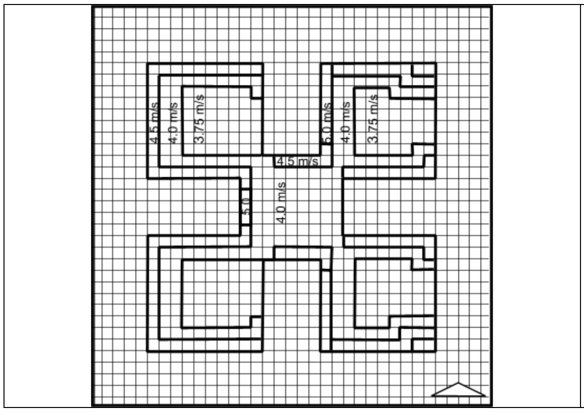


Fig. 301 *'Open' towns edge*

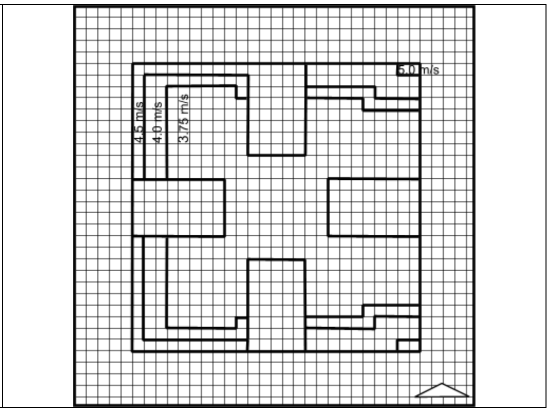


Fig. 302 *'Closed' towns edge*

Fig. 301 shows lobes penetrating from four directions. In Fig. 302 the lobes are filled with forest of the same roughness as the urban area keeping the urban surface equal.
From the ventilation losses belonging to wind velocity 3,75, 4, 4,5 and 5m/sec due to westerly wind, Fig. 303 calculates the difference.

Windvelocity	Open	Closed	Ventilationloss in kWh due to westerly wind			
m/sec	ha	ha	per dwelling	per ha	total open	total closed
2,75	154	305	504	20160	3104640	6148800
4,00	184	74	521	20840	3834560	1542160
4,50	106	82	557	22280	2361680	1826960
5,00	21	4	597	23880	501480	95520
Totaal	465	465			9802360	9613440

Fig. 303 *Difference in ventilation loss by 'open' and 'closed' town edge*

The difference is 9 802 360 – 9 613 440 = 188 920 kWh per year (Approximately 10 kWh per dwelling). Multiplying Westerly wind impact by 10 the total average profit is approximately 100 kWh x 1860 dwellings.

2.4.6 Wind directions, temperature and built form

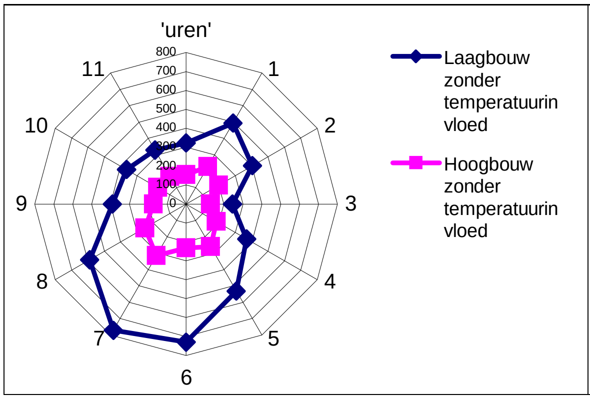
In chapter 2.2 we restricted our thought experiments to two wind directions and in this chapter even to one (Westerly wind). Assuming an average temperature for all wind directions we reported virtual ventilation losses of non airtight, low rise buildings due to Westerly wind as an indicator. Their *differences* clarified an impact of environmental roughness useful for other impacts as well. We exclusively varied regional and local environment applying different roughnesses, keeping the rest constant. Otherwise the impact of environmental roughness on itself could not be clarified. It would be mixed up with other causes (possible measures). To clarify other causes the reverse we have to keep environmental rougness constant. If we take one layout of roughnesses in the environment – the one we will use in next chapters for experiments in the wind tunnel (Fig. 308) – we can compare the contribution of every several wind direction and their temperature properly (Fig. 304). We calculated energy losses by ventilation for every wind direction in the same way we did above (column A and B) and for airtight dwellings (column C and D).

		without temperature influence				temperature influence		with temperature influence			
		non airtight		airtight		non airtight	airtight	non airtight		airtight	
wind direction		A	B	C	D	E	F	A x E	B x E	C x F	D x F
'hours'	degrees	kWh		kWh				kWh		kWh	
1	30	322	6%	154	6%	70%	66%	227	4%	101	4%
2	60	492	9%	228	9%	116%	111%	570	10%	254	10%
East 3	90	405	7%	201	8%	168%	151%	681	12%	304	12%
4	120	246	4%	129	5%	205%	174%	504	9%	225	9%
5	150	369	7%	186	8%	64%	57%	238	4%	106	4%
South 6	180	530	10%	259	10%	71%	65%	377	7%	168	7%
7	210	729	13%	232	9%	100%	141%	731	13%	326	13%
8	240	769	14%	315	13%	107%	116%	819	15%	365	15%
West 9	270	591	11%	253	10%	107%	111%	631	11%	281	11%
10	300	389	7%	172	7%	90%	91%	349	6%	156	6%
11	330	366	7%	173	7%	71%	67%	260	5%	116	5%
North 12	0	329	6%	167	7%	45%	40%	149	3%	67	3%
	Total	5537	100%	2469	100%			5536	100%	2469	100%

Fig. 304 *Contributions per wind direction to total energy loss by ventilation*

In the lowest row 'Total', column A shows we can multiply the loss of Westerly wind by 10 to have an idea of total loss from all directions indeed. The totals without temperature influence are the same as those including temperature influence, because in columns A, B, C and D we assumed an average temperature of all directions.

Columns E and G show tentative weight factors for temperature, based on Visser (1986). Multiplying A, B, C and D by these factors produces the necessary correction to get a better idea about the real losses per direction. They are used in next chapters as well.



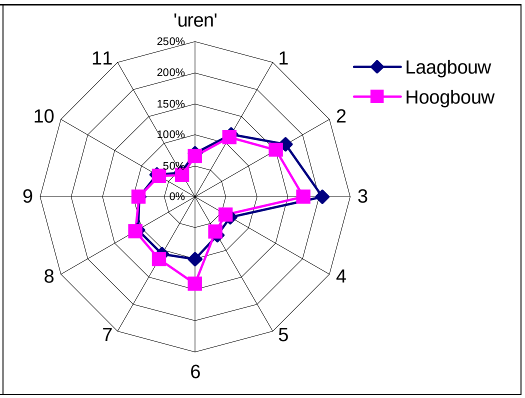


Fig. 305 *Contributions per wind direction to total energy loss by ventilation without temperature influence (A and C in* Fig. 304*)*

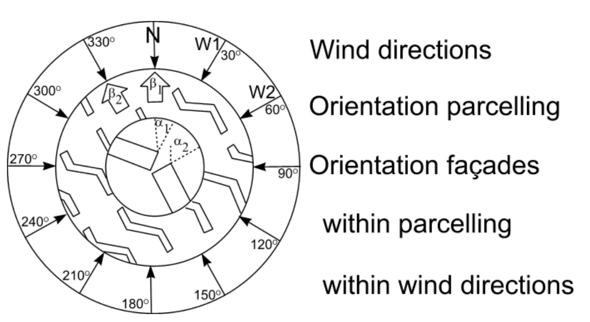
Fig. 306 Tentative correction factors for temperature influence *(E and F in* Fig. 304*)*

Fig. 305 and Fig. 306 show Easterly winds being less probable but colder have a larger impact on energy losses by ventilation than South Westerly winds. To understand why Southerly winds contribute more in airtight buildings (Hoogbouw in Fig. 306) than in non airtight ones (Laagbouw) you have to look at Fig. 221.

2.5 District and neighbourhood variants

2.5.1 From calculable ‘rough surface’ into allotments in a wind tunnel

Changing location and size of a homogenuous undirected roughness, influences every external wind direction in the same way. However, changing form on a lower level of scale introduces internal directions within that field of roughness behaving differently even for one single external wind direction. And design can vary form within form. This complication you can imagine as 3 potter’s wheels turning around the same centre. If we consider 12 directions, there are 12 x 12 x 12 combinations (Fig. 307).



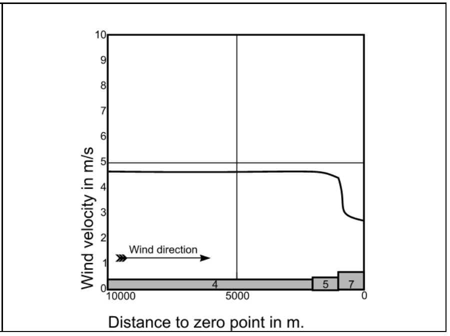


Fig. 307 *Three levels of schale where orientation has to be taken into account*

Fig. 308 *Supposed wind tunnel context by standard Northerly wind*

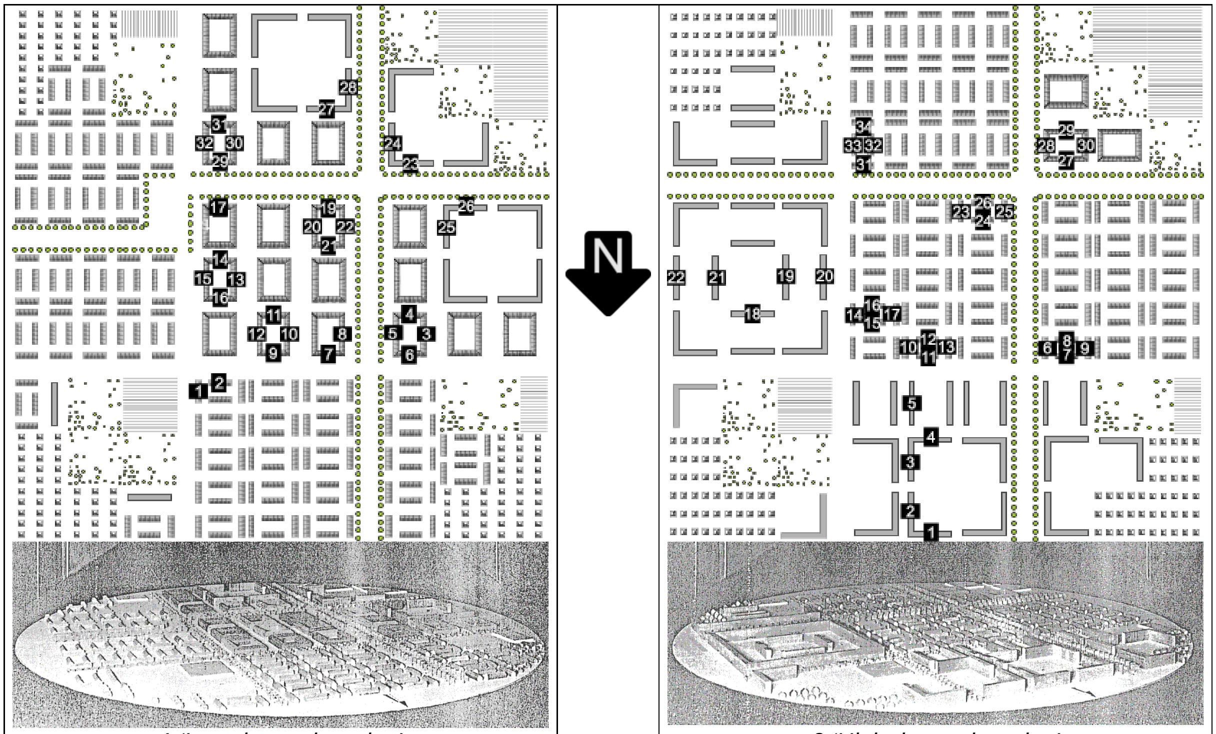
The external wheel represents 12 local wind statistics (W1, W2, W3 … concerning probability, velocity and temperature) as it applies outside and at the edge of the urban fragment we consider. The second wheel represents the considered fragment with its own arrow indicating North (β_1). In this chapter the direction of the allotment as a whole (β_1, β_2, β_3 ...) is variable. The middle wheel represents façades within the allotment having variable orientations (α_1, α_2, α_3 ...), causing different ventilation losses locally. In previous paragraphs α and β were neglected. Ventilation losses were averaged over all directions of allotments and façades.
In this chapter α and β are varied by interpreting tests of 18 different allotments in the wind tunnel of Visser (1986) from 7 different angles (0^{o} – 90^{o} by steps of 15^{o}) with a standarised W and foreland roughness (Fig. 308). From these 7 measured angles, 4 (0^{o} – 90^{o} by steps of 30^{o}) appeared to be sufficient to draw conclusions about all directions of allotment.

2.5.2 Wind tunnel experiments

On the level of districts and neighbourhoods 4 configurations 1 x 1 km Jong (1986) - fully elaborated in models 1:500 - are tested by Visser (1986). In each of the four models 30 x 2 measuring points were installed at front and back side of different building blocks to measure pressure differences (Fig. 309).

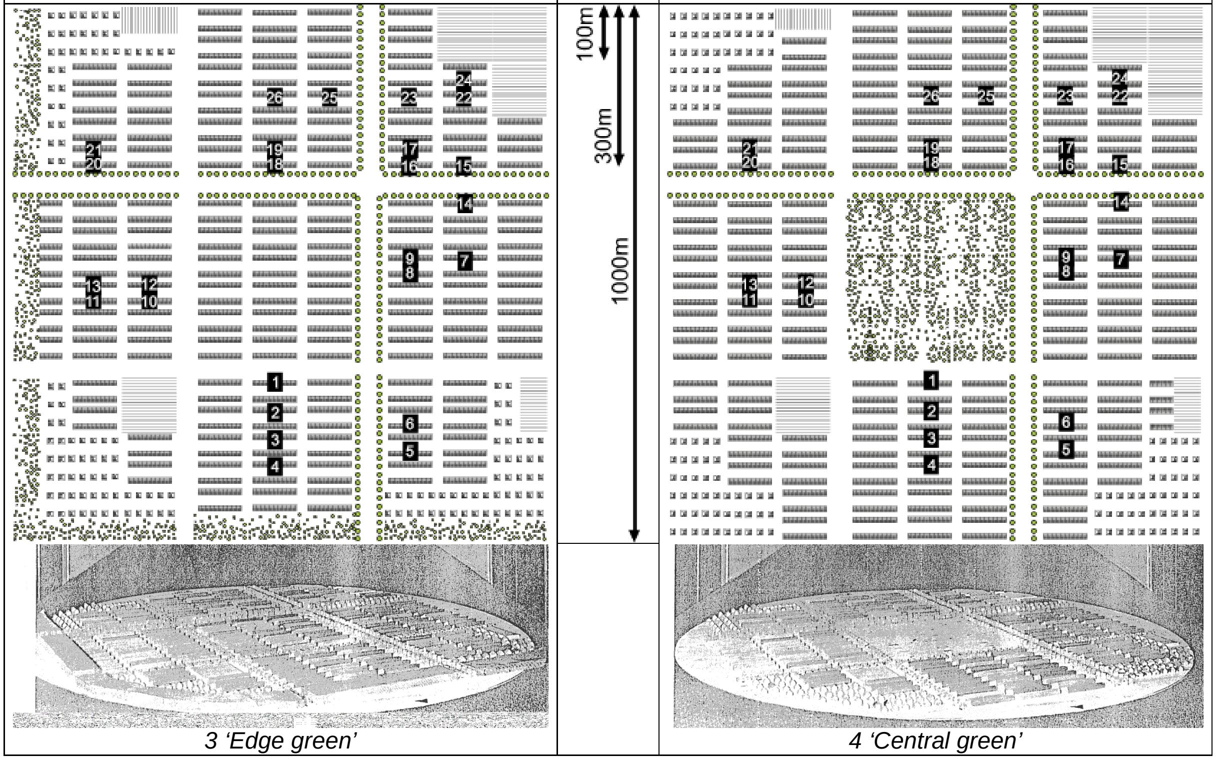
Right above in each configuration (Fig. 309) each time you find a quarter of a district centre. So, any configuration could be thought mirrored twice around this centre into a full district 2x2km consisting of 4 district quarters. Each configuration consists of 9 neighbourhood quarters 300x300m (one central, 8 peripheral). Each neighbourhood quarter consists of 9 ensemble quarters (hectares 100x100m one central, 8 peripheral). District roads are planted with trees; neighbourhood and ensemble roads are not.

The configuration is outside blown along from North to East (90o from North). At South and West side the configuration as a district quarter is part of an imaginary district filled up with equal roughness.
In this paragraph we study the differences between the four configurations not trying to develop calculation models.



1 *'Low rise at the edge'*

2 *'High rise at the edge'*



3 *'Edge green'*

4 *'Central green'*

Fig. 309 *District configurations in wind tunnel with measuring points indicated*

Concerning the average result of all measuring points the differences between the configurations are remarkably small. However, there are substantial differences between locations within configurations. (Fig. 316and Fig. 319). Fig. 310 shows hectare allotments applied in the tested configurations.

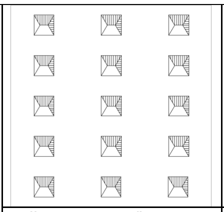
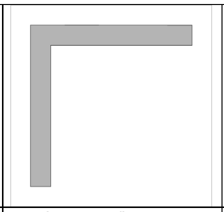
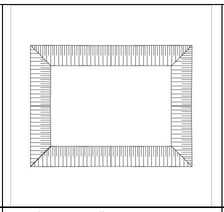
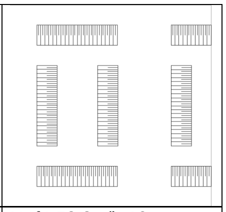
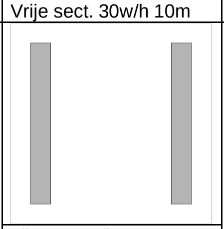
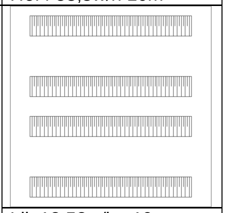
In configuration 1 and 2	 Vrije sect. 30w/h 10m	 Hoek1a 22w/ha 22m	 Hof1 96 w/ha 15,5m	 Hof4 53,3w/h 10m
In configuration 2	 Lijn10 84w/ha 17m		In configuration 3 and 4:	 Lijn12 53w/ha 10m

Fig. 310 *Hectare allotments applied in the tested configurations*

In paragraph 2.6.1 we study the results of 14 wind tunnel experiments by Visser (1986) on hectare level; 7 with green and 7 without. In these experiments a number of theoretical repeating point, line, corner and courtyard allotments 500x500m elaborated in models 1:250 are tested. The force these allotments ondergo by standard wind is measured. From these tests TNO developed a calculation method for allotments repeating in two dimensions. By this method more types of allotment are calculated.

2.5.3 Pressure differences between front and back façades

Ventilation loss of a dwelling not only depends on wind statistics derived from year average wind velocity vg on z=10m height in the nearest wind measuring station (vg(10), for example 5,4m/sec near Schiphol). It depends also on the environment and orientation of the building block. On these more local factors pressure differences between front and back façades follow determining ventilation losses at last.

Pressure differences are proportional to driving pressure of wind: $0{,}5 \times \rho \times vg(10)^2$. In this formula ρ ('ro') is the density of air. Pressure differences between front and back façades determining ventilation are measured in wind tunnel. Dividing such pressure differences by the local driving pressure of wind produces a factor $\Delta Cp(10)$ representing the resistance of an allotment independent from wind velocity. The result of wind tunnel tests are expressed in $\Delta Cp(10)$. Fig. 311 shows the relation between ventilation loss near Schiphol and $\Delta Cp(10)$ in any wind direction Visser (1986). Airtight buildings in vg(10) lose less energy by increasing pressure because inhabitants close windows they opened in less pressure!

Inside urban areas energy yield of wind turbines is less relevant. However, pressure difference is important as well for comfort of outdoor space, dispersion of air pollution and wind loads. But we have measured ventilation losses and will use it as an indicator.

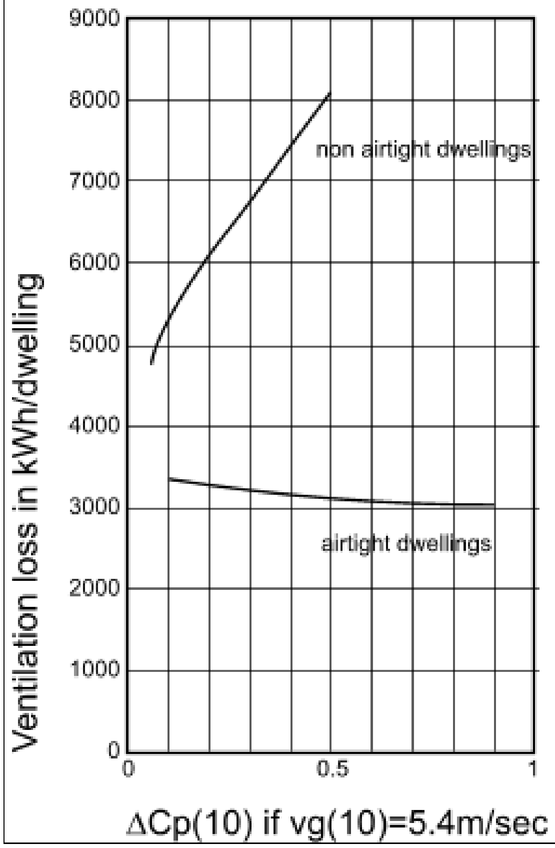


Fig. 311 *Ventilation loss related to ΔCp(10) if vg(10) = 5,4m/sec*

	Degrees from y-axis				
Point	0	30	60	90	av.
1	0,00	0,18	0,32	0,32	0,21
2	0,10	0,16	0,07	0,04	0,09
3	0,10	0,02	0,10	0,02	0,06
4	0,02	0,14	0,24	0,05	0,11
5	0,12	0,08	0,11	0,11	0,11
6	0,34	0,38	0,02	0,04	0,20
7	0,34	0,26	0,10	0,04	0,19
8	0,08	0,05	0,12	0,16	0,10
9	0,35	0,28	0,11	0,05	0,20
10	0,10	0,00	0,10	0,12	0,08
11	0,11	0,12	0,02	0,05	0,08
12	0,10	0,19	0,24	0,19	0,18
13	0,01	0,10	0,12	0,01	0,06
14	0,18	0,08	0,04	0,05	0,09
15	0,02	0,13	0,25	0,38	0,20
16	0,10	0,19	0,14	0,13	0,14
17	0,02	0,12	0,22	0,30	0,17
18	0,18	0,11	0,01	0,16	0,12
19	0,19	0,16	0,01	0,06	0,11
20	0,02	0,08	0,19	0,07	0,09
21	0,04	0,10	0,14	0,01	0,07
22	0,00	0,16	0,12	0,16	0,11
23	0,38	0,36	0,30	0,13	**0,29**
24	0,14	0,32	0,35	0,35	**0,29**
25	0,17	0,06	0,28	0,24	0,19
26	0,53	0,28	0,05	0,12	0,25
27	0,23	0,20	0,04	0,22	0,17
28	0,34	0,03	0,22	0,48	0,27
29	0,13	0,08	0,07	0,05	0,08
30	0,06	0,01	0,08	0,02	0,04
31	0,08	0,07	0,02	0,10	0,07
32	0,05	0,07	0,16	0,30	0,15
Gem.	0,14	0,14	0,14	0,14	0,14

Visser (1986)

Fig. 312 *ΔCp(10) in measure points of configuration 1 in 4 directions*

Fig. 312 shows ΔCp(10) measured in every measure point of configuration 1 four times while wind was blowing 0^o to 90^o from y-axis each time turning the model 30^o (any direction could be North). Measuring points 23 and 24 (high rise at a crossing, see Fig. 309 conf. 1) suffer the largest pressure differences, 23 on 0^o, 24 on 60^o and 90^o. This kind of details we study in paragraph 2.5.5. This paragraph studies the averages in lowest row compared with the averages of the other configurations.

2.5.4 District lay out

The averages in lowest row of Fig. 312 seem to show the direction of wind does not matter but this is only the case in configuration 1. It is explained best because half of the measured blocks there are oriented perpendicular to the other half. So, the minimum ventilation loss of one building block compensates the maximum of the other one. Configuration 2 is less balanced that way and configurations 3 and 4 have only one orientation of building blocks (Fig. 313).

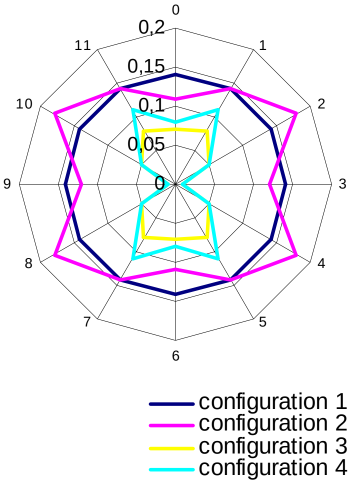


Fig. 313 *Average ΔCp(10) in different configurations two times mirrored around the centre.*

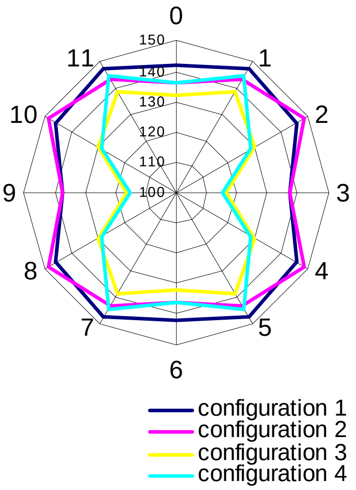


Fig. 314 *Average ventilation loss of a non airtight dwelling in kWh per allotment direction if standard Northerly wind would blow from all directions*

Comparing the impact of locations and allotment directions we should use an equal standard wind (here Northerly wind, representing approximately 2.69% of the virtual total ventilation loss per allotment direction) for every allotment direction (Fig. 314).The virtual total ventilation loss then is 100%. Fig. 315 shows averages multiplied into such a virtual total.In configuration 1 it is 5 344kWh for non airtight dwellings. That is less than we calculated by roughness 7 in Fig. 304 (5 536kWh in column A X E), and for airtight dwellings it is more (3 266 kWh instead of 2 469 in column C x F). Perhaps the roughness class of configurations is closer to 8 than class 7 we used in paragraph 2.4.6 and supposed in Fig. 308.

	Configuration 1			Configuration 2		Configuration 3		Configuration 4	
	calculated								
	roughness	average	virtual	average	virtual	average	virtual	average	virtual
	100%	2,69%	100%	2,69%	100%	2,69%	100%	2,69%	100%
non airtight	5536	144	5344	141	5233	129	4787	131	4862
airtight	2469	88	3266	89	3303				
ΔCp(10)		0,14		0,14		0,05		0,06	

Fig. 315 *Estimating average ventilation losses from 4 allotment directions multiplied into a virtual total.*

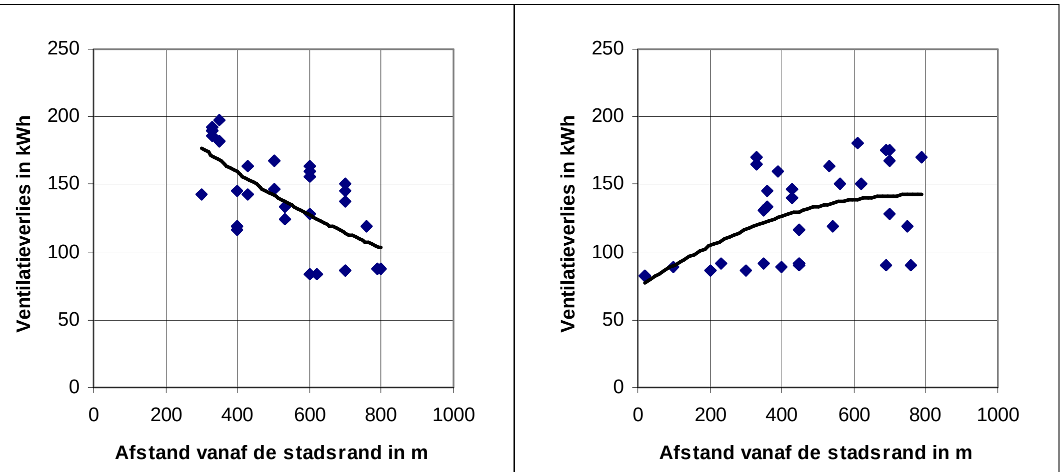
Average pressure difference in configuration 2 (high rise on the edge) is the same (ΔCp(10)=0.14) as in configuration 1 (low rise on the edge). But there are differences per *allotment direction*. So, you can not yet conclude both configurations should have the same ventilation loss. *Wind directions* deliver different contributions and their reduction depends on the North direction arrow of the allotment in the compass card of *wind directions*. Because configuration 3 (edge green) and configuration 4 (central green) have lower pressure differences in *all* directions (Fig. 314) we can conclude they will have less ventilation loss than configurations 1 and 2 indeed. However, the difference between a lay out with green on the edge or within the centre is negligible!

Configuration 1 (low rise on the edge) has more ventilation losses from non airtight low rise dwellings and less from airtight high rise ones than configuration 2 (high rise on the edge). Fig. 311 shows airtight highrise has less ventilation loss by more wind pressure. Inhabitants close their windows earlier.

Slant flow along (30^o of 60^o) causes in all cases maximum loss (Fig. 313). Perhaps we should orientate allotments with two perpendicular directions East or South West sheltering one of them best and the othe not at all. This yields more than both half. We tested that hypothesis by calculating perpendicular and slant flowing along for 12 North direction arrows but the result disappointed because adjacent wind directions score high as well by slant flow. They dim the aimed impact into a negligible result.
That is of course not the case in parallel blocked configurations 3 and 4.
So, measures on the level of district or neighbourhood have more local than general impacts. Big local impacts level out in the district as a whole in such a way that differences in its lay out become marginal.

2.5.5 Neighbourhoods

We restrict ourselves to perpendicular flow with Northerly wind character (2.7%) from 0^o and 90^o out of y-axis. In both cases wind meets on 300m from town edge a 30m wide neighbourhood road and on 600m a 70m wide district road with trees.
A roughness approach (paragraph 2.4.6) would show decreasing loss until 100m from town edge stabilising on approx. 150kWh for non airtigh low rise and for airtight high rise increasing stabilising on 75 kWh. Fig. 316 shows wind tunnel results elaborated into kWh (paragraph 2.4) from configurations 1 (low rise on the edge) and 2 (high rise on the edge) as a working of distance to town edge.

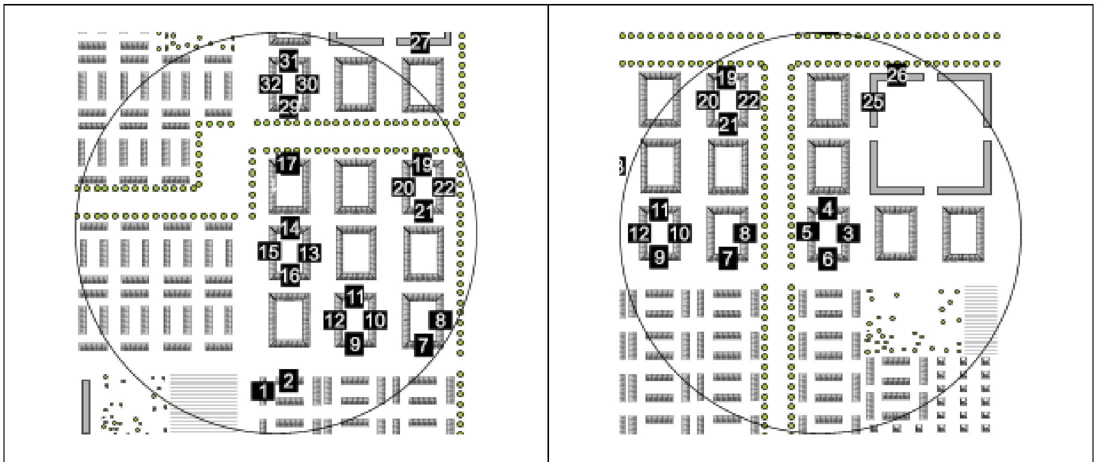


configuration 1 (low rise on the edge)

configuration 2 (high rise on the edge)

Fig. 316 *Ventilation losses of non airtight low rise and iartight high rise dwellings by standard Northerly wind (2.7% of virtual total) as a function of distance to town edge in configurations 1 and 2*

Wind tunnel experiments now specified to location give a clearer distinction between low rise and high rise on the edge then leveled out over the district. The largest low rise loss in configuration 1 appears in measure point 15 (197kWh), a 15.5m high building located on a 15m wide road without trees and a foreland of 10m high dwellings. The smallest appears in measure point 13 (116kWh), a courtyard dwelling. The difference is approx. 80 or virtually 3000kWh.



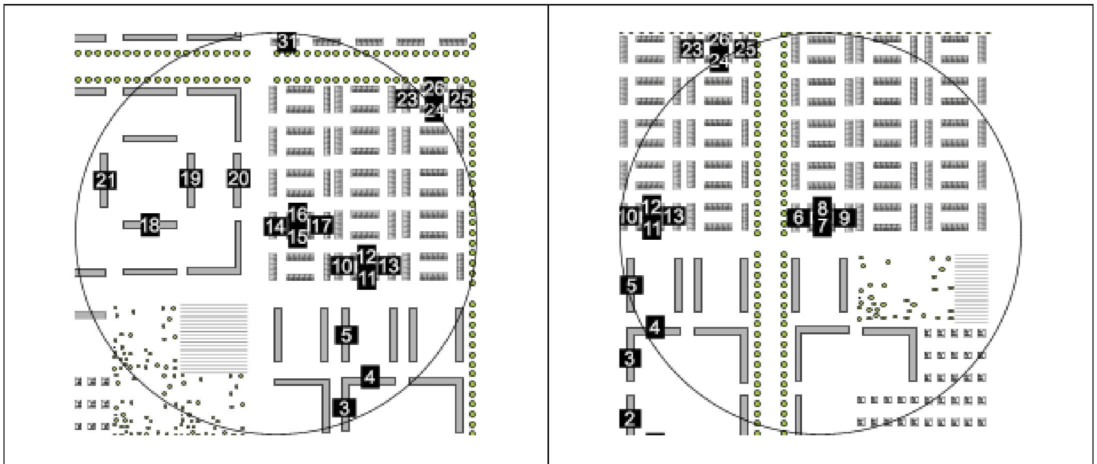
Measure points 1, 9, 15, 29, 32

Measure points 5, 6, 7, 9

Fig. 317 *Measure points in configuration 1 in a radius of 300m*

Measure points 1(186kWh), 6(190kWh), 7(190kWh), 9(163kWh), 15(197kWh) and 32(182kWh) score high by wind over a 40m neighbourhood road without trees. Measure points 5(145kWh), 17(143kWh) and 29(150kWh) get wind over a much wider district road (80 to 100m) with 6m heigh trees. The local importance of trees in large urban spaces is indicated here. The difference is approx. 40 or virtually 1500kWh.

In configuration 2 measure points 7(147kWh), 11(170kWh) en 14(131kWh) lie on a 40m wide neighbourhood road without trees. Measure point 14 scores low because it is shelterd by 22m high high rise buildings on the other side of the road. The low rise minimum measure point 10(116kWh) lies on 10m wide ensemble streets. The maximum in measure point 25(180kWh) is most likely explained by its position on the edge of the used model.

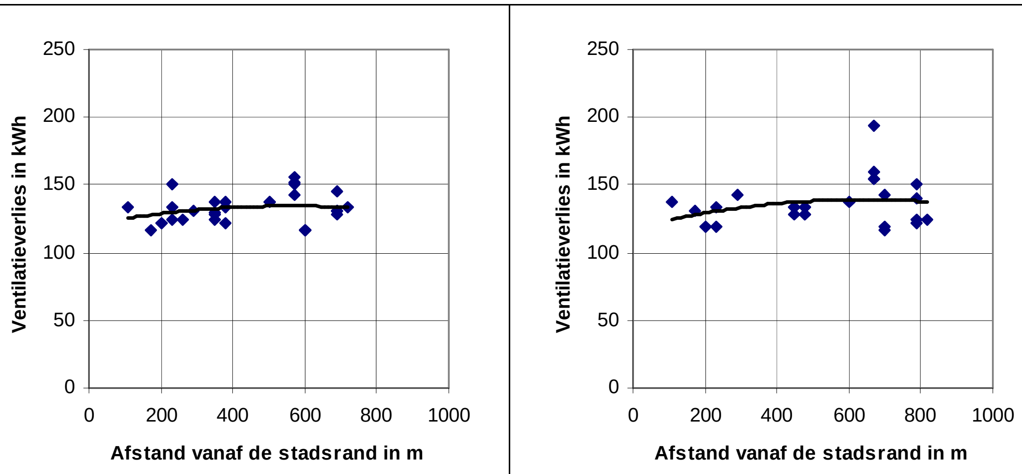


Measure points 10, 14, 25

Mearusre points 7, 11

Fig. 318 *Measure points in configuration 2 in a radius of 300m*

Fig. 319 shows the same figures as Fig. 316 for configuration 3 en 4 without high rise.

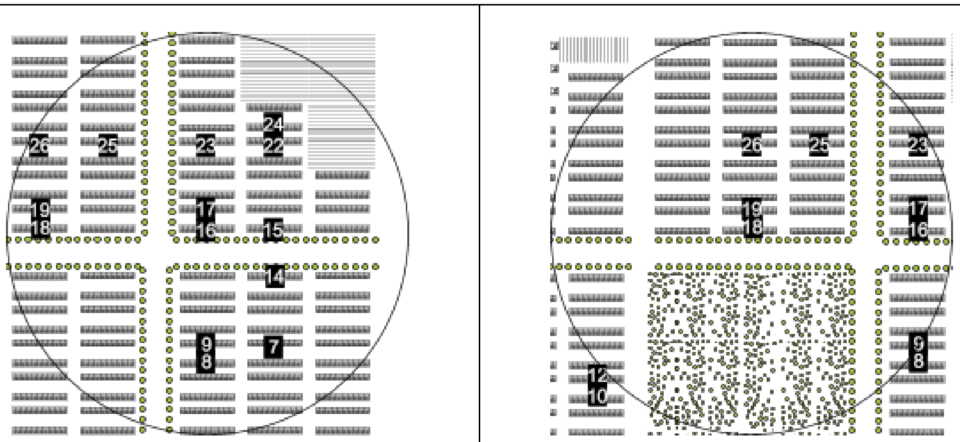


configuration 3 (green on the edge)

configuration 4 (central green)

Fig. 319 *Ventilation losses of non airtight low rise dwellings by standard Northerly wind (2.7% of virtual total) as a function of distance to town edge in configurations 3 and 4*

In configuration 3 measure point 27(150kWh) lies on a 40m wide neighbourhood road without trees. Measure points 20(156kWh), 18(152kWh), 15(150kWh) and 16(143kWh) score approximately equaly high ying on a 70m wide district road with trees. Minima 2(116kWh), 17(116kWh), 19(116kWh) and 21(116kWh) get wind from a backyard lying on 10m wide ensemble roads.



Measure points 15, 17, 18, 19, 22
in Configuration 3

Measure points 17, 18, 19
in Configuration 4

Fig. 320 *Measure points in configuration 3 and 4 in a radius of 300m*

In configuration 4 measure point 18(194kWh) scores extremely high. It gets wind from 300m wide open green area in the centre of district quarter. Even district road trees do not help much on this location. Minima 21(116kWh), 6(119kWh), 5(119kWh) and 17(119kWh) again lie on small ensemble streets. Measure point 19(143kWh) lies on a small street as well, but that is the first street behind the green behind measure point 18(194kWh), and that is still apparent there.

2.6 Allotment of hectares

2.6.1 From wind tunnel experiments into methods of calculation

From the results of 14 wind tunnel experiments on repeating theoretical point, line, corner and courtyard allotments with and without green a calculation method is developed Visser (1987; Visser (1987) predicting average pressure differences between front and back façades of dwellings ΔCp(z) (ΔCp on heigth z). The reference height z is 2.5 times the average building height.

The calculation is restricted to allotments with two main directions at most. For two directions we have to determine the value of ΔCp perpendiculary blown along by wind (ΔCp_0). Façades may bend 30^o from main direction at most. Within that margin measuring a second main direction is not necessary. The expected ΔCp per flow direction is calculated for 100 x 100m allotment types in Fig. 321.

Visser (1987; Visser (1987)

Fig. 321 *Allotment types 100x100m with different height Visser (1987) calculated ΔCp(z) for*

Fig. 322 shows the result of these calculations.

	height	vert.surf.	without green					with green 6m high					with green 10m high				
	m	F/O	N	+30	+60	+90	av.	N	+30	+60	+90	gem.	N	+30	+60	+90	av.
Punt01	10	0,24	0,14	0,13	0,09	0,00	0,09	0,13	0,12	0,09	0,00	0,09	0,12	0,11	0,08	0,00	0,08
Punt02	10	0,24	0,14	0,13	0,09	0,00	0,09	0,13	0,12	0,09	0,00	0,09	0,12	0,11	0,08	0,00	0,08
Punt03	10	0,24	0,19	0,17	0,13	0,00	0,12	0,18	0,17	0,12	0,00	0,12	0,12	0,19	0,11	0,00	0,11
Punt05	10	0,16	0,19	0,17	0,12	0,00	0,12	0,18	0,17	0,12	0,00	0,12	0,12	0,19	0,11	0,00	0,11
Punt06	10	0,30	0,14	0,13	0,10	0,00	0,09	0,14	0,13	0,09	0,00	0,09	0,13	0,12	0,08	0,00	0,08
Punt07	15,5	0,14	0,23	0,21	0,15	0,00	0,15	0,22	0,20	0,14	0,00	0,14	0,20	0,19	0,13	0,00	0,13
Punt08	15,5	0,21	0,16	0,15	0,11	0,00	0,11	0,16	0,14	0,10	0,00	0,10	0,14	0,13	0,03	0,00	0,08
Punt09	22	0,09	0,20	0,19	0,13	0,00	0,13	0,20	0,10	0,10	0,00	0,10	0,20	0,19	0,13	0,00	0,13
Punt10	22	0,18	0,19	0,18	0,13	0,00	0,13	0,19	0,18	0,10	0,00	0,12	0,18	0,12	0,12	0,00	0,11
Lijn01	10	0,24	0,21	0,19	0,14	0,00	0,14	0,20	0,18	0,13	0,00	0,13	0,18	0,12	0,12	0,00	0,11
Lijn02	10	0,24	0,21	0,19	0,14	0,00	0,14	0,20	0,19	0,13	0,00	0,13	0,18	0,17	0,12	0,00	0,12
Lijn05	10	0,32	0,14	0,13	0,03	0,00	0,08	0,13	0,12	0,08	0,00	0,08	0,12	0,11	0,09	0,00	0,08
Lijn06	15,5	0,25	0,20	0,19	0,13	0,00	0,13	0,19	0,18	0,10	0,00	0,12	0,18	0,16	0,12	0,00	0,12
Lijn07	11	0,18	0,28	0,26	0,18	0,00	0,18	0,27	0,24	0,18	0,00	0,17	0,24	0,22	0,16	0,00	0,16
Lijn08	22	0,35	0,12	0,11	0,08	0,00	0,08	0,12	0,11	0,08	0,00	0,08	0,11	0,10	0,07	0,00	0,07
Lijn09	22	0,35	0,12	0,11	0,08	0,00	0,08	0,12	0,11	0,08	0,00	0,08	0,11	0,10	0,07	0,00	0,07
Hoek01	22	0,18	0,28	0,26	0,18	0,00	0,18	0,28	0,26	0,18	0,00	0,18	0,27	0,24	0,19	0,00	0,18
Hoek02	22	0,35	0,28	0,26	0,18	0,00	0,18	0,28	0,26	0,18	0,00	0,18	0,27	0,24	0,18	0,00	0,17
Hof01	15,5	0,25	0,14	0,13	0,09	0,00	0,09	0,13	0,12	0,09	0,00	0,09	0,12	0,11	0,08	0,00	0,08
Hof01>	15,5	0,19	0,25	0,23	0,17	0,00	0,16	0,24	0,22	0,16	0,00	0,16	0,22	0,20	0,15	0,00	0,14
Hof02	10	0,16	0,22	0,20	0,14	0,00	0,14	0,21	0,19	0,14	0,00	0,14	0,19	0,18	0,17	0,00	0,14
Hof02>	15,5	0,19	0,25	0,23	0,17	0,00	0,16	0,24	0,20	0,16	0,00	0,15	0,22	0,20	0,15	0,00	0,14
Hof03	10	0,16	0,22	0,20	0,14	0,00	0,14	0,21	0,19	0,14	0,00	0,14	0,19	0,18	0,10	0,00	0,12
Hof03>	10	0,12	0,33	0,30	0,21	0,00	0,21	0,31	0,28	0,20	0,00	0,20	0,28	0,26	0,10	0,00	0,16
Hof04	10	0,24	0,26	0,24	0,17	0,00	0,17	0,25	0,23	0,16	0,00	0,16	0,23	0,21	0,15	0,00	0,15
Hof05	15,5	0,37	0,19	0,18	0,13	0,00	0,13	0,18	0,17	0,12	0,00	0,12	0,17	0,15	0,11	0,00	0,11
average			0,20	0,19	0,13	0,00	0,13	0,20	0,18	0,13	0,00	0,12	0,08	0.17	0,12	0,00	0,12

Fig. 322 *ΔCp(z) for 4 flow along directions in 23 allotment types (> second measurement perpendicular)*

Hof01, Hof02 and Hof03 have two main directions of front-back façades. So, ΔCp had to be measured two times. Hoek01, Hoek04, Hof04 and Hof05 have two directions with the same characteristics perpendicular. So, the same measurement can be used the reverse (90° is 0°, 60° is 30° and so on) for the perpendicular part. Averaging the impact of both directions proportional to the number of dwellings you get numbers for corner and courtyard allotments comparable with point and line alotments.

Then we have to take other windstatistics than Northerly into account. The quarter we calculated is only very exceptionally equal to a quarter of all ventilation losses as well. This is for instance the case if that quarter (0° to 90° from y-axis) coincides with wind directions West to North. For every other North indicating arrow the calcuated quarter will contribute more or less than 25% of the ventilation loss, dependent from the wind statistics exposed. This contribution is calculated for 12 North indicating arrows and completed into a 100% virtual total loss. The supposition that a dwelling surrounded by repeating allotments is equally sheltered into the other quarters is better justified than in previous paragraphs.

2.6.2 Impact of trees

Fig. 323 shows the result of this calculation on the average of Fig. 322 itemized for airtight high rise allotments and low rise ones supposed to be non airtight.

	without green					with green 6m height					with green 10m height				
main direction	0	30	60	90	virt.	0	30	60	90	virt.	0	30	60	90	virt.
average															
low rise	162	249	599	507	**5162**	161	247	594	506	**5130**	158	244	585	505	**5075**
high rise	90	136	343	414	**3343**	90	136	343	414	**3343**	90	136	343	414	**3347**

Fig. 323 *Ventilation loss as a consequence of standard Northerly wind.*

The impact of 6m high (young) trees is negigible. However, when for instance after 10 years trees reach a height of 10m there is some impact. However, locally the impact may be substantial (page 147).

2.6.3 Comparing repeated allotments 100x100m

Fig. 324 and Fig. 325 show some allotment types in seqeunce of virtual ventilation losses.

	loss	height	density	distance
	kWh/won	m	dwell./ha	m
Lijn05	4789	10	64	15
Punt01&02	4795	10	48	15
Punt06	4817	10	48	17
Punt08	4901	15	72	18
Hof01	4906	15	96	40
Punt05	4980	10	36	23
Punt03	4982	10	48	23
Lijn06	5008	15	64	40
Lijn01&02	5025	10	48	23
Punt07	5068	10	64	35
Hof02	5086	14	64	40
Hof03	5130	10	48	40
Lijn07	5187	11	64	40

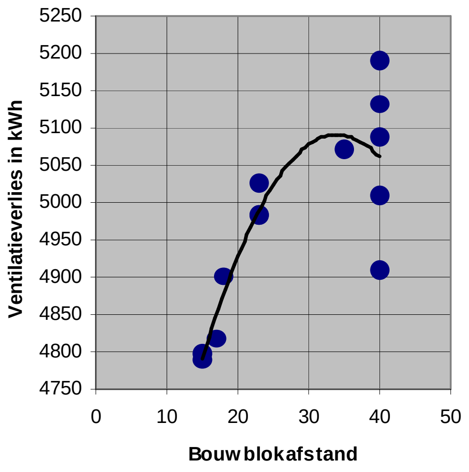


Fig. 324 *Allotment types in sequence of loss*

Fig. 325 *Relation loss and block distance in m*

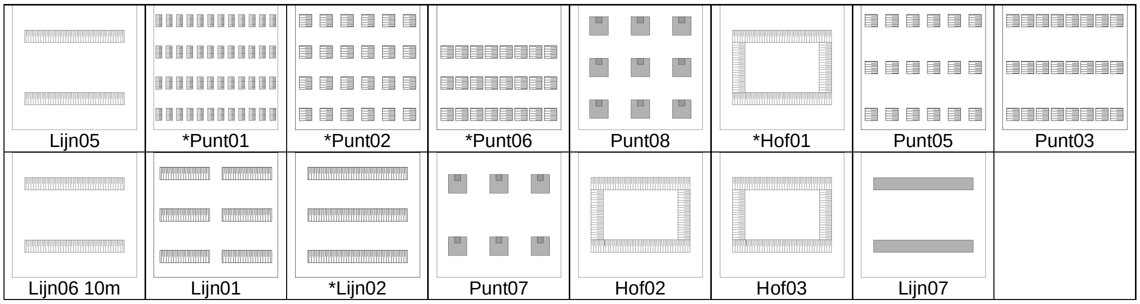


Fig. 326 *Allotment types in sequence of highest to lowest loss*

Remarcably there is nearly no relation with dwelling density. Lijn05 and Lijn07 of equal dwelling density (64 dwellings in the hectare concerned) and nearly the same height (10 and 11m respectively) have lowest and highest loss. However, frontal density F/O (vertical surface F per horizontal surface O) is determining (see Fig. 322) reasonably related with distance between building blocks (drawn as polynome regression in Fig. 325), but diverging at higher distances.

Fig. 327 and Fig. 328 show the results for point and line allotments on any orientation.

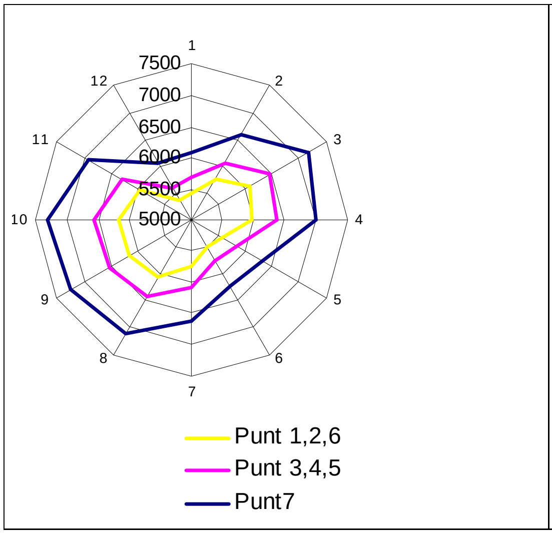


Fig. 327 *Ventilation loss of point allotments*

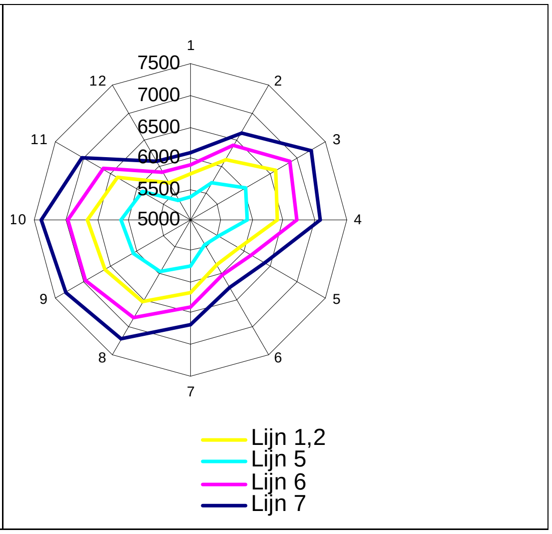


Fig. 328 *Ventilation loss of line allotments*

Biggest loss is reached when you orientate façades of point and line allotments 7 due West. Smallest loss is reached by line allotments 5 or point allotments 1,2 and 6 orientated on North North West (330^{o}). The virtual difference is more than 1000kWh/dwelling.

Fig. 329 shows courtyard allotments. Orientation sensitivity levels out most in hof04 and hof05 because perpendicular blocks have equal length. Higher blocks like hof01 and hof05 (15.5m high) lose less than lower ones like hof03 and hof04 (10m).

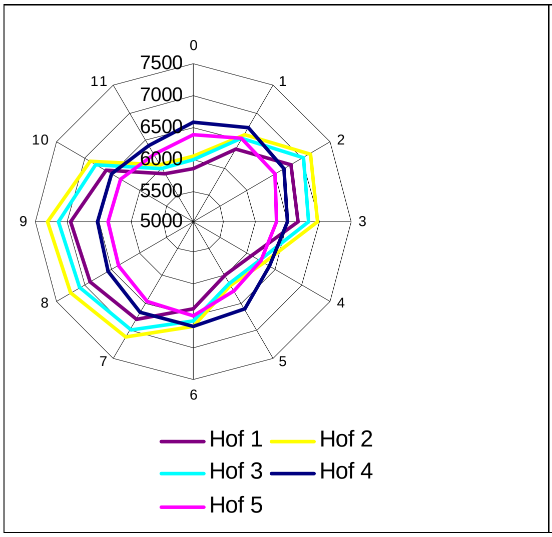


Fig. 329 *Ventilation loss of courtyard allotments*

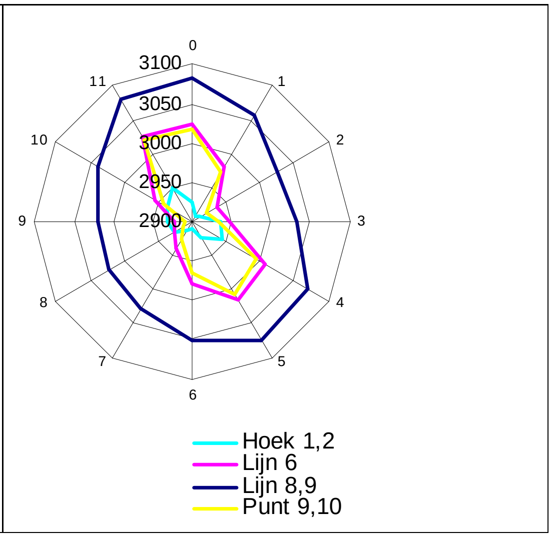


Fig. 330 *Ventilation loss of high rise allotments*

Fig. 330 shows losses of airtight high rise allotments on a much smaller scale. Total variation is less than 100kWh. Inhabitant’s behaviour causes maxima where low rise non airtight allotments showed minima.

2.6.4 Wind behaviour around high objects

Wind behaviour on smallest scale is decribed more in detail by Voorden (1990). From that publication we derive some conclusions only. The accidental physical context and size or form of the objects cause unpredictable turbulences. Without windtunnel experiments calculations do not produce much general conclusions. However, scale models of free standing sharp edged buildings higher than 15m above the environment in a frontal flow of wind in the wind tunnel show some regularity in causing whirls windward and leeward recognisable on real scale (Fig. 331).

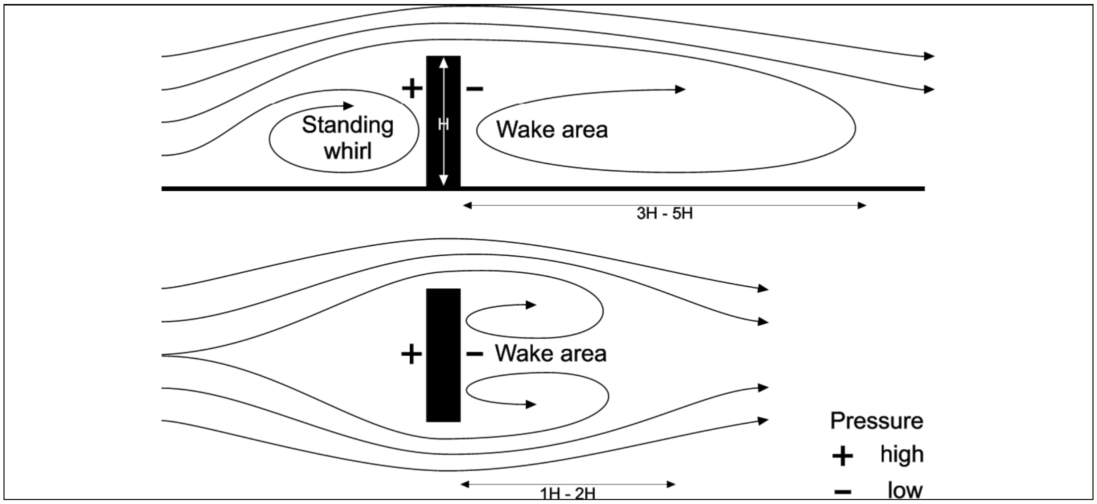


Fig. 331 *Whirls around a free standing building*

Windward and leeward a standing whirl arises causing unexpected wind directions on ground level. Walking or cycling along windward of the building, but especially through the wake area (zog-gebied) leeward you can experience sudden and diametral changes in wind direction. Protecting yourself with an umbrella against the wind from your left side you suddenly get wind from the right side. Fig. 331

(below) shows the same impact horizontally. The density of lines indicates wind velocity. At ground level near the edges of the building (no entrances there!) and 1H to 2H leeward, that velocity could be as high as at the top of the building. The whirls leeward are caused by low pressure on that side; the wind ‘comes back’ to fill the gap caused by high velocities at the edge pulling calm air with them. Openings in the building at ground level may avoid whirls there, but yield new wind velocities at ground level like Fig. 331 (below) now not considered as a plan but as a cross section.

Permeable walls like applied at the entrance of the Faculty of Architecture in Delft or dense shrubs avoid pressure differences causing whirls. They can slow down wind velocity at ground level and protect windy areas, supposed they can resist high wind velocities themselves. Networks of small wind turbines utilise local wind velocity, but they still have to be designed.

2.7 Sound and noise

2.7.1 Music

Comment [T.M.7]: Pagina: 164
kan uitgebreider

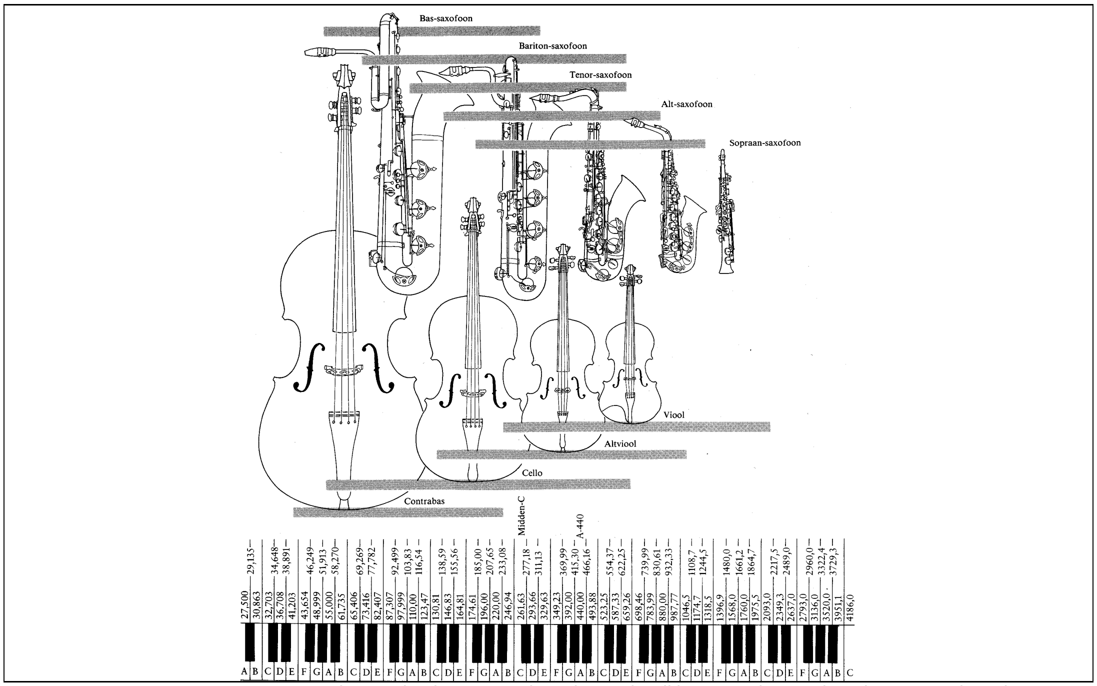
Movement of air is measured as wind when it is moving into one direction longer than 5 seconds (2.2.1). When it is flowing back in the next 5 seconds it is not even counted in wind statistics. But if the wind is blowing at average into one direction more than an hour we count it as wind and we calculate the 'hour average wind velocity' we used in chapters above. Wind is caused by slowly increasing temperature differences on the Earth's surface causing differences in air pressure. Sometimes these differences are leveled out by wind in an hour, sometimes in weeks and seldom the air is flowing back into the area it came from. If the air transported in a minute would flow back in the next minute and the reverse like water on a beach we would call it vibration. It would have a vibration time T of 60sec with a frequency f of 1/60 = 0.017 vibrations per second or 0.017Hz (hertz).

Vibrations in the air from 16 vibrations per second (vibration time 0.063 sec) to 20 000 are accepted by our eardrums as sound. Vibrations slower than 16Hz are called infrasonic, faster than 20 000 ultrasonic. You can not hear infrasonic vibrations in the air until 16Hz, but you sometimes can feel them in your lungs Minnaert (1975). The frequences used in music are nearly competely covered by the 88 keys of piano. It counts more than 7 octaves (Fig. 332) starting with 27.5Hz (the most left key A_1) and ending with 4186Hz (the most right key c_5, part of the 8th octave, not fully covered).

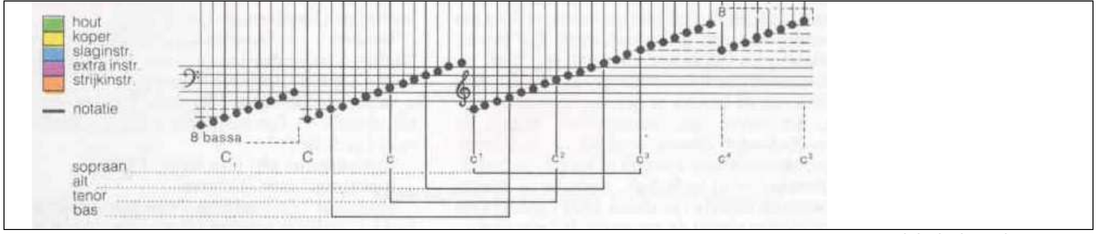
code	A_1	A	a	a_1	a_2	a_3	a_4	a_5	
frequency f	27.5	55	110	220	440	880	1760	3520	Hz
wave length λ	12.364	6.182	3.091	1.545	0.773	0.386	0.193	0.097	metres
f x λ	340	340	340	340	340	340	340	340	m/sec

Fig. 332 *Starting notes of octaves on the piano*

Any next octave doubles the frequency. An octave is subdivided in 12 notes (named a, ais or bes, b, c, cis or des, d, dis or es, e, f, fis or ges, g, gis). Because $2^{1/12} = 1.0594630944$, the frequency of any next key is a factor 1.0594630944 higher than the previous one. So you can calculate the frequency of any note (n=0…87) by $f(n)=27.5 \times 1.0594630944^n$ (Fig. 333).



McMahon and Tyler Bonner (1983), Dutch edition McMahon and Tayler Bonner (1987) page 98



Michels (1993) page 24

Fig. 333 *The span of music*

The travel speed of sound c in air is in normal conditions 340m/sec (in steel 5064m/sec). And speed is the number of vibrations per second f times their length λ: c=f x λ (Fig. 332). So, the wave length λ of audible sound in air (λ = c / f) varies between 340/20 000 = 21.25m and 340/16 = 0.017m.

Take a drawing tube of L = 0.65m closed at one side (width does not matter), drum on it and you hear primarily a sound of 130Hz, which is musical note c with wave length 4 x 0.65 = 2.60m. But it is mixed with a specific range of overtones (Fig. 334).

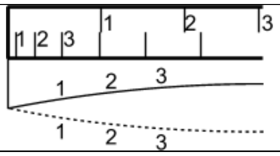
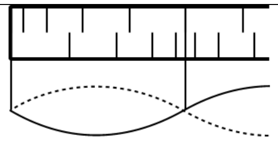
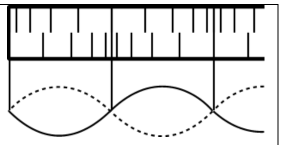
			
	λ_0=4L/1=2.60m	λ_1=4L/3=0.867	λ_2=4L/5=0.52
	f_0=340/λ_0=131Hz	f_1=340/λ_1=392Hz	f_2=340/λ_2=654Hz
	‘c’	‘g_1’	‘cis_2’

Fig. 334 *Tones produced by a tube of 0.65m closed at one side.*

The lines drawn in the tube represent the position of particles in extreme phases as if there were only some of them. The distance between the extreme phases (1-1, 2-2, 3-3 …) are different, represented in the sinuses below. The closed left side of the tube forces a ‘node’ (line elongated into the sinus) where particles stand still as centres of condensing and thinning, the open side an ‘antinode’, where they move most, enjoying the freedom of the end of the tube. So, possible wavelengths are restricted to λ = 4/1, 4/3, 4/5 … x L and frequences to a proportion of 1:3:5…. In tubes open (antinodes) or closed (nodes) at both sides they are restricted to λ = 2/1, 2/2, 2/3 … x L, supposed you do not force local antinodes by openings (like a flute does). The frequences appear in a proportion of 1:2:3…, just like strings fixed at two sides do. A voice with less than 9 overtones sounds dim, a voice with more than 14 overtones sounds shrill.

The primary frequency of a string f_s depends on length L, tension σ and density ρ (1 290g/m3) according to $f_s = L/2 \sqrt{} \sigma/\rho$. A string with given density and tension tuned by the right force will give a lowest tone with wavelength 2 x L. Touching the string softly (flageolet, causing a node there without losing the lowest tone) half way you will hear a tone with wavelength L (one octave higher) as well. Touching at one third you will hear a tone with wave length 2/3 x L as well, a combination called fifth (kwint, 2:3). Dividing further you get fourths (kwart, 3:4), tierces (terts, 4:5) and so on.

2.7.2 Power or intensity

Air particles between nodes move very fast around their quiet position like a sinus shown in Fig. 334 causing change in air density. Concentration causes increase of temperature and heat loss. However the particles move fast enough to prevent substantial energy loss by heat exchange (keeping the process reversible, adiabatic). The maximum divergence of particles is called amplitude A. The power of a sound wave (called intensity ‘I’ and expressed in W/m^2) depends on that amplitude, but also on frequency f, air density (normally $1.290 kg/m^3$), and travel speed (normally 340m/sec) according to $I = \rho \times (2 \times \pi \times f \times A)^2 \times c/2$. So, in normal ρ and c conditions power depends on amplitude A and frequency f according to $I = 8658 \times (f \times A)^2$.

A speaking voice produces 10^{-5} W. A globe with a radius of 28cm has a surface of $1m^2$. So, at 28cm distance that voice has a power of 10^{-5} W/m^2. It is composed by adding $8658 \cdot (f \times A)^2$ for every frequency and its accompanying amplitude in the voice. But suppose it produces tone c only, without overtones (in reality produced by electronic device only), then frequency is 131Hz, and amplitude A should be 0.0000003m. A piano produces maximally $0.2W/m^2$ and if it would be produced by tone c only the amplitude should be 0.0000367m. For an exended symphony orchestra and a loudspeaker the figures would be 5W/m2 (A=0.0000183m) and $100W/m^2$ (A=0.00082m).
Fig. 336 shows the dependency of intensity I on these particular amplitudes and on musical frequencies from 27.5 to 4000Hz).

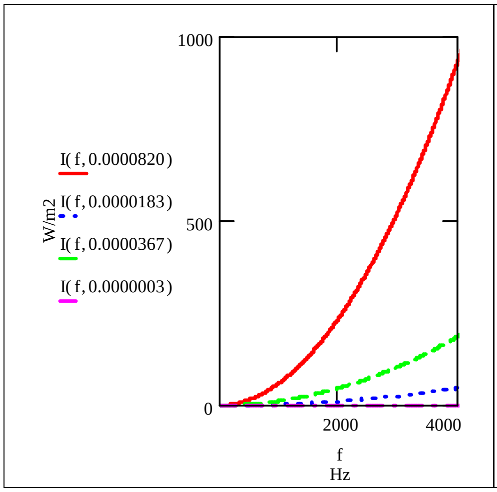


Fig. 335 *Intensity (frequency, amplitude)*

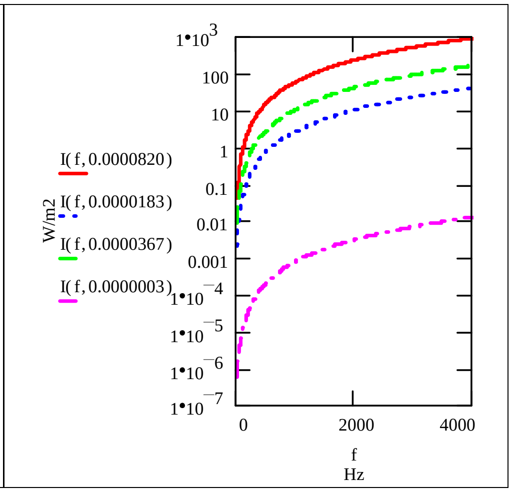


Fig. 336 *Represented logaritmically*

The logarithmical representation (Fig. 336) shows the range from soft to loud better. Dividing the intensity by a standard of 10^{-12} W/m2 (comparing it with that standard) we get positive logarithms from 0 to 14 only, starting with what is just audible. Multipying it by 10 we get a useful range of decibells (dB) from 0 to 150 (Fig. 337).

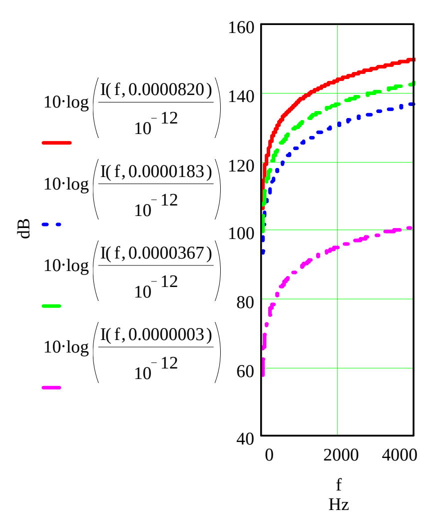


Fig. 337 *Changing intensity into decibells*

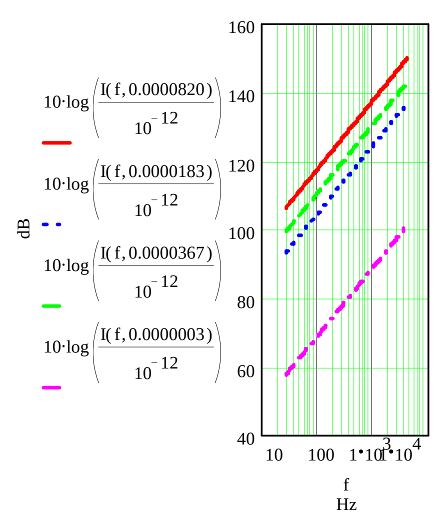
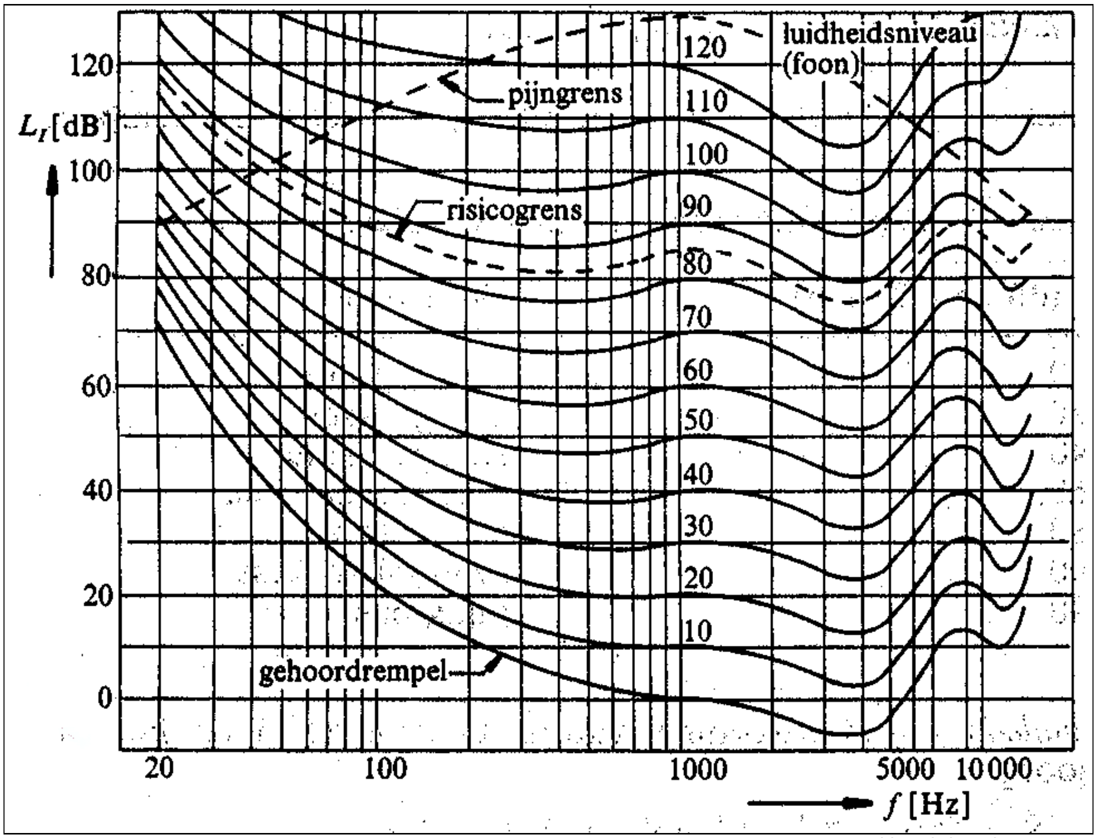


Fig. 338 *Represented logaritmically*

Changing the frequency axis in a logaritmical scale (Fig. 338) we get beautiful straight lines of growing deciBells by increasing frequencies for every amplitude. Fig. 339 is the same graph with the boundary of what we think to hear.



Creemers, Atteveld et al. (1983) page 186

Fig. 339 *Pain boundary (above) and impression of sound.*

At 1000Hz our impression of sound could be approximated by deciBells. However, on both sides of this centre we hear less from the actual pressure of lower and higher tones on our eardrums. That can be dangerous. Lines of equal sound impression more or less parallel to the boundary below connect the same levels of sound impression (loudness) expressed in ‘foons’ in the same range of deciBells at 10^3Hz. An often used rough correction is the audible deciBell dB(A) (Fig. 340).

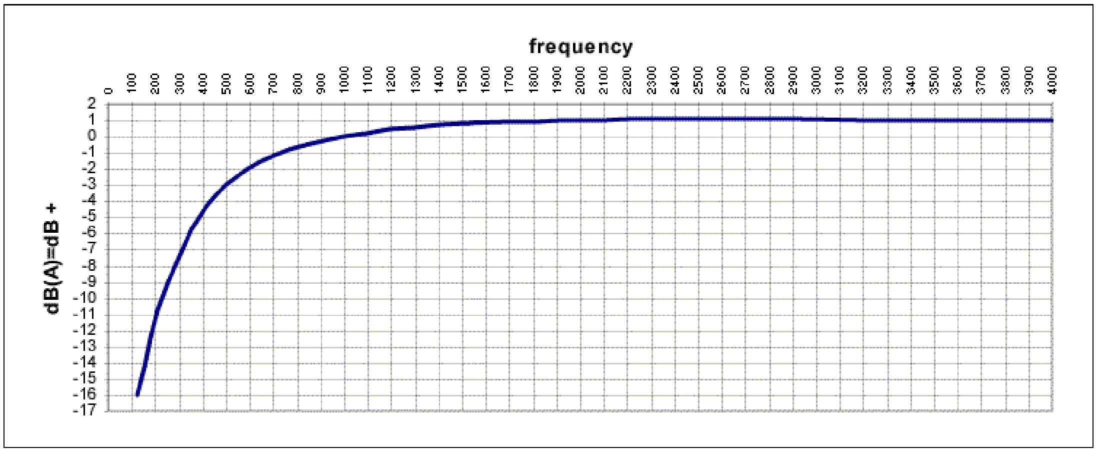
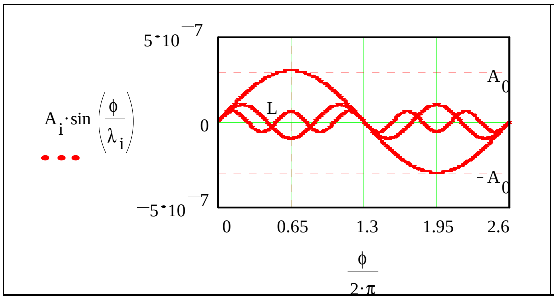


Fig. 340 Corrections on deciBells to get audible dB(A).

2.7.3 Sound and noise

The combined tones of an instrument make a sound. When we complete the sinuses into λ = 4 x 0.65m and add the overtones of Fig. 334 with supposed smaller amplitudes neglecting the higher overtones we get a representation of the sound of the tube (Fig. 341).



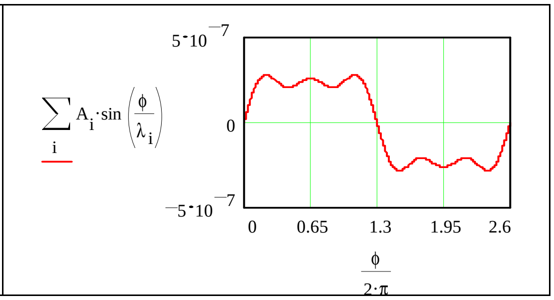
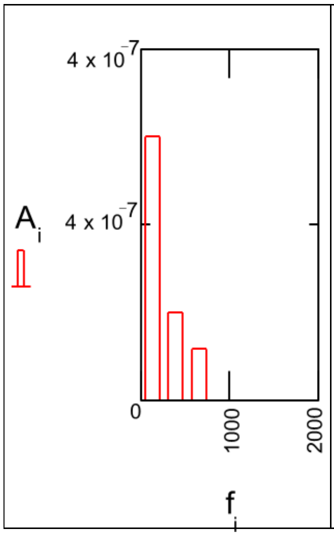
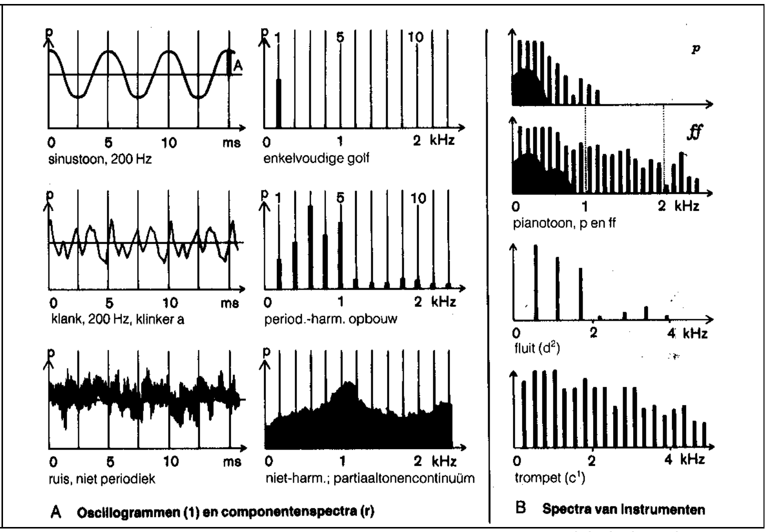


Fig. 341 *Combined complete sinuses of Fig. 334*

Fig. 342 *Fig. 341 added*

However, especially string instruments have to improve the contact with the air by surfaces vibrating with the string to get a louder sound. These constructions resonate with the own velocities, amplitudes and frequencies of their material and form adding new wave lengths producing the typical sound of the instrument. The amplitudes per frequency are called the spectrum of the instrument (Fig. 343 and Fig. 344).





Michels (1993) page 16

Fig. 343 *Supposed amplitudes of the tube from Fig. 334*

Fig. 344 *Spectra of other instruments*

There are harmonious spectra with natural proportions of frequencies and chaotic spectra called noise. When you are able to recognise the composing sinuses by Fourier analysis or measurement you can calculate the power of a spectrum summing all intensities per amplitude by integration to predict power. But there are deciBell meters to do it afterwards.

2.7.4 Birds

Fig. 345 shows the spectrum of an electric piano with little overtones for the tone ‘A’ in eight octaves with seconds on the x-axis. Here we clearly see the doubling from 27.5, 55, 110, 220, … until 3520 kHz for pure tones. The tones of the piano fluctuate around these averages.

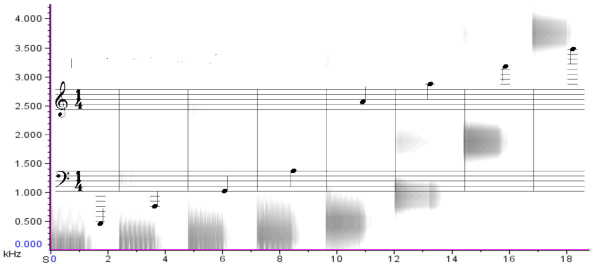


Fig. 345 Spectrum of an electric piano

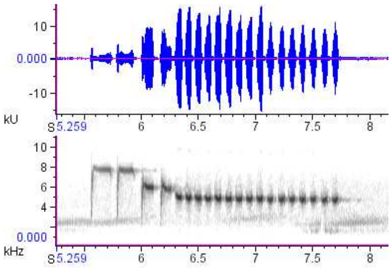


Fig. 346 Oscillogramme and spectrum of a bluetit (pimpelmees)

Fig. 346 we see the spectrum of a bluetit-song with frequencies reaching twice as high as our voice until 8 kHz. The oscillogramme above shows the amplitude or power. Enlargement would show the sinusoid waves. Their invisibly small wave-lengths determine the frequency below. *Fig. 347*, *Fig. 348* and *Fig. 349* show the oscillogrammes and spectra of three other birds often heard around your house. They show how characteristic birds’ songs are. These songs are present in any city, but you do’nt hear them any more and few will recognise them.

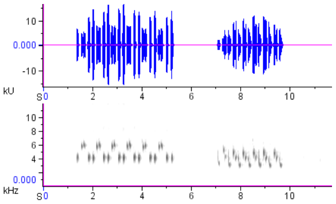


Fig. 347 Great tit (koolmees)

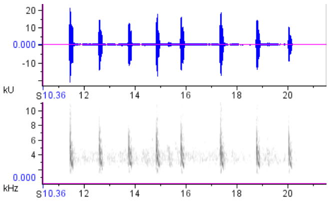


Fig. 348 House sparrow (huismus)

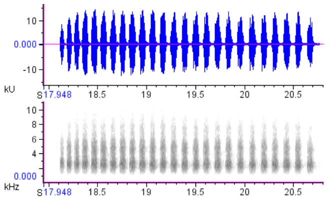


Fig. 349 Magpie (ekster)

These spectra are made with the Raven Lite programme, free downloadable from http://www.birds.cornell.edu/brp/raven/Raven.html .

2.7.5 Traffic noise

There are many sources of noise in town. Traffic and aviation are the most important ones.

	speed	quantity	emission	
	km/h	*mv/h*	*dB(A)*	
light motor vehicles	50	300	69,48	
middle heavy motor vehicles	50	50	72,90	
heavy motor vehicles	50	50	77,70	
motorcycles	50	100	75,21	
Total		500	**80,81**	+
% truck traffic	10	%		
road surface				
Road surface correction			**3,63**	+
distance to crossing	100	*m*		
Crossing correction			**0,80**	+
%reflection other side of road	75	%		
Reflection correction			**1,13**	+
distance to source	10	m		
Distance reduction			**10,00**	-
Air muffling reduction			**0,20**	-
height of observer	1,5	m		
height of source	0	m		
%soft ground to road axis	0	%		
Ground reduction			**0,00**	-
Meteo reduction			**0,57**	-
Total			**75,59**	*dB(A)*

Jong (2003)

Fig. 350 Calculating traffic noise

Traffic is a linear and fluctuating source. You can predict the average intensity in dB(A) from 7 o'clock during 12 hours day or night according to Volksgezondheid Volksgezondheid en Milieuhygiene (1981), SRM1, see *Fig. 350*. Backgrounds are discussed in Nijs (1995) . Download Jong, T.M. de (2003) *TrafficNoise.xls* from http://team.bk.tudelft.nl publications 2003, say 'yes' to the macro's, fill in the yellow parts and try.

This calculation is valid only if:
- there are no noise protection screens or buildings;
- there are no slopes;
- the road is more or less straight;
- some other conditions,

otherwise you should use SRM2.

Fig. 351 shows some indications for traffic load you can use in designing stage.

Indication:

radius served urban area			traffic lanes	width	mv/h
30m			1	3m	2
100m		street	2	10m	20
300m	neighbourhood	street	2	20m	200
1km	district	road	2	30m	1000
3km	town	highway	4	40m	2000
10km	subregional	highway	8	50m	10000
30km	regional	highway	10	60m	16000
100km	subnational	highway	16	70m	24000

Fig. 351 Indications of traffic load

National Law (see *www.overheid.nl* click Wet- en regelgeving, look for ‘geluidhinder’) demands in new plans for urban area less than 50 dB(A) within 200m from streets with 1 or 2 traffic lanes or within 350m from roads and highways with more than 2 traffic lanes causing that amount of noise. But Burgomaster and Aldermen can request the Provincial Council on the basis of a noise survey to increase the norm to 55 dB(A). In special cases named in the Law it can be increased until 70 dB(A). Comparable norms are given for other souces like industy.
To calculate noise from aeroplanes Kosten units (Ke) are used. They take into account maximum level of noise per movement, number of movements per year and time of the day.

3 Water, networks and crossings

Contents

3.1 Water balance

3.1.1 Earth

In case all ice would melt

The surface of the Earth is approximately 510,000,000 km^2 large (see page 23) and there is 1 390 000 000 km^3 water. So, if there were no differences in temperature or ground level and water was equally dispersed over the Earth, the planet would be fully covered by a 2.7km deep ocean (Fig. 352)[82]. The 48m upper layer would be ice.
However, there is 148 900 000 km^2 land and 361 100 000 km^2 water. So, 29% is land. It contains 3% of all existing water, and 2/3 of that part is frozen. If all ice would melt by gobal warming sea level would raise 66m. Water would submerge the most densily populated areas of the Earth.
Fortunately the sun still adds snow to the poles.

The case of maximal glaciation

On the other hand, during an age of maximal glaciation the the amount of glacier ice would have been three times larger as the present ice volume. The sea level would have been lowered as much as 140 meters. The continental shelves would have been exposed to the air so man could live there.
The average height of the land is 823 m above sea level. We can calculate the potential mechanical power of the system of the water streaming to the sea over the land. Assuming that 37,000 km^3 of runoff water will flow downhill 9 TW (see *Fig. 2* and also *Fig. 16*) would have been produced by the runoff water.

The amounts of water

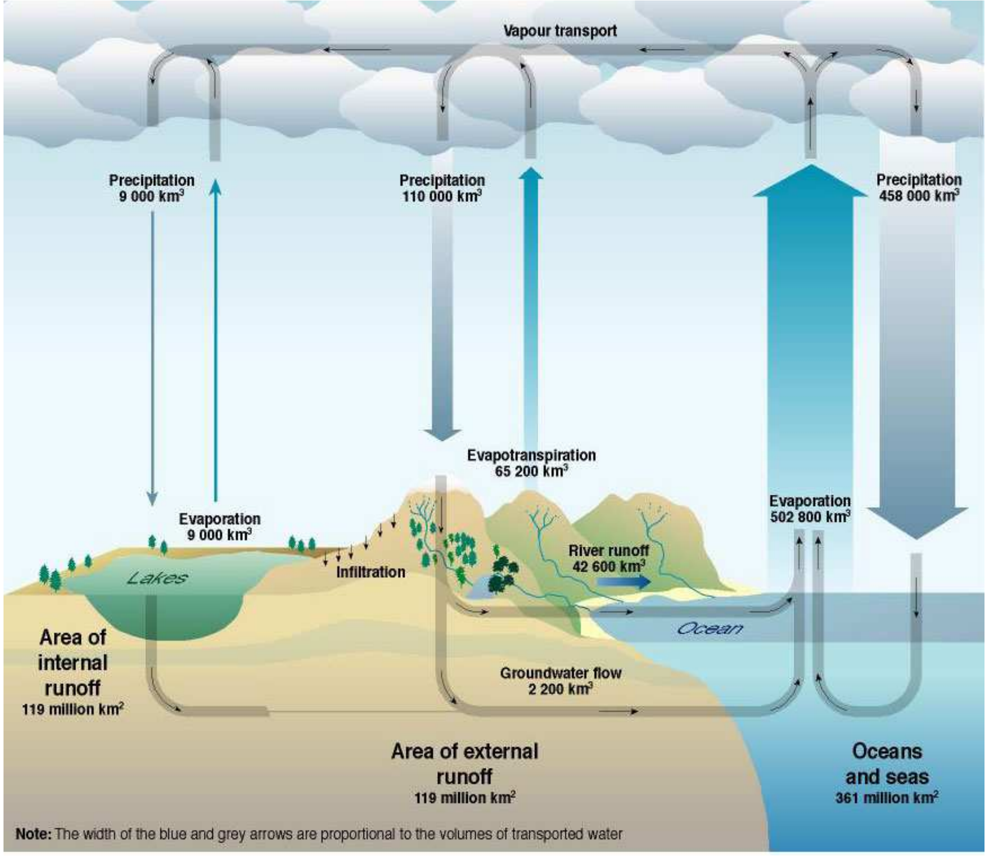
1000 km3	**salt**	**fresh**	**total**	**m3/m2**	**mm**
atmosphere		12,9	12,9	0,025	25
sea	1 338 000		1 338 000	2 624	2 624 021
land, from which	12 957	35 004	47 960	94	94 057
snow and ice		24 364	24 364	48	47 782
subterranean	12 870	10 530	23 400	46	45 891
lakes	85,4	91	176,4	0,346	346
soil moisture		16,5	16,5	0,032	32
swamps		2,1	2,1	0,004	4
life	1,1		1,1	0,002	2
total	1 350 957	35 004	1 385 960	2 718	2 718 079

Fig. 352 *Total amount of water on Earth(see also* ***Error! Reference source not found.****)*

The amounts of water on the Earth are confined in reservoirs of different size and form. In their order of importance these reservoirs are: oceans, glaciers, groundwater, lakes and rivers, atmosphere and biomass (all living matter man included). In actual fact 97% of all surface water is confined in the oceans and most of the other 3% is fixed in glaciers. So, little water is left over for the other reservoirs.

3.1.2 Evaporation and precipitation

The cycle of water



Note: The width of the blue and grey arrows are proportional to the volumes of transported water

Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999; Max Planck, Institute for Meteorology, Hambuirg, 1994, Freeze, Allen, John, Cherry, Groundwater, Prentice-Hall: Englewood Cliffs NJ, 1979.

Fig. 353 The hydrological cycle

Continuously changing the state of water

The sun is the generator or motor of the changes in the state of water. The sun will evaporate water of the oceans and other other water reservoirs to the 100% water vapour saturation of the air. The saturation of the air with water vapour is determined by the temperature. The higher the temperature the more vapour the air can contain. The vapour is perceptible by the clouds in the air because of the always present condensation nuclei .The wind will move the clouds from the oceans to the continents and depending the temperature above the continents will happen nothing (temperature ≥ temperature in the cloud) or it will rain or snow (in both cases is the temperature ≤ temperature in the cloud). Rain, hail and snow is called precipitation.

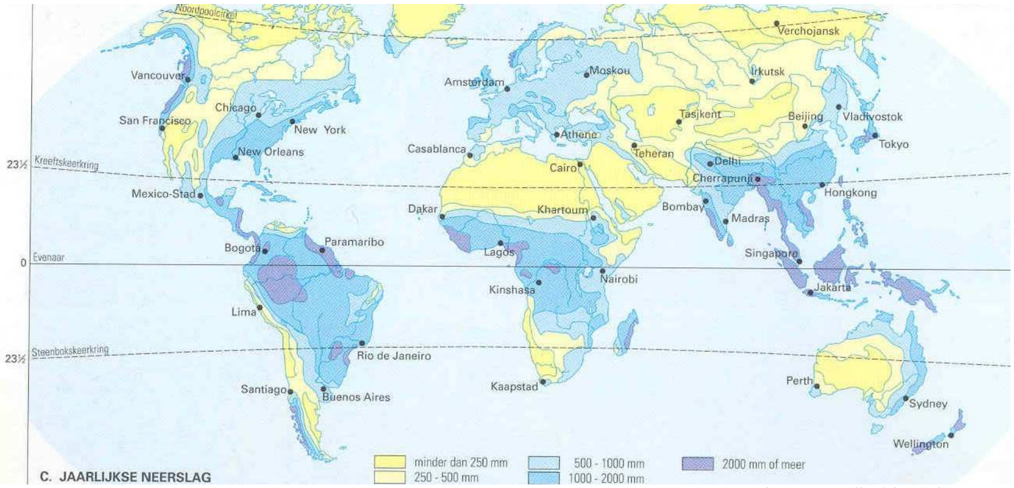
Energy needed for evaporation

You can evaporate 1m^3 water by 2.26GJ, 2.26GWs, 630kWh or 72Wa (say 72 m^3 natural gas). The Earth's surface receives 81 PW from sun. So the sun could evaporate 1.1 million km^3 per year. Actually less than half is evaporated in unsaturated air only (Fig. 354). It falls down discharging its solar heat in the same time as soon as the air becomes saturated in cooler areas by condensation (precipitation). That is nearly 1m^3/m^2 or 1m and more precise 957mm (Fig. 354).

	evaporation	**precipitation**	**runoff**	**evaporation**	**precipitation**	**runoff**
	1000 km3/a			**mm/a**		
sea	419	382		1157	1055	
land	69	106	37	467	717	250
total	488	488		957	957	

Fig. 354 *Yearly gobal evaporation, precipitation and runoff*

Areas like deserts receive less than 200mm, areas like tropical rain forests more than 2 000mm average per year (Fig. 355).



Wolters-Noordhof (2001) page 181

Fig. 355 *Global distribution of precipitation*

Europe has the same extremes (Fig. 356).

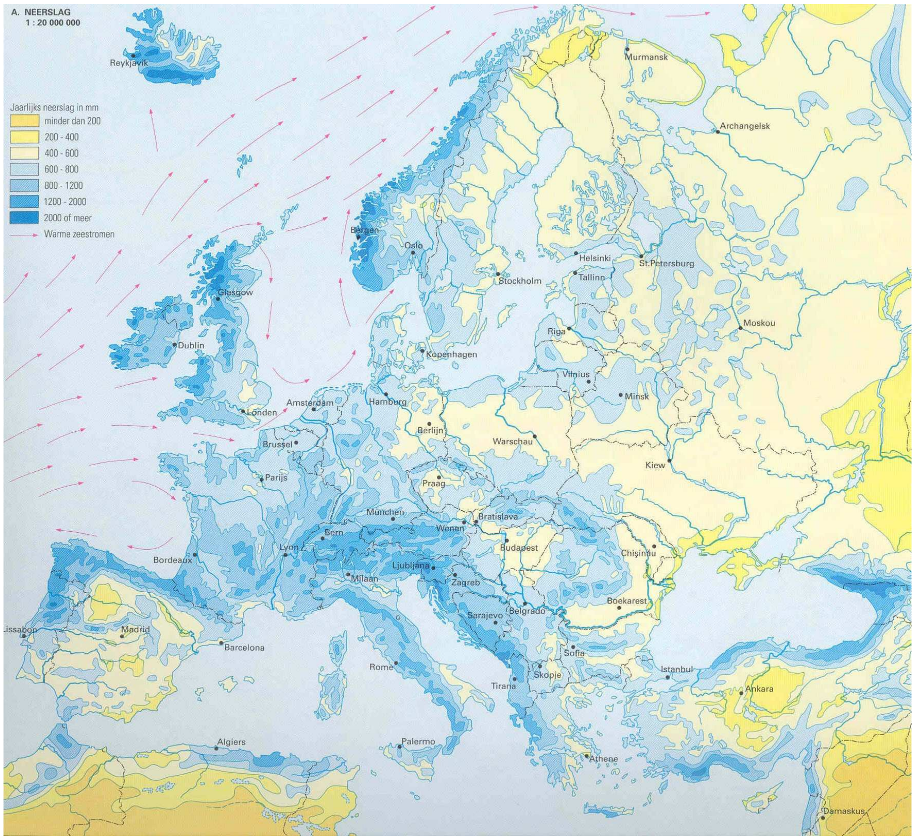


Fig. 356 *European distribution of precipitation* (Wolters-Noordhof (2001) page 61)

3.1.3 Runoff

The Netherlands receives from 700mm in East Brabant to 900mm precipitation in central Veluwe (*Fig. 357*), but there have been years of 400mm and 1200mm precipitation.

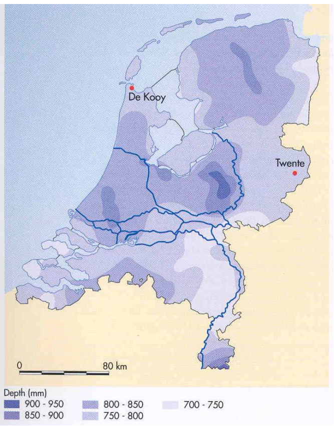


Fig. 357 Distribution of precipitation in the Netherlands (Huisman, Cramer et al., 1998; page 18)

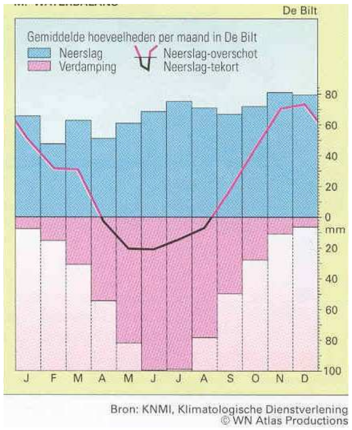


Fig. 358 Precipitation minus evaporation in the Netherlands (Wolters-Noordhof, 2001; page 53)

If precipitation exceeds evaporation lakes and subterranean aquifers fill up. As soon as these cannot be filled up in time, water runs off subterranean or along brooks and rivers (*Fig. 359* and *Fig. 360*).

That part of the precipitation that reaches a stream is called runoff. The water during rainfall will gather into rills and streams down the slope. During and after the rain part of the water will soak into the ground. If the soil is saturated with water the remaining water will stream together in small streams and form a river. The groundwater flows also downhill and where the water bearing layer crops the slope a source will come out. The surface water and the subterranean water feed together a river. When the catchment area is large enough a permanent river will be the result. An estimation is made that ⅛ of the annual runoff will reach directly overland the sea while the remainder part will go underground.

the Netherlands receive runoff from catchment areas of the Rhine (entering the Netherlands in Lobith), Meuse and Scheldt rivers.

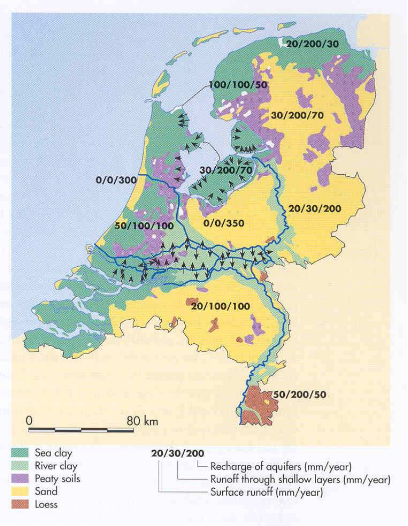


Fig. 359 Major soil types and average annual runoff in the Netherlands
(Huisman, Cramer et al., 1998; page 21)

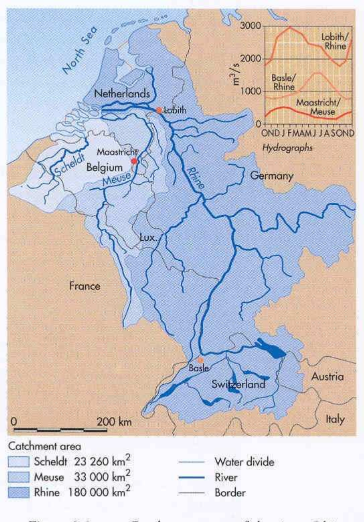


Fig. 360 Received runoff in the Netherlands (Huisman, Cramer et al., 1998; page 13)

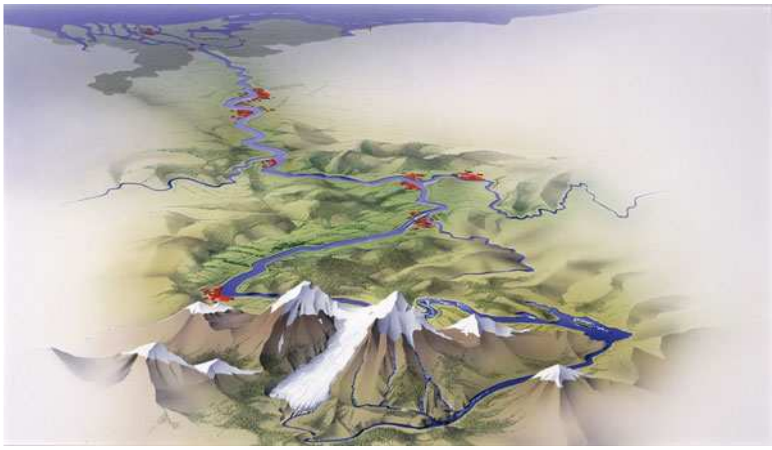


Fig. 361 The river basin of the Rhine
(Paul Maas, opdrachtgever: Thieme Meulenhoff)

The river Rhine for example

The river Rhine has a catchment area of 160 000km^2 with an annual average of 1 775mm precipitation minus 1 392mm evaporation in the part of that area as far as Lobith. So, approximately 383mm over an area of 160 000km^2 produces 61km^3/year. So, on average 1942m^3/sec of water should run off and enter at Lobith.

Levelling by seasons

Snow and ice in mountains level out seasonal fluctuations of rivers by storing precipitation in winter, releasing it in summer[83] (see *Fig. 361* and *Fig. 363*).

Fig. 362 Source of the Rhine
(http://www.natuurdichtbij.nl/kennismaken/)

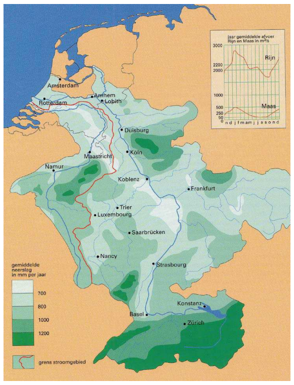


Fig. 363 Precipitation in the basin
(http://www.natuurdichtbij.nl/kennismaken/)

Discharge related to catchment area

In *Fig. 364* a rough approximation of discharge related to catchment area is shown. A big spot indicates the mentioned values of the river Rhine and a line is drawn for any catchment area producing a discharge in the Rhine circumstances. However, if precipitation is more than the average mentioned the line shifts upward, if evaporation or other reductions are more than mentioned, it shifts downward.

As a rule of thumb the m^3/sec of discharge is 1/100 of the km^2 catchment area[84], but any river has its own graph, less regular than suggested here.

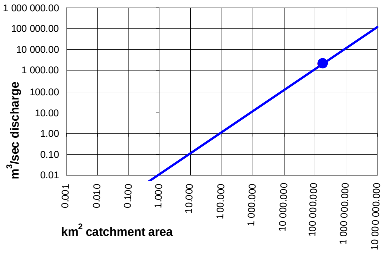


Fig. 364 Discharge Q roughly related to catchment area
(author Jong)

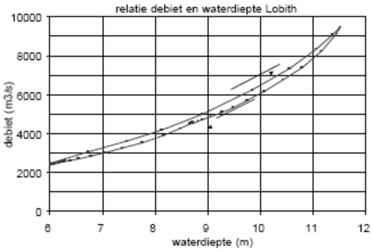


Fig. 365 Discharge Q related to water depth H near Lobith
(http://www.geog.uu.nl/fg/mkleinhans/teaching/tgrs-hw.pdf#search=%22waterdiepte%20Rijn%22)

Discharge related to depth

The relation of discharge to the water level near Lobith in *Fig. 365* is important for the height of dikes and the draught of ships, but it changes in time because of sedimentation and excavation.

Discharges in time

Because precipitation and evaporation differ much per day, the discharge of the Rhine differs daily (see *Fig. 366*), as unpredictably as the weather forecast.

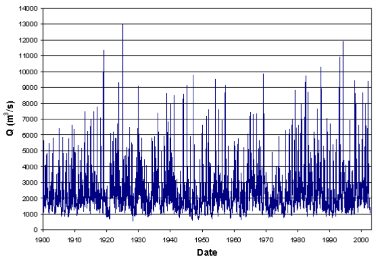


Fig. 366 Daily average discharge of the Rhine at Lobith (Lecture Marc F.P. Bierkens UU Faculty of Geosciences)

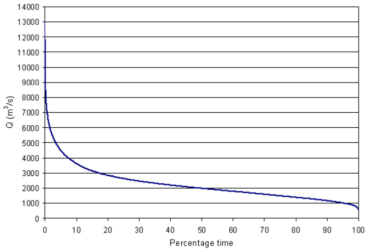


Fig. 367 Duration line of Rhine discharge at Lobith (Lecture Marc F.P. Bierkens UU Faculty of Geosciences)

Ranking *Fig. 366* you can derive a 'duration line' as in *Fig. 367*, indicating how often you can expect a given discharge to be exceeded.[85] From that figure you can conclude that 50% of the time the discharge of the Rhine did not exeed 2000m^3/sec. The mirrored graph gives the percentages of underspending.

Local impact of rain on discharge

The discharge of a river fed by a catchment area increases some time after the first rainfall (see *Fig. 368*) and after the last rainfall it continues some time, depending on the size of the area.

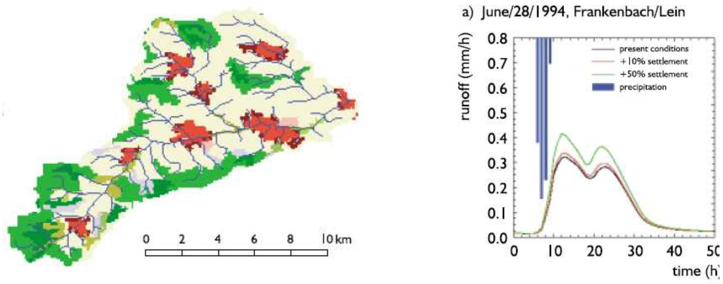


Fig. 368 Local impact of rain in hours R=10km (http://www.ncr-web.org/downloads/NCR18nl-2002.pdf)

Extreme situations

Suppose an unusual system of heavy showers follows the basin around the course of the Rhine and those of its feeding rivers like the Main and Mosel

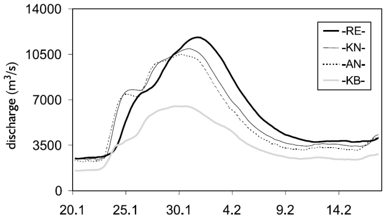


Fig. 369 Flood 1995 (http://www.ncr-web.org/downloads/NCR18nl-2002.pdf)

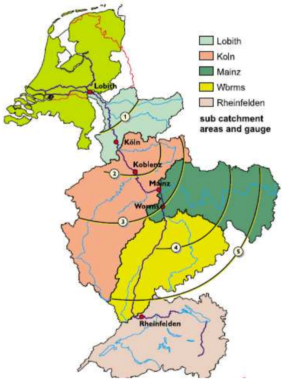


Fig. 370 Impact of rain in days R=300km (http://www.ncr-web.org/downloads/NCR18nl-2002.pdf)

from Switzerland to Lobith and everywhere in the basin drainage is optimal. A wall of water then nears Lobith. How often will that happen, how long will it last? These are the questions to be answered to calculate risks of flooding.

3.1.4 Static balance

Static forces and the potential energy along a slope

The weight W of a bullet on a slope of α degrees can be resolved in factors perpendicular and parallel to the slope (see *Fig. 372*). The force parallel to the slope equals W·sin(α).
For example, if $\alpha = 30^o$ that force is ½W, because $\sin(30^o) = ½$.

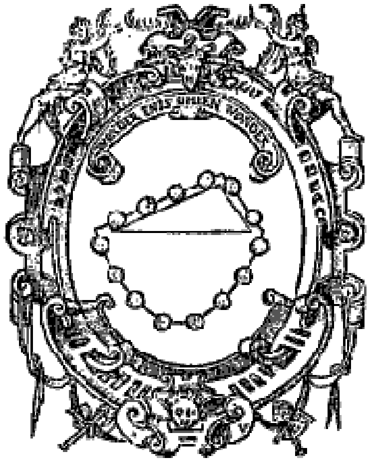


Fig. 371 Stevin: Clootcrans

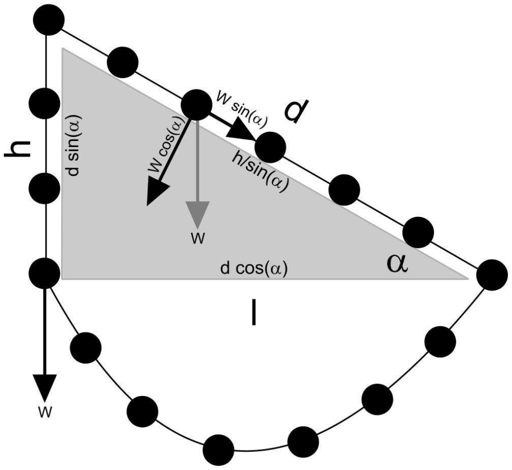


Fig. 372 Balance on different slopes

However, the distance d any bullet has to cover parallel to the slope into the base equals the vertical height *divided* by sin(α). So, force times distance (potential energy) remains the same at both sides of the summit. For example, if $\alpha = 30^o$, the force is ½·W, but the distance d to cover is 2·h.
The ‘Clootcrans’ Stevin used as his logo (see *Fig. 371*) shows the equal potential energy of bullets according to their slope by intuition (count those at the corners in *Fig. 372* half).

Potential acceleration

Force is defined as mass times acceleration ($F = m \cdot a$).
At the vertical wall the potential acceleration equals the gravitational acceleration $g = 9.807$ m/sec^2.
If the masses of the bullets are the same, but the force F parallel to the slope is reduced by $\sin(\alpha)$ then the acceleration 'a' parallel to the slope should be reduced by the same factor.
In case $\alpha = 30^o$, $a = ½ \cdot g = 4{,}904$ m/sec^2.

3.1.5 Movement ignoring resistance

Bullets falling or rolling along a slope

Suppose we disconnect all bullets and supply every second a bullet on the summit at both sides.
Acceleration 'a' is defined as velocity v divided by time t ($a = v / t$).
As long as there is no resistance the velocity v of any bullet will increase constantly with the time t according to $v = a \cdot t$. But, the covered distance will increase disproportionally, because every next second the bullet has covered a larger distance according to its increased velocity.

So, we can conclude a source distributing an equal amount of bullets per second produces a stream thinning downstream gaining mutual distance by increasing velocity (see *Fig. 373*).

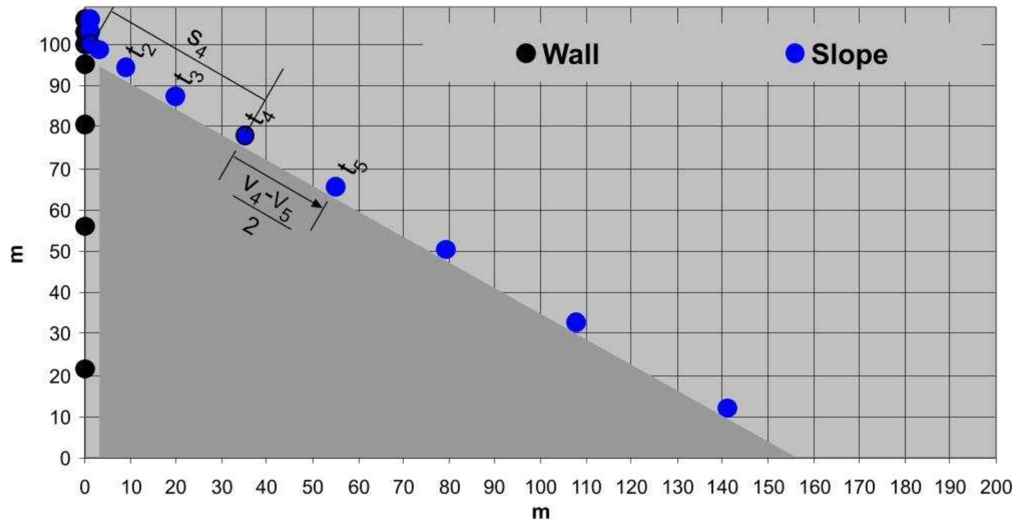


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Fig. 373 Bullets falling and rolling along a slope every second with a growing distance and velocity

Calculating increasing velocity v and covered distance s along a slope

The growing velocity v and covered distance s shown in *Fig. 373* are calculated as follows.
Between any two moments t_p and t_q ($t_p<t_q$) velocity grows from v_p into v_q with a constant acceleration a: $v_q - v_p = a \cdot (t_q - t_p)$. Let the time interval ($t_q - t_p$) near zero. Then $v_q - v_p = a \cdot t$, or $v_q = v_p + a \cdot t$.
At time t half way any t_p and t_q the mean velocity v_m equals $(v_p+v_q)/2$. Here you can substitute v_q .
So, $v_m=(v_p+v_p+a \cdot t)/2$ or $v_m=v_p+ ½ \cdot a \cdot t$.

The distance s covered at any moment equals $v_m t$ if you take for v_p the velocity v_0 at the beginning.
So, $s = (v_0 + ½ \cdot a \cdot t)t$ or $s = v_0 t + ½ \cdot a \cdot t^2$, shortly calculated as a time summing integral of $s/t = v = a \cdot t$:

$$s = \int a \cdot t \, dt = C + \frac{1}{2} \cdot a \cdot t^2$$

Supposed the bullets start in rest ($v_0=0$) and then begin to fall or roll without resistance, then s equals $½ \cdot a \cdot t^2$ without initial C.

The velocity at the end of the slope is reached at slope length $d = ½ \cdot a \cdot t^2 = ½ \cdot g \cdot \sin(\alpha) \cdot t^2$.

And $d = h/\sin(\alpha)$ (see *Fig. 372*). So $t^2 = (h/\sin(\alpha))/(½\cdot g\cdot \sin(\alpha))$ or $2h/g\cdot\sin(\alpha)^2$.
So, $t_{end} = \sin(\alpha)^{-1}\cdot\surd(2\cdot h/g)$.
At that time $v_{end} = a\cdot t_{end} = g\cdot\sin(\alpha)\cdot\sin(\alpha)^{-1}\cdot\surd(2\cdot h/g) = \surd(2\cdot g\cdot h)$.
So, the velocity at the end of the slope is independent from α: it is the same velocity of a falling bullet at the end of the wall. The average velocity along the slope is half of v_{end}: $v_m := ½\ \surd(2\cdot g\cdot h)$.

Kinetic energy

If a bullet of mass m [kg] hits you with a velocity of v [m/sec], and you resist its force stepping back slower bringing its velocity back to zero, the bullet has lost $m\cdot v\cdot(v - 0\text{ m/sec})/2 = ½\ m\cdot v^2$ energy.
That kinetic energy E_k could have been built up falling or rolling h [m] with an acceleration a [m/sec^2], according to $E_p = F\cdot h = m\cdot a\cdot h$. Falling or rolling, the bullet lost E_p, gaining E_k, while $E_p := E_k$ at last.
So, the process is described as $m\cdot a\cdot h := ½\ m\cdot v^2$ [joule].

Running water in a pipe

Suppose running water is a stream of more or less cohesive incompressible drops, flowing downstream in a volume per second of Q [m^3/sec] everywhere.
Suppose the bullets of *Fig. 373* are cubic metres water forced in a pipe of minimal cross section.
The average velocity will be the velocity at the end of the natural slope $\surd(2\cdot g\cdot h)$ divided by two: $v_m = ½\cdot\surd(2\cdot g\cdot h)$.
So, the cross section of a pipe with capacity Q should be at least $A = Q/v_m = 2\cdot Q/\surd(2\cdot g\cdot h)$ [m^2].
Its water content is $A\cdot h/\sin(\alpha)$ [m^3]. If the mass m [kg] of water relates to its volume [m^3] as ρ (normally 1000 kg/m^3) its mass equals $\rho\cdot A\cdot h/\sin(\alpha)$ [kg].

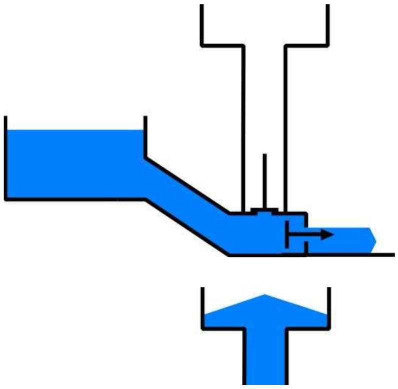
A water ram

A sudden obstacle at the end of the pipe (like a tap closed at once) shows the large amount of energy built up in flowing water. Such an obstacle has to resist a force F_1 equal to the weight of the water column divided by A [newton/m^2] and a force F_2 resulting from kinetic energy $E_k = ½\cdot m\cdot v^2$ divided by some distance s (braking distance) to get the force (energy is force times distance). If that braking distance is very small F_2 increases into infinity, breaking the water pipe.

A water column of height h on a surface A produces a force $F_1 = \rho\cdot h\cdot A\cdot g$ [newton].
A mass $m = \rho\cdot h\cdot A/\sin(a)$ [kg] water with a velocity $v = ½\cdot\surd(2\cdot g\cdot h)$ [m/sec] reduced to zero over a distance of s metre (braking distance) produces a force $F_2 = ½\cdot m\cdot v^2/s$:

$$F2 = \frac{1}{2}\cdot\frac{\rho\cdot h\cdot A}{\sin(\alpha)}\cdot\frac{\left(\frac{1}{2}\cdot\sqrt{2\cdot g\cdot h}\right)^2}{s} \quad\text{or}\quad F2 = \frac{1}{4}\cdot\rho\cdot A\cdot\frac{h^2}{\sin(\alpha)}\cdot\frac{g}{s}$$

The kinetic force F_2 is many times larger than $F_1 = \rho\cdot h\cdot A\cdot g$ caused by the weight of the water column (the difference is $¼\cdot h/s\cdot\sin(\alpha)$). In the example of *Fig. 374* a kinetic force of flowing water is calculated as 500 times the weight of the water column.



slope angle	α	30.0	deg	(Input)		
slope	one to	1.73				
acceleration	a	4.9	m/sec^2			
height summit	h	1.0	m	(Input)		
slope length	d	2.0	m			
time to reach end of slope	t	0.90	sec			
end velocity free flow	v	4.43	m/sec		16	km/hr
average velocity	v_m	2.21	m/sec		8	km/hr
discharge	Q	1	m^3/sec	(Input)		
min. sectional plane of pipe	A	0.4516	m^2			
radius of pipe	r	37.9	cm	diameter	75.8	cm
content of pipe	C	0.90	m^3			
density of water	ρ	1000	kg/m^3			

braking distance	s	0.001	m	(Input)			
force by weight	F_1	4429	newton	452	kgf		
kinetic force	F_2	2213997	newton	225757	kgf	226	ton
proportion	F_2/F_1	500					
pressure at tap	p	4912447	newton/m^2	500912	kgf/m2	501	ton/m2
m height of rise		501	m				

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Fig. 374 Water ram

That force is utilised in a pumping device called 'water ram'. The pressure p built up in the water ram by suddenly closing the tap braking the flow to yield its kinetic force is utilised to push up the water through a valve. Theoretically the water column can be built up until 500 m. However, the pressure falls away shortly after the valve opens, so the procedure has to be repeated often to near that theoretical value.

Free flow

The cross section of a free flow $A = Q/v$ will be smaller downstream according to its increasing local velocity $v = ½ \cdot a \cdot t$ (if there are no other sources feeding the stream).
You can see that decreasing width already on the tap (see *Fig. 375*).
Since $s = ½ \cdot a \cdot t^2$ or $t = \sqrt{(2 \cdot s/a)}$ and consequently $v = s/\sqrt{(2 \cdot s/a)} = \sqrt{(s \cdot a/2)}$, the cross section on any distance from the source will be $A = Q/\sqrt{(s \cdot a/2)}$.

Fig. 375 Water flowing from the tap

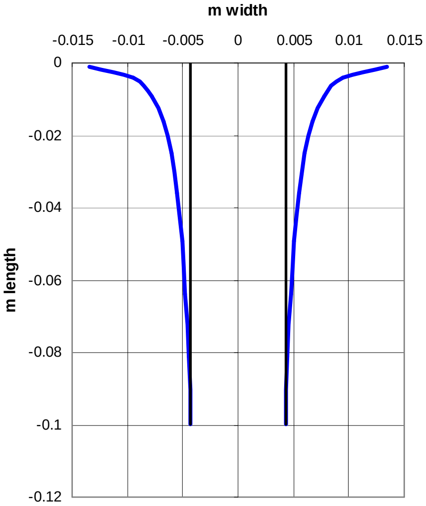

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Fig. 376 Simulation of 0.00004 m3/sec falling water

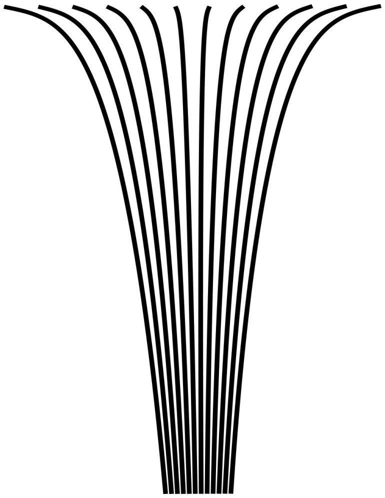

Fig. 377 A river stemming from different separate streams

However, what you see is the diameter, $2 \cdot r$. And $A = \pi \cdot r^2$. So, $2 \cdot r = 2 \cdot \sqrt{(A/\pi.)}$
In *Fig. 375*, the water from the tap has an intial velocity, perhaps comparable with the 0.02m level of the falling water in *Fig. 376*. As soon as a critical velocity is passed a continuous flow is falling apart in drops like rain. It shows the limits of water cohesion.

A river

A river, stemming from different separate streams with smaller cross sections (see *Fig. 377*) will end up flowing faster in the end. Moreover, its resistance reduces because of less contact with its bed, becoming more and more smooth (less rocky) downstream. However, its slope reduces also coming closer to the sea. How do these circumstances balance locally?

3.1.6 Resistance

Until now, we supposed flows, running without resistance.
But, any liquid flowing along a surface encounters a shearing force in the opposite direction dependent on its roughness. That force causes deceleraton or even partially flowing back (turbulence).
Force is mass times acceleration. If mass remains the same, the accelerations ‘a’ of previous paragraph 3.1.5 should be reduced. How much is that reduction in a stream flowing through a landscape?

Many parameters play a role, but the result mainly will be that shearing stress reduces the force of water and consequently its acceleration and velocity substantially only if the water level is less than 2m to bottom. However, it always plays an important role in transporting sediments.

So, a river can not adapt its discharge, but rather its form to bring the water most efficiently to the sea. However, that search for the most efficient course may take a very long time, sometimes waiting for a year of extreme rainfall to improve the course, clearing up bottle necks, looking for steeper slopes lessening its tress.

Shearing stress

Manning[a] created the formula of *Fig. 378* to calculate the force τ every square metre wetted surface exerts [newton/m^2] in opposite direction of the flow (‘shearing stress’).

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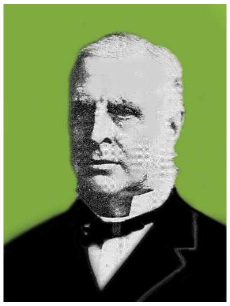
[a] *http://64.233.183.104/search?q=cache:2qsQymRjhqcJ:manning.sdsu.edu/+Manning+hydrology&hl=nl&gl=nl&ct=clnk&cd=1*



$$\tau := \rho \cdot v^2 \cdot \frac{n^2 \cdot a}{R^{\frac{1}{3}}}$$

Fig. 378 Robert Manning and one of his formulas

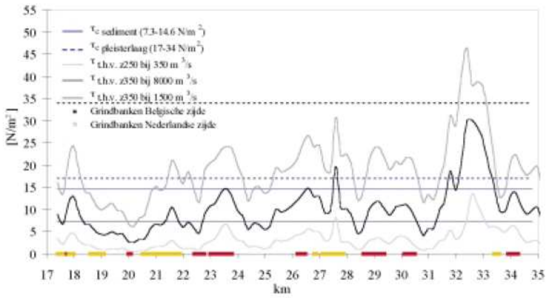
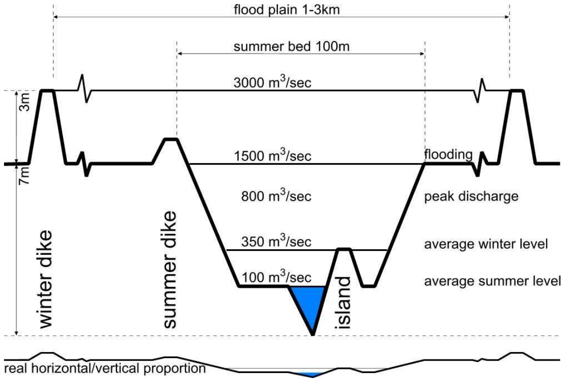


Fig. 379 Shearing stress τ due to different discharge suppositions and local roughnesses and bed forms along 17.5 km of the river Meuse (Grensmaas)[a]

Fig. 379 shows τ for different circumstances a part of the river Meuse (Grensmaas) ranging from 1 to 50 newton/m^2. *Fig. 382* shows the studied part in *Fig. 379*, folded along the boundary of The Netherlands and Belgium within its winter dikes.

The river Meuse for example

Fig. 380 shows a cross section of a river like the river Meuse approximately half way of its 925 kilometres course. Suppose the surface of its cross section A = 300m^2 and its discharge Q = 600m^3/sec (often in winter). In that case its water level is 5.7m and it transports a mass m = 600 000kg of water per second over 2 metre (so, velocity v = 2m/sec or 7.2km/hr). That represents E_k = 1.2 million joule kinetic energy over 2 m, and a force F_2 = 600 000 newton equivalent to a weight of approximately 60 tons.



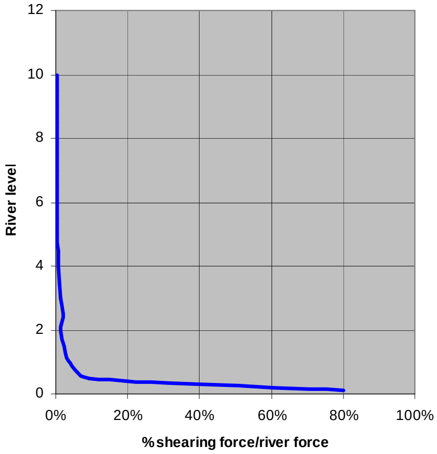


Fig. 380 Typical cross section and wetted surface of a river like the Meuse half way (Grensmaas)[b]

Fig. 381The influence of shearing force by different water levels in Fig. 380[c]

According to Mannings formula in this circumstances the shearing stress τ would be 10 newton/m^2. If it shears over the river bed taking 100 m in the cross section ('wetted contour'), then perpendicular to that cross section in 1sec over a length of 2m the river has to overcome 2 000 newton resistance. That is only 0.3% of the local force of the river. And in this two metres we did not even count the pushing power of many kilometres moving water coming down upstream.

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[a] *http://viwc.lin.vlaanderen.be/water/ts2003_09_grensmaas.pdf*

[b] *http://viwc.lin.vlaanderen.be/water/ts2003_09_grensmaas.pdf*

[c] *http://team.bk.tudelft.nl/* > publications 2006 Hydrodynamics.xls

Low shearing stress

So, the influence of the shearing stress τ on velocity and acceleration on a water level of 5.7m is negligible, but in many centuries it has given the actual form to the river by loosening material from the bed. Water with a velocity of 2m/sec could even move stones of 0.5kg, but at the bottom a shearing stress of 10newton/m^2 will only move some smaller sediment.

High shearing stress

However, at water levels in the same circumstances lower than 2m, τ becomes more than 1%, increasing into 80% on very low water levels (see *Fig. 381*). You can calculate it yourself for different circumstances downloading *http://team.bk.tudelft.nl/* > publications 2006 Hydrodynamics.xls.

So, in small brooks τ will play an important role on the resultant force, acceleration, velocity and kinetic energy.

Kinetic energy per m3 water ½ $\rho \cdot v^2$

In Mannings formula ρ is the mass of 1m^3 water (mainly 1000 kg/m^3). The kinetic energy reduced by roughness like earlier shown by the water ram (see page 176) is ½ $m \cdot v^2$ (see page 176).

So, $\rho \cdot v^2$ in the formula represents twice the kinetic energy per m^3 water.

You can measure the velocity v [m/sec] on different spots in the cross section to calculate the average velocity (see Fig. 423).

Kinetic energy [newton·m] per m^3 is the same as force per m^2 like τ [newton/m^2].

So, the rest of the formula is a dimensionless factor, but how to calculate it?

Roughness n

The roughness of river beds is expressed in a roughness factor n [sec/$m^{1/3}$] shown Fig. 432, ranging from 0.01 for very smooth concrete until 0.1 sec/$m^{1/3}$ for flooded tight forest.[a]

Hydrolic radius R

R [m] in Mannings formula is the 'hydrolic radius', the wet surface 'A' of the cross section divided by the length of its wetted contour 'P' (R = A/P). The larger 'A' is (for example increasing by a larger discharge (see *Fig. 380*) the less influence the wetted contour has.

The surface/contour proportion is an important factor in many physical phenomena like roads around an urban island (public investment), volume/surface of buildings or growing animals (insolation). If a volume increases by a third power of distance, a minimal surface containing that volume increases quadratically (slower), while the minimum contour (a circle) containing a surface increases in the same time linear (again slower).

A 'wetted contour' of a river is not a circle, but it increases slower than the contained cross sectional surface also because the horizontal upper surface is ignored.

Fall and acceleration a

Most difficult to estimate is local 'a' in Mannings formula. The total acceleration of a river can be calculated according to page 175 and reduced by varying shearing stress, but that average is locally changed by varying slopes and forced by water masses upstream into increased acceleration in narrow cross sections, partly compensated by higher water levels storing potential energy for accelerations later.

Reduction of acceleration

The part of the river Meuse studied, falls 10m (from 40 to 30 above sea level) over 17.5km length with varying resistance (see *Fig. 383*). However, the total fall of the river Meuse from source to sea is 409m over 925km. That is the tangent of α = 0.0253 degree. So, you could expect an average acceleration of $a = g \cdot \sin(\alpha) = 9.807 \cdot \sin(0.0253) = 0.004$ m/sec^2, partly reduced by a substantial τ in the many feeding brooks at the boundary of the basin (see *Fig. 385*).

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[a] *http://www.fhwa.dot.gov/bridge/wsp2339.pdf*

Fig. 382 17.5km of Meuse (Grensmaas)[a]

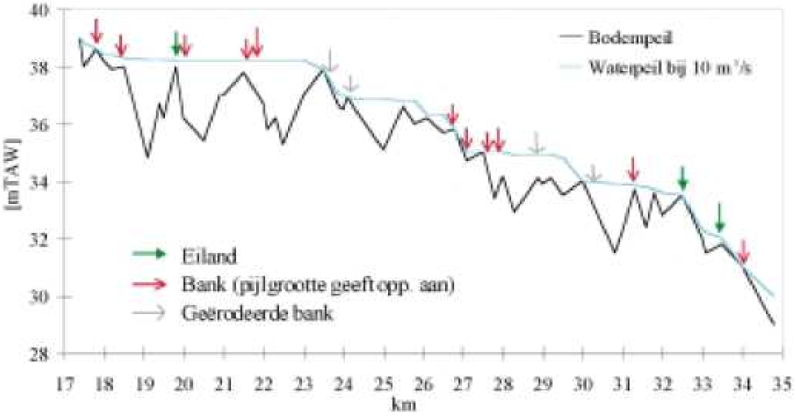

Fig. 383 A fall of 10m along 17.5 km of the river Meuse (Grensmaas)[b]

Because v = a·t and consequently t = v/a, the distance covered s = a·t^2/2 = a·(v/a)^2/2.
So, at distance s = 500km from source the velocity should be v = √(2·a·s) = 66m/sec.
However, we counted v = 2m/sec, to reach Q = 600m^3/sec through a cross section (wetted surface) of 300m^2. So the reduction by τ in all upstream shallow brooks and small rivers of the basin together should be 97%!

Discharge

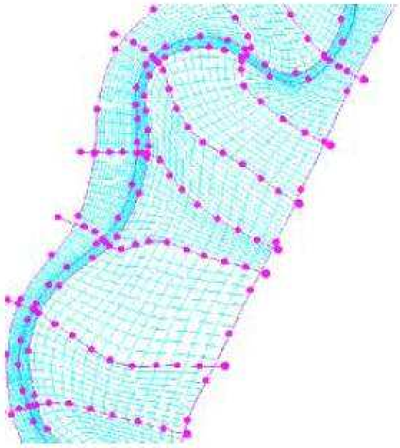

Fig. 384 Successive SOBEK cross-section trajects along the Grensmaas

Fig. 385 Meuse river basin of 36 000 km^2 through France, Belgium, Germany and The Netherlands

If you measure the cross section 'A' [m^2] of a stream and the velocity v [m/sec], the discharge Q = A·v. However, you also can measure the rainfall of the Meuse river basin in Belgium and France (23 500km^2)[c]. If in that area at average in a year 1000mm rain has fallen of which 200mm is evaporated or temporarily sunken down into the earth, then Q = 800mm·23500km^2/yr. That is 600 m3/sec of water coming into the Netherlands at the boundary of Belgium averaged over a year (see *Fig. 385*).

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[a] *http://viwc.lin.vlaanderen.be/water/ts2003_09_grensmaas.pdf*

[b] The Belgian standard TAW in *Fig. 383* means 'above average sea level at ebb-tide on Ostende, 2.426m higher than NAP, the Dutch standard for measuring heights.

[c] *http://nl.wikipedia.org/wiki/Stroomgebied_van_de_Maas*

However, in a a concurrence of circumstances like in january 1995, there can be more rainfall (up to 350mm *per day*), less evaporation, no storage in a saturated earth, faster discharge because that earth is frozen, but starting to melt, delivering previously fallen water in the same time.
In such a case you can expect floodings.

Velocity and discharge

A river has its largest velocity on its surface, decreasing into the bottom.
The average velocity v is often measured at 0.4·h (see *Fig. 386*). However, the velocity distribuition over the cross section varies substantially (see *Fig. 387*).

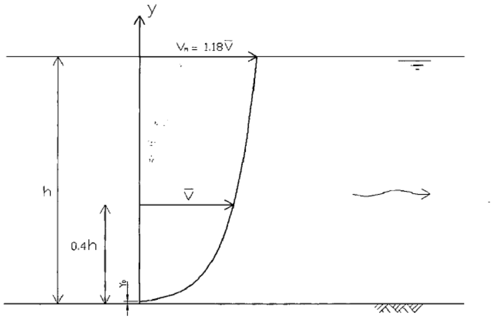

Fig. 386 Velocity in a longitudinal cross section[a]

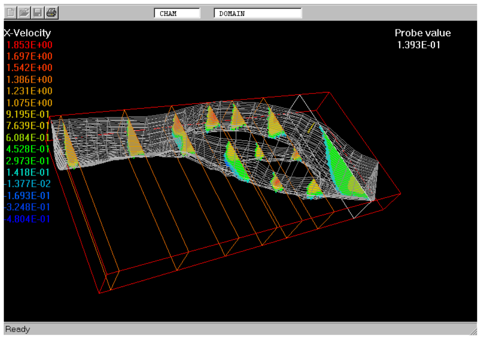

Fig. 387 River cross sections with simulation of velocity profiles[b]

Many rivers have a relation $v = k \cdot Q^m$, but 'k' and 'm' differ from river to river (in Fig. 388 Bovenrijn and Waal obey approcimately to $v = Q^{0.3}$).

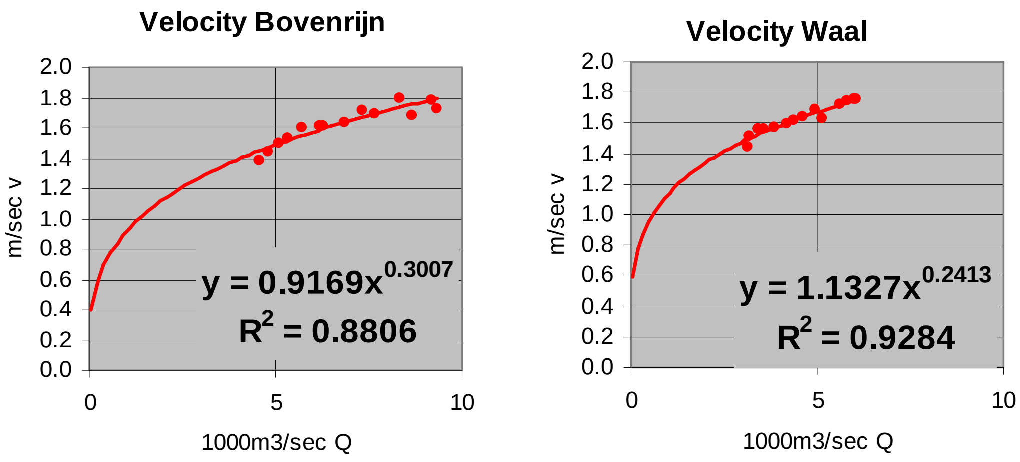

Fig. 388 Flood and velocity in Bovenrijn and Waal[c]

Different sensibility of velocity for discharge

Fig. 389 shows that relation for two extremely different American rivers. In a logarithmic representation the measurements fit very well a straight line. An increasing factor 'k' shifts the whole line up, an increasing exponent 'm' makes it steeper (v more sensitive for Q). If the line is horizontal (m = 0), there

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[a] Huub Savenije (2001) Stroming *7* Nummer 4 TU Delft, *hsa@ihe.nl*
[b] *http://www.simuserve.com/cfd-shop/uslibr/vrgeom/vrg4.htm*
[c] Derived from *http://www.engr.colostate.edu/~pierre/ce_old/Projects/Paperspdf/Julien-Klaassenet%20alASCE2002.pdf#search=%22river%20Rhine%20cross%20sections%20Lobith%22*

is no relation between v and Q whatsoever. Even if the discharge increases, the velocity will not. These are stoic rivers having other possibilities to give space to their discharge, for example in the lowlands. The steep liners are nerveous ones, apparently limited in their cross sections in the highlands.

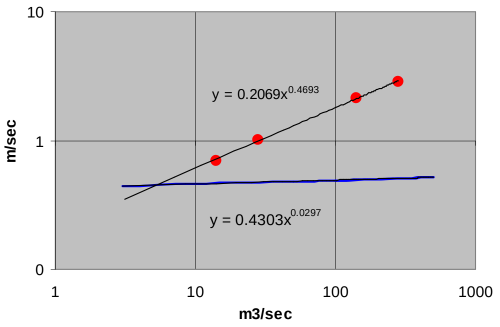

Fig. 389 Different relations between velocity and discharge[a]

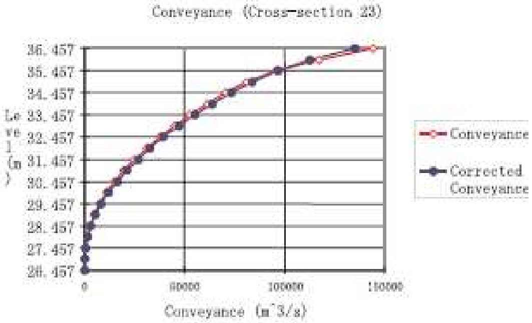

Fig. 390 SOBEK simulation of level related to discharge processed with correction for spatial variations between successive crosssections of Fig. 384[b]

Depth related to discharge

Many rivers have a relation depth D = c·Q^f, but 'c' and 'f' differ from river to river (in *Fig. 391* Bovenrijn and Waal obey approcimately to D = 5·$Q^{0.4}$).

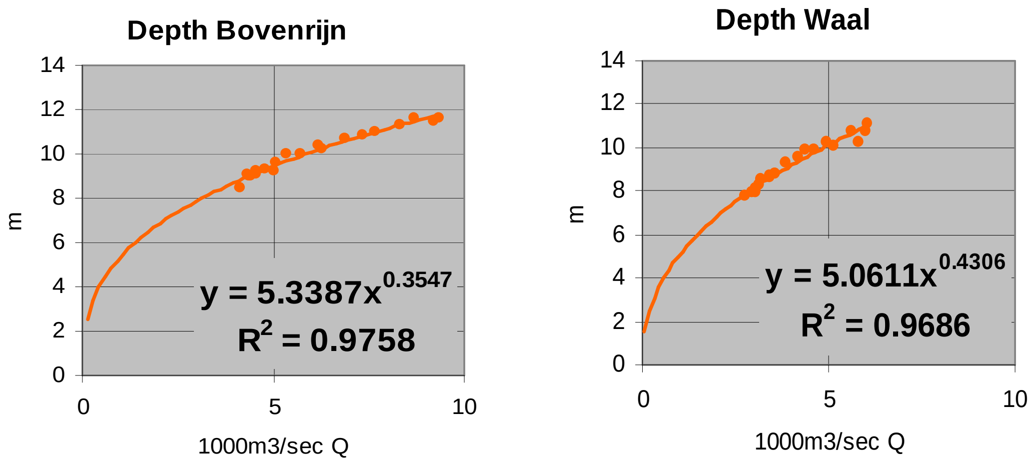

Fig. 391 Depth related to discharge in Bovenrijn and Waal[c]

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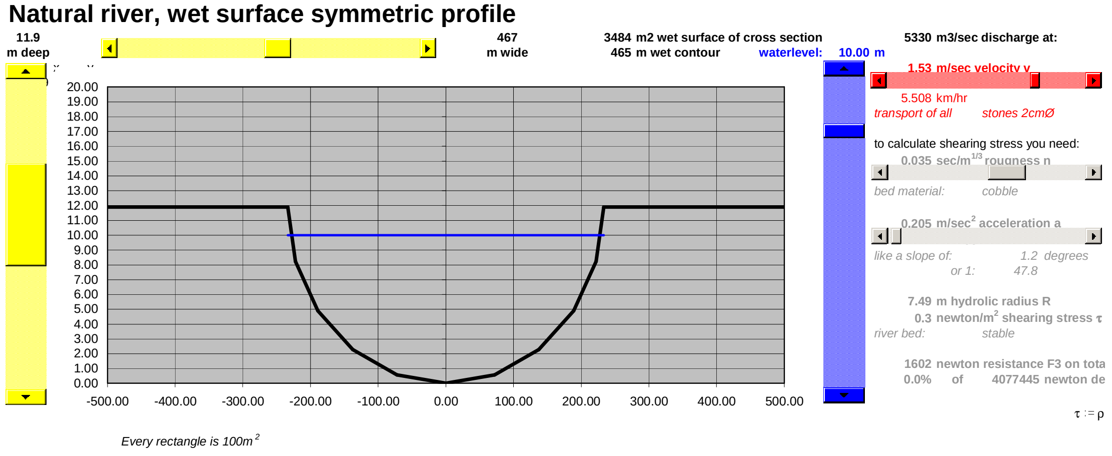
[a] Leopold *http://eps.berkeley.edu/people/lunaleopold/(043)%20Downstream%20Change%20of%20Velocity%20in%20Rivers.pdf#search=%22velocity%20rivers%22*

[b] *http://www.wldelft.nl/rnd/pdf/rnd2001.pdf#search=%22river%20Rhine%20cross%20sections%20Lobith%22*

[c] *http://www.engr.colostate.edu/~pierre/ce_old/Projects/Paperspdf/Julien-Klaassenet%20alASCE2002.pdf#search=%22river%20Rhine%20cross%20sections%20Lobith%22*

Width related to discharge

Many rivers can be simulated by an ellipsoid cross section (see).


Natural river, wet surface symmetric profile

11.9 m deep

467 m wide

3484 m2 wet surface of cross section

465 m wet contour waterlevel: 10.00 m

5330 m3/sec discharge at:

1.53 m/sec velocity v

5.508 km/hr

transport of all stones 2cmØ

to calculate shearing stress you need:

0.035 sec/m$^{1/3}$ rougness n

bed material: cobble

0.205 m/sec^2 acceleration a

like a slope of: 1.2 degrees

or 1: 47.8

7.49 m hydrolic radius R

0.3 newton/m^2 shearing stress τ

river bed: stable

1602 newton resistance F3 on tota

0.0% of 4077445 newton de

τ := ρ

Fig. 392 Simulation of an ellipsoid cross section[a]

For a river in weak soil (not forced by artificial measures) it is easier to find space in width than in depth, because sedimentation reduces depth.

3.1.7 Erosion and sedimentation

Material from the river bed (silk, sand and gravel) is transported dependent from the velocity of water.

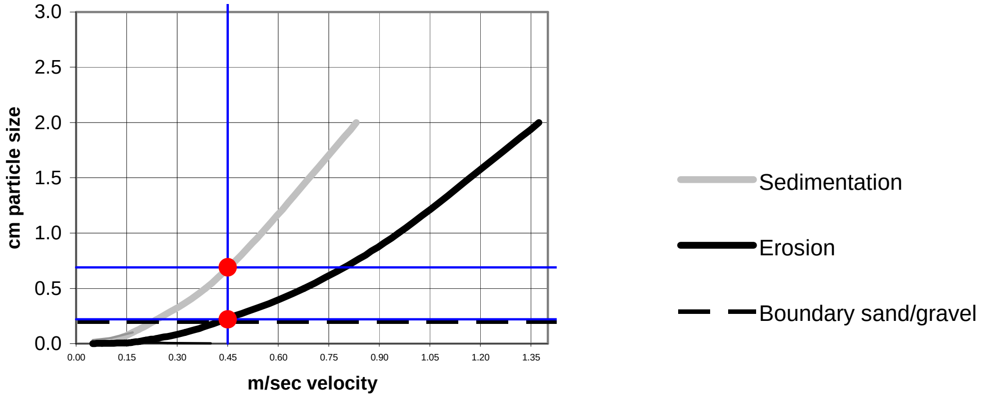


Fig. 393 Erosion and sedimentation dependent from the velocity of water[b]

From >0.2 cm particle size we call it gravel (see *Fig. 393*).
Until <0.2 cm it is named sand or silk (see *Fig. 394*, an enlargement of *Fig. 393*).

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[a] *http://team.bk.tudelft.nl/* > Publications 2006 > Hydrodynamics .xls
[b] redrawn according to Pannekoek ( ) Algemene geologie ( ) pag. 225

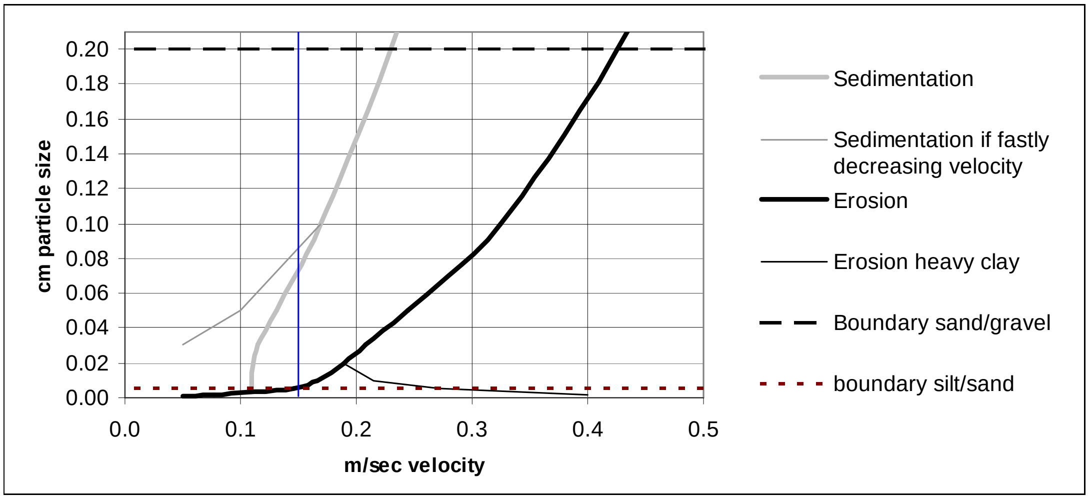

Fig. 394 Erosion and sedimentation at the boundary of silk < 0.0.005 cm and sand >0.005cm dependent from velocity of water, detail from Fig. 393[a]

In *Fig. 394* until **0.05m/sec** you can conclude that the river bed is stable. Or the reverse: if you see a stable bed, the velocity should be less than 0.05m/sec.

Silt

From a velocity **0.15m/sec** all loose silt is moving. So, if you see silt on the bottom, the velocity of the water should be usually less than 0.15/sec. If you do not see silt, it should usually be more. However, heavy clay densified into a cohesive plaster layer needs a higher velocity to erode than you would expect from their particle size.

Sand

From **0.45m/sec** (ample 1.5km/hr, slowly walking) onwards all sand is moved. So, if you do not see sand, the velocity will be probably more than 0.45m/sec.

Gravel and stones

At higer velocities you have to look at gravel and stones in to estimate the water velocity (see *Fig. 393*). From **1m/sec** (3.6km/hr) you see stones of 1cm diameter rolling, from **1.45m/sec** (5km/hr) stones of 2cm, from **1.7m/sec** (6km/hr) stones of 3cm, from **1.95m/sec** (7km/hr) stones of 4cm.
On that level the diameter of stones moved grows approximately parabolically with the square of velocity. So, stone diameter ≈ v^2 like 1 ≈ 1^2, 2 ≈ 1.45^2, 3 ≈ 1.7^2 and 4 ≈ 2^2. That seems logical, because according to page 176 the kinetic energy of running water (½ $m \cdot v^2$) is proportional to the square of velocity.

Higher velocities widen passages, lower velocities narrow them.

At the long term wider passages of a river with lower velocities will be filled up with sedimentation and narrow passages with high velocities will be widened by erosion or floodings. So, by an equal discharge Q in older natural rivers the velocity v is equalised as well. However we have artificially narrowed our rivers to save land and to make them deeper for ships.

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[a] redrawn according to Pannekoek ( ) Algemene geologie ( )   pag. 225

3.1.8 Hydraulic geometry of stream channels

Width (w), depth (d) and stream velocity (v)

The study of the changes of channel width (w) and depth (d), stream velocity (v) and suspended load with a discharge Q = w·d·v is the next step for a better understanding of the behaviour in a landscape. Channel width, depth and current velocity increase during rising water. This is no surprise to anyone familiar with the regime of rivers, but the regular change of each separately is amazing.

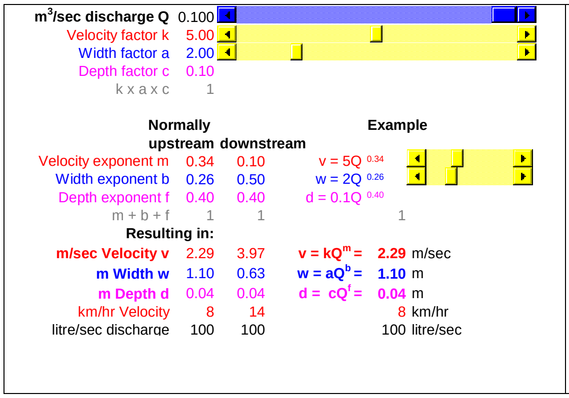
With the help of a wide range of streaming conditions it was found experimentally (Leopold and Maddock, 1953) that width, depth, velocity and load increase as simple power functions of discharge. This can be translated in the following equations:

$w = aQ^b$ $d = cQ^f$ $v = kQ^m$ (see page 182)

The numerical values of the arithmetic constants a, c and k are not significant for the hydraulic geometry of streams. On the other hand the numerical values p,q and r are very important. All these values are found by measurements. Leopold and Maddock found that the average for some 20 more or less comparable stations in the United States gave the following values:

$b = 0.26$ $f = 0.40$ $m = 0.34$

In these cases during a flood the *width* of a channel at a specific cross-section will increase slowest ($w = aQ^{0.26}$), the *depth* (level) fastest ($d = cQ^{0.4}$) and the *velocity* in between ($v = kQ^{0.34}$).



m^3/sec discharge Q	0.100				
Velocity factor k	5.00				
Width factor a	2.00				
Depth factor c	0.10				
k x a x c	1				
	Normally upstream	**downstream**	**Example**		
Velocity exponent m	0.34	0.10	$v = 5Q^{0.34}$		
Width exponent b	0.26	0.50	$w = 2Q^{0.26}$		
Depth exponent f	0.40	0.40	$d = 0.1Q^{0.40}$		
m + b + f	1	1		1	
Resulting in:					
m/sec Velocity v	2.29	3.97	**$v = kQ^m =$**	**2.29**	m/sec
m Width w	1.10	0.63	**$w = aQ^b =$**	**1.10**	m
m Depth d	0.04	0.04	**$d = cQ^f =$**	**0.04**	m
km/hr Velocity	8	14		8	km/hr
litre/sec discharge	100	100		100	litre/sec

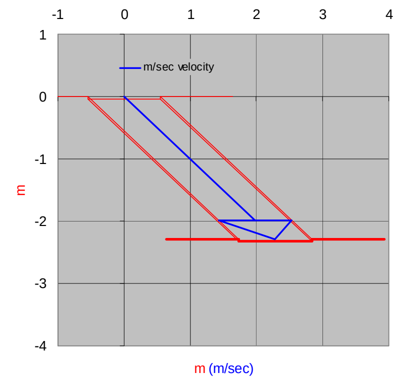


Fig. 395 Calculating v, w and d

Fig. 396 The geometry of the stream[a]

Comparing measurements of channel shape and stream velocity in a downstream direction gives surprising results. Normally the discharge of a river downstream increases. The same equations are found to apply at the different downstream cross-sections. Research and measurements proved that:

Width, depth *and* velocity increase downstream.

According to *Fig. 373* this empirical results also reject the idea that streams in the mountains flow wildly and more rapidly than downstream.[86] These higher streams are characterized by a flow in circulair eddies with almost as much backward as forward motion.

The numerical value of the exponents b and m from the equations above are not the same for changes downstream as for changes with discharge passing an upstream cross-section.
In the downstream direction the average values for the exponents become:

$b = 0.5$ $f = 0.4$ $m = 0.1$

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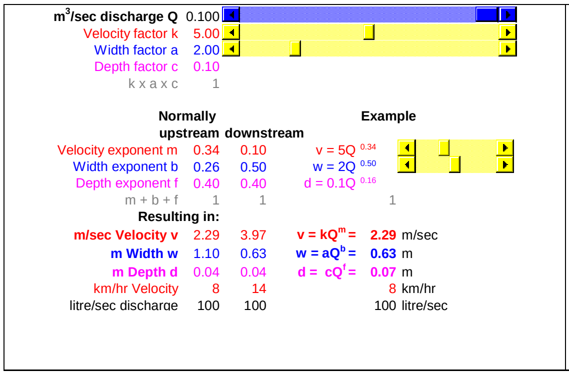
[a] *http://team.bk.tudelft.nl/* > Publications 2006 > experiments: Hydrology *.xls*

Downstream, the *width* of the channel will increase most rapidly, the *depth* a little bit less rapidly, but the mean *velocity* will increase only slightly.



m^3/sec discharge Q	0.100				
Velocity factor k	5.00				
Width factor a	2.00				
Depth factor c	0.10				
k x a x c	1				
	Normally		**Example**		
	upstream	**downstream**			
Velocity exponent m	0.34	0.10	$v = 5Q^{0.34}$		
Width exponent b	0.26	0.50	$w = 2Q^{0.50}$		
Depth exponent f	0.40	0.40	$d = 0.1Q^{0.16}$		
m + b + f	1	1		1	
Resulting in:					
m/sec Velocity v	2.29	3.97	**$v = kQ^m =$**	**2.29**	m/sec
m Width w	1.10	0.63	**$w = aQ^b =$**	**0.63**	m
m Depth d	0.04	0.04	**$d = cQ^f =$**	**0.07**	m
km/hr Velocity	8	14		8	km/hr
litre/sec discharge	100	100		100	litre/sec

Fig. 397 Calculating v, w and d

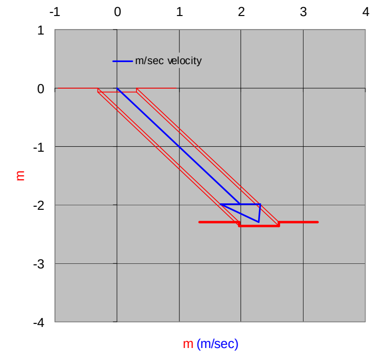


Fig. 398 The geometry of the stream[a]

It is believed that the increasing depth downwards permits a more efficient flow in a river and so overcompensates the decreasing slope. As a result a slight net increase in velocity at mean annual discharge will take place.

Further mathematical calculations of the hydraulic geometry equations suggests useful applications of the principles.

The discharge is defined as $Q = wdv$

and if $w = aQ^b$ $d = cQ^f$ $v = kQ^m$

then by substitution: $Q = (aQ^b)(cQ^f)(kQ^m)$

or: $Q = ackQ^{b+f+m}$

it follows that: $a \times c \times k = 1.0$ and $b + f + m = 1.0$

As is stated above the arithmic constants a, c and k are not important. But it is interesting that for all the made measurements and calculations for the different cross-section b + f + m =1.0 agree.

3.1.9 River morphology

The morphology of a river system depends mainly on climate, gravity, height, slope, bedrock, soil type and vegetation. Human impact on the system cannot be neglected and especially not downstreams with all artfiicial interventions varying from storage reservoirs both for the generation of electricity and for storage purposes of water and for alterations in the system itself and dumping of materials in the system.

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[a] *http://team.bk.tudelft.nl/* > Publications 2006 > experiments: Hydrology *.xls*

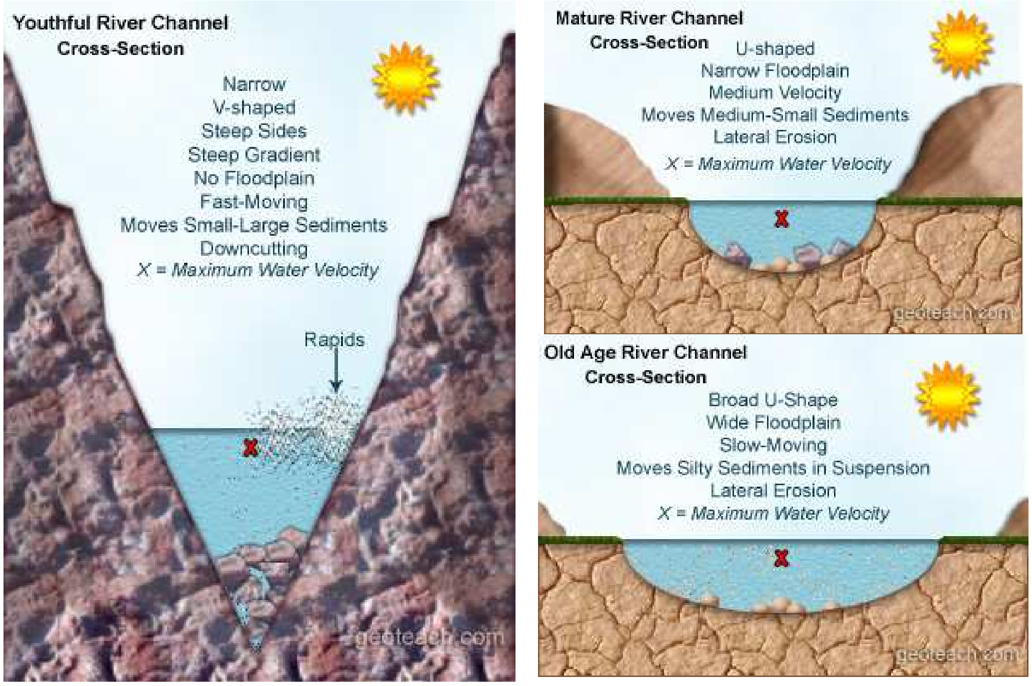

Fig. 399 Development of river beds[a]

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[a] *http://geolor.com/geoteach/rivers/Three_Stages_of_River_Development-geoteach.htm*

3.1.10 Simulating a simple drainage system

Wind, water and traffic flow along the earth´s surface. Some of these flows collect into streams.

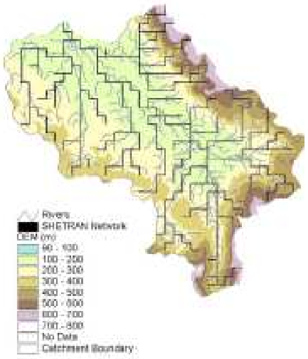

Fig. 400 Schematic of SHETRAN model setup.

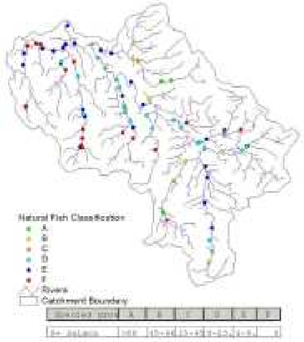

Fig. 401 Salmon Abundance across the Eden catchment[a]

Fig. 402 shows a landscape with 24 x 24 squares (sloped mountain areas or a polder with outlets) with 4 possible drainage directions, producing a converging feather or tree like drainage system. Computer programme Jong (2003) ‘*river(drainage.exe)*’ (see *http://team.bk.tudelft.nl/* publications 2003), made from the ‘random walk’ example of Leopold and Wolman cited by Zonneveld (1981), arouses such random landscapes producing drainage systems. The image is built up in columns from upper left to down below. The programme prevents convergent arrows and smallest circuits by changing lowest arrow 90^o into right or downward if they occur. So, the runoff tends towards ‘South East’ as if the landscape has a main slope or a mein drainage outlet. Watersheds become visible separating catchment areas. Why do they concentrate into separate basins and converge into main streams?

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[a] *http://www.ncl.ac.uk/swurve/downloads/2002Synthesis.pdf#search=%22river%20Rhine%20cross%20sections%20Lobith%22*

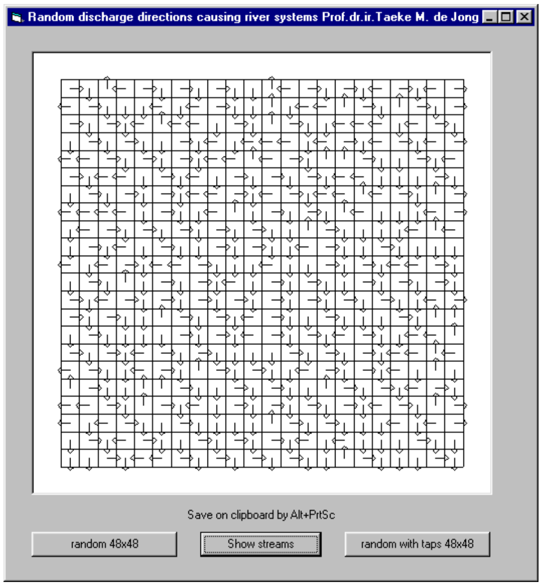

Fig. 402 Directions of drainage in a landscape

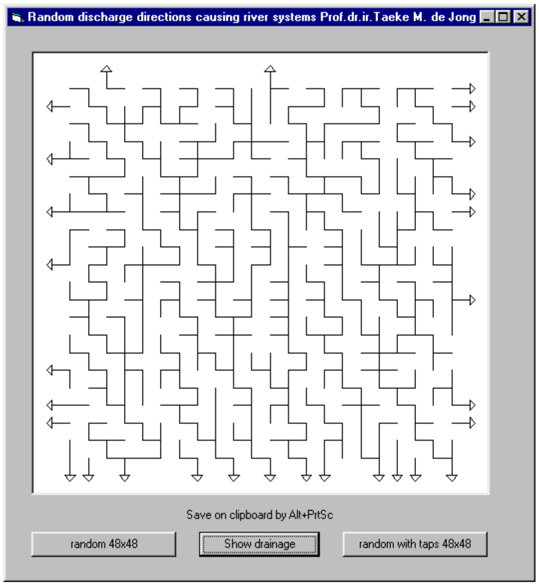

Fig. 403 Surface streams caused by Fig. 402[a]

Getting a feeling for runoff calculations

Run the program or take Fig. 403, draw the catchment basin of an outlet and calculate the discharge Q for one hour taking arbitrary European precipitation and evaporation values into account. Neglect subterranian flows, width and depth of streams, obstacles or retardatons. Suppose surfaces and altitudes, draw the altitude lines and estimate velocities. An exercise like that makes you understand the problems elaborated in next sections.

Truncation orders in river systems

You can divide a river system in different truncation orders from source to the mouth of the system. *Fig. 404* shows four methods. All the ordering systems are more or less based on a method starting with the source and going downstream. The first order is called a source river without any tributaries and so on. The differences are more determined by the nomination of the different tributaries than by the diffences in system. Strahler (above right) considers small source brooks without tributaries above as first order. Streams collecting water from first order rivers are second order rivers and so on. Try to divide Fig. 403 in such an order system[b].

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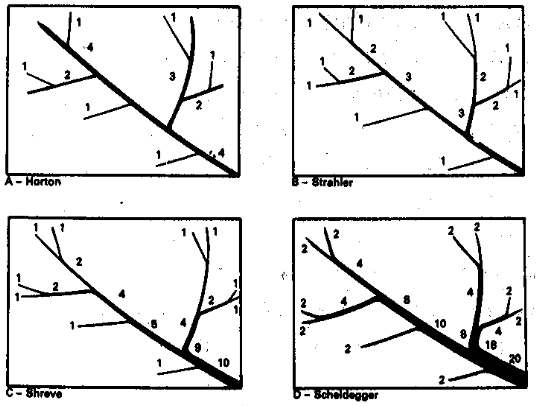
[a] Zonneveld (1981)

[b] Mail pattern and calculation to T.M.deJong@bk.tudelft.nl



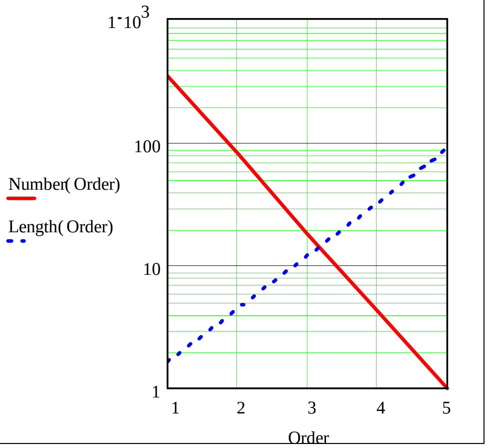


Fig. 404 Four methods to distinguish 'orders' in a feather like drainage pattern[a]

Fig. 405 Average number and length of orders in 'random walk rivers'[b]

Leopold and Wolman calculated that random rivers have 4.4 upstream branchings of lower Strahler orders according to Strahlers method at average. In practice it varies between 2 and 5. The longer a river is the more orders can be distinguished.

3.1.11 Bifurcation or trunking in traffic networks

This 'bifurcation ratio' plays a rôle in traffic as well, though street patterns and artificial drainage systems in flat lands are not like a tree but like a grid (compare Alexander (1966))[87]. If there are 20km streets per km^2, you can raise some 7km of them into the order of neighbourhood roads with a higher capacity and transform 2km into district ways with an even higher capacity. So, the optimal proportion between the density of ways and sideways in a grid seems to be approximately a factor three. Do not take it for granted, it is an easy rule of thumb, based on calculations of Nes and Zijpp (2000) indicating factors 2 and 4 are suboptimal in three different types of calculation.

Density of roads and orders of roads

Suppose a metropolis of 30km radius has 60 x 60 = 3600km^2 surface with 2km/km^2 district roads (see Fig. 498). There should be 7200km district roads in a grid of average 1x1km. To calculate density from the grid mesh bordered by 4km district roads, you have to count them half because they serve adjacent meshes as well. Many of them would be overloaded by through traffic when you would not raise 1/3 of them into city highways (2400km in a grid of 3x3km, 0.67km/km^2) with a capacity of 3000 mv/h and less exits. However, on their turn they would be overloaded. So, this argument produces a semi logaritmic range of orders (Fig. 406).

	km nominal mesh	km/metropolis	km/km^2 inclusive density	exclusive	mv/h
district roads	1	72000	2,00	1,33	1000
city highways	3	24000	0,67	0,47	3000
local highways	10	7200	0,20	0,13	10000
regional highways	30	2400	0,07	0,05	30000
national highways	100	720	0,02	0,02	100000
and so on			nearly 3.00	2.00	total

Fig. 406 *Theoretical orders of urban traffic infrastructure*

The total density of ways is 2km/km^2. One third of them we have transformed into highways of several orders. So, the density of ways includes the highways. Exclusing highways, there are 1.33km/km^2

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[a] Zonneveld (1981) page 179
[b] After Zonneveld (1981) page 183

small district ways left. If we would like to reduce the amount of exits of local highways to save velocity, we have to disconnect district ways into dead ends. If we like to connect them mutually with extra parallel service roads along side the city highway we need the inclusive density at least.

If we try to draw a system of highways in a square of 60x60km we firstly draw a grid of 10x10km. There are 14 local highways of 60km, but 6 of them we transform into a higher order. So, their exclusive density is 8x60/3600=0.13 indeed. However, we can not fill 10km space between local highways with 3.3 city highways. So we choose 3 highways lowering the inclusive density from 0.67 into 0.60km/km2. This causes a raise of exclusive district way density from 1.33 into 1.40, but on this scale we can not draw them anyhow.

Comparing truncing in rivers and roads

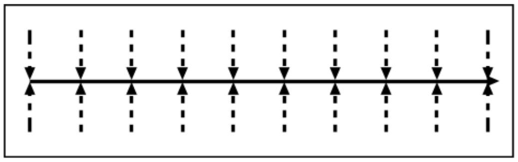
For wet connections the same applies when we call city highways supply channels, local highways brooks and regional highways rivers. In Dutch such orders of water ways can be named more precise than in English.

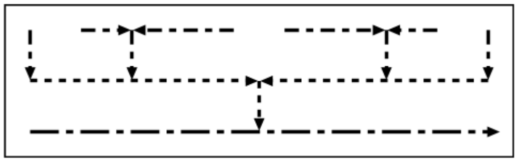
Riviersystems		**Road systems**	
Dutch	English	Dutch	English
hoofdrivier	mainriver	hoofdweg	highway
hoofdader	trunk stream	wijkverzamelweg	trunkroad
zijrivier	tributary	zijweg	sideroad
aftakking	distributary	zijweg	secundary road
beek	brook	buurtweg	tertiairy road
geul	channel	woonstraat	residential road
geultje	rill	woonerf	residential area

Fig. 407 Naming orders of river and road systems according to Moens

Bifurcation ratio, orders and network density

In Fig. 408 left, the bifurcation ratio of brooks before meeting a river is 20.
However, the same network density could be reached with a bifurcation ratio 2 and 5 orders (Fig. 408 right).





	Feather like	*Tree like*
density	29 sections	29 sections
bifurcation ratio	18	2
number of 'orders'	2	5

Fig. 408 *Feather and tree -like connection patterns*

Multiplying and extending these patterns into square surfaces (Fig. 409) tree like connection patterns seem to require a little higher density to open up all parts and consequenly higher costs when restricted to bifurcation ratio 2.[a] I do not understand why. Is halving the number of outlets responsible for a higher density? If somebody can design a lower density within this boundary conditions or prove its possibility mathematically I will publish it next time.
On the other hand, tree like opening up every point of the area makes many variants and greater diversity of locations possible when you have more space to lay out (Fig. 409).

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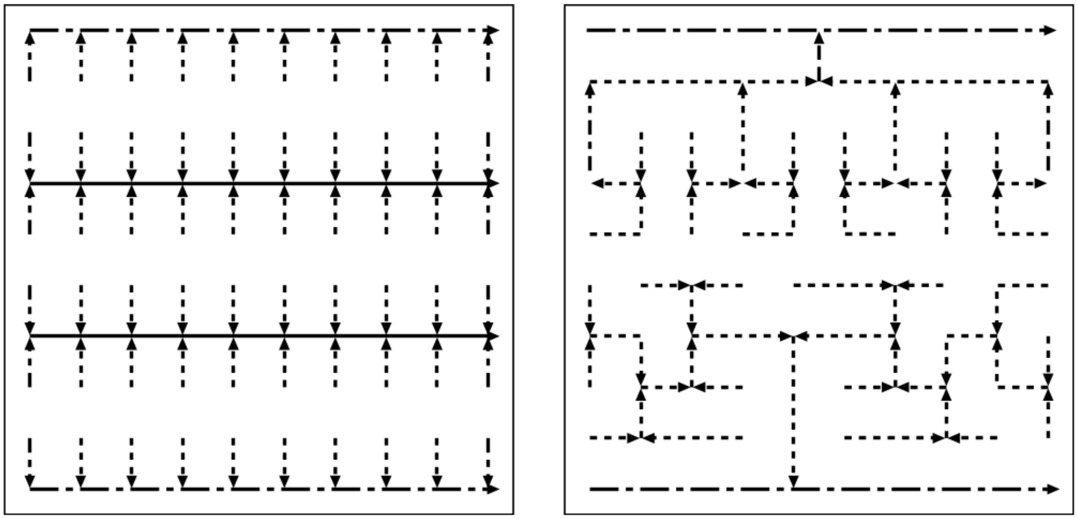
[a] Perhaps because this restriction combined with mirroring vertically and horizontally has used all possibilities of external connection by two axes (above and below) counting half. So, vertically opening up the whole area makes more vertical sections necessary.



	Feather like	*Tree like*
density	96 sections	98 sections
bifurcation ratio	20	2
number of 'orders'	2	6 or 9

Fig. 409 *Feather and tree like connection patterns opening up a square*

Perhaps opening up a square in a tree-like way with bifurcation ratio 3 could reach the same or even lower densities and consequently lower costs. Try it. Does it result in less nodes and longer sections, a better readability of the area? The number and characteristics of nodes and the length of sections are important for spatial quality. Which rôle does the length of individual *sections* L play instead of total length per order in *Fig. 405*?

3.1.12 Catchment area and river length

The average length L of a random walk river *section* is a power its catchment area A ($L=A^{0.64}$). If length L is given the inverse the catchment area is a power of the length ($A=L^{1.563}$, Fig. 410 and Fig. 411). All the figures are experimental, obtained by observing many catchment areas and rivers.

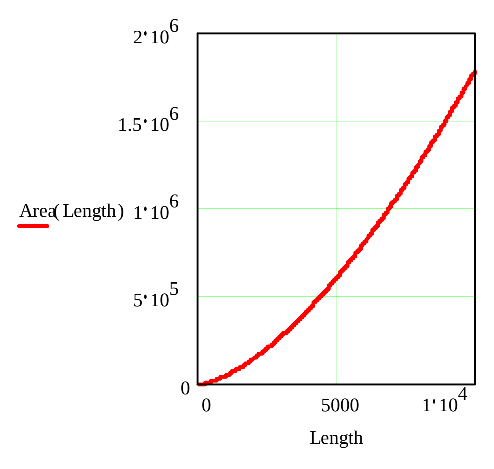


Fig. 410 Catchment area related to the length of a river section

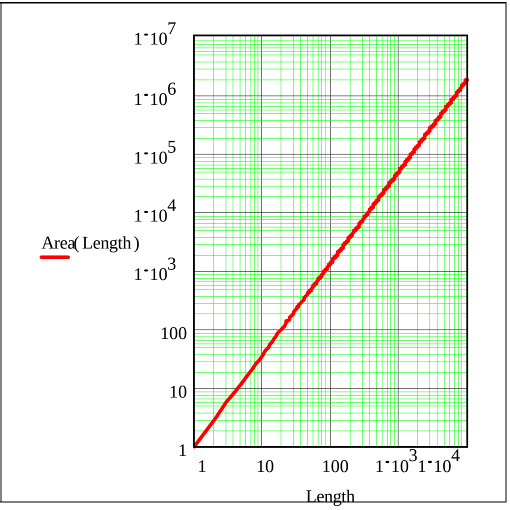


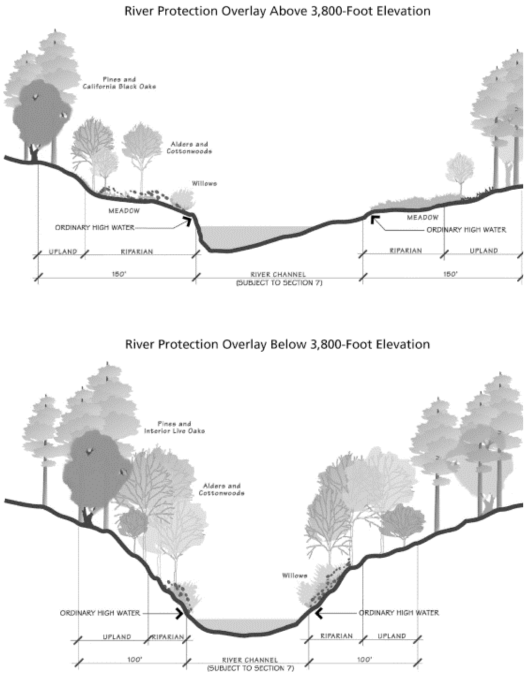
Fig. 411 Logaritmic representation of Fig. 410

Check Fig. 403 by counting the corresponding squares in Fig. 402 of a specified order and its length. Compare your measurements with Fig. 411 and *Fig. 405*.

3.1.13 Local morphologies

A river can be described by its morphology. It is the credit of William Morris Davis (1912, die erklärende Beschreibung der Landformen (Leipzig und Berlin) that for the first time a system is formulated based on development according to evolution. He describes the evolution of the valleys of the first order rivers as a V-shape without a valleybottom that develops in a wide valley with a valleybottom. This river will develop at the end in a real lowland river as we all know in The Netherlands from the river Rhine. Later scientists built further on his theory and adapted it where it was necessary. Fig. 414 - Fig. 420 show such a development with adaptations.

A classification according deposits is also developed. The faster the water streams the coarser material can be transported as load. This means that at decreasing velocity of streaming a river will deposit first the coarse material. The slower the stream becomes the finer the sediment will be that will be deposited. Near glaciers coarse material is sedimented and a lowland river will deposit fine material as sediment. Moreover a river in a flat will tend to meander. By doing so the meander curves will move downstream due to the undermining of the outside curve by the streaming water.


River Protection Overlay Above 3,800-Foot Elevation

River Protection Overlay Below 3,800-Foot Elevation

Fig. 412 River curves causing different vegetation[a]

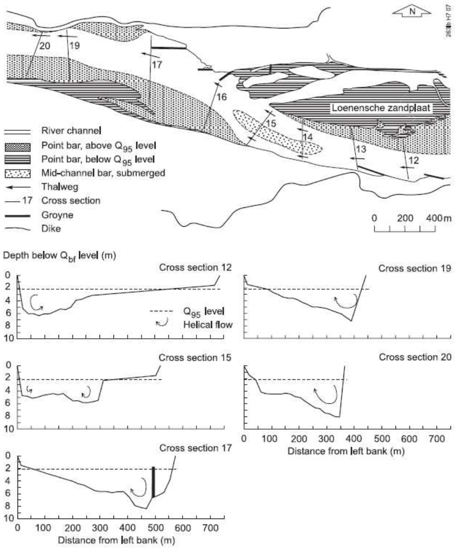


Fig. 413 Water flows causing different river bottoms[b]

Every unevenness can cause an alteration the course of the river; many different channels of a river can be recognized in lowland river. So the water takes diverse and changing courses. Lower sections still bear rough material wearing out the outside parts of a bend into meanders, because rough material laid down there in the same time becomes a water barrier until heavy showers force a break through Fig. 415 and Fig. 417.

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[a] *http://geographyfieldwork.com/RiverEfficiencyCompetency.htm*; http://www.nps.gov/archive/yose/planning/mrp/html/07_rmrp_ch1.htm

[b] *http://igitur-archive.library.uu.nl/dissertations/1983151/c7.pdf*

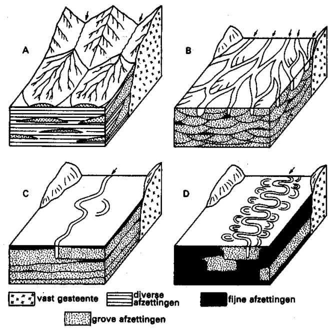

Fig. 414 Forms of deposit[a]

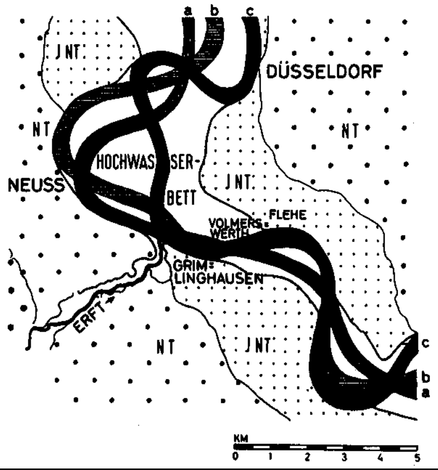

Fig. 415 Move of Rhine near Neuss from Roman times (a) via Middle Ages (b) until recently[b]

In low lands finer deposits raise the bed in calm periods forcing water to find easier courses. A high discharge of a river causes even an river system with many branches in a lowland area. Such a system is called a braided river.

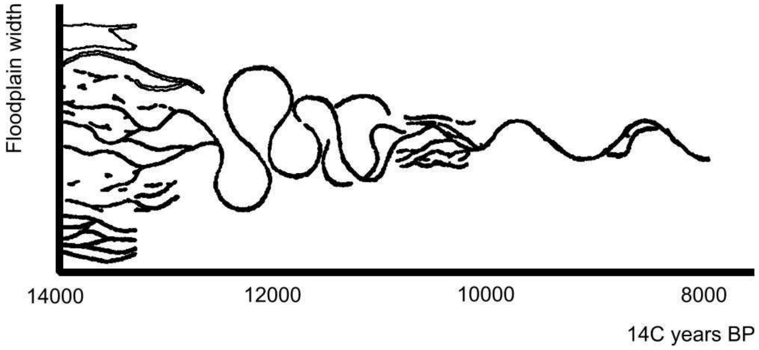

Fig. 416 Change of river behaviour in time[c]

The morphology of the braided river is not very stable; it changes often depending the amount of water.

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[a] Allan cited by Zonneveld (1981) page 148

[b] Hoppe cited by Zonneveld (1981) page 149

[c] Tebbens et al. (1999), cited by Kroonenberg (2006)

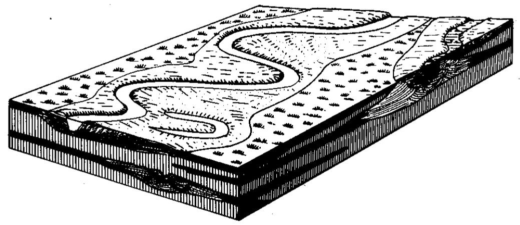

Fig. 417 Meandering river with historical deposits[a]

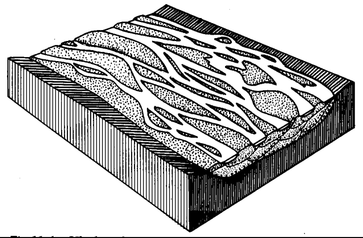

Fig. 418 Twining river[b]

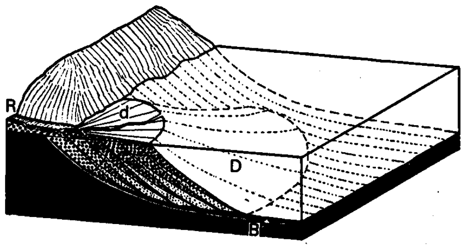

Fig. 419 Delta development with river (R), top-sets (d) and fore-sets (D)[c]

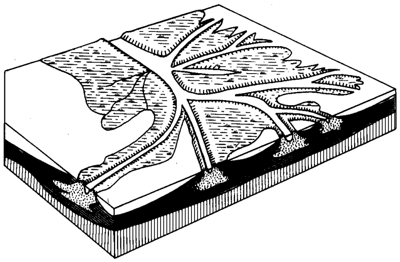

Fig. 420 Mississippi delta[d]

The Rhine area downstream of Lobith is formed by both the process of meandering during quiet periods and braiding during periods with large differences of water discharges (Fig. 421).

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[a] Zonneveld (1981) page 143
[b] Zonneveld (1981) page 144
[c] Escher 1948 cited by Zonneveld (1981) page 160
[d] Zonneveld (1981)page 161

From Lobith Rhine distributes water via Waal, Lower Rhine and IJssel in historically changing proportions.

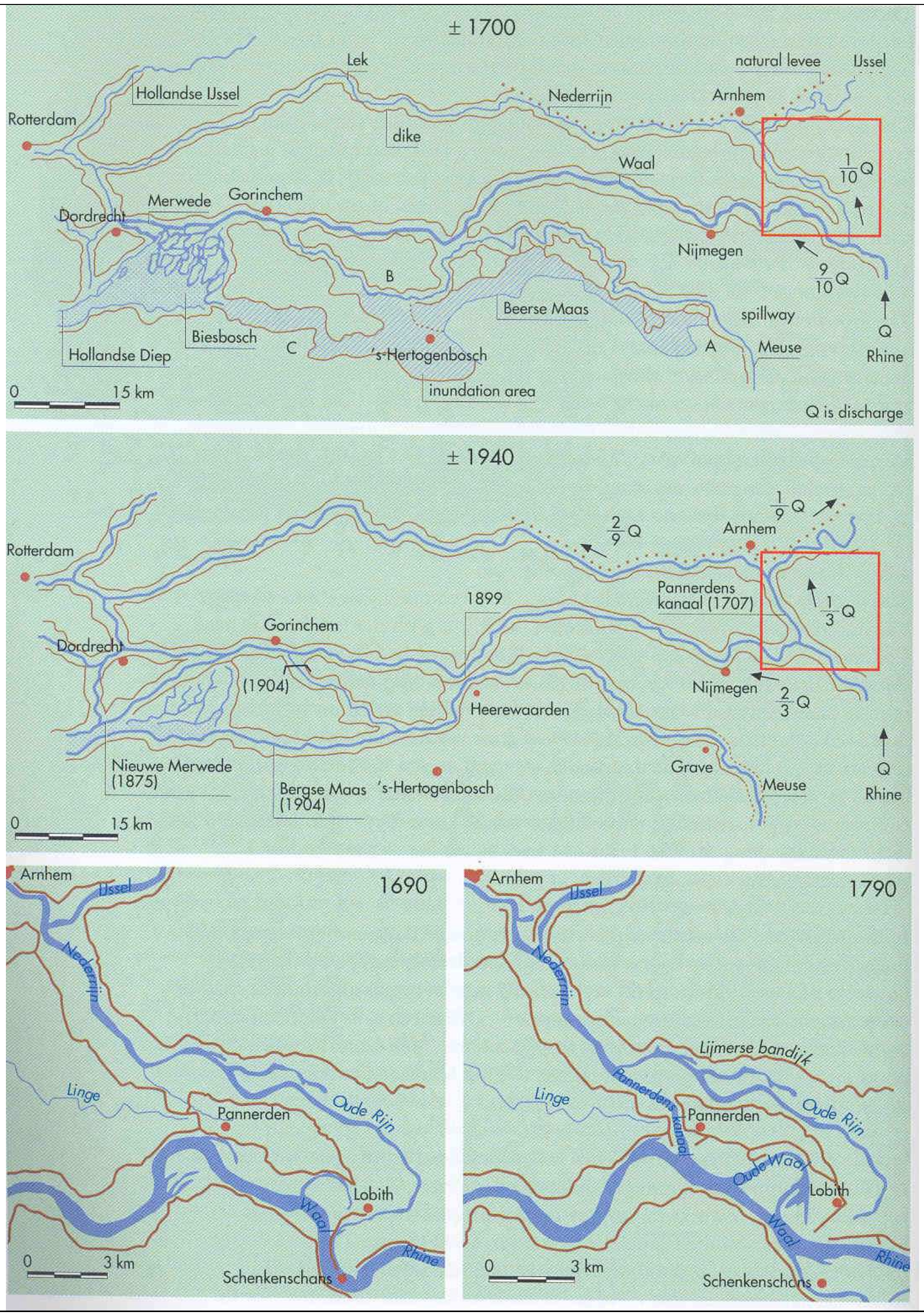

Fig. 421 *Historical distribution of Rhine water from Lobith*[a]

3.1.14 Measuring velocities to get Q

---

[a] Huisman, Cramer et al. (1998) page 38

The velocity v of water in a river can be measured on different depth vertical lines h with mutual distance stretches b of the cross-section B (Fig. 422). You can determine any partial discharge by multiplying v x b x h.The summon of the outcomes in cross section A for the different stretches b to get $Q = \Sigma(v \cdot b \cdot h)$ is an approach for the discharge
In the equation v is the mean stream velocity of the river and the velocity can easily be measured on site.

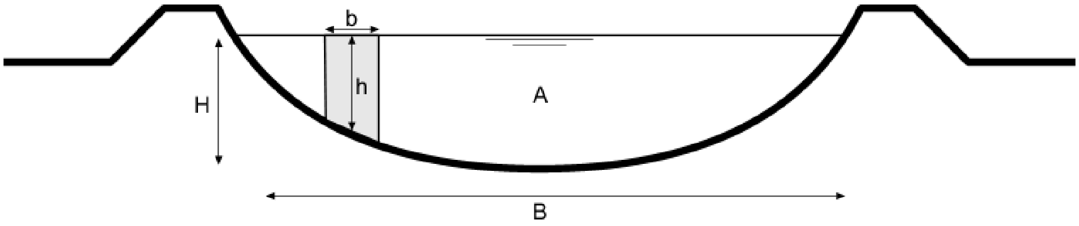

Fig. 422 *Profile of a river*[a]

For example: asked the river drainage Q (Fig. 424), given h_i, b_i and v_i from profile subdivisions (Fig. 423).

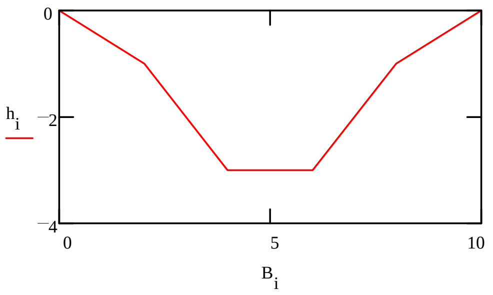	$h := \begin{bmatrix} 0 \\ -1 \\ -3 \\ -3 \\ -1 \\ -0 \end{bmatrix} \cdot m$	$b := \begin{bmatrix} 0 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \end{bmatrix} \cdot m$ $B_i := \sum_{x=0}^{i} b_x$	$v := \begin{bmatrix} 0 \\ 1 \\ 2 \\ 3 \\ 2 \\ 1 \end{bmatrix} \cdot \frac{m}{sec}$
	height h	*width b* *coordinate B*	*velocity v*

Fig. 423 *Data from profile*

---

[a] Akker and Boomgaard (2001)

$i := 0..5$ $a_i := b_i \cdot -h_i - \frac{1}{2} \cdot b_i \cdot \left(-h_i - -h_{i-1}\right)$ $A := \sum_i a_i$ $A = 16 \cdot m^2$	$Q_i := v_i \cdot a_i$ $Q := \sum_i v_i \cdot a_i$ $Q = 36 \cdot m^3 \cdot sec^{-1}$	v_i $0 \cdot m \cdot sec^{-1}$ $1 \cdot m \cdot sec^{-1}$ $2 \cdot m \cdot sec^{-1}$ $3 \cdot m \cdot sec^{-1}$ $2 \cdot m \cdot sec^{-1}$ $1 \cdot m \cdot sec^{-1}$	a_i $0 \cdot m^2$ $1 \cdot m^2$ $4 \cdot m^2$ $6 \cdot m^2$ $4 \cdot m^2$ $1 \cdot m^2$	Q_i $0 \cdot m^3 \cdot sec^{-1}$ $1 \cdot m^3 \cdot sec^{-1}$ $8 \cdot m^3 \cdot sec^{-1}$ $18 \cdot m^3 \cdot sec^{-1}$ $8 \cdot m^3 \cdot sec^{-1}$ $1 \cdot m^3 \cdot sec^{-1}$
profile subdivisions	*drainage per subdivision*	*velocity*	*surface*	*drainage*

Fig. 424 *Drainage (profile subdivisions and velocities)*

3.1.15 Discharge Q on different water heights

The depth H of the river in a cross-section varies, but it can be measured on site. Then, the drainage Q(H) can be calculated by a practical formula apparently characteristic for the profile concerned. However, periods of high drainage Q or regular floodings in winter change profile and … the formula. Comparing measurements like in Fig. 423 on different water heights you often find a curve like a parabola, approached by $Q = a \cdot H^b$ or $H=(Q/a)^{1/b}$ (Fig. 425). Parameters ‘a’ and ‘b’ should be found non-theoretically by experiment, seem to characterise the profile.

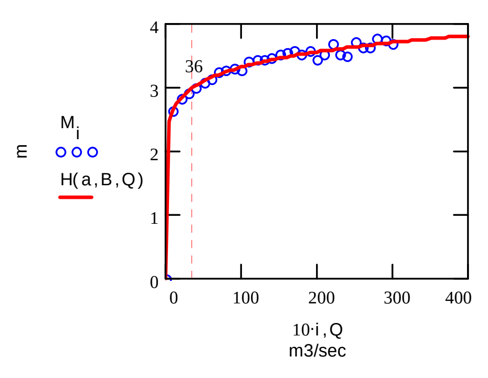

Fig. 425 ‘*Measurements’ M_i and* $Q(a,B,H) = a \cdot H^B$ or the inverse *H(a,B,Q)*= $(Q/a)^{1/B}$ to get H on the y-axis

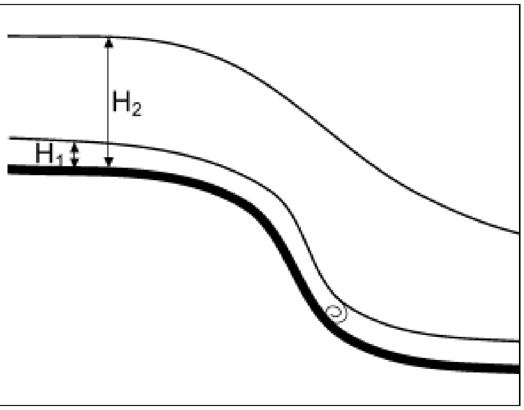

Fig. 426 *Change of boundary condition downstream; a ‘drowning’ waterfall*[a]

Measurements deviate from the formula because velocity varies. When measurements can not be simulated by a smooth curve, it is probable that conditions downstream are changed by high water levels. Two graphs should then be drawn; one until the point of change, one for the higher values. When for example a waterfall downstream suddenly ‘drowns’ at increasing water levels (Fig. 426) the slope of the curve will change by the increase of velocity.

3.1.16 Interpolation of experimental data by using Excel

Constants a and b can be found by the least squares method provided by Excel using graphs (see *Fig. 427*). Enter the data of the measurements of height and drainage calculated according to Fig. 425 in two columns. Make a point graph and select it.

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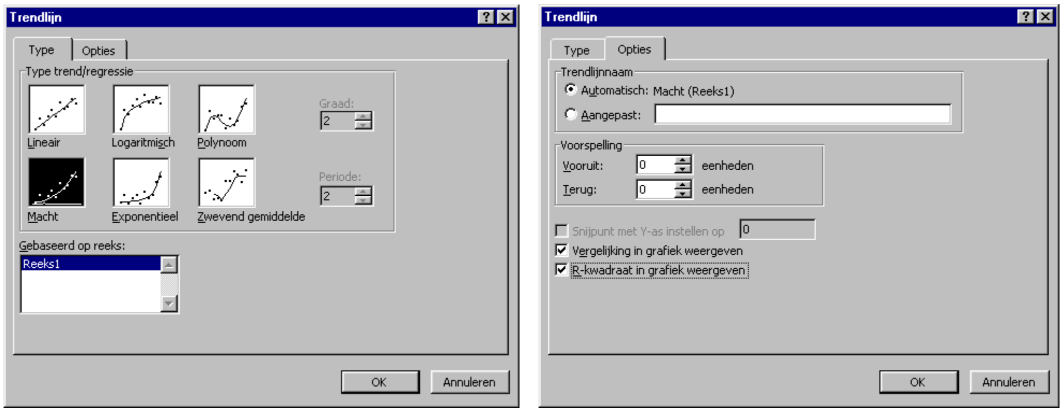
[a] Akker and Boomgaard (2001)



Trendlijn – Type
Type trend/regressie: Macht
Graad: 2
Periode: 2
Gebaseerd op reeks: Reeks1

Trendlijn – Opties
Trendlijnnaam
● Automatisch: Macht (Reeks1)
○ Aangepast:
Voorspelling
Vooruit: 0 eenheden
Terug: 0 eenheden
☐ Snijpunt met Y-as instellen op 0
☑ Vergelijking in grafiek weergeven
☑ R-kwadraat in grafiek weergeven

choose power, click both lowest,

As opmaken – Schaal
Schaal waardeas (X)
Automatisch
☑ Minimum: 1
☐ Maximum: 10
☑ Primaire eenheid: 10
☑ Secundaire eenheid: 10
☑ Waardeas (Y)
Snijdt bij: 1
Weergave-eenheden: Geen ☑ Gebruikte eenheden weergeven in grafiek
☑ Logaritmische schaal
☐ Waarden in omgekeerde volgorde
☐ De waardeas (Y) snijdt bij maximumwaarde

As opmaken – Schaal
Schaal waardeas (Y)
Automatisch
☑ Minimum: 0,1
☐ Maximum: 100
☑ Primaire eenheid: 10
☑ Secundaire eenheid: 10
☑ Waardeas (X)
Snijdt bij: 0,1
Weergave-eenheden: Geen ☑ Gebruikte eenheden weergeven in grafiek
☑ Logaritmische schaal
☐ Waarden in omgekeerde volgorde
☐ De waardeas (X) snijdt bij maximumwaarde

click axis, choose logarithmic,

Fig. 427 Adding regression lines in Excel point graphs

Choose ‘add trend’ in ‘graph’ from the main Excel window above, and graphs like Fig. 428 and Fig. 429 with power regression line and formula are calculated by the program.
With R^2 near to 1 you have a reliable formula. In Fig. 428 we used ‘measurements’ of Fig. 425 putting the independently variable measurements on the x-axis this time to find a=0.0003 and b=8.7398.

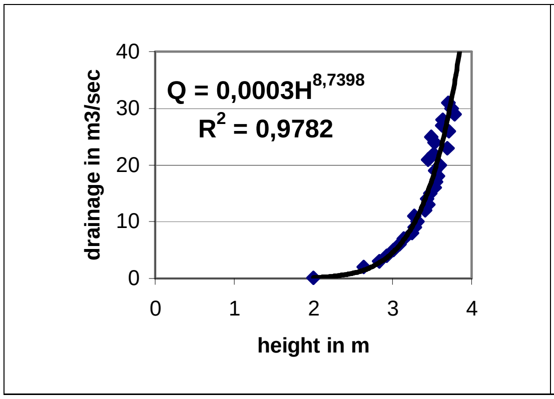


Fig. 428 ‘*Measurements’ M_i and* Q(a,b,H) = a·H^b

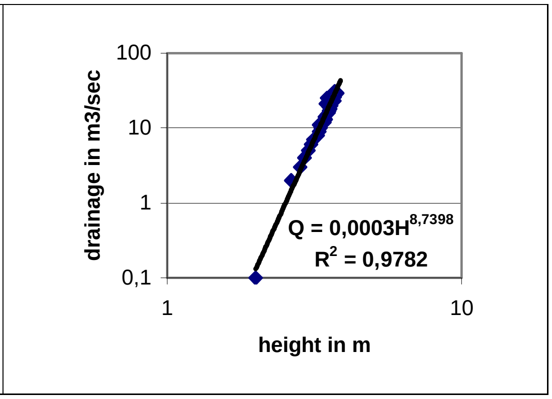


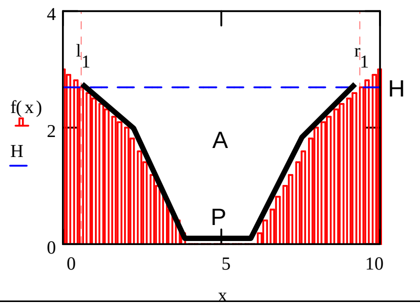
Fig. 429 *Logarithmic representation of* Fig. 428

The logarithmic representation log Q = log a + b log ($H-H_0$) produces a straight line easy to extrapolate to other heights and drainages. But be careful, there could be jumps in velocity by downstream events.

If you have made graphs before and after the jump because measuremens could not be simulated by a smooth curve, each interval in Fig. 429 has different slopes representing different behaviour.

3.1.17 Calculating drainage Q with a rough profile

Just like wind, water slows down by roughness of the bed. The cross length of roughness in a wet profile P (Natte Omtrek) is calculated by summing hypothenuses of triangles according to Pythagoras characterised by the square root of $(b_i)^2+(h_i-h_{i-1})^2$ (see Fig. 422 and Fig. 431).
Considering the profile as a function H=f(x) we can read the waterlevel H from accompanying left border x_1=l and right border x_2=r as values from f(x) (Fig. 430). The length of roughness P within the cross section (Natte Omtrek = wetted contour) and the surface of the wet cross section A are both calculated as a function of H (Fig. 431).



Cross length by Pythagoras:

$$P = \sum_{j=l_1}^{r_1} \sqrt{\left(X_{j+1}-X_j\right)^2+\left(Y_{j+1}-Y_j\right)^2}$$

Surface wet cross section:

$$A(H) := H\cdot\left(r_1-l_1\right) - \int_{l_1}^{r_1} f(x)\,dx \qquad R(H) := \frac{A(H)}{P}$$

Fig. 430 *Profile as a function*

Fig. 431 *Calculating wet cross section A and cross length of roughness P (NatteOmtrek)*

When we divide the surface of the wet cross section A of a stream by this cross length of roughness P we get a measure indicating what part of the flowing water is hindered by roughness called ‘hydrolic radius’ R = A/P in metres.

Method Chézy

The average velocity of water v = Q/A in m/sec is dependent on this radius R, the roughness C it meets, and the slope of the river as drop of waterline s, in short v(C,R,s).
According to Chézy v(C,R,s)=C√Rs m/sec, and Q = Av = AC√Rs m^3/sec. Calculating C is the problem.

Method Strickler-Manning

Instead of v=C√Rs, Strickler-Manning used

$$v := \frac{R^{\frac{2}{3}}\cdot s^{\frac{1}{2}}}{n}\cdot\frac{m}{sec}$$

with roughness n taken from Fig. 432.

acteristics of bottom and slopes	**n**	
	from	until
Concrete	0.010	0.013
Gravel bed	0.020	0.030
Natural streams:		
Well maintained, straight	0.025	0.030
Well maintained, winding	0.035	0.040
Winding with vegetation	0.040	0.050
Stones and vegetation	0.050	0.060
River forelands:		
Meadow	0.035	
Agriculture	0.040	
Shrubs	0.050	
Tight shrubs	0.070	
Tight forest	0.100	

Fig. 432 *Indication of roughness values n according to Strickler-Manning*[a]

Method Stevens

Instead of $v=C\sqrt{R}s$ Stevens used $v=c\sqrt{R}$ considering Chézy's $C\sqrt{s}$ as a constant c to be calculated from local measurements. So, $Q = Av = cA\sqrt{R}$ m^3/sec and c is calcuated by $c=(A\sqrt{R})/Q$. When we measure H and Q several times (H_1, H_2 …H_k and Q_1, Q_2 … Q_k), we can show different values of $A(H)\sqrt{R(H)}$ resulting from Fig. 431 as a straight line in a graph (Fig. 433). We can add the corresponding values of Q we found earlier in the same graph reated to $A(H)\sqrt{R(H)}$. When we read today on our inspection walk a new water level H1 on the sounding rod of the profile concerned we can interpolate H1 between earlier measurements of H and read horizontally an estimated Q1 between the earlier corresponding values of Q to read Q from graph.

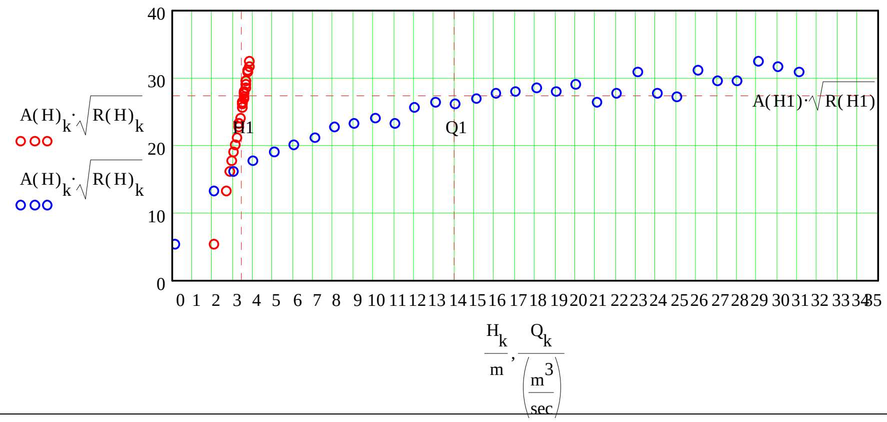


Fig. 433 *Graph used according to Stevens with 'measurements' of* Fig. 428

However, from these 'measurements' c appears to be not very constant, but the graph remains a practical way to estimate Q from H.

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[a] Akker and Boomgaard (2001)

3.1.18 Level and discharge regulators

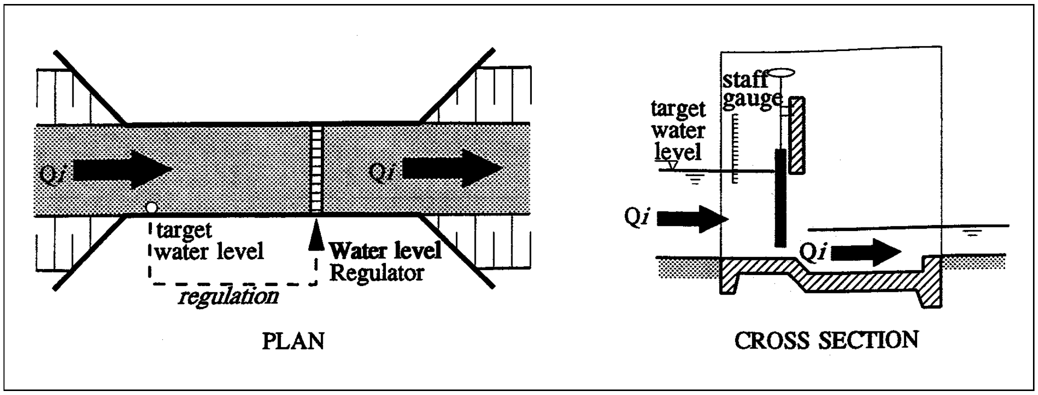

Fig. 434 *Level regulator with level as target*[a]

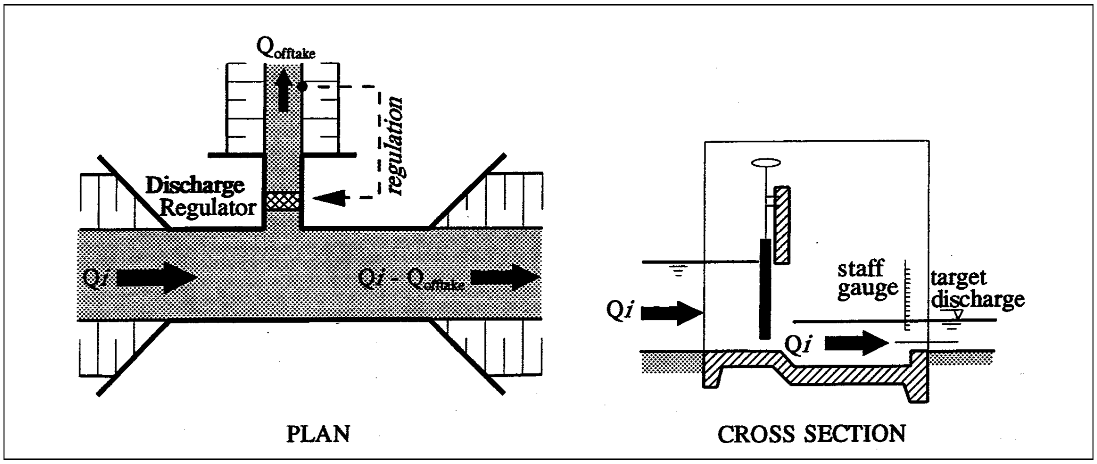

Fig. 435 *Discharge regulator with discharge as target*[b]

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[a] Ankum (2003) page 156
[b] Ankum (2003) page 156

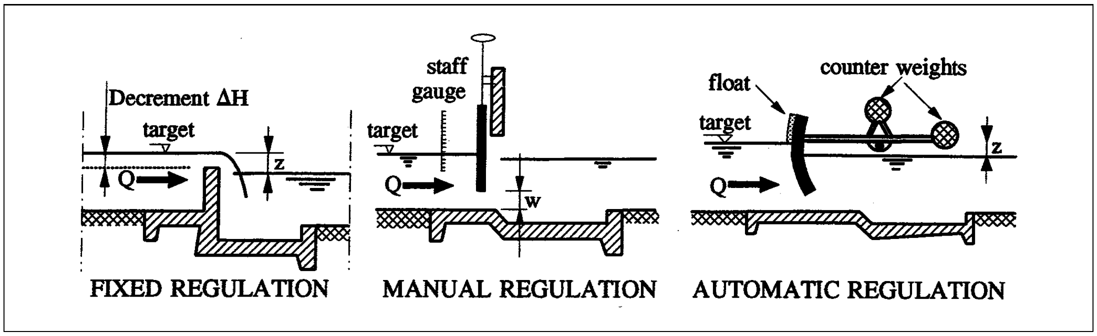

Fig. 436 *'Manners' of regulation*[a]

The fixed regulators are called weirs (stuwen), manual or automatic regulators are called gates (schuiven).

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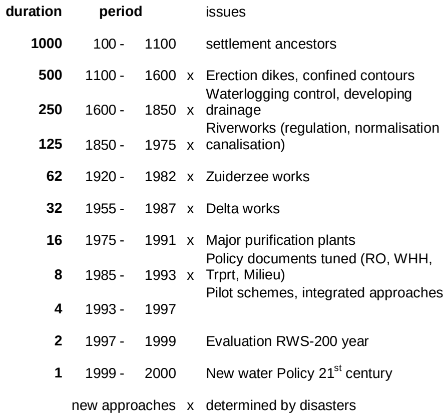
[a] Ankum (2003) page 167

3.2 Civil engineering in The Netherlands

3.2.1 History

The colors of *Fig. 437* indicate the area in the Netherlands that would become submerged if there were no flood protection dikes. The flooding area as indicated is supposed to occur during modest river floods (up to 4000 m^3/sec at the German/Dutch border) and a normal high tide at sea. However, it was not always like that. In 2000 years that area has increased into the current surface by rising external water levels and falling ground levels (see *Fig. 464*).

Fig. 437 Potential threads[a]



duration	period			issues
1000	100 -	1100		settlement ancestors
500	1100 -	1600	x	Erection dikes, confined contours
250	1600 -	1850	x	Waterlogging control, developing drainage
125	1850 -	1975	x	Riverworks (regulation, normalisation canalisation)
62	1920 -	1982	x	Zuiderzee works
32	1955 -	1987	x	Delta works
16	1975 -	1991	x	Major purification plants
8	1985 -	1993	x	Policy documents tuned (RO, WHH, Trprt, Milieu)
4	1993 -	1997		Pilot schemes, integrated approaches
2	1997 -	1999		Evaluation RWS-200 year
1	1999 -	2000		New water Policy 21st century
	new approaches		x	determined by disasters

Fig. 438 Reverse half time of the Dutch water management[b]

To cope with regular floods Dutch water management started by erecting terps in the first milennium A.D. and dikes in the next 500 years. At that time the dynamic water surface was confined and the next 250 years the emphasis of water management became waterlogging control and drainage of reclaimed land. Then, in a period of 125 years the Dutch regulated, normalised and canalised their rivers. In a continuing half time of water management policy new priorities developed like Zuiderzee, Delta and purification works (see *Fig. 438*). In the last few decades all these continuing efforts were integrated by national policy documents, pilot schemes and evaluation for future safety.

Apart from its threats, water as a medium for trade and transport and as a military barrier for external attacks was also a crucial ally in the development of Dutch independence and perhaps a factor in keeping the nation out of World War I.

Water as military barrier

In the past, the Dutch have created again and again water corridors and water defence systems for the military defence of (parts of) the country. In addition, all major cities developed their own defence system, quite often this is still visible on today's maps of the old cities. In the east and south, huge wild peat areas offered some kind of natural protection against invaders from the east and south east. Where the sub soil contained solid sandy deposits, in other words where realistic chances existed that enemies could penetrate, military fortresses were developed (Nieuwe Schans, Boertange, Coevorden, Grol, Doesburg, Mook, Roermond, etc., see *Fig. 439*) Also along the southern flank of the river area cities developed as military fortresses against invaders from the south (Grave, Den Bosch, Hedel, Willemstad).

Water as primary connection

In parts of the country, through the ages there always have been various options to create water corridors during (threatening) wartime, in particular in north – south direction. These wet corridors were

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[a] *RWS*
[b] *author De Bruin*

situated in between major military fortresses. To get these systems activated, a well designed (and maintained!) system of sluices, dikes and locks was developed, in combination with natural water systems that could provide sufficient inundation water during critical periods. Today, the remnants of these provisions are cultural elements in the landscape. Quite often money is spent on renovation and restoration, no longer for military reasons but to safeguard a cultural heritage.

Transport

Paved (or railed) roads in the water saturated soft soil areas in the Netherlands gradually started developing from the middle of the 19th century. Around 1800, the best, safest and quickest way to move from the government buildings in The Hague to the navy harbours in Den Helder and Hellevoetsluis was still taking a horse via the beach! That is a major reason why through the ages all the major waterways in the Netherlands were also used for shipping. Until late in the 20th century, most domestic transport of cargo and passengers was done by ship (‘trekvaart’, beurtvaart). In fact for all important routes and waterways specific (sailing) vessels were developed. The remains of this fleet are now the backbone of the leisure industry. Today, about 35% of all the cargo transport in the Netherlands is still going via waterways; compared to this figure in other countries this is extremely high.

The daily water management of major waterways as shipping routes is still crucial. Shipping developments on the international Rhine also determine the major nautical developments on Dutch domestic waterways. The historic and today’s development of cargo transport on the international Rhine (in other words the economic importance of that river), has not been and is not determined by (fluctuations in) the Dutch economy, but first of all by the German economy. The Rhine is the major hinterland connection of the ARA ports (Amsterdam, Rotterdam, Antwerp), and shipping developments have been coordinated and controlled by the International Central Commission for Navigation on the Rhine (CCNR) since the defeat of Napoleon (1813 Waterloo, Vienna Congress 1815). It is the oldest still functioning international body in the world.

International trade

International trade always has been important for the development of the Netherlands. More in particular sea trade on a global scale. It has also determined the intensive navy orientation of society. It is remarkable that for the protection of the capital (Amsterdam, the old trade centre) the so called ‘Stelling van Amsterdam’ has developed, while for the military protection of the national government centre (The Hague) only a poorly functioning water corridor was available.

Fig. 439 Water as ally[a]

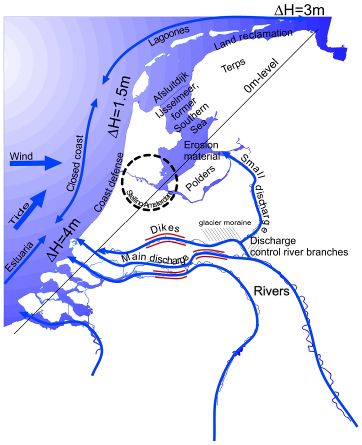

Fig. 440 Water as enemy [b] 88

3.2.2 The distribution of water

The purpose of the Rhine canalisation (3 weirs in the Lower Rhine/Lek branch, plus some bend cuts in the upper reach of the IJssel river) was to gain more control, during low river discharges (of the Rhine at the German Dutch border), of the fresh water distribution via the two bifurcations (Pannerdensche Kop-PK-, IJsselkop -IJK-) to the rest of the country (see *Fig. 441*). Extra fresh water to the north is needed during the dry season, because the IJsselmeer (IJssellake) evaporates about one cm a day during a warm summer day, causing too many shallows in the navigation channels in the IJsselmeer after some weeks of a dry period. In addition, such a dry period often occurs in the growing season of crops in the adjacent polders around the IJsselmeer , so at that time an extra need exists for fresh water. More fresh water coming down via the IJssel (being the main feeder of the IJsselmeer) can be achieved by closing the weir at Driel.

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[a] *author Bruin*

[b] *author Bruin*

Fig. 441 Weirs directing water northwards and southwards[a]

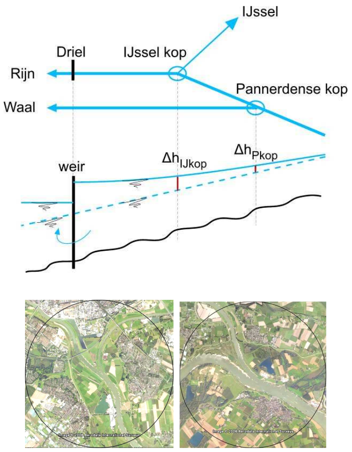

Fig. 442 IJK, PK, Weir of Driel regulating Dutch water distribution[b]

The Driel weir is the most important fresh water tap of the country. By lowering (= partly or entirey closing the Lower Rhine) the so called visor gates, a backwater effect is noticeable till upstream Lobith, so also at both bifurcations IJK (more) and PK (less). Because the width of the major channel in the Waal branch is 260 m, and the width of the IJssel major channel only 80 m, the amount of discharge taken from the Lower Rhine will distribute over IJssel and Waal in the order of magnitude 40–60 % / 60-40 %, so as an average 50/50%. However, the lowering of the Driel weir is only possible if first the two other weirs at Hagestein (Lek) and Amerongen (Lower Rhine) are lowered, with the purpose to create sufficient navigable depth in the entire length of the river between IJK and the tidal zone near Rotterdam.[89]

Salt water intrusion

Because the weirs are only closed during dry periods (low discharge of the Rhine at the German-Dutch border), the fresh water discharge coming down the Lek to Rotterdam will be minimised; as a consequence the salt water intrusion from the sea may harm the drinking water inlet east of Rotterdam along that river. This is not acceptable, so there must be compensation to minimise that salt water effect. It can be done by first closing the Haringvliet sluices, in a way that a backwater effect is created up till at least the Moerdijk zone. Then, all the fresh water coming down both the Meuse and Waal rivers will be sent north to Rotterdam and Hook of Holland. This surplus fresh water is sufficient to stop the salt water intrusion as mentioned.[90]

So one can conclude that a strategic water management of the IJsselmeer is determined by the flush regime of the Haringvliet sluices, via the canalisation of the Lower Rhine.

3.2.3 The threat of floods

The major rivers and the sea always have threatened the Dutch society during severe floods. The tidal characteristics and the regime of the river discharges have determined the development of the flood protection systems in the country. Due to large scale drainage and reclamation over a period of many centuries, major parts of the land where peat deposits at the surface and in the subsoil exist(ed), have subsided. This process is still going on as long as the polders are kept dry with artificial means (pumps, see *Fig. 470*). Due to climate change, expectations are that the sea level will rise and the regime of the major rivers will change (higher peak flows, longer dry periods[91]). As a result, the dense populated areas in the western and centre part of the country will further subside and the river levels and sea level will rise (see *Fig. 446*).

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[a] *author Bruin*
[b] *De Bruin, Google Earth*

In the past, dike breaches along the rivers have occurred frequently during floods, more in particular during severe winters when ice jams blocked the major streams. There are also well known examples of severe floods by storm surges from the sea, the last major attack was in 1953. During the last 50 years, strong political policy decisions on safety against flooding have determined how flood control measures (coastal defence systems, dike strengthening along estuaries, lakes and rivers) have been designed and implemented. Due to expected climate change, new standards and approaches for adapted policies are considered or already carried out (Room for the Rivers programme). Safety along the major rivers can only be achieved in concert with measures taken by riparian countries in all river basins situated upstream of the Netherlands.

The present map of the Netherlands is fully determined by human intervention with the purpose of flood control and safety. One has to distinguish the rivers and the coastline.

The rivers

Along the rivers, the regulation, normalisation and sometimes canalisation (Meuse, Lower Rhine), in combination with (confined) flood plain management and dike structures (often but not always with a public road on top) have determined safety; as have the controlled discharge distribution over the various Rhine branches Waal, Lower Rhine and IJssel) during all stages at two bifurcations (Pannerdensche Kop, PK; Ijsselkop, IJK) and the artificial drains at the downstream end of the rivers (Nieuwe Merwede, Bergse Maas, Keteldiep/Kattendiep. Note: the normalised major channels of the river branches are state owned; however the land in the flood plains is mostly owned by private people, including foreign landownership).

The coast

Along the coastline, one has to distinguish at least four major systems of coast development (see *Fig. 440*):[92]

1. estuaries and (clay) island fixation in the south west;
2. a closed sandy coastline in the west (dunes);
3. a fully controlled lagoon in the centre with a primary (Afsluitdijk) and secondary (bunds around reclaimed polders) defence system, and
4. land reclamation in between sandy islands and a clay protection dike in the north (Waddenzee).

There is a litoral drift of the tide along the coast in northerly direction, tidal differences fluctuate between the southwest , the centre and the north east between 5m - 1,5m - 4m (see *Fig. 443*).

Levels and kinds of water

The line on *Fig. 441* between Sluis (Zeeuws Vlaanderen) and Eemshaven (Groningen) is exactly 45 degrees to the north arrow. It is a symbol, representing the 0-line (NAP, normal Amsterdam level, the one and only uniform chart datum in the whole country).

Fig. 443 shows the effort of increasing the elevation of dikes above the sea level along this line after the rare desastrous floods of 1953. They are mainly elevated to 4 metres above regular high tide (different along the coast). It shows also the ground level in Holland, as far as Amsterdam being even lower than the bottom of the IJsselmeer. The blue and red bars left in the drawing show the level of rivers and roads, canals and lakes in the polders. This representation indicates the logic of crossings by tunnels rather than by bridges even if the soil is weak, if dikes have to be crossed and if the densely populated area offers many spatial barriers.

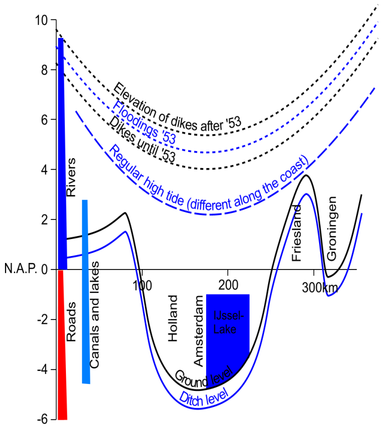

Fig. 443 Levels on the line of Fig. 441[a]

	SURFACE WATER					
	SALT		BRACKISH		FRESH	
	cur.	stag.	cur.	stag.	cur.	stag.
deep	Oosterschelde, Waddenzee	Grevelingen, Veerse Meer	Haringvliet	Biesbosch	Uiterwaarden Maas Uiterwaarden Rijn	IJsselmeer, Oostvaarders plassen
shallow						
bank						
swamp						
bottom						
	GROUNDWATER					

Fig. 444 Kinds of water in the Netherlands[b]

The many resulting kinds of surface water (deep, shallow, bank, swamp, bottom, salt, brackish, fresh, current, stagnant) in the Netherlands are an important basis for its ecological diversity (see *Fig. 444*).

Rainfall and seepage

Heavy rainfall and seepage determine also the design criteria of water management measures in the country. In populated and industrialised areas, a severe rainfall with critical intensity must be pumped out completely within a period of 24 to 48 hours.[93] This urges the need for adequate pumping and drainage systems in the flat and low situated areas where due to wind effects, proper drainage by gravity is impossible; in addition proper maintenance of these systems is necessary. This can only be achieved by proper supervision and effective enforcement, so also the institutional aspect of water management (legislation, rules and regulations, set up of management authorities, finances, skill and staff, etc.) is a matter of crucial importance.

3.2.4 Risks of flooding

February 1995

At Lobith in February normally a water level of approximately 10m NAP and 3000m^3/sec is measured. But in 1995 it was approximately 17m NAP and 12 000m^3/sec, the second highest discharge of the century (1925: 13 000m^3/sec). Evacuation of 200 000 inhabitants was ordered by the Royal Commissioner of Gelderland Terlouw when floods threatened Betuwe area downstream of Lobith. One million cattle had to be moved. It caused extreme traffic jams on roads the like of which had never been envisaged. The dikes barely held out, becoming wetter and wetter.[94]

Active debate on safety

Afterwards, the real threat of inland floods raised public awareness and the need to make plans to increase safety.[c] If the present state of inland dikes and other hydraulic circumstances is not changed, we apparently have to expect threats of a disaster like 1995 twice a century (a recurrence time of 50 years).

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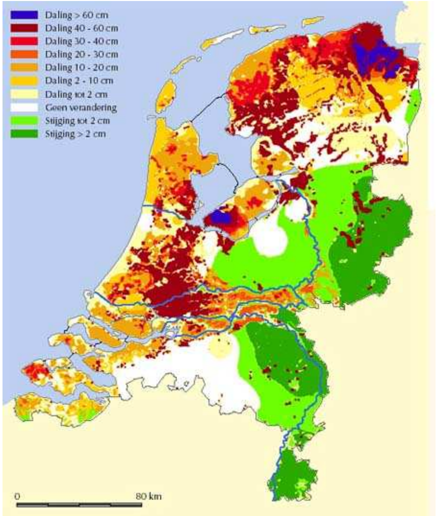
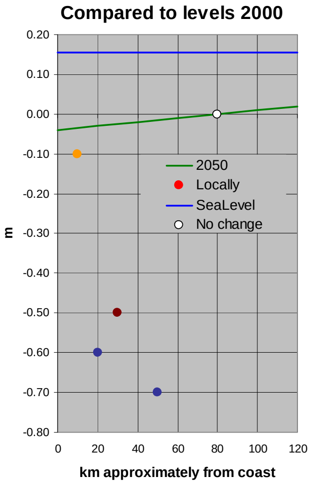
[a] *author Bruin*
[b] *author Bruin*
[c] *http://www.ruimtevoorderivier.nl/upload/WAAL-MAATREGELENBOEK.pdf*





Source:

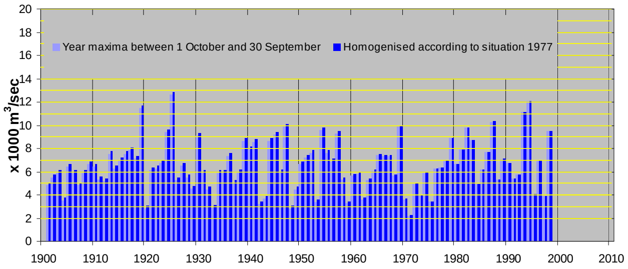
Fig. 445 Subsidence expected by 2050[a]

Fig. 446 Sealevel rise and subsidence expected by 2050

But the hydrological circumstances change. Perhaps we should expect more rain in winter (less in summer) as a result of climate change. Germany and Switzerland have drained their meadows so much, that any rainfall upstream reaches the river Rhine faster than ever. Moreover, the west of the Netherlands faces a general subsidence of at least -3cm until 2050 (locally –70cm, see *Fig. 445*).[95] Increasing the height of dikes along the rivers is necessary, but it does not solve the question how to drain the discharge into the sea while its level rises through climate change (15 cm by 2050?, see *Fig. 446*).

Normal distribution of maximal discharges

Looking at the average yearly maximal discharges[b] of past years (see the 98 years in *Fig. 447*) you can calculate their average maximum discharge (6.6454m^3/sec) and their standard deviation (2.1408m^3/sec) to draw a ‘normal distribution’ based solely on these two numbers (see *Fig. 448*). From that normal probability distribution you can extrapolate the probability per class of 1000m^3/sec wide (see *Fig. 449*).



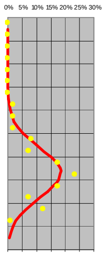


Fig. 447 Extreme discharges of the river Rhine per year

Fig. 448 Probability

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[a] *RWS*

[b] *http://www.rijkswaterstaat.nl/rws/riza/home/publicaties/rapporten/2002/rr_2002_012.pdf*

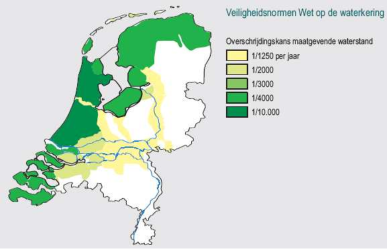
m^3/sec year maximum measured in 98 years		**m^3/sec class**	**probability/year**		**Year/probability (recurrence time)**	
average	**6 645**		➪			
standard deviation	**2 141**		➪			
		>1 000<2 000	0.58%	once in	174	year
smallest observed	2 280	>2 000<3 000	1.77%	once in	57	year
		>3 000<4 000	4.37%	once in	23	year
		>4 000<5 000	8.68%	once in	12	year
		>5 000<6 000	13.87%	once in	7	year
average	**6 645**	>6 000<7 000	17.81%	once in	6	year
		>7 000<8 000	18.38%	once in	5	year
		>8 000<9 000	15.25%	once in	7	year
		>9 000<10 000	10.18%	once in	10	year
		>10 000<11 000	5.46%	once in	18	year
		>11 000<12 000	2.35%	once in	42	year
largest observed	12 849	>12 000<13 000	0.82%	once in	122	year
		>13 000<14 000	0.23%	once in	439	year
		>14 000<15 000	0.05%	once in	1,961	year
		>15 000<16 000	0.01%	once in	10,881	year
		>16 000<17 000	0.00%	once in	75,115	year
		>17 000<18 000	0.00%	once in	644,950	year
		>18 000<19 000	0.00%	once in	6,887,859	year
		>19 000<20 000	0.00%	once in	91,495,720	year

Fig. 449 Normal probabilities per discharge class of the river Rhine

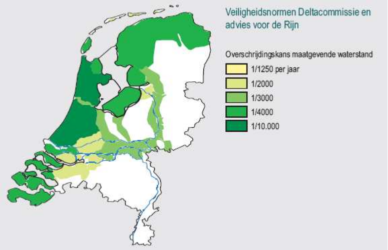
However, that is only a very first approach, because the formula for an asymmetrical distribution (see *Fig. 367*) or a distribution otherwise different from the normal distribution may fit the data better.
The percentages are represented less precisely and eloquently than their reciprocal value: the number of years you can expect between two occurrences of that class (recurrence time). That measure has political value.

Risk acceptance

The Parliament of the Netherlands once decided to accept 1 casualty per million inhabitants per year caused by environmental disasters (accepted risk). So, the number of casualties per class of discharge causing floods has to be calculated to plan the measures to meet the accepted risk of that rare discharge. Which area is flooded by which discharge, and how many people live there? Many studies have been executed to get answers on that question. They make clear that 1 casualty per million inhabitants per year would lead to unacceptable measures producing other kinds of risks. So, the Parliament decided in 1960 to accept the higher risk of a disastrous flooding of rivers once in 1250 years.[96] In other areas surrounded by dikes (dijkringen) that risk acceptance is lower or higher according to their economic value (see *Fig. 450*).



Source:
Fig. 450 Current safety standards for floods (*MNP, 2004*)



Source:
Fig. 451[a] *Proposed changes of safety standards* (*MNP, 2004*)

However the ‘human and economic value’ has increased substantially compared to the costs of water safety management. So, these safety standards are in discussion (see *Fig. 451*).

Calculating and extrapolating recurrence time directly from data

If you number the discharges Q from high to low (rank number r), in 98+1 years of experience the first largest maximal discharge has a recurrence time of 99/1 year, the second (including the first!) 99/2 and so on (see *Fig. 452*).

year	**m^3/sec**	**rank**	**recurrence time**
	Q	**r**	**99/r**
1901	5 058	77	1.3
1902	5 715	68	1.5
1903	6 081	60	1.7
1904	3 731	89	1.1
1905	6 697	44	2.3
1906	6 121	57	1.7
1907	5 058	77	1.3
1908	6 101	58	1.7
…	…	…	…
1925	12 849	1	99.0
…	…	…	…
1992	5 758	65	1.5
1993	11 100	4	24.8
1994	12 060	2	49.5
1995	4 112	84	1.2
1996	7 004	38	2.6
1997	3 912	87	1.1
1998	9 487	11	9.0

Fig. 452 Ranking maximum discharge per year, calculating recurrence time

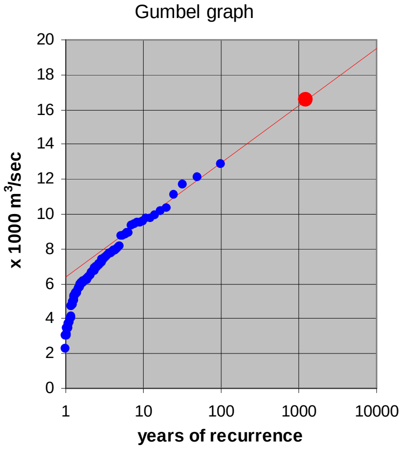


Fig. 453 A Gumbel graph of Fig. 452

If you plot them in a graph with a logarithmic x-axis (Gumbel graph[97], see *Fig. 453*) you can extrapolate the higher discharges to be expected roughly by a straight line.[b] *Fig. 453* shows a discharge of approximately 16 500 m^3/sec recurring every 1250 years with a big spot. So, for any river you can indicate every observation y on that graph if you know the last time that level was reached (x years ago)[c]. Nearly any kind of theoretical probability distribution (like the normal one on page 212) will also produce a nearly straight line for the higher levels in the Gumble graph. That method is used for many kinds of natural disasters like earth quakes and eruptions of vulcanoes.

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[a] *http://www.rivm.nl/bibliotheek/rapporten/500799002.html*
[b] *http://www.humboldt.edu/~geodept/geology531/531_handouts/equations_of_graphs.pdf*
[c] Download Gumble paper from *http://geolab.seweb.uci.edu/graphing.phtml*

However, the slope ‘s’ and elevation ‘e’ of the straight line chosen have great effect. In *Fig. 453* a line with formula $Q(r) = s \cdot \ln(r) + b$ m^3/sec was chosen, where s = 1.43 and e = 6.36.[a]

3.2.5 Measures to avoid floods

Inundation?

One of the proposed measures is, to inundate indicated polders preventively in case of emergency. But a 1m deep polder of 1km^2 (1 000 000m^3) would store 12 000m^3/sec water only for 83 seconds at least if it is not sloping. In case of sloping you should half that capacity. If you would like to store 16 000m^3/sec during a week to be safe for many centuries because you cannot discharge that amount into the sea because of sea level rising after these centuries, you need 10 000km^2 (a quarter of the Netherlands). However, you can reduce the needed storage because you still can discharge into the sea, be it at low tide or by huge pumps. But this simple and much too rough calculation shows at least the dimensions of the problem.

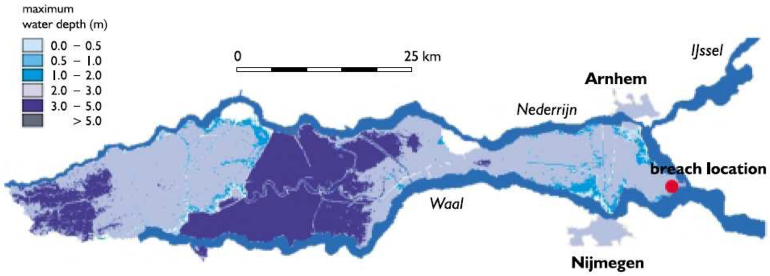

Fig. 454 Maximum water depth during a flooding in Betuwe along the Rhine after a dike breach and a peak discharge of 18.000 m^3/s[b]

Other measures

So, construction of retention basins or more general widening of the riverbed in the Netherlands solely cannot be a substantial solution to avoid rare flooding in a river system. Dikes along the rivers have to be heightened, but which height is enough? Deepening the river (filled up quickly with sediment) or making the dikes higher increases the capacity to discharge, but moves the problem to the west where more people live. So, retention in the Rhine basin upstream has to increase to avoid extreme situations downstream. This is discussed by the international Rijncommissie Koblenz.

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[a] *http://team.bk.tudelft.nl/* > publications 2006 Hydrology.xls

[b] *http://www.ncr-web.org/downloads/NCR18nl-2002.pdf*

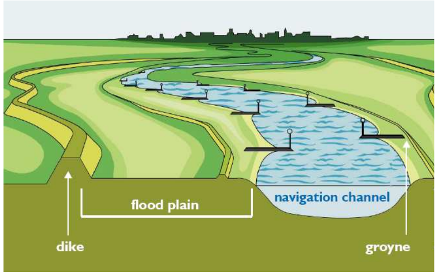

Fig. 455 Schematic representation of a low land river[a]

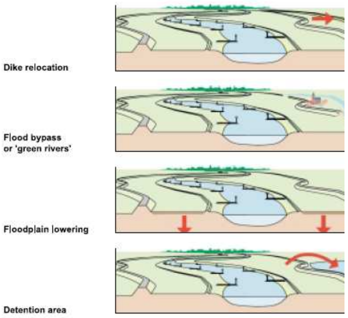

Fig. 456 Measures improving Rhine discharge[b]

How to design for floods?

To be prepared for floods a landscape will have to be designed mainly as a natural area (see *Fig. 457*).

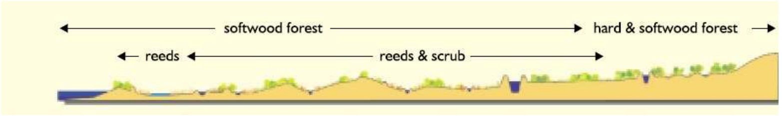

Fig. 457 Anticipated vegetation structure and land use along the Dutch Rhine as a 'green river'[c]

Room for the river

On 19 December 2006 the Dutch Parliament accepted a Spatial Planning Key Decision (SPKD, in Dutch: Planologische Kernbeslissing PKB) concerning a series of measures along the rivers known as 'Room for the river' (see *Fig. 458*). However, the final set of measures should be determined by commitment of local stakeholders and administrators. To get that commitment Delft Hydraulics has developed a game to determine the effects of any single measure in solving the problem[d].

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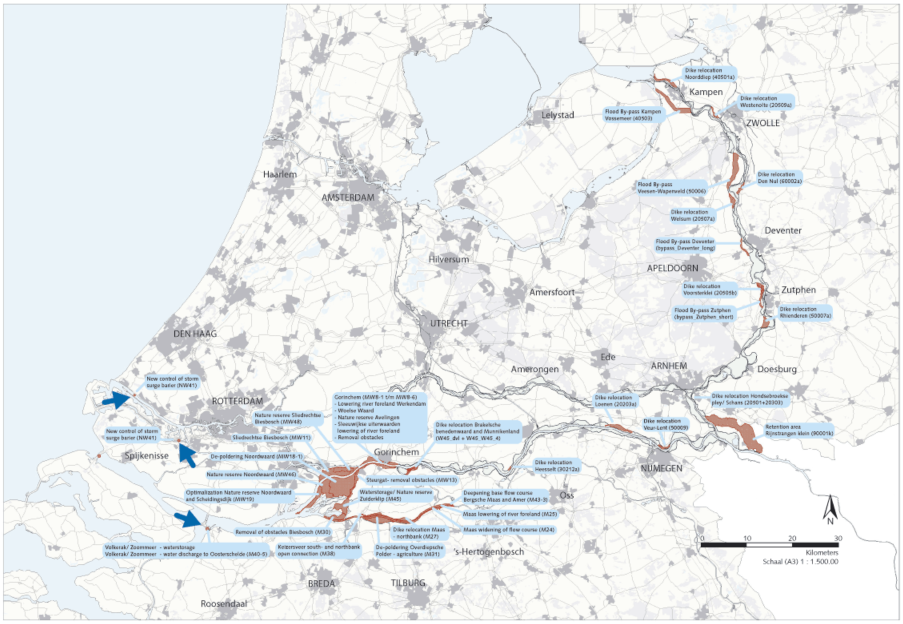
[a] *http://www.ncr-web.org/downloads/NCR18nl-2002.pdf*

[b] *http://www.ncr-web.org/downloads/NCR18nl-2002.pdf*

[c] *http://www.ncr-web.org/downloads/NCR18nl-2002.pdf*

[d] *RWS d*ownload from *http://www.wldelft.nl/soft/blokkendoos/*



topografische ondergrond (c) Topografische Dienst Emmen

Fig. 458 A series of measures known as 'Room for the river'[a]

3.2.6 Coastal protection

Disasters stimulating major civil engineering works

As shown in the sketch map of the Netherlands (see *Fig. 440*), there are various major coast forms, differing fundamentally. For the design, strengthening and maintenance of the coastal defence, all these major forms need continuously specific tailor made attention. A universal fact is that disasters are needed to make progress. Also in coastal water management, tragic disasters have determined human intervention in developing the Dutch coast line. One can refer to the big flood in the southern part of the former Zuiderzee in 1916, when severe flooding occurred causing nearly 20 deaths and huge damage; this disaster accelerated the political approval of starting the Zuiderzeewerken (Zuiderzee works) designed by Lely. And of course the storm surge on February 1st, 1953, which initiated the Deltawerken (Deltaworks).

History

In the past, coastal and river works were done by trial and error and on a relatively small scale. If the works that needed to be done were simply too big and complicated, land was given up (again). In those days, coastal engineering was more or less a matter of ''If we cannot do what we want, we will do what we can.''. Apart from not having proper large tools, current knowledge and practical experience were not enough to justify efforts in coastal development on any sort of large scale. Fundamental coastal research and model investigations were only developed in the Netherlands from the early 1930s. At that time, three major civil engineering works were developed, i.e. the Afsluitdijk (Enclosure dike, whereby the 'Zuiderzee' was renamed the 'IJsselmeer'), the big lock for seafaring vessels at IJmuiden at the end of the Noordzeekanaal (North Sea Canal) and the completion of the Maaswerken (Meuse works; Julianakanaal locks, with the biggest head in the country). Till then, water related research for Dutch clients was often done abroad, for example in Karlsruhe (Rehbock laboratory).

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[a] *http://www.ruimtevoorderivier.nl/*

Zuiderzeewerken and Afsluitdijk

The preparations and design for the Zuiderzeewerken in the 1920s urged the need for developing a good mathematical basis for proper tidal computations, to be able to predict with sufficient accuracy changes in water levels along the coast of the Wadden Sea after the closure of the Afsluitdijk. In this respect in particular one name must be mentioned: Lorentz. He developed modern tidal calculations, needed to estimate the impact of the Zuiderzee works (Afsluitdijk) on the tidal regime along the northern Dutch coastline. In fact, one can conclude even after 75 years that the sandy bottom of the Wadden Sea has still not reached a new equilibrium since the closure in 1932, due to the severe changes in the tidal movements as introduced by human intervention at that time.

3.2.7 The Delta project

For all major infrastructure, political approval is necessary by means of a special law being adopted by Parliament. Such a law not only describes the need for the work itself, but also the financing and how institutions are required for design and implementation. The Delta Act was adopted in 1956, three years after the February ’53 surge. At the time, repair to the damage and building of new structures was already going full speed ahead. So in fact the financing of those efforts had not yet been approved by Parliament till 1956. The country was in a sense at war, so military means were accepted. For nearly 25 years (in the period 1953 – 1977), the execution of the solid dams in the south west was never a real political question: the need for implementation was simply a political fact because ‘safety first’ was the guiding motive after the disaster in ’53 when about 1850 people were killed. Only in the mid-seventies, when the last episode of the Deltaworks scheme started with the closure of the Oosterschelde (Eastern Scheldt), socio economic and environmental changes on a national scale prompted the need for a complete revision of the engineering approach to this major work (*Fig. 459*) showing many innovative coastal constructions.

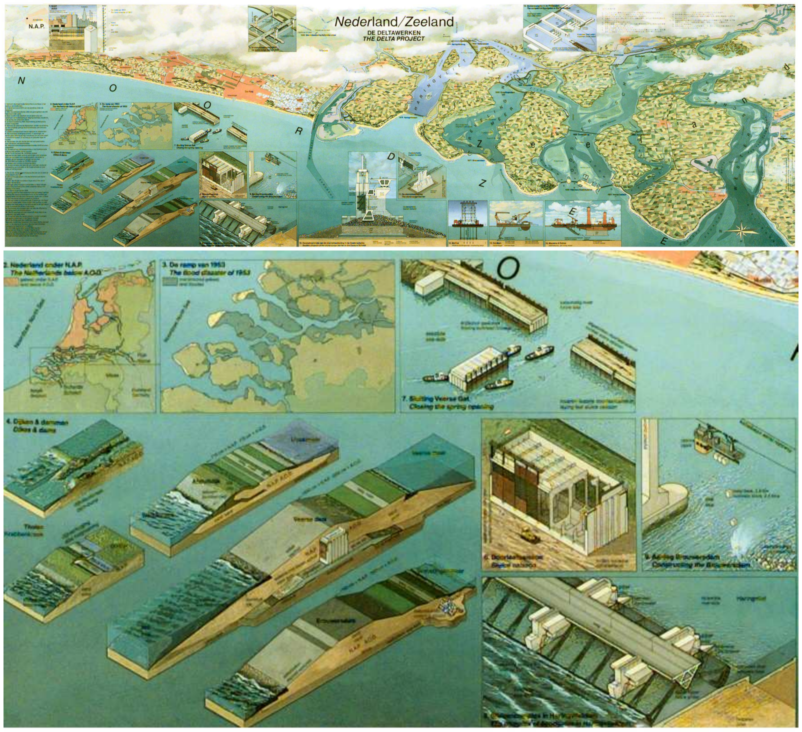

Fig. 459 Delta project[a]

A variety of interventions

It is remarkable to notice the huge level of human intervention since 1953, needed to close the estuaries in the south west. As the crow flies over a distance of about 100 km between Hook of Holland and Cadzand/Belgian border, 9 different ways have been used for closing off tidal creeks and estuaries, involving (systems of) primary dams (years as mentioned indicate year of commissioning). From north to south they are: the Nieuwe Waterweg (floating movable barrier, 1998), Brielse Maas (sand supply, 1952), Haringvliet (sluices, dam and by passing lock, 1970), Brouwersdam (caissons and cable, 1968), Oosterschelde (open barrier, 1986), Veerse Gat (caissons, 1961), Westerschelde (open estuary, dike strengthening, 1985), Braakman (sand supply, 1951), and Zwin (gradually closed by natural phenomena).

In addition there are 6 other solutions for the closure of so called secondary dams (some of them located on a former tidal slack) in the Deltaworks scheme, for example the Hollandse IJssel barrier (a main steel gate and a second one just for safety reasons in case the first one has a failure, 1956), the Volkerakdam (caissons plus major locks, and sluices (1969), Grevelingen (cable, minimising the tidal volume in the Brouwershavense Gat before closure (1961), Krammerdam (major locks with a sophisticated salt/fresh water control system, 1982), Markiezaatdam (compartment dam of clay and sand with a lock, to minimise the tidal volume at the Oosterschelde barrier and to control water quality in the Scheldt-Rhine canal, around 1980), Zandkreekdam (sand supply, minimising the tidal volume in the Veerse Gat before closure, 1960). To complete the variety of closure works in this part of the Netherlands, one must also mention the Sloedam and the Kreekrakdam, both needed for the railway connection to Vlissingen (clay and sand dams, 1870).

Funding

Considering all this, in the 20th century the Dutch have reached apparently a point that can now be characterised as ‘we can do what we want”. Such a huge and costly scheme could only be

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[a] *Hettema and Hormeijer, 1986*

implemented because the Dutch society was prepared to allocate the necessary funds from its own resources, so political support remained consistently positive. On the other hand: if a country in the Third World were to ask a donor organisation (for example the World Bank) to finance a closure scheme in a complicated tidal area with at least ten solutions, this would never been accepted. Such an investment for the safety of only 200,000 inhabitants behind the structures is according to present standards of international donor organisations simply NOT considered as feasible (!).
Note that in 1990, Rijkswaterstaat was awarded the Maaskant Prize for the Deltaworks, in particular for the way the whole project is flexible in its spatial planning and technical set up, and for the way it has proven to be useful also for new sectors developed after the period of design and execution, for example leisure and environment. For more general information on these works, see the jury report.

3.2.8 The central coast line

The centre coast line of the Netherlands between Hook of Holland and Den Helder can be characterised by a system of sandy dunes. Because of the lateral drift in northerly direction along the coast, there is some continuous ongoing erosion of the sandy coastline(see *Fig. 460*). The effect over time is visible at the Hondsbosse Zeewering, where the original tow of the revetments at the seaside was constructed (stone construction, 1875) in line with the low water line on the beach in those days. Today, the low water coastline has moved over about 70 m in easterly direction.

Sand transport

In 1991, Parliament adopted a coastal defence law, giving the green light for regular sand supply (beach nourishment) to maintain the position of the low water line as it was in 1991. Since then, year after year, at some places along the entire coast, nourishment works are carried out outside the tourist season. Like the closure of the IJsselmeer by the 30km Afsluitdijk in 1932 this major project of the fifties caused changes of yearly natural sand transport in the North Sea and Wadden Sea The sand moved mainly from the inland waters as growing islands in front of these works. To stabilise protruding beaches and islands, large amounts of sand from the sea had to be added artificially to these beaches(see *Fig. 461*).

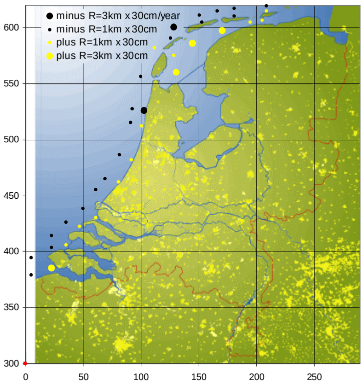

Fig. 460 Natural yearly sand transport[a]

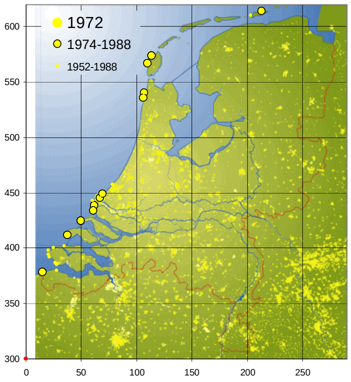

Fig. 461 Artificial incidental sand supply[b]

Fresh water in dunes

Over their entire length, the sandy dunes are important for building up and maintaining a ‘fresh water bubble’ in the sub soil, floating on the salt groundwater underneath. This fresh water system is an extra (groundwater) protection against salt intrusion in critical areas behind the dunes, for example the Westland. In many cases, the fresh water volume in the dunes is artificially kept above certain levels for drinking water supplies in the west. The inlet water originates from the major rivers in the country, Rhine and Meuse, and is pumped through pipelines.

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[a] *After: Waterman, 1992*
[b] *After: Waterman, 1992*

A special development is de Kerf, west of Schoorl (Noord-Holland). There, in the late nineties, the primary dune ridge was artificially cut to allow the penetration of salt water during rather high tides (about twice a year). The environmental development and habitat have been carefully studied and followed by many institutions since then.

The Afsluitdijk

The Afsluitdijk is presently being renovated, to meet the recent standards for flood protection and safety/reliability. Also the capacity of the sluices may be increased shortly. Sluices, bridges across the locks bypassing the sluices, and dike (alignment) had special design criteria for military reasons. They really have worked: in 1940, Kornwerderzand was the only place in Holland where the invaders could not get through. In the original design of the dam, space was reserved for the construction of a rail track as well. A deep cut for the planned track is still visible on the former island of Wieringen, alongside the motorway to Den Helder. The excavated clay from that deep cut has been used for the creation of the last refuge hill (terp) built in the Netherlands to date; at Wieringerwerf in the Wieringermeer. Indeed it was used by some locals after the German army blew up the surrounding polder dike at the end of WWII. Today, on top of that ‘terp’ there is a public swimming pool (again the world upside down).

3.2.9 The northern defence system

The sea defence system in the north is rather complicated, because of the sandy islands, the Wadden Sea with all its environmental and morphological extremes, the so called old ‘Landaanwinningswerken’ and the strengthened long clay sea defence dike between the Afsluitdijk and the Dollard. For the purpose of this chapter, the most interesting aspects are the auxiliaries in the sea coastal defence system, for example the ferry terminals, harbour law outs and terminal structures, the various breakwaters (Harlingen, Delfzijl), navigational aid systems, and the leisure facilities. They all can be used as informative and illustrative examples when designing a specific issue in relation to coastal engineering aspects. Whatever further intervention will be needed in the near future, the fact is that for the 21st century the situation of designing and constructing large scale works can now be described as ‘are we still allowed to create what we can?’.

The historical value of the northern islands

Finally, a last aspect when it comes to coastal engineering, the logistics of the execution and implementation of impressive works. It deals with the supply of material in isolated and so far undeveloped areas. This can be illustrated with two examples from the past. For more modern and contemporary equivalents, everyone can use their common sense.
First, when visiting the Wadden islands in the north, many brick houses can be seen that have been built through the ages. This is remarkable, because there have never been brickyards on the islands. Even some lighthouses, like the famous Brandaris (Terschelling), were constructed exclusively with bricks. One may wonder where originally all those bricks came from.

This has everything to do with the flourishing Hanseatic League in the past. Wooden sailing vessels came from the Rhine basin, heading for the Hansa cities in the north and beyond (Baltic Sea). Bricks were transported by ship from brick yards in the river area (flood plain), and handled manually. In those days, where no machinery existed, this was done stone by stone by so called head loading. More astonishingly, each stone of the Brandaris light house must have been handled this way at least six times (or most probably even more), when being moved between the brick yard somewhere in the flood plain to its final place in the structure. En route they were brought on rather small vessels over dangerous and difficult waters.

Second, a similar development can be seen on a larger scale, for distant overseas destinations. The VOC vessels in the 17th-18th century took bricks as ballast on their journey from Holland to the Far East, for example to present-day Jakarta. When visiting the city today, one can still see the typical bricks and tiles of Dutch origin, used in the construction of buildings there.

Design with nature

To stimulate local inland movement of sand and clay from the sea (stopped after these ‘hard’ defence works) the policy of coastal defence has changed gradually into a ‘design with nature’ approach.

Fig. 462 Slufter on the isle of Texel[a]

This involves opening up some ‘hard’ defences where it is safe (slufters) allowing the sea to come in, bringing sand and clay into these calm inland waters causing the development of beautiful dynamic natural areas calling the original state of the Netherlands to mind.

3.2.10 Polders

3.2.11 Need of drainage and flood control

History

Wetland areas may need drainage to be used for living and agriculture. The draining was started to obtain more space for these activities. The first method of draining was with the help of open ditches and trenches. The water was drained by sluices on lower lying waterways like rivers or at low tide at the sea (see *Fig. 463*). Later when the difference in height of water between the drainage area and the river or sea became too small or even negative, the land was drained by pumps (see *Fig. 464* and *Fig. 470*).

A polder is a piece of land that forms a hydrographical entity. In low lying areas a polder is surrounded by embankments or dikes. Even a lake can be transformed into land (see *Fig. 463*).
This reclamation is also called a polder because the groundwater level is managed in an artificial manner. Such land reclamations are always situated below the surrounding water level.

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[a] *Google Earth*

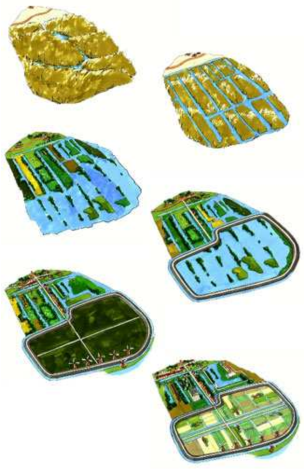

Fig. 463 A short history of polders[a]

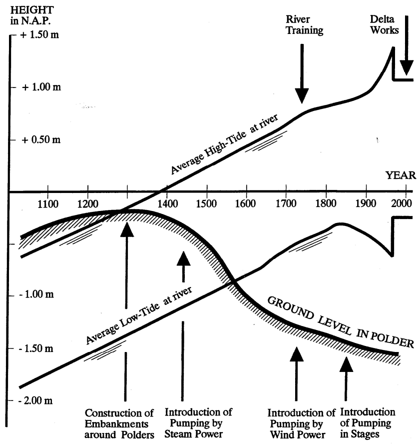

Fig. 464 Rising outside water levels and dropping ground levels[b]

Draining an area starts a process of changes in the soil. The ground level will settle and drop depending on the type of soil. Peat soil will actually totally disappear by chemical processes and the ground level will be lowered by the equivalent of the thickness of the peat layer. Also the introduction of better methods and pumps will lower the groundlevel (see *Fig. 464*).

Desired groundwater levels

It is obvious that since the groundwater level is managed artificially , there are several desirable groundwater levels. The depth of the groundwater level depends on the activity that will take place in that area and the type of soil. For grassland a high groundwater level is no problem for growing, but having cattle on that land will be more problematical as the cattle will destroy the grass by walking on it and no food will be left. For crops the depth of the groundwater level is dependent on the type of crop. Grasslands may be wetter, dryland crops should be dryer than 1m below terrain (*Fig. 465*

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[a] *Source unknown*
[b] *Ankum, 2003; page 71*

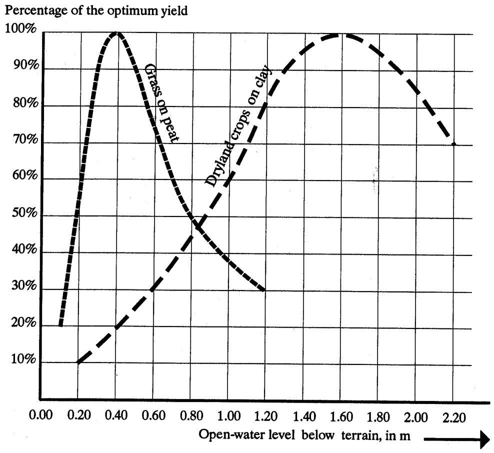

Fig. 465 Crop yields for different open water levels[a]

Urban areas

For urban areas the groundwater level is kept at approximately 1m below ground level for different reasons such as foundations and wet crawl spaces. Also the construction of cables and pipes in the streets is easier under dry circumstances.(see *Fig. 466*).

Fig. 466 Flooding of a canal in Delft[b]

Fig. 467 Deep canal in Utrecht

Urban areas need dry crawl spaces to keep unhealthy moist out of the buildings but they need wet foundations as long as they are made of wood. Groundwaterlevel is often recognisable from open water in the area. In higher parts of the Netherlands like in Utrecht canals show a level of several metres below ground level (see *Fig. 467*).

The distribution of polders worldwide

Lowlands with drainage and flood control problems cover nearly 1million km^2 all over the world (Fig. 468) and nearly half the world population lives there because of water shortages elsewhere (RWS (1998).

x1000 km2	1 crop	2 crops	3 crops	Total
North America	170	210	30	400
Centra America		20	190	210
South America	60	290	1210	1560
Europe	830	50		880

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[a] *Ankum, 2003; page 53*

[b] *Paul van Eijk*

Africa		300	1620	1920
South Asia	10	460	580	1050
North and Central Asia	1650	520	20	2190
South-East Africa			530	530
Australia		310	120	430
				9170

Fig. 468 *Area of lowlands with drainage and flood control problems*[a]

3.2.12 Artificial drainage

Inhabited or agricultural areas below high tide river or sea level (polders) have to be drained by one way sluices using sea tides or pumping stations (see *Fig. 470*, *Fig. 473*).
Fig. 469 is the oldest known example of draining by one way sluices at low tide dating from the 11th century.

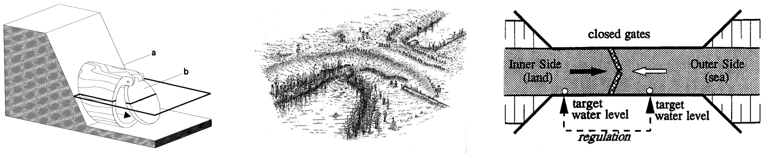

Fig. 469 *The oldest one way sluice found in the Netherlands and its modern principle*[b]

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[a] *Ankum, 2003, page 2*
[b] *Ankum, 2003, page 68 and 38*

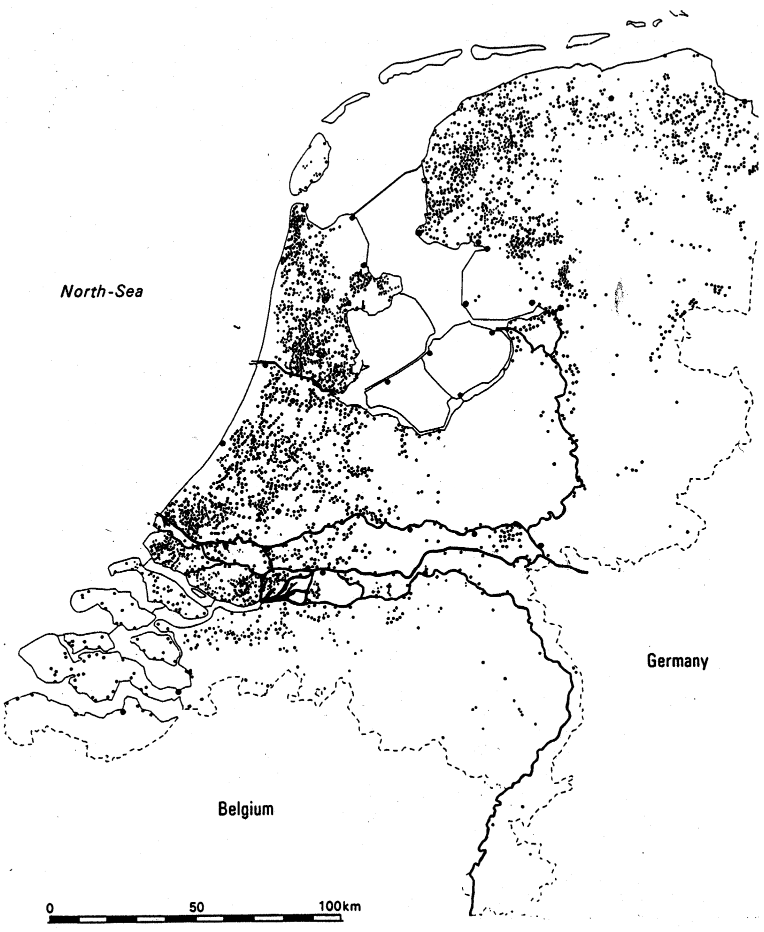

Fig. 470 Pumping stations in the Netherlands[a]

One way sluices lose their purpose when average sea and river levels rise and ground level drops mainly because of the subsidence of peat polders (*Fig. 464*). Drying peat oxidates and disappears and so the ground level of the polder will drop below river or sea level.

The area is divided in smaller entities or compartments that are surrounded by belt canals (boezemkanalen), protected by dikes and internally drained by races (tochten), main ditches (weteringen), ditches (sloten), trenches (greppels), and pipe drains. As the system of outlet canals(boezemkanalen) transports the water from the land to the river or the sea and they are all connected with each other it is also possible to use these waterways for shipping. The area is made accessible for shipping traffic by locks.

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[a] *Ankum, 2003, page 78*

Compartments

Fig. 471 shows the belt system of Delfland and the compartments. Each compartment has its own sluice or pump and outlet canal or 'boezem'.

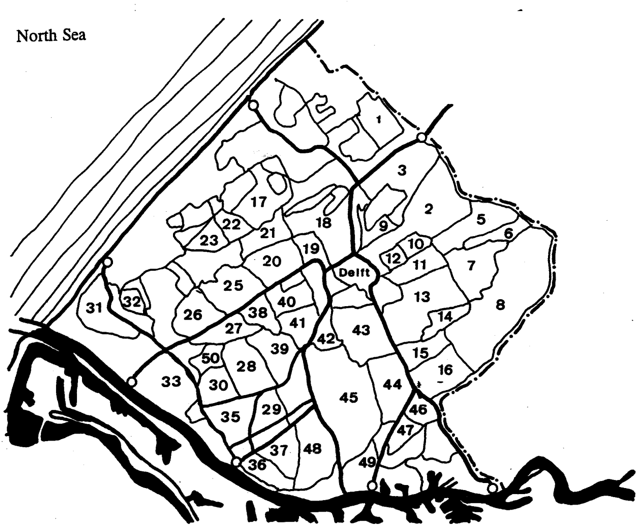

Fig. 471 The belt ('boezem') system of Delfland[a]

Methods of impoldering or pumping step by step

The reclamation and drainage of the polders is done by pumps. The pumps are driven by wind, steam or electricity depending the technical knowledge of the time. The methods used depend on the depth of the polder. Draining marshland is often done by one step of pumping or even by a one way sluice when the land is adjacent to a tidal river or the sea. But after settling of the soil in the course of time it can be necessary to use more steps for pumping. Especially when the only force to drive the pumps was by wind, rows of windmills were used for draining the polder. The most famous row of windmills in the Netherlands are those of Kinderdijk in Zuid Holland.

The methods used for draining polders with different altitudes are pumping at once from the deepest part using gravity by collecting first the water from the deepest level or draining step by step compartments separated by dikes and weirs saving potential energy (*Fig. 473*).

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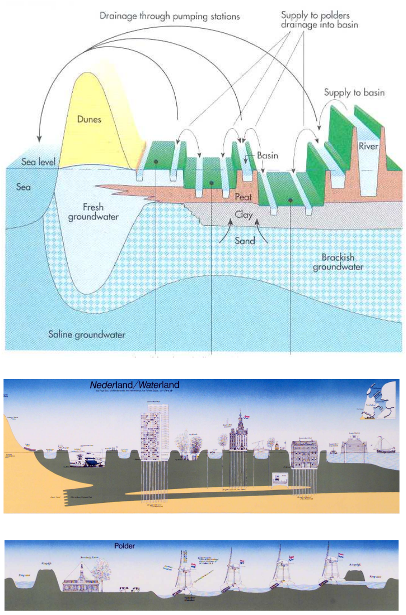
[a] *Ankum, 2003; page 62*



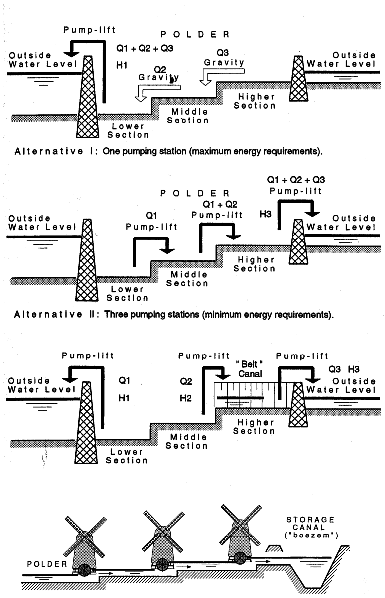


Fig. 472 Lowland system[a]

Fig. 473 Drainage by one to three pumping stations, in earlier times by a 'row of windmills' ('molengang')[b]

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[a] *Huisman, Cramer et al., 1998 page 36 ; Veer*
[b] *Ankum, 2003; page 76 and 55*

3.2.13 Configuration and drainage patterns of polders

Polders are optimally drained by a regular pattern of ditches (see *Fig. 474*, *Fig. 475*).

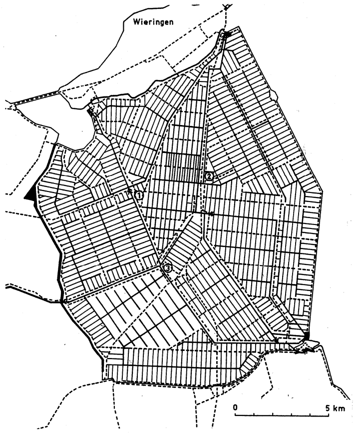

Fig. 474 Wieringermeer polder[a]

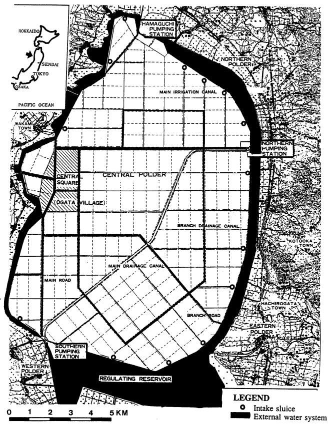

Fig. 475 Hachiro Gata Polder in Japan[b]

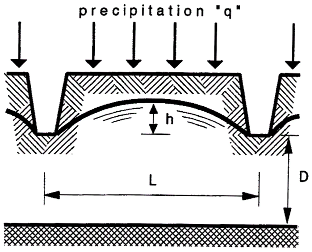

Fig. 476 Variables determining distance L between trenches[c]

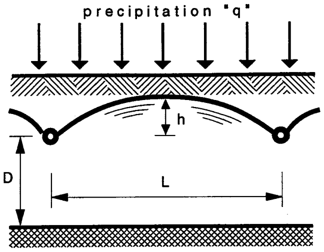

Fig. 477 Variables determining distance L between drain pipes[d]

Calculation of distance for drains in a polder

The necessary distance L between smallest ditches (see *Fig. 476*) or drain pipes (see *Fig. 477*) is determined by precipitation q [m/24h], the maximum acceptable height h [m] of ground water above drainage basis between drains and by soil characteristics. Soil is characterised by its permeability k [m/24h] (see *Fig. 478*).

$L=2\sqrt{(2kh/q)}$ is a simple formula to calculate L. If we accept $h=0.4$m and several times per year precipitation is 0.008m/24h, supposing $k=25$m/24h the distance L between ditches is 100m.

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[a] *Kley 1969*

[b] *Ankum, 2003 page 42 and 82*

[c] *Ankum, 2003; page 36*

[d] *Ankum, 2003; page 36*

Type of soil	***Permeability k in m/24h***	
gravel	>1000	
coarse sand with gravel	100	1000
coarse sand, fractured clay in new polders	10	100
middle fine sand	1	10
very fine sand	0.2	1
sandy clay	0.1	
peat, heavy clay	0.01	
un-ripened clay	0.00001	

Fig. 478 Typical permeability k of soil types

However, the permeability k [m/24h] differs per soil layer.
To calculate such differences more precisly we need the Hooghoudt formula described by Ankum (2003) page 35.

3.2.14 Drainage and use

Parcel ditches are used as property boundaries. In this way agricultural and urban activities are easily to separate from each other. Any use has its own requirements for parcel division. Systems of parcel division have to take dry infrastructure into account. Different network systems have to be combined in the polder for a good completion of drainage as well traffic.

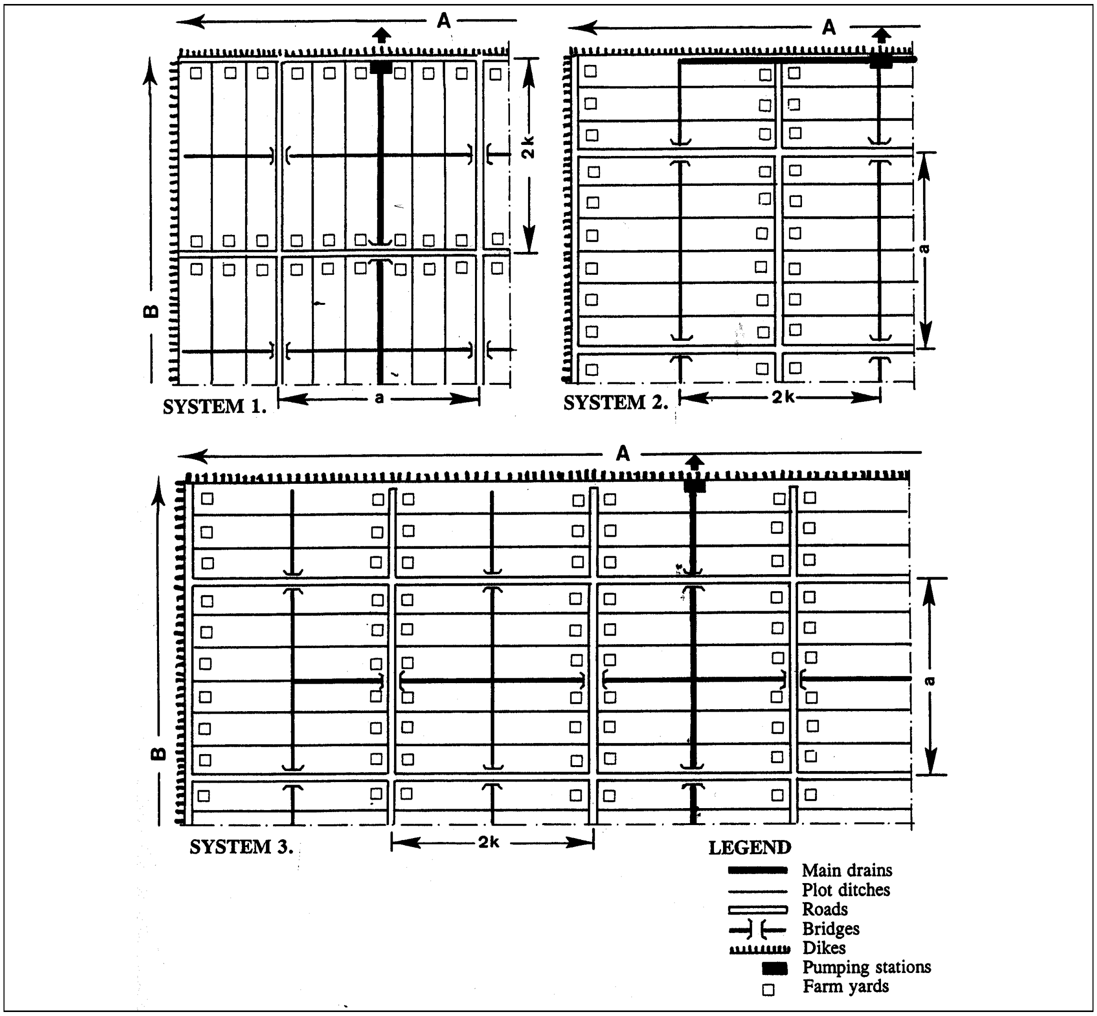


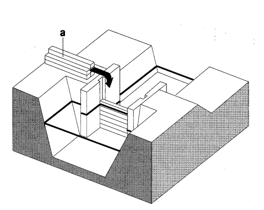
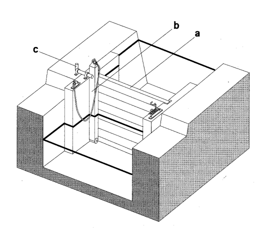
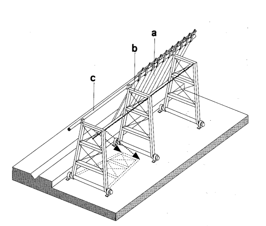
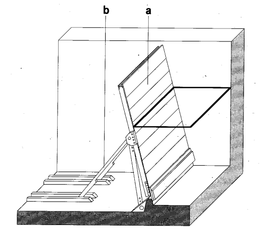
Fig. 479 *Alternative systems of plot division in polders*[a]

We will elaborate that in 3.4.16.

3.2.15 Weirs, sluices and locks

There are many types of water level regulators elaborated by Arends (1994) (Fig. 480, Fig. 481, Fig. 482).

Weirs

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[a] Ankum (2003) page 59

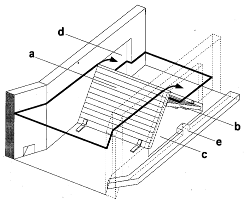
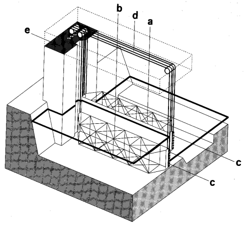
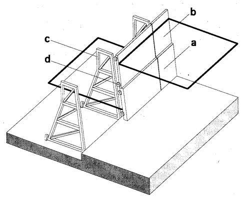
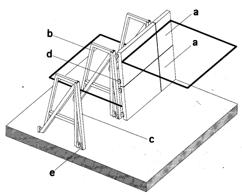
Schotbalkstuw	Schotbalkstuw met wegklapbare aanslagstijl	Naaldstuw	Automatische klepstuw
			
Dakstuw	Dubbele Stoneyschuif	Wielschuif rechtstreeks ondersteund door jukken	Wielschuif via losse stijlen ondersteund door jukken

Fig. 480 *Types of weirs*[a]

Sluices

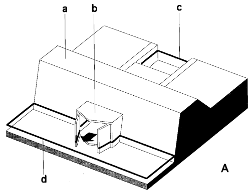
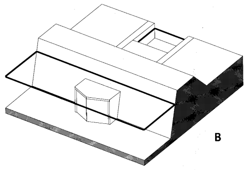
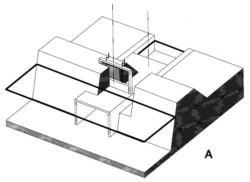
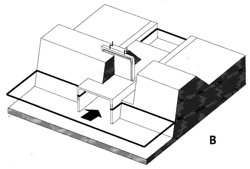
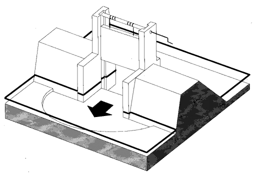
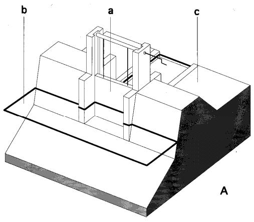
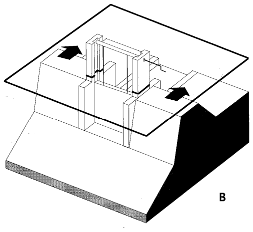
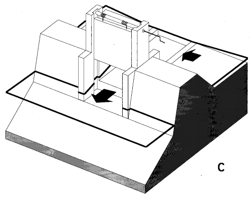
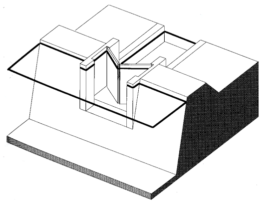
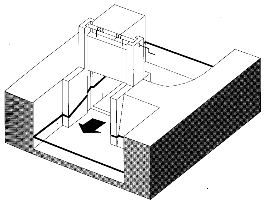
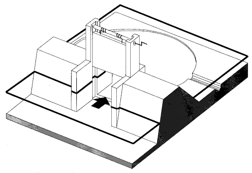
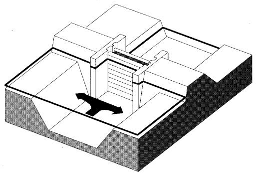
			
Uitwateringssluis open	Uitwateringssluis closed	Inlaatsluis open	Inlaatsluis closed
			
Irrigatiesluis	Ontlastsluis closed	Ontlastsluis flooded	Ontlastsluis open
			
Keersluis	Spuisluis	Inundatiesluis (military)	Damsluis (military)

Fig. 481 *Types of sluices*[b]

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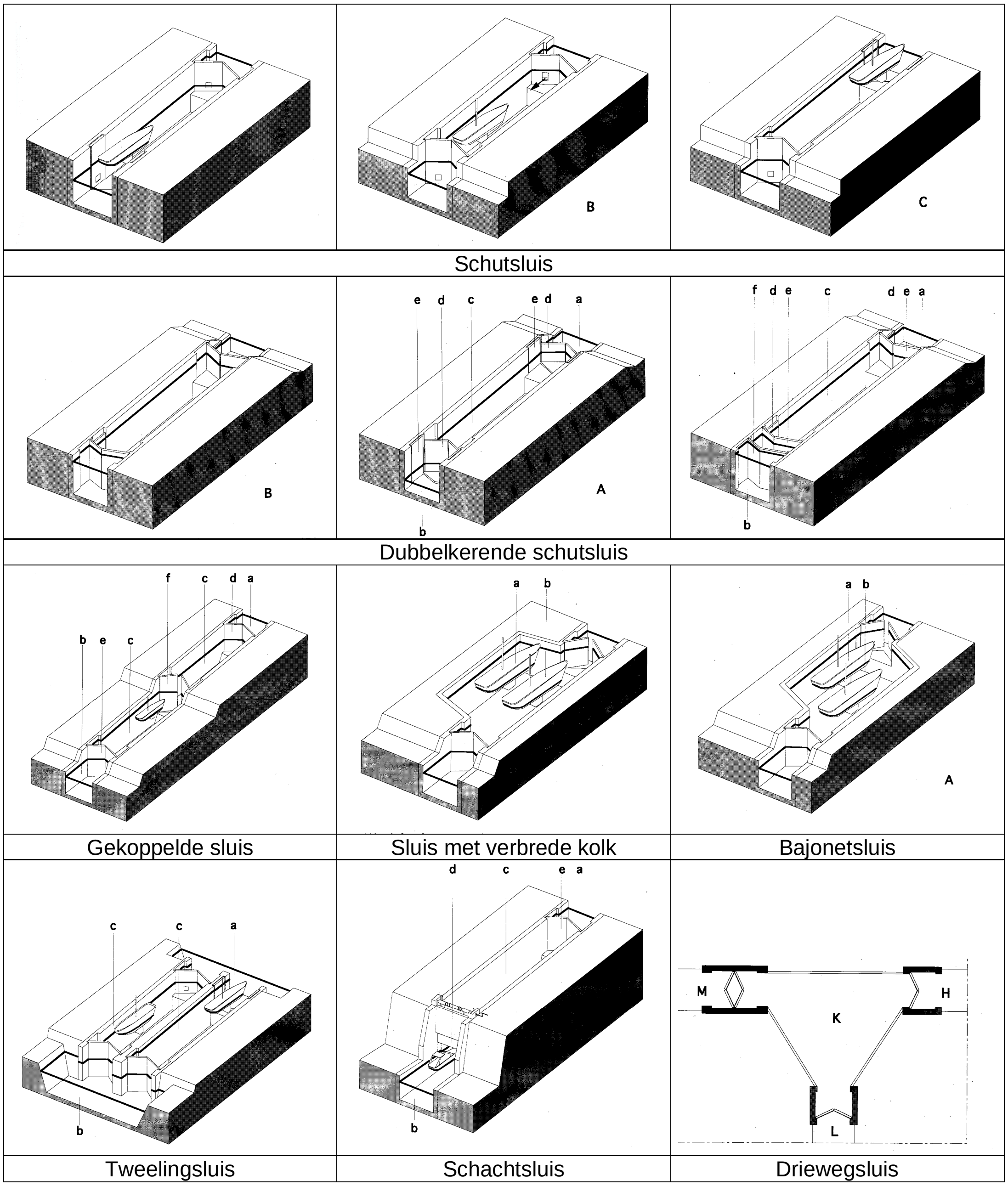
[a] Arends (1994)
[b] Arends (1994)

Locks

To allow accessibility of shipping traffic you need locks at every transition of water level.



Schutsluis

Dubbelkerende schutsluis

Gekoppelde sluis

Sluis met verbrede kolk

Bajonetsluis

Tweelingsluis

Schachtsluis

Driewegsluis

Fig. 482 *Types of locks*[a]

Entrance and exit

Any regulator, culvert, sluice, lock or bridge requires a structure with entrance and exit of water needing space themselves (Fig. 483).

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[a] Arends, G.J.(1994) Sluizen en stuwen (Delft) DUP Rijksdienst voor de Monumentenzorg

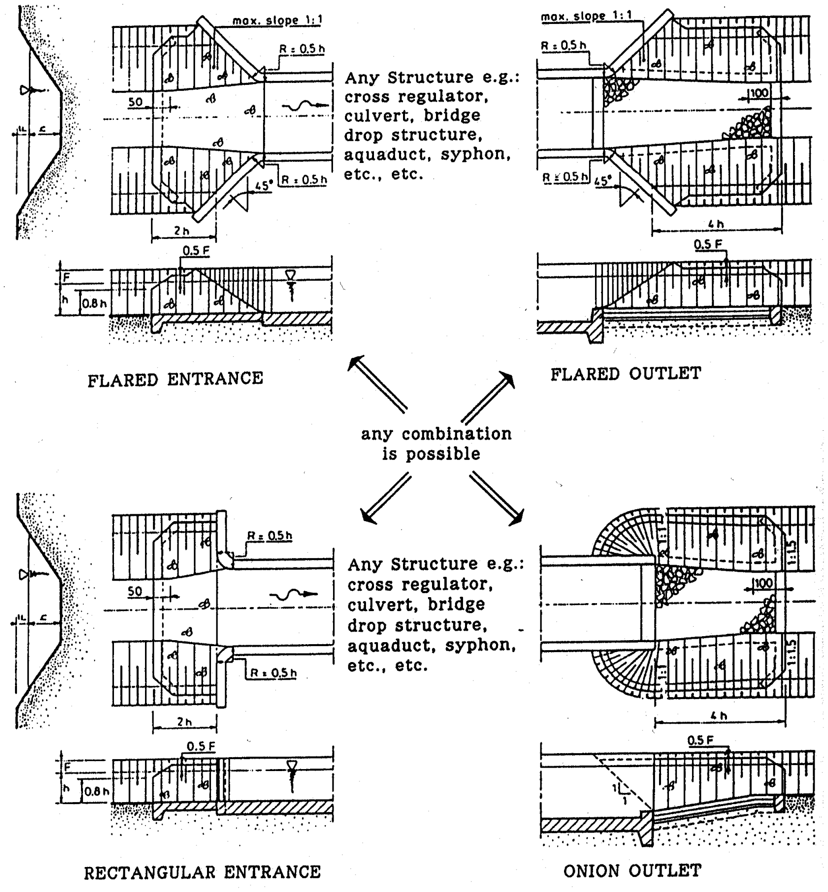

Fig. 483 *Samples of the 'entrance' and 'exit' of a structure*[a]

3.2.16 Water management tasks in the landscape

Civil engineering offices are involved with many water management tasks (see *Fig. 484*).

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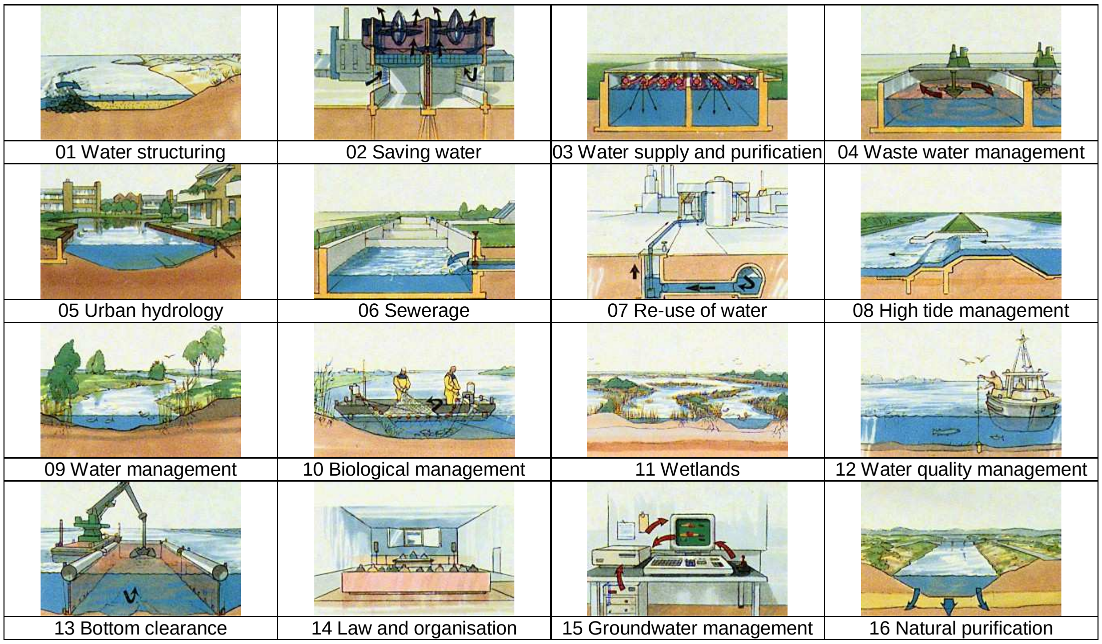
[a] Ankum (2003) page 164



01 Water structuring
02 Saving water
03 Water supply and purificatien
04 Waste water management
05 Urban hydrology
06 Sewerage
07 Re-use of water
08 High tide management
09 Water management
10 Biological management
11 Wetlands
12 Water quality management
13 Bottom clearance
14 Law and organisation
15 Groundwater management
16 Natural purification

Fig. 484 Water managemant tasks in lowlands[a]

3.2.17 Local water management maps

For a long time now, maps have existed of The Netherlands showing the areas governing their own water management (Waterschappen)[b], and their drainage areas (*Fig. 485* above). Overlays show hydrological measure points (*Fig. 485* below left) and the supply of surface water (*Fig. 485* below right).

RWS (1985)

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[a] *Das (1993)*

[b] *http://www.uvw.nl/pagina_6390.html*

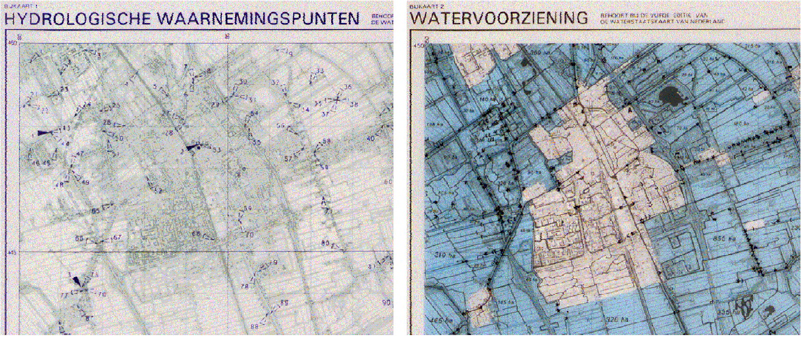

Fig. 485 Hydrological maps of Delft and environment[a]

On the first map you can find the names of compartments, pumping-stations, windmills, sluices, locks, dams, culverts, water pipes. However, these maps are no longer available in hardcopy anymore by fast development of GIS in the nineties.

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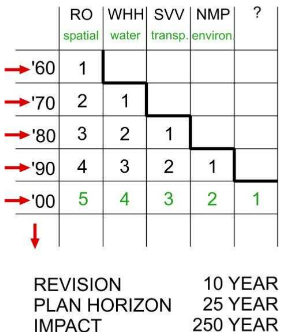
[a] *RWS, 1985, 1984*

3.3 Water policy

3.3.1 Coordination of different administrative sectors

The storage of water in the lower parts of The Netherlands will put heavy demands on the surface. The 4th National Plan of water management policy V&W (1998, stressing environment), and its successor 'Anders omgaan met water' V&W (2000) (stressing security) marked a change from the accent on a clean to a secure environment, as did the 4th National Plan of environmental policy VROM (2001) compared with its predecessors. Several floods in The Netherlands and elsewhere in Europe have focused the attention on global warming and water management. The future problems and proposed solutions are summarised in the figures below. Storage is a central item in reducing the risks for lowlands.



	RO spatial	WHH water	SVV transp.	NMP environ	?
'60	1				
'70	2	1			
'80	3	2	1		
'90	4	3	2	1	
'00	5	4	3	2	1

REVISION 10 YEAR
PLAN HORIZON 25 YEAR
IMPACT 250 YEAR

Fig. 486 Dutch Policy documents

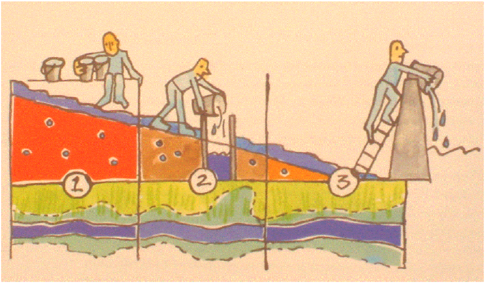


Fig. 487 Strategies: 1 care, 2 store, 3 drain[a]

Budget

Public sector institutions dealing with infrastructure must spend a lot of money over a time span, always longer than a budget year. Planned expenses must be properly argued (transparency) in annual work plans and need the approval of Parliament (democratic decision making). The approval must be based on a long term policy (political consistency).

Stakeholders

Water related infrastructure facilities are always multi functional; there are always more users and uses, so priorities must be set after political debates (public disclosure) and approval, and the management must integrate the interests that exists in society (integrated water management). The public must be informed on developments and criteria (regular communication with media and NGOs), data must be accessible (preferably for free) reliable and retrievable(web site). All this has to do with good governance.

An acceptable vision first

Integrated water management means that attention must be given to many sectors. Often, first an acceptable vision is needed to start a firm discussion. But usually a vision alone has no legislative status, it is just a recommendation (reference is made to 'Omgaan met Water' –V&W, 1984- and 'Plan Ooievaar' -1986-). More is needed for generating fundamental commitments for the infrastructure sector. In practice, means are always limited so choices must be made based on priorities and criteria. Avoiding random and un-controlled diffuse discussions, a strong target must be set and made visible to all involved parties in both the public and private sector. Such a well documented target needs political approval in Parliament, its implementation must be feasible in economic terms of course, and also both in technical and socio-economic terms.

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[a] *V&W, 2000*

Parliamentary approval of long term organisation and finance

Yhis meant that Parliament must not only give its approval to a policy target as such, but also to the finances and the institutional set up needed for implementation over a longer period of years. Such a period is always longer than the ruling period of an elected politician in power. So, there is a need for political consistency to avoid a (sudden) change of major political targets during the implementation period of infrastructure schemes. One may guess how many cabinets with different political colour have ruled the Dutch nation in the period 1953 – 1986, the implementation period of the Deltaworks. During such a long period there always must one ministry as implementing agent and an institution as executing agent that is accountable for the project.

Gradual development of policy documents

The above pleads for a gradual development of one or more Policy document(s) with sufficient legislative status. This cannot be done over night. The way this has been developed in the Netherlands is elaborated hereafter, see also *Fig. 486*.

Rebuilding the nation after World War II

After World War II, in the late forties and fifties the rebuilding of the Dutch nation took shape. In the late fifties it led to a public awareness that at least some coordination was needed on spatial planning; it finally led to a first policy document on spatial planning around 1960. By law it was approved that a revision should take place every 10 to 12 years, and that the planning horizon of a policy document was 25 years. For the implementation, annual workplans of the involved ministries and related public sector organisations needed approval of Parliament (and –of course- still do). Also the way consistent spatial planning had to develop at various levels (national, regional, local) was described. And with additional proper legislation, matters such as disclosure, supervision, enforcement and management (in the public sector) became organised as well.

New public awareness of problems in the sixties

The country developed further, but due to industrialisation and urbanisation, pollution of surface waters became manifest. There was a growing public awareness that a new policy paper was needed on the water management of surface waters. A first version was adopted in Parliament in 1970, a period in which the second version of a revised policy paper on spatial planning was also developed. But because spatial planning and water management were two main responsibilities of different ministries under politicians of different political parties and the public sector organisations responsible for execution were still working in a top-down approach, there was hardly any coordination between the working floors of the two involved ministries during the preparations of these two policy papers.

Traffic and transport in the seventies

In the late seventies, traffic and transport in the Netherlands became a real problem. In a period where the working culture in the public sector changed from a top-down approach to a bottom-up attitude, and the working floors of separate ministries were allowed to exchange information and views directly with colleagues from other ministries, a first policy document on transport developed. First there were some separate draft versions for different sub-sectors and modes (rail-road-water-pipeline-transmission-telecom).

Integrating policies in the eighties

But Parliament forced the three main ministries involved (Economic Affairs, Public Works, Housing) to prepare a second version in the late eighties on inter modal and integrated transport issues, to be relevant also to water management and spatial planning. In the meantime, a third and fourth version of the policy paper on spatial planning developed, as well as a second and third version of the policy paper on water management (revision compulsory by law, every 10 to 12 years). Also in the late eighties, a first policy paper on nature development and environment got Parliamentary approval, finally leading to a situation at the beginning of the 21st century where four major policy papers on infrastructure sub-sectors were aligned and adopted by parliament: on Spatial Planning, on Water Management, on Transport and on Environment and Nature (respectively the 5th, 4th, 3rd, and 2nd version, see again *Fig. 486*).

Bottom-up and horizontal external contacts on the working floor

An important lesson learned from the development as described is the fact that altogether the time for a more effective alignment of the policy papers could have been shorter from the very beginning if the

ministries had accepted an internal working culture, to be characterised as ‘bottom-up and horizontal external contacts on the working floor’.
Furthermore it is obvious that when every square inch of land surface has at least a triple function, and every cubic meter of water multi purpose function, adequate planning is only possible when integrated policy plans are adopted by Parliament, and when consistent political support is more or less guaranteed over many years (at least decades).

Public transparency

And it has been experienced during the numerous public disclosure meetings throughout the years, in particular during discussions with well informed NGOs, that the transparency of infrastructure plans and projects is really crucial. Much time (and money!) would have been saved if, as part of the process of public disclosure, relevant files and data had been made public and accessible (web site in recent years) in advance, and if important NGOs had been consulted at much earlier stages of planning preparations. We all have noticed the negative image of more recent large scale projects, such as HSL (High-Speed Line), Betuwelijn (railway), 2nd Maasvlakte (extension of Port of Rotterdam), dike strengthening, 5th runway at Schiphol, etc. One may guess why …….

One integrated policy document?

Today, one may ask how the situation will be after a new revision (following the law) of all these policy documents shortly. It is expected that in the near future only one integrated policy document will be issued, dealing with the complete national infrastructure (wet and dry), nature and environment, and transport, including budget allocations (see last horizontal bar and vertical column in *Fig. 486*). For an efficient implementation and execution, it includes that further fundamental reform of public sector institutions is unavoidable. No doubt more independent Agencies will be separated from the public sector (as has been done recently with Rijkswaterstaat), and that as a whole the present number of civil servants in the public sector will further decrease due to privatisation schemes and the streamlining of public sector organisations. Legislation, rules and regulations will further become adapted and aligned to international standards and developments (EU, global warming, international waters, CO_2 emissions, etc.). Technical and operational tasks will further shift from the public to the private sector. EU-directives will further develop and determine the daily management of infrastructure (water directives, bird habitat directives, etc.).

3.3.2 Water boards

Water boards are among the oldest government authorities in the Netherlands. They literally form the foundation of the whole Dutch system of local government; from time immemorial they have shouldered the responsibility for water management for the residents of their area. In polders this mainly involves regulating the water level. It has always been in the common interest to keep water out and polder residents have always had to work together. That is what led to the creation of water boards. Due to mergers, there are 27 water boards in The Netherlands (2006)[a]. Their borders don't coincide with municipal borders.

What is a 'waterboard'?

A water board is a public body with a special function; it is in charge of the water management of a certain area. In Holland there are in total some 27 water boards, in the last hundred years many smaller water boards have joined, so the number has decreased substantially.

Goals and tasks of waterboards

The general goal of water boards is water management in the broadest sense of the word. In Holland where half of the country is located below sea level, this requires special measures. The western part of the country is for the larger part located below sea level; polders determine the landscape and water management.

1. Maintenance, construction and keeping up the water defense in the form of dikes, dunes, quays and dams.
2. Management of water level, water quantity, water quality
3. Taking care of waterways, roads as traffic systems

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[a] *http://www.uvw.nl/pagina_6390.html*

Territories of water boards are defined on the basis of watersheds, either naturally defined like in the east or man-made like in the case of polders. Borders quite often cross provincial and municipal borders

The structure of the water boards varies, but they all have a general administrative body, an executive board and a chairperson. The general administrative body consists of people representing the various categories of stakeholders: landholders, leaseholders, owners of buildings, companies and, since recently, all the residents as well. Importance and financial contribution decide how many representatives each category may delegate. Certain stakeholders (e.g. environmental organisations) may be given the power to appoint members. The general administrative body elects the executive board from among its members. The government appoints the chairperson (Dijkgraaf) for a period of six years. The general administrative body is elected for a period of four years (as individuals, not party representatives). Unlike municipal council elections, voters do not usually have to go to a polling station but can vote by mail or even by telephone.

3.3.3 Delfland Waterboard

The city of Delft and also the campus of Delft University of Technology is located in a landscape that is composed of polders. The watersystem of these polders is managed and maintained by a water board that is called 'Delfland Water Board'.

Fig. 488 Delfland Waterboard

The campus area is located in two polders (see).

Fig. 489 The 'Wippolder'

Fig. 490 The 'Zuidpolder'

Delfland is one of our country's twenty-seven water authorities. The area in which Delfland operates is bordered by the North Sea, the Nieuwe Waterweg and the Berkel en Rodenrijs line, Zoetermeer and Wassenaar. On an area of 41,000 hectares, about 1.4 million people live and work, and approximately 40,000 businesses are established. This makes the Delfland region one of the most densily populated and most highly industrialized areas of the Netherlands. The region is furthermore renowned for its intensive glasshouse horticulture both in the Westland area and around Pijnacker.

The three key tasks of Delfland - maintenance of dikes and dams, water level control, and water quality control. These are intricately related. The manner in which you construct and maintain quays, for example, has consequences for the quality of the water. Delfland always performs its tasks from "a broad view"; taking into account all possible relevant factors, a form of integrated water management. To achieve tha, Delfland strives for cooperation with other authorities and institutions both public and private. A good execution of the key tasks, cooperation and consideration for natural qualities; these are the three directives of Delfland's policy. The Water Board thereby does not limit itself to the struggle against water, but also for water. Because no water means no life. Water is life!

Maintenance of dikes and dams

The Delfland region is located far below sea level. And if a dune or dike should collapse, the land behind it would flood immediately. The consequences of a collapse in the Delfland region would be felt as far as the Utrechtse Heuvelrug. To limit the danger, Delfland maintains the sea and river flood defence structures and quays. Safety is, of course, crucial in the management and maintenance of the dikes and dams. In addition to safety, the past few years have also seen increasing attention being devoted to the landscape, nature and recreation.

The main or so-called primary maintenance of dikes and dams consists of two components: the seawall and the river flood defence structure. This primary maintenance of dikes and dams of Delfland must be able to withstand a wind-force and water level which, on average and statistically speaking, do not occur more than once every 10,000 years.

Water management

Water management involves the regulation of the water level in streams, lakes, ditches, moats and canals. This is vital for developments, agricultural businesses, the shipping industry, nature and recreation. The height at which the water level of an area is set depends on the use and function of that area. The level in nature reserves and protected areas, for instance, often fluctuates, while farmers prefer a relatively low water level to prevent their land from becoming too wet. The management of water levels is also of great importance for the shipping industry. If the water level is too low, large ships will run aground; if it is too high, the vertical clearance under bridges will become insufficient.

Water quality

Delfland ensures an optimum quality of the surface water in its management region. This key task entails the purification of wastewater and the limiting of discharges into surface water wherever possible. After all, clean and pure water is important to humans, but also to animals and plants. Delfland therefore creates conditions that lead to a better-optimized habitat for plants, aquatic plants and animals. This can be done by constructing nature-friendly banks for example, or through ecological maintenance of waters and quays

3.3.4 Spatial plans checked on their impact on water: 'Watertoets'

The text below is derived from official papers[a] concerning the way spatial plans have to be checked on their impact on water management in The Netherlands. From 1 November 2003 onwards the 'watertoets'[b] is legally obligatory in making regional plans, master plans and zoning plans in The Netherlands.

Scope

The 'watertoets' concerns all waters and all water management aspects like:

1. guaranteeing the level of safety;
2. reducing floods, increasing resilience of water systems: care, store, drain (see *Fig. 487*);
3. sewage: care, store, drain; reducing hydraulic load of sewage purification installations;
4. water supply: right quality and quantity at the right moment; counteract adverse effects of changes in land use on the need for water;
5. public health: minimising risks of water related diseases and plagues, reducing risks of drowning;
6. counteracting increasing subsidence and reduction of land use possibilities;
7. counteracting ground water inconvenience;
8. surface water quality: achieving and maintaining good water quality for people and nature
9. preservation / realisation of proper ground water quality for man and nature;
10. counteracting drying out (verdroging): protecting characteristic ground water depending on ecological values, cultural history and archaeology;
11. development and protection of a rich, varied and natural wet nature.

Waterparagraph

In any of the plans concerned, a description of the way the consequences of the plan have been taken into account (water paragraph) has to be included.
Beyond safety and water inconvenience the consequences for water quality and drying out have to be mentioned and how the obligatory water advice of the water manager has been taken into account.

Contents of a watertoets

Generally:
1. elaboration of roles of different participants;
2. products: appointments, water advice and waterparagraph;

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[a] *http://www.watertoets.net/pdf/aandeslag.pdf*
[b] *http://www.watertoets.net/pdf/bestuurlijkenotitie.pdf*
http://www.watertoets.net/paginas/helpdesk/handleidingen.html?reload_coolmenus
http://www.watertoets.net/paginas/contact.html?reload_coolmenus

3. spatially relevant criteria;
4. the relationship with the obligartory environmental impact assessment;
5. the environmental impact assessment;
6. compensation: legislative aspects and examples.

Embedding in procedures:

1. municipal procedures: master plans, zoning plans, elaborations, changes and exceptions;
2. regional plans, their elaborations and non-legal provincial plans;
3. environmental impact assessment procedures for traced out roads;
4. plans for broadening roads and provincial roads;
5. reconstruction, land use - and ground clearing plans.

Regional elaborations

In 2007 the Province of South-Holland published indications of surface claims for water surface in zoning plans[a]: 8,5% times the paved surface and + 1,5% x the unpaved surface.
The Waterboard Rijnland (around Leiden) suggested in 2007 keeping 6% of the overall urban area to be water surface[b]. The Waterboard Delfland claims volumes of water per specific surface according to *Fig. 491* [c]. However, these global norms nowadays should be determined according to the local context.[98]

	m^3/ha
paved surface (housing, employment, greenhouse areas)	325
unpaved surface (grassland, nature, leisure)	170
arable land	275

Fig. 491 Standards for water reservoirs inside and outside the urban area[d]

3.3.5 Water management in spatial design

Water is the source of all life on earth. The distribution of water, however, is quite varied; many locations have plenty of it while others have very little. Oceans, rivers, clouds, and rain, all of which contain water, are in a frequent state of change (surface water evaporates, cloud water precipitates, rainfall infiltrates the ground, etc.). The circulation and conservation of earth's water is called the 'hydrologic cycle' (see *Fig. 353* and Verhallen, 1999). There are five processes in the hydrologic cycle: condensation, precipitation, infiltration, runoff, and evapotranspiration. These processes occur simultaneously and, except for precipitation, continuously. The hydrologic cycle takes place in the hydrosphere, this is the region containing all the water in the atmosphere and on the surface of the earth.

What is the problem with water?

Shortage of fresh water world-wide is already apparent right now but will be even larger in the future. The world population is still growing, at this moment not all people have access to good quality fresh water and finally the consumption of fresh water per person is still increasing.
Water is the most valuable of our natural resources. It is, however, predicted that an alarming percentage of major cities are going to be running short of it in the next decade. How will this rising demand for water be met? In the 2nd International Architecture Biennale in Rotterdam (Flood, 2005), the world wide problem of water shortage was the key issue of the Biennale and its exhibitions.

The systems approach; water and water system

The hydrologic cycle is based on a systems approach; the cycle is seen as a system. It is important to realise that this approach is also needed in all planning and design. This means that for every site the hydrologic cycle has to be defined and quantified in headlines. For instance in Holland we have a surplus of rainwater in winter, while we have a shortage in summer due to higher evaporation and less

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[a] *http://www.helpdeskwater.nl/watertoets/*
[b] *http://www.rijnland.net/*
[c] *http://www.hhdelfland.nl/*
[d] *Waterboard Rijnland 2007*

rainfall. Hydrologists can calculate the quantities related to the hydrologic cycle at a given site. Of course soil conditions, topography and ground water table are also important to consider the impact of the water cycle as a whole.

3.3.6 Hydrologic cycle and water system

A dynamic aspect of water management

The hydrologic cycle is a conceptual model that describes the storage and movement of water between the different spheres; biosphere, atmosphere, lithosphere, and hydrosphere at a given site or area. Water on earth can be stored in any one of the following reservoirs: atmosphere, oceans, lakes, rivers, soils, glaciers, snow fields, and groundwater. Water moves from one reservoir to another by processes like evaporation, condensation, precipitation, deposition, runoff, infiltration, sublimation, transpiration, melting, and groundwater flow.

The planetary water supply is dominated by the oceans. Approximately 97 % of all the water on earth is in the oceans. The other 3 % is held as freshwater in glaciers and ice caps, groundwater, lakes, soil, the atmosphere, and within life. Water is continually cycled between its various reservoirs. The typical residence times of water in the major reservoirs is different. On average water is renewed in rivers once every 16 days. Water in the atmosphere is completely replaced once every 8 days. Slower rates of replacement occur in large lakes, glaciers, ocean bodies and groundwater. Replacement in these reservoirs can take from hundreds to thousands of years. Some of these resources (especially groundwater) are being used by humans at rates that far exceed their renewal times.

The need for water management

It is clear that we need a certain strategy for water management that is based on the hydrologic cycle in a certain area. Here we want to work out an example of water management policy in Holland: Water Assessment.

The Netherlands is a highly urbanised delta of which a large part is situated below sea level. The problem of water management is already an old one, like in other delta landscapes. In the past decade the country has been faced with extremely high river discharges which forced thousands of people to evacuate, with flooded areas caused by extreme rainfall, with groundwater problems in urban areas and drying out of certain nature reserves. It is widely acknowledged that, to prevent a further increase of these problems, changes are necessary in water management as well as in spatial planning. In contrast with what the name may suggest, Water Assessment (WA) is a process of interaction during spatial design, rather than a test on water aspects of a completed spatial plan afterwards.

The objectives of Water Assessment (WA)

The objectives of WA are to guarantee that water interests are taken into account in spatial and land use planning, so that negative effects on the water system are prevented or compensated for elsewhere. This integration of water in spatial planning works in two ways: a plan is assessed on its implications for the water system and the restraints that the water system puts on land use are made explicit.

WA is not meant to be a new procedure, but a process of interaction that is fully integrated into existing spatial planning procedures. When Environmental Impact Assessment or Strategic Environmental Assessment (as prescribed by the EU) has to take place as well, both assessments partly take place parallel and provide each other with information.

Water Assessment as part of spatial and landuse planning

To ensure the integration of water aspects into the spatial planning process, ‘Water Assessment’ has been introduced in 2001. Water Assessment is a process in which water managers are involved actively in the development of any spatial plan from the earliest stages on. This instrument has only recently been introduced, but the results up till now are promising.

The different steps in WA

1. The initial phase; agreements on water criteria and co-operation during the planning process. In the initial phase, which starts as soon as the ideas about the plan start developing, the spatial planning authority takes the initiative to inform the water authority. The result of this initial phase is an agreement on the assessment criteria and the further process to be followed.

2. The developing phase; water recommendation In this phase the water authority and the spatial planning authority work interactively and creatively together on the design of the plan. In the Water Recommendation - which is a formal advice - the water authority informs the spatial planning authority on its findings and makes, if necessary, recommendations for adjustments of the plan.
3. The decision-making phase; water paragraph Based on the Water Recommendation the spatial planning authority makes the necessary final adjustments to the plan.
4. The reviewing phase; a 'go!' for realisation

3.3.7 Water quality and management

A qualitative aspect of water

The hydrologic cycle is not only needed to get insight into the quantitative aspects of water and the water system, it also forms the basis for the management of water quality. The earth's water supply remains constant, but man is capable of altering the cycle of that fixed supply. Population increases, rising living standards, and industrial and economic growth have place greater demands on our natural environment. Our activities can create an imbalance in the hydrologic equation and can affect the quantity and quality of natural water resources available to current and future generations. Water use by households, industries, and farms have increased. People demand clean water at reasonable costs, yet the amount of fresh water is limited and the easily accessible sources have been developed. As the population increases, so will our need to withdraw more water from rivers, lakes and aquifers, threatening local resources and future water supplies. A larger population will not only use more water but will discharge more wastewater. Domestic, agricultural, and industrial wastes, including the use of pesticides, herbicides and fertilisers, often overload water supplies with hazardous chemicals and bacteria. Also, poor irrigation practices raise soil salinity and evaporation rates. These factors contribute to a reduction in the availability of potable water, putting even greater pressure on existing water resources.

Urbanisation

Large cities and urban sprawl particularly affect local climate and hydrology. Urbanisation is accompanied by accelerated drainage of water through road drains and city sewer systems, which even increases the magnitude of urban flood events. This alters the rates of infiltration, evaporation, and transpiration that would otherwise occur in a natural setting. The eplenishing of ground water aquifers does not occur or occurs at a slower rate. Together, these various effects determine the amount of water in the system and can result in negative consequences for river watersheds, lake levels, aquifers, and the environment as a whole. How to deal with our water resources is one of the major problems in the future since the world population is still growing, the consumption per person is still increasing and the demand for industrial use of water also increases.

Water resources

On the basis of the hydrologic cycle you can determine how much water from natural resources you have available on the basis of natural renewal of the water quality. Renewable water resources include waters replenished yearly in the process of the water turnover of the earth. These are mainly runoff from rivers, estimated as the volume per unit of time (m^3/s, km^3/year, etc.) and formed either within a specific region or from external sources, including groundwater inflow to a river network. This kind of water resource also includes the yearly renewable upper aquifer groundwater not drained by the river systems. However it should be noted that, on the global scale, these volumes are not large compared with the volume of river runoff and are of importance only for individual specific regions. Another important aspect is to take into account how much time these processes take.

What we see now on a large scale is that we renew water resources on the basis of technological means; by waste water purification and even the production of fresh water from sea water at an industrial scale. Even though this might technologically be possible, the cost is extremely high. In ecological sense it takes also lots of energy and material. So in the long run it is much more efficient to make use of water resources in a conscious way; to not overuse, to store the rainwater in stead of pumping it into the sea and to keep the different water qualities apart.

3.3.8 Sustainability and water management

The planning and design on the basis of watersheds

The aspect of sustainability in landscape planning is addressed in planning and design on the basis of watersheds. A watershed is the geographic area where all water running off the land drains to a given stream, river, lake, wetland, coastal water or other waterbody. Watershed planning and management comprise an approach to protecting water quality and quantity that focuses on a watershed as a whole. This is different from the traditional approach of managing individual wastewater discharges, and is necessary due to the nature of polluted runoff, which in most watersheds is the biggest contributor to water pollution. Polluted runoff is caused by a variety of land use activities, including development, transportation, agriculture and forestry, and may originate anywhere in the watershed. Watershed planning is sometimes a difficult subject to define because of all the different ways in which it has been practised throughout the world is depending on each watershed's unique characteristics, people, and other factors (Verhallen, 1999).

Landscape planning

In landscape planning not only the landuse types and their possible pollution is taken into account, also the storage or infiltration of water for dry periods is part of the problem. The location of both depending on stream direction of the waterways is crucial; no polluting landuse upstream! The amount and location of waterstorage depends on the quantities that are described in the hydrologic cycle. Most planning efforts share a few common points like:

1. Inclusiveness and co-ordination between people involved
2. Watershed framework and the hydrologic cycle for the region in question as a basis for the landscape plan
3. Plan to preserve and/or improve the quality of life and the environment
4. Long term planning and management
5. Development of a watershed plan

A watershed plan

A watershed plan is a document that includes a

1. Characterisation of the watershed as a physical network (total area, land ownerships, natural resources, environmental concerns, etc.)
2. Prioritisation of environmental concerns (water quality, urban growth, recreation, etc.)
3. Implementation plan (strategy for the long run, best management practices, funding opportunities, etc.)

In landscape planning the approach should always be based the principles of watershed planning. Landscape planning does take into account more aspects than watershed planning; the topographical and historical aspects of the site and most important it develops a strategy for the landscape development in the long run (Simonds, 1961, 1997). It is not only a static description of aspects of the watershed alone, it looks ahead on the basis of the principles defined in the watershed plan. In landscape architecture the work of McHarg (1971) is a good example of a more comprehensive and integrated approach to landscape planning than watershed planning alone. Also Clay (1979) gives a series of examples from landscape architecture in which water plays an important role and the principles of watershed planning are applied. Note how old these plans are! For Holland, Boekhorst et al. (1996) give examples of the work of Nico de Jonge in which water plays an important role at the scale of the Dutch region. We can conclude with the statement that no sustainability in landscape planning is possible without taking into account the watershed and the hydrologic cycle.

An integrated approach of water management and spatial planning

The problem of water management needs a comprehensive scope and approach (Verhallen, 1999). Planning and design can contribute to that approach in a general approach for design and water management; the water systems approach as an integrated approach for landscape design at different levels.

I. Water forms the basis for the understanding and insight into the landscape as a natural system.

- The start of any project should be the distinction of different levels of the water system and their spatial form. In all cases you first define the watershed and drainage pattern. In mountainous areas this is fairly simple if you have a topographic map with the contour lines. In delta landscapes like in Holland you mostly use the polders as the spatial and hydrological units in the landscape.
- A next step is the global description of the hydrological cycle in the study area. Rainfall spread over the year, evaporation and topography help you define the understanding of the water system in headlines.

II. If you have done the landscape analysis, you can start to apply the spatial representation of the program to the existing site. In this phase of spatial organisation of the landuse there are the following guiding principles as a basis:

- Water runs from high to low; use this in the location of the different types of landuse
- Organise forms of landuse according to their rate of pollution; the least polluting in the higher areas, the most polluting downstream.
- In Delta landscapes organise water flows from fresh to salt water environments
- In the organisation of time, start with a long term strategy and then work out the short term interventions.
- Another principle is to work from ‘natural’ to ‘artificial’

III. General principles for the approach of the water management for the 21st century

- Conserve water at the place as much as you can locally
- Store what you can not conserve, locally
- Organise letting in and transport elsewhere of water. Make a distinction and also a spatial separation of clean and polluted water; do not mix them!

3.4 The second network: roads

There are other networks than wet connections, for example the roads (dry connections) we add in this chapter. And they interfere. More kinds of networks like those of pedestrians, cyclists, public transport, rail and their characteristics we will elaborate later.

3.4.1 Names and scale

Everybody knows many names of wet and dry connections, regardless of their function (*Fig. 492*). They seem to fit nearly logarithmically on a constant difference of scale multiplying the mesh width each time approximately by 3. That rather precise scale articulation has practical backgrounds.[a]

NETWORK		BLUE LEGEND		BLACK LEGEND	
density	mesh/ exit interval		NAME	nominal width	NAME
km/km^2	km nominally	width 1%		m	
0.002	1000	≥10000	**sea**		
0.007	300	3000	**lake**	120	**continental highway**
0.02	100	1000	**stream/pond**	100	**national highway**
0.07	30	300	**river/waterway**	80	**regional highway**
0,2	10	100	**brook/canal**	70	**local highway**
0.7	3	30	**race**	60	**urban highway**
2	1	10	**watercourse**	40	**district road**
7	0.3	3	**ditch**	30	**main street**
20	0.1	1	**small ditch**	20	**street**
70	0.03	0.3	**trench**	10	**path**

Fig. 492 Names of networks on the higher levels of scale[99]

However, in reality it is sometimes more, seldom less than 3 and often the highest and lowest orders are missing. For example clay grounds do not need trenches and sandy grounds start their drainage by brooks. In the same way rural areas do not need streets every 300m. In The Netherlands they start with roads every 1km as you can check on topographic maps.

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[a] Nes, R.v. and Zijpp, N.J.v.d. (2000) *Scale-factor 3 for hierarchical road networks: a natural phenomenon?* (Delft) Trail Research School Delft University of Technology.

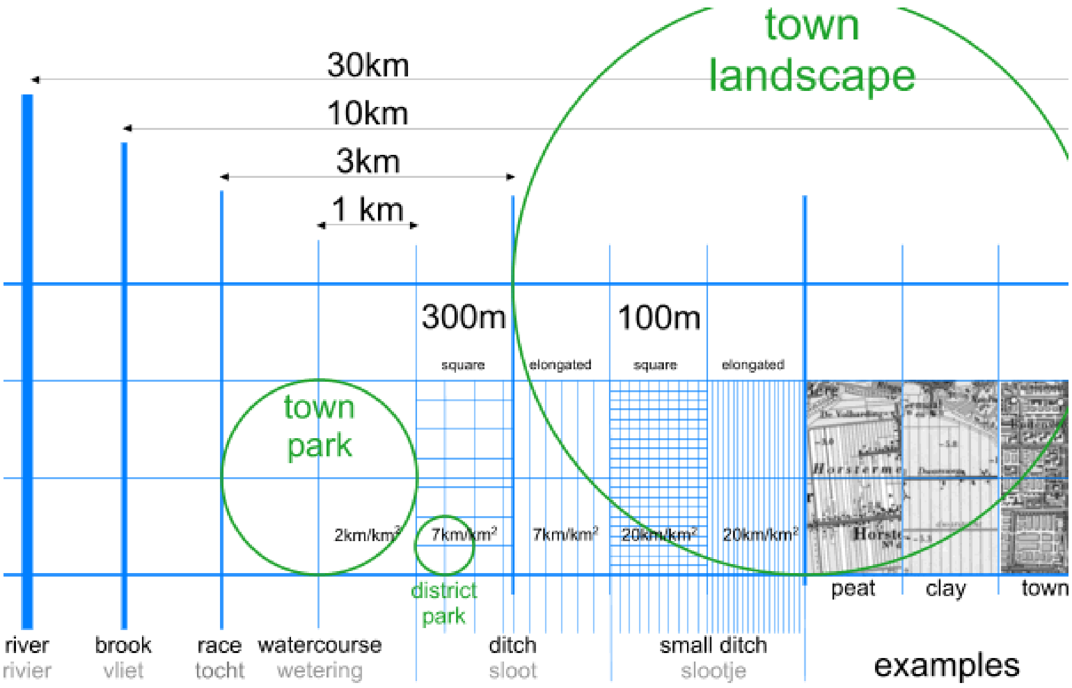


Fig. 493 The styling of wet connections

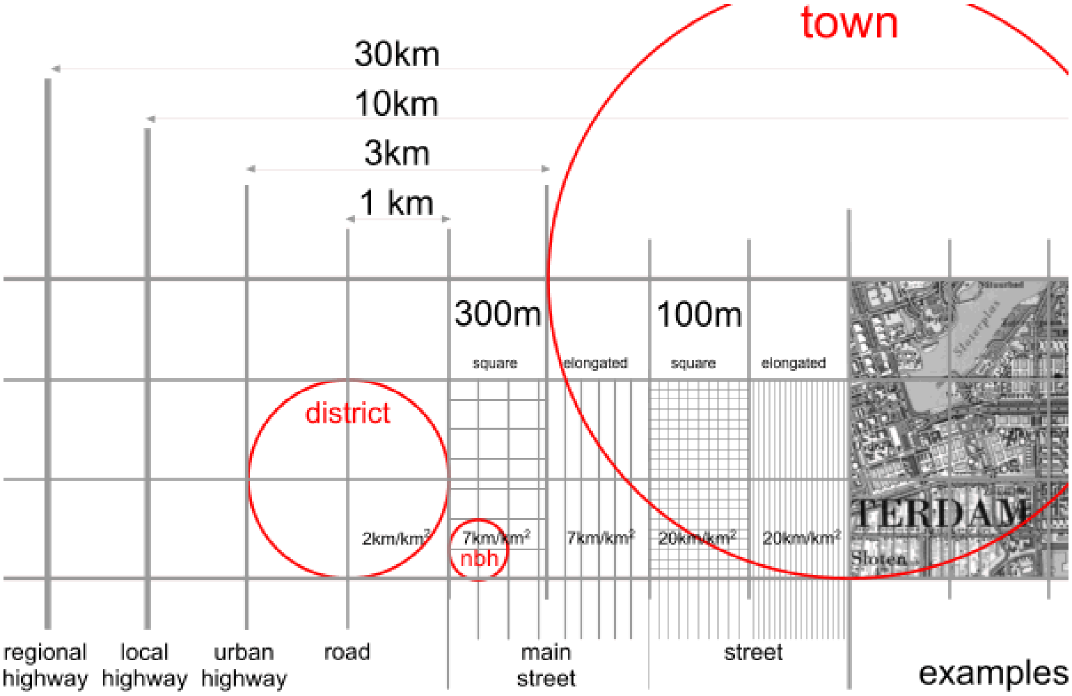


Fig. 494 The styling of dry connections[100]

3.4.2 Functional charge of networks

These neutral names get their time-bound character by changing function. Dry and wet networks get their contemporary meaning by ‘functional charge’ in Fig. 495. Their density implicates the level of investment.[101]

Nominal mesh width	***30m***	***100m***	***300m***	***1km***	***3km***	***10km***	***30km***	***100km***
Density (km/km^2)	*70*	*20*	*7*	*2*	*0.7*	*0.2*	*0.07*	*0.02*
wet connections								
name	**trench**	**small flooded ditch**	**a flooded ditch**	**watercourse**	**race**	**brook**	**river**	**lake**
indicative width 1%		*1m*	*3m*	*10m*	*30m*	*100m*	*300m*	*1000m*
other names			stream	stream	stream	stream		
		urban canal	urban canal	urban canal	urban canal	industrial canal/waterway	canal	canal
functions			draining			drainage pool (from polders)		
Nominal mesh width	***30m***	***100m***	***300m***	***1km***	***3km***	***10km***	***30km***	***100km***
dry connections								
name	**path**	**street**	**main street**	**road**	**urban highway**	**local highway**	**regional highway**	**national highway**
an exit every ...km	*10m*	*30m*	*100m*	*300m*	*1km*	*3km*	*10km*	*30km*
indicative width	*10m*	*20m*	*30m*	*40m*	*60m*	70m	80m	100m
functions	pavement	opening to a hamlet	neighbourhood street	district road, village road, country road	urban highway, main road	urban highway	provincial highway	national highway
	footpath	residential walk	walking route	cycle route	cycle ride			
Duurzaam Veilig (long-term safety)	Woonpad, free of cars	Woonstraat, restricted entry for cars	Erftoegangs-weg, sojourn function	Gebieds-Onsluitings-Weg, opening to an area	Stroomweg, throughway			
public					bus	express	fast bus	Interliner
Nominal mesh width	***30m***	***100m***	***300m***	***1km***	***3km***	***10km***	***30km***	***100km***
railway line					tram	lightrail	regional	national
a supportive base					*300m*	*1km*	*3km*	*10km*
functions						*the underground/metro*	*local train*	*intercity train, Argus*
					hybrid systems	*hybrid systems*	*hybrid systems*	

Fig. 495 *The time-related functional charge of networks*

3.4.3 Rectangularity forced by connections of a higher level

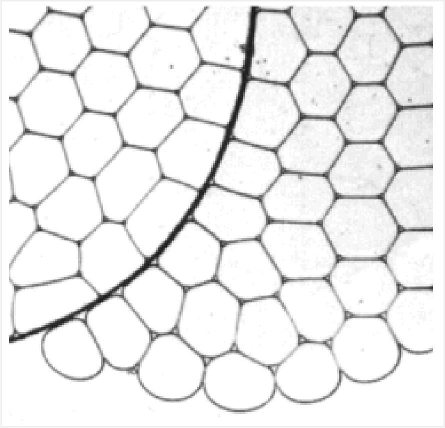
The most efficient enclosure is made by surrounding the enclosed area with a minimum length of road. As well known, the result is a circle. But in a continuous network, it is approximated by a hexagonal system.[102] This minimal ratio between periphery and area is demonstrated 3D by many natural phenomena[a] (cells in a tissue) where preference is given to a minimal ratio between outer area and inner content.

Soap bubbles

A good example is a cluster of soap bubbles. A cluster of soap bubbles forced into a thin layer produces a two-dimensional variant. The bubbles arrange themselves in polygons with an average of six angles.

However, if one pulls a thread through them, the nearest bubbles will re-arrange themselves again into an orthogonal pattern (*Fig. 496*). Urban developments from radial to tangential can also be interpreted against this background. The interlocal connections pull the radial system straight, as it were. The additional demand for straight connections over a distance longer than that between two side roads (here called a ‘stretch’) introduces rectangularity.

Every deflection from the orthogonal system then is less efficient.[103]



Hildebrandt and Tromba (1989) [b]

Fig. 496 The formation of right angles

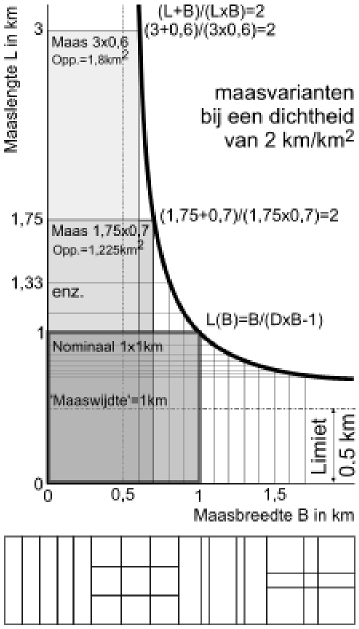


Fig. 497 Length (L) and width (W) of the mesh for a given net density of (D=2)[104]

Marbles in a framework

This can be clarified by engaging in a thought experiment: Imagine a rectangular framework with hinged corners that is completely filled with marbles. If one re-shapes this framework into an ever narrower parallelogram, then there will be space for fewer and fewer marbles, so, in every case, the rectangular shape proves to be optimal, in this respect. The only network that could compete with this, which has lines running from a rectangular grid, is a triangular grid, but it is immediately clear that it is inferior because of its unfavourable perifery/area ratio. For instance, the parallelogram in the thought experiment that became ever more skew, matches an angle of 60° in an equilateral triangular grid. Apart from the disadvantage caused by deviating from the right angle, an extra connecting line is needed to cut the parallelogram into two equilateral triangles.

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[a] d’Arcy Thomson, W. (1961). *On growth and form*. (Cambridge UK) Cambridge University Press.

[b] This figure is taken from: Stefan Hildebrandt and Anthony Tromba, *Architectuur in de natuur, de weg naar de optimale vorm* (Mathematics and optimal form), Wetenschappelijke Bibliotheek Natuur en Techniek, Maastricht/Brussel, 1989, ISBN 90 70157 81 0.

Mesh width and mesh length

Fig. 497 shows a sequence of relationships between mesh width and length in rectangular meshes with a net density of 2 km per km^2 (the same density means the same investment!).
Length and width of *squares* are 2/density. The same density also occurs in a pattern of roads that go infinitely in one direction every 0.5 km. Thus, when the length and width of the mesh 1/d = 0.5 km, the ratio between length and width is at its limit.[105] In that case, where the net density is 2 km per km^2 there can be no 'crossroads' any more.[106] This consideration only applies to an orthogonal system.

3.4.4 Superposition of levels

In connection with the red and blue legend one can imagine their superposition as follows:

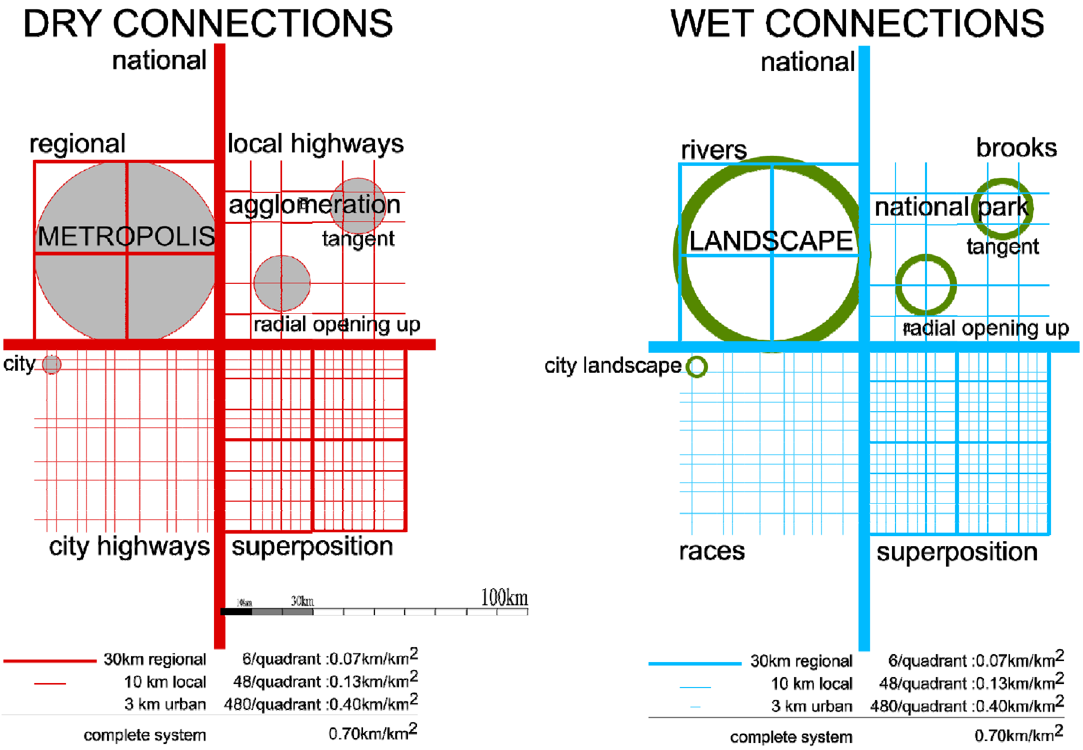


Fig. 498 *Superposition of networks*

Urban area is radially crossed or tangentially surrounded by infrastructure.
By superposition of the higher order over the lower order, the density of the lower order decreases.[107]
By superposing the wet connections over or under the dry connections, both networks interfere (interference, see page 3.4.5).

3.4.5 Interference of different networks

When one lays different (wet and dry) networks over each other, an interference occurs that defines the number of crossings, and, because of this, the level of investment in civil engineering constructions (Fig. 499).This can be done in different ways. Separating instead of bundling them fragments space more. The diversity of interference has important impacts on ecology and cultural identity.

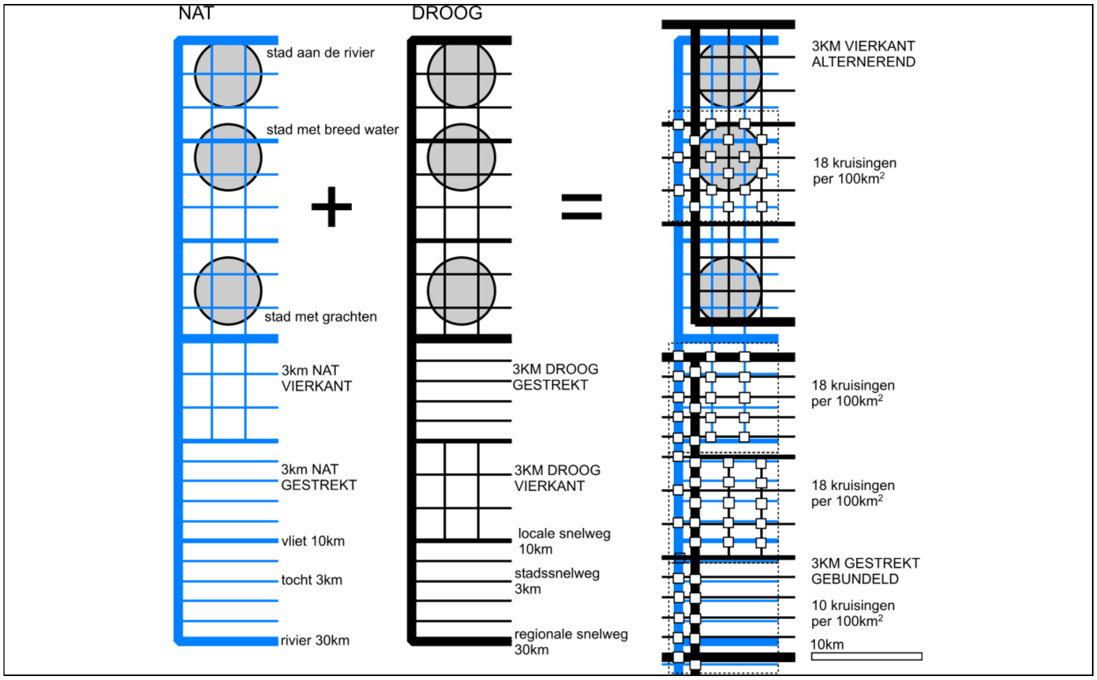
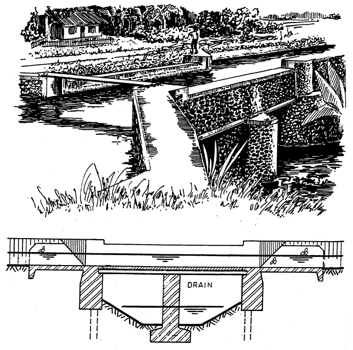


Fig. 499 Interference between wet and dry networks.

The position of urban areas with respect to orders of magnitude of water and roads dictates their character to a large extent. The elongation (stretching) of networks reduces the need for engineering constructions when their meshes lie in the same direction.[108] If one bundles them together, this also helps to prevent fragmentation. The aim of the 'Two network strategy', on the other hand, is to position water, as a 'green network', as far away as possible from the roads (in an alternating manner). However, this has the effect of increasing fragmentation by roads and watercourses.

3.4.6 Crossings

Mutually crossings of waterways seldom separate their courses vertically (*Fig. 500*) as motorways do (*Fig. 501*).



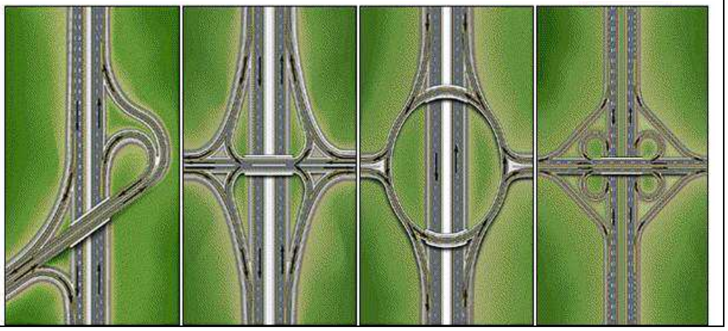


Fig. 500 Crossing of separated waterways[a]

Fig. 501 Crossings of highways[b]

More often their water levels are separated by locks or become inaccessible for ships by weirs or siphons.

However, crossings between ways and waterways have to be separated vertically in full function anyhow. And they often occur.

Fig. 502 Rivers, canals and brooks

Fig. 503 Superposition races

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[a] Ankum (2003) page 160
[b] Standaard and Elmar (?)

Fig. 504 Interference with highways

Fig. 505 Interference with highways and railways

The same kind and level

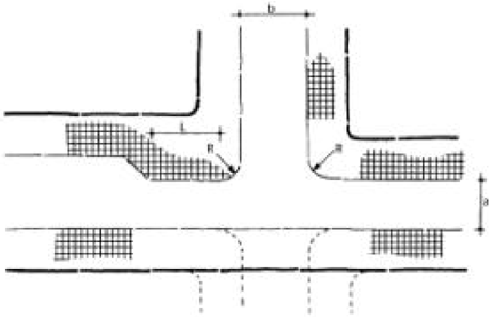

Fig. 506 R=300m Sojourn area road crossing for mixed traffic[a]

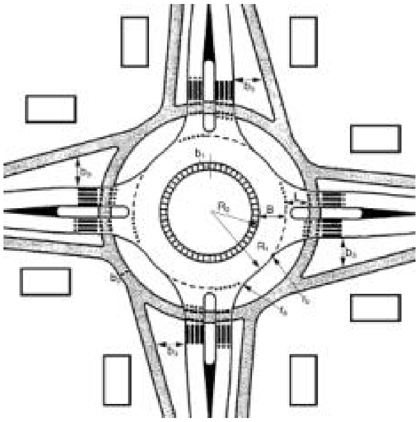

Fig. 507 R=1km Opening up road (GOW) single lane roundabout – with freely located cycle path and cyclists having right of way[b]

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[a] A.S.V.V.(2004): 12.3.1

[b] A.S.V.V.(2004): 11.2.3

Limitating crossing movements

Camillo Sitte[a] already showed T crossings have less conflict points (*Fig. 508*). Modern roundabouts translate a normal crossing in 4 T-crossings.[109]

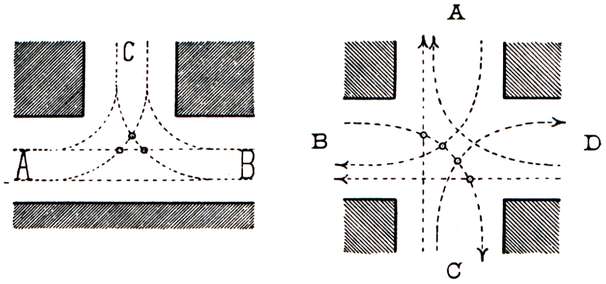

Fig. 508 Less conflict points in T-crossings[b]

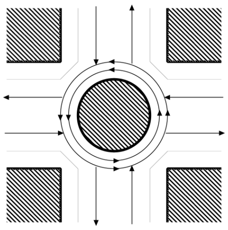

Fig. 509 An actual roundabout[c]

Before roundabouts came into use, attempts were made to design safer T-crossings on town (R=3km) and district (R-1km) level.

Town level

Fig. 510 Sketch Zoetermeer 1969[d]

Fig. 511 Actual situation[e]

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[a] Sitte, C. (1991). *De stedebouw volgens zijn artistieke grondbeginselen*. (Rotterdam) Uitgeverij 010.
[b] Camillo Sitte (1889) Der Städtebau nach seinen künstlerische Grundsätzen
[c] Bach en De Jong (2004)
[d] B. van Gent (1999), p. 2/6
[e] CDRom de nationale Stratengids van Nederland met kaarten van de Topografische Dienst te Emmen (Den Haag) Citydisc

District level

Fig. 512 Sketch for district Driemanspolder-West (Meerzicht)[a]

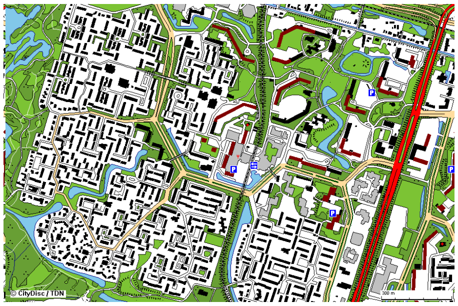

Fig. 513 Actual situation[b]

However, gaining safety this way produced faster driving. So T-crossings did not produce more safety after all. Moreover, non-perpendicular T-crossings make orientation more difficult. Roundabouts are safer.

The same kind and different level

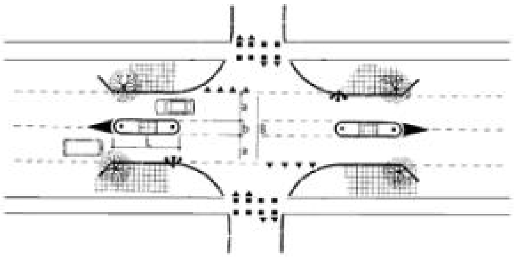

Fig. 514 Central guiding – at a crossing R=1km Opening up road (GOW) – R=300m Sojourn area road[c]

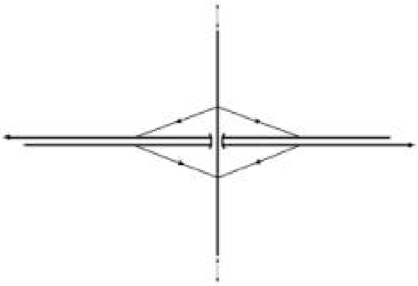

Fig. 515 Haarlemmermeer solution – at a crossing R=3km Throughway – R=1km Opening up road (GOW)[d]

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[a] B. van Gent (1999), p. 2/30

[b] CDRom de nationale Stratengids van Nederland met kaarten van de Topografische Dienst te Emmen (Den Haag) Citydisc

[c] A.S.V.V.(2004): 11.2.5

[d] A.S.V.V.(2004): 10.1

Different kind and level

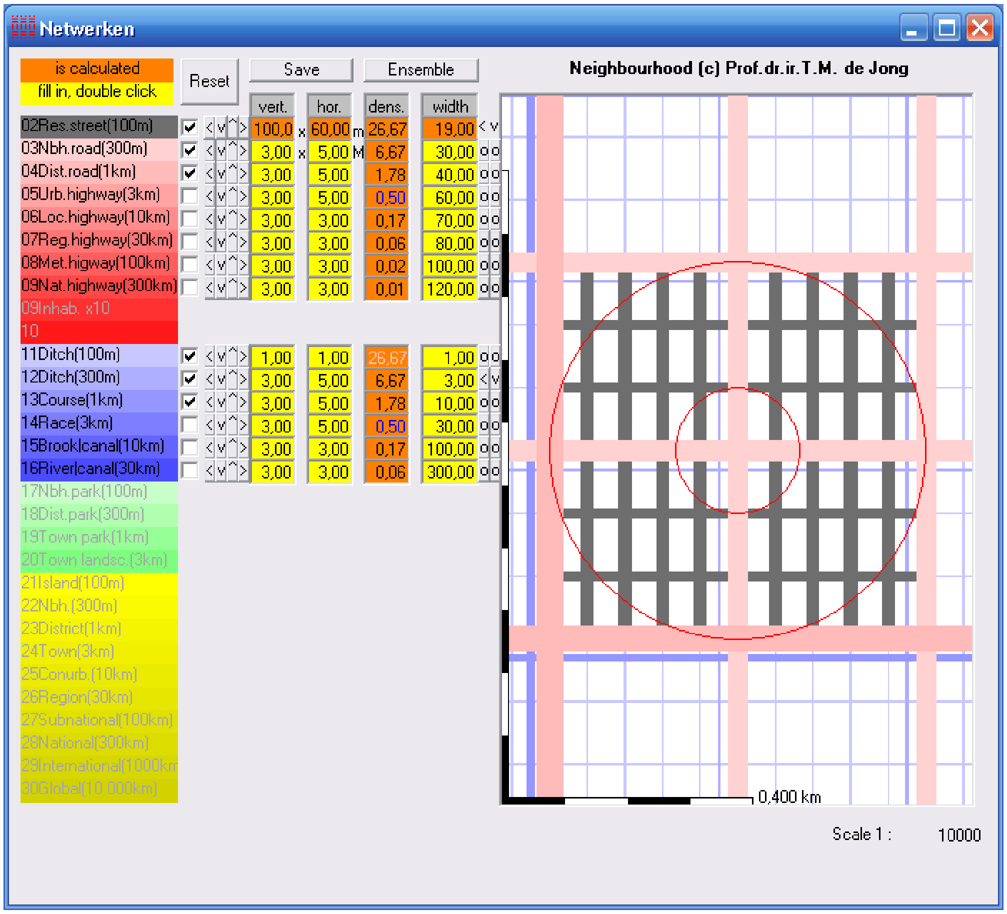
Especially when the canal is a belt canal with a higher level than the other waterways many complications arise. Extra space is needed for weirs, dikes and sluices, perhaps even locks and many slopes not useful for building. The slope the city highway gets from crossing the high belt canal could force to make a tunnel instead of a bridge. Anyhow, several expensive bridges will be necessary and some of them will be dropped from the budget, causing traffic dilemmas elsewhere.

Fig. 516 Neighbourhood street crossing canal and railroad in Utrecht

The slope behind the bridge in *Fig. 516* is not steep enough to get a tunnel under the railway high enough for busses (2.60m here is too low).

Count your crossings (costs)

Fig. 517 shows how different dry and wet networks in different orders cause crossings of different kinds.



Netwerken

is calculated
fill in, double click

Neighbourhood (c) Prof.dr.ir.T.M. de Jong

		vert.	hor.	dens.	width
02Res.street(100m)	☑	100,0	60,00	26,67	19,00
03Nbh.road(300m)	☑	3,00	5,00	6,67	30,00
04Dist.road(1km)	☑	3,00	5,00	1,78	40,00
05Urb.highway(3km)	☐	3,00	5,00	0,50	60,00
06Loc.highway(10km)	☐	3,00	3,00	0,17	70,00
07Reg.highway(30km)	☐	3,00	3,00	0,06	80,00
08Met.higway(100km)	☐	3,00	3,00	0,02	100,00
09Nat.highway(300km)	☐	3,00	3,00	0,01	120,00
09Inhab. x10					
10					
11Ditch(100m)	☑	1,00	1,00	26,67	1,00
12Ditch(300m)	☑	3,00	5,00	6,67	3,00
13Course(1km)	☑	3,00	5,00	1,78	10,00
14Race(3km)	☐	3,00	5,00	0,50	30,00
15Brook|canal(10km)	☐	3,00	3,00	0,17	100,00
16River|canal(30km)	☐	3,00	3,00	0,06	300,00
17Nbh.park(100m)					
18Dist.park(300m)					
19Town park(1km)					
20Town landsc.(3km)					
21Island(100m)					
22Nbh.(300m)					
23District(1km)					
24Town(3km)					
25Conurb.(10km)					
26Region(30km)					
27Subnational(100km)					
28National(300km)					
29International(1000km					
30Global(10.000km)					

Scale 1 : 10000

Fig. 517 Interference of dry and wet networks in different orders causing crossings of different kinds[a]

Trenches and ditches become drains or (underneath roads) culverts in the urban area, but main ditches (3m wide) and water courses (10m) or even larger waterways have to be crossed by bridges. From 6 different kinds of interfering crossing in *Fig. 517*, *Fig. 518* counts 35 crossings in 5 types.

	residential streets (20m wide)	neighbourhood streets (30m wide)	district roads (40m wide)
main ditches (3m wide)	16	8	4
water courses (10m wide)		5	2

Fig. 518 Five types of interfering crossings supposed in Fig. 517

And there are superposed crossings as well.

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[a] Jong (2001)

Bridges

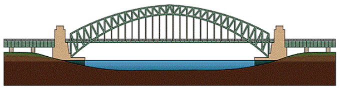
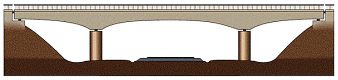
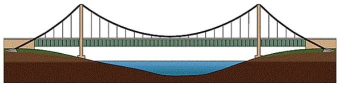
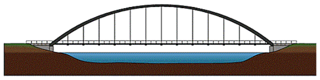
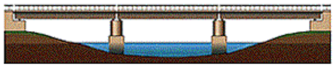
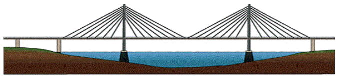
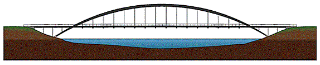
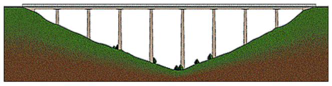
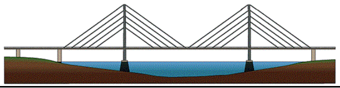
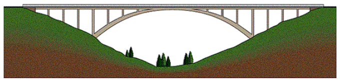
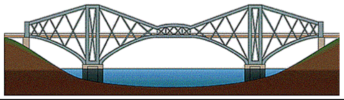
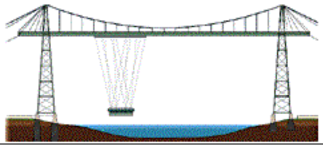
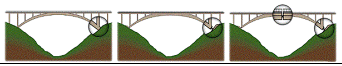
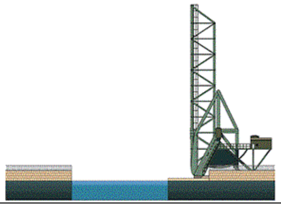
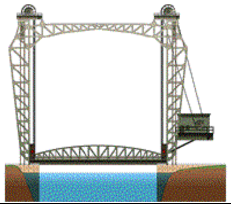
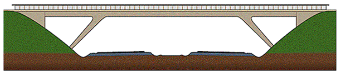
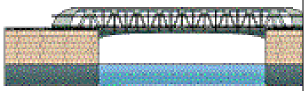
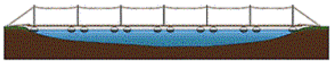
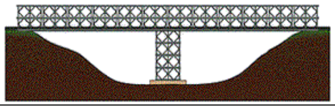
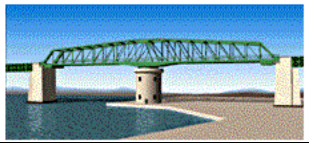
based on pressure	*or*	*tension*
		
arch bridge (boogbrug) approach ramp(aanbrug) thrust (horizontale druk) deck (rijvloer) trussed arch with upper and lower chord (vakwerkboog boog met boven- en onderrrand) abutment (landhoofd)	beam bridge (balk- of liggerbrug) abutment (landhoofd) overpass, underpass (bovenkruising, onderdoorgang) deck (brugdek) continuous beam (doorgaande ligger) pier (pijler) parapet (leuning)	suspension bridge (hangbrug) anchorage block (ankerblok) suspension cable (hangkabel) suspender (hanger) deck (rijvloer) center span (middenoverspanning) tower (toren) side span (zijoverspanning) abutment (landhoofd)
		
trough arch bridge (boogbrug met laaggelegen rijvloer)	multiple span beam bridge (balk- of liggerbrug met meer overspanningen)	fan cable stayed bridge (waaiertuibrug) cable stay anchorage (tuiverankering)
		
half-through arch bridge (boogbrug met tussengelegen rijvloer)	viaduct	harp cable stayed bridge (harptuibrug)
		
deck arch bridge (boogbrug met hooggelegen rijvloer)	cantilever bridge (kraagliggerbrug, cantileverbrug) suspended span (zwevend brugdeel) cantilever span (uitkragende zijoverspanning)	transporter bridge (zweefbrug) trolley (wagen) platform (platform)
		
fixed two-hinged three-hinged arch (ingeklemde, tweescharnier~, driescharnierboog)	single-leaf bascule bridge (enkele basculebrug) counterweight (contragewicht)	lift bridge (hefbrug) guiding tower (heftoren) lift span (val)
		
portal bridge (schoorbrug) portal frame (portaal) pier (pijler)	double-leaf bascule bridge (dubbele basculebrug)	floating bridge (pontonbrug) manrope (mantouw) pontoon (ponton)
		
	Bailey bridge (baileybrug)	swing bridge (draaibrug)

Fig. 519 *Names of Bridges and their components*[a]

---

[a] Standaard and Elmar (?)

based on pressure	*or*	*tension*

These types of bridges could be made of steel, concrete or wood. Depending on the material they have a different maximum span (Fig. 352).[110] [111] [112] [113]

english name	**dutch name**	**span in m.**	**notes**	
multiple span beam bridge	balk- liggerbrug met meer overspanningen	unlimited		
viaduct	viaduct	unlimited	old-fashioned	
ferry bridge	pontbrug	unlimited		
suspension bridge	hangbrug	2000	wind-sensitive	
fan cable stayed bridge	waaiertuibrug	1000	wind-sensitive	
harp cable stayed bridge	harptuibrug	1000	wind-sensitive	
cantilever bridge	kraagliggerbrug, Gerberligger	550		
arch bridge	boogbrug	500	steel	
trough arch bridge	boogbrug met laaggelegen rijvloer	500	? with draw connection	
fixed two-hinged three-hinged arch	ingeklemde, tweeschanier-, driescharnierboog	500	? with draw connection	
half-through arch bridge	boogbrug met tussengelegen rijvloer	500	?	
deck arch bridge	boogbrug met hooggelegen rijvloer	500	?	
beam bridge	balk- of liggerbrug	250	steel truss, framework	
arch bridge	boogbrug	200	stiffened bars	
floating bridge	pontonbrug	200	military	movable
lift bridge	hefbrug	150	old-fashioned	movable
portal bridge	schoorbrug	150	between supports with tube beam	
beam bridge	balk- of liggerbrug	100	steel concrete	
beam bridge	balk- of liggerbrug	100	concrete tube beam	
transporter bridge	zweefbrug, transbordeur.	100	? old fashioned 1895-1920; 2 in europe left	movable
double-leaf bascule bridge	dubbele basculebrug	100		movable
swing bridge	draaibrug	60	even as aquaduct	movable
arch bridge	boogbrug	50	hout	
single-leaf bascule bridge	enkele basculebrug	50		movable
portal bridge	schoorbrug	40	? concrete	
beam bridge	plaatliggerbrug	30	or wider with large construction height	
beam bridge	balk- of liggerbrug	30		
strauszbridge	ophaalbrug	25		movable
beam bridge	balk- of liggerbrug	20	2m wood truss, framework	
beam bridge	spoorverkeer staal	15	small construction height	
ship bridge	schipbrug	10	? te doesburg	movable
beam bridge	balk- of liggerbrug	10	wood	

english name	**dutch name**	**span in m.**	**notes**	
raft bridge	vlotbrug	10	? floating from under approach ramp	movable
crane bridge	kraanbrug	10	old-fashioned	movable
roll bridge	rolbrug	8	one example 67m	movable
clap bridge	klapbrug	8	without counterweight	movable
	valbrug	5	old-fashioned (castles)	movable
	oorgatbrug	1	for mast only, old-fashioned (hindeloopen)	movable
Bailey bridge	Baileybrug		military	

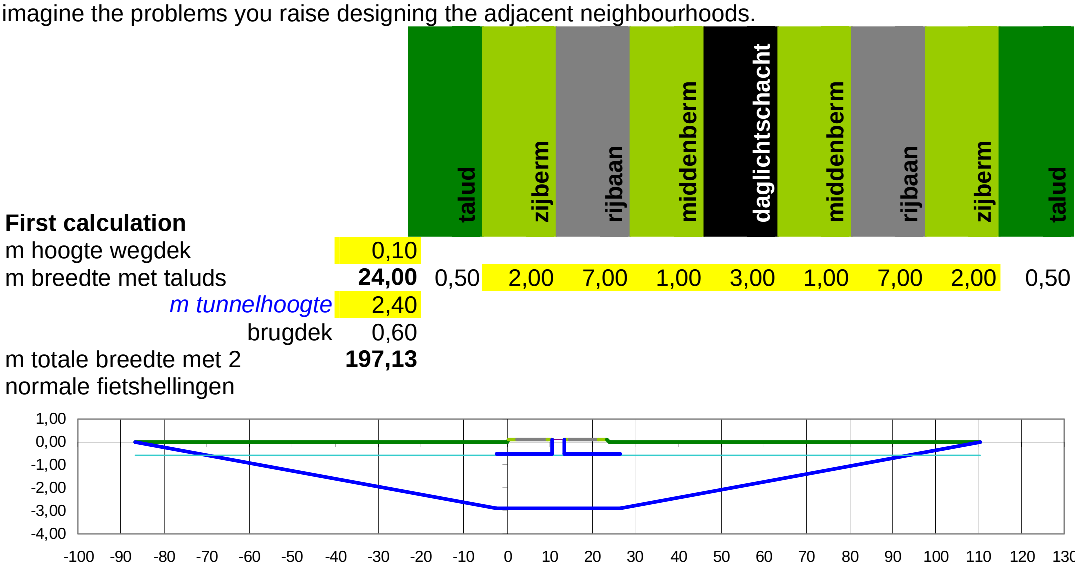
fig. 520 *Maximum span of different bridges*[a]

The construction height below deck is often limiting factor.

Costs of bridged P.M.

Tunnels

3D crossings need slopes. *Fig. 521* shows a highway on 0.1m height without slopes. You have to dig out the tunnel until –2.9m. By doing so, you need cycle slopes of more than 80m at both sides.[114] The tunnel construction extends to 197.13m width. Imagine the problems to keep it dry, imagine the costs, imagine the problems you raise designing the adjacent neighbourhoods.


First calculation

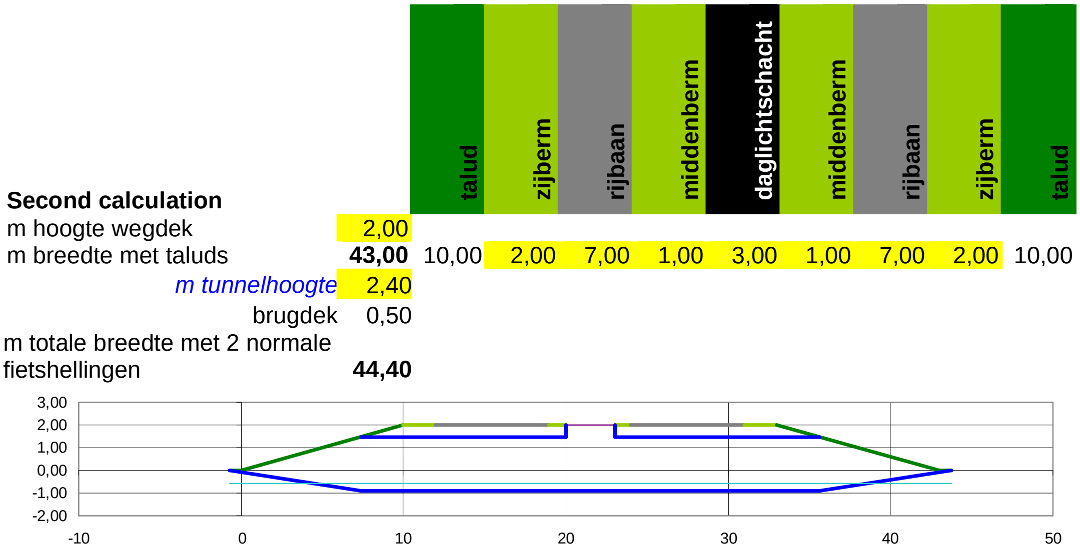
		talud	zijberm	rijbaan	middenberm	daglichtschacht	middenberm	rijbaan	zijberm	talud
m hoogte wegdek	0,10									
m breedte met taluds	**24,00**	0,50	2,00	7,00	1,00	3,00	1,00	7,00	2,00	0,50
m tunnelhoogte	2,40									
brugdek	0,60									
m totale breedte met 2 normale fietshellingen	**197,13**									

Fig. 521 First calculation of slopes in a tunnel for cyclists below a highway

---

[a] Jong (1996)

Fig. 522 shows a highway on 2m with slopes on both sides, totally 43m wide. The tunnel can be made on –1m, so the slopes meet nearly on 0m making the total width 44.4m.



Second calculation		talud	zijberm	rijbaan	middenberm	daglichtschacht	middenberm	rijbaan	zijberm	talud
m hoogte wegdek	2,00									
m breedte met taluds	**43,00**	10,00	2,00	7,00	1,00	3,00	1,00	7,00	2,00	10,00
m tunnelhoogte	2,40									
brugdek	0,50									
m totale breedte met 2 normale fietshellingen	**44,40**									

Fig. 522 Second calculation of slopes in a tunnel for cyclists below a highway

3.4.7 A traffic network

A street is more than traffic space. However, this chapter restricts itself to traffic space, like traffic specialist would do if (s)he had no attention for context. A street is not a summing up of measures needed for traffic, but is is good to know which measures are used by specialists. Many measures mentioned here, are no more than rules of thumb to start with.

3.4.8 Measures

Any kind of traffic has characteristic measures.
Design measures are deduced from the distribution of actual measures (see *Fig. 523*).
Normally the 5% largest measures are left aside for design.

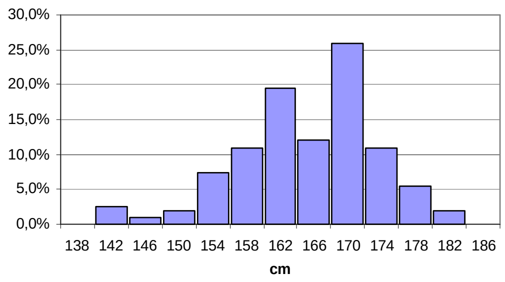


Fig. 523 Dispersion of real car widths in 2004; 95% < 1.80m [a] [115]

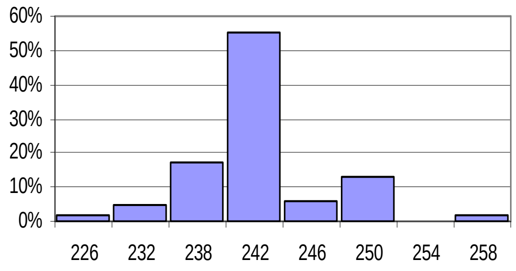


Fig. 524 Width of parking places in 1980 [b] [116]

However, these measures can change in time and occasionally not apply. So, you need margins. For example, in *Fig. 524* the parking space for a car is much wider than the width of an average car,

---

[a] *A.S.V.V(2004) p. 77-78*
[b] *ANWB-Verkeerskunde (1980) nummers 6 en 10*

because at parking places people have to step in and out at both sides. Moreover, taking the largest turning circle of cars you need space to turn in, not only in width, but also in length. So, a street with cross parking should be wider than the 95 percentile of car lengths (5m).
That is why car parking requires a quarter of pavement in the urban surface.

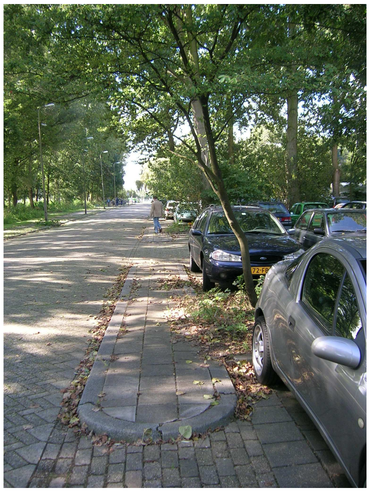


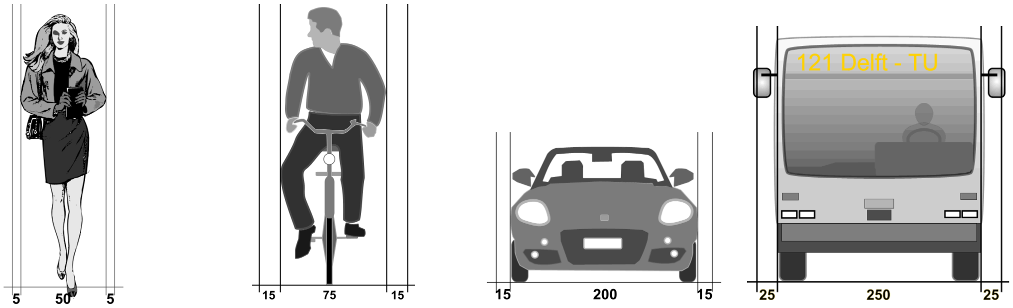
Fig. 525 1.20m for a pedestrian

Fig. 526 2.40m for a parked car

In The Netherlands normal paving-stones used on side walks are an unit of measure easy for reference if you are walking on the street or taking photographs (0.30x0.30m). From *Fig. 525* you can learn a kerb is half a tile wide and for walking you need at least two tiles if you don't have luggage. From *Fig. 526* you can learn that the parking spaces of our Faculty are 2.40m wide.

3.4.9 A residential street

In a residential street occasionally you need space for larger vehicles like moving vans, ambulances, vans of police, fire brigade or service vehicles, often necessary in residential areas.
Pedestrians carrying luggage or pushing baby buggies need 1.5x more space than without such loads as shown in *Fig. 527*.



Pedestrian
50 + 2 x 5 ≅
60 cm[117]

Cyclist
75 + 2 x 15 ≅
100 cm[118]

Car 30 km/h
200 + 2 x 15 ≅
230 cm[119]

Bus 50 km/h
255 +2 x 25≅
300 cm[120]

Fig. 527 Primary profile spaces needed

A usual residential street gives way to two loaded pedestrians walking both ways (for instance one with luggage and one with a baby buggy passing each other, say 2m paved surface with 6 tiles of 0.30m + a 0.15m kerb + 0.05m margin) as sidewalks. On the roadway two vans should be able to drive both ways with a margin because they swing a little when they move (say 6m). If you draw sidewalks at both sides the pavement will count 2+6+2=10m. That is easy to remember for residential streets without parking places (as in *Fig. 524*). With parking places and gardens it could be =20m (*Fig. 528*), but we do not yet take them into account. We will do that at page 266 and further.[121]

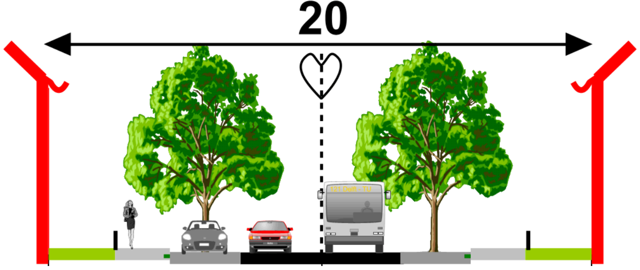


Fig. 528 A residential street (2.5 + 2 + 2.5 + 6 + 2.5 + 2 + 2.5 = 20m)[a]

However, you do not need that width of pavement all along the road. Cars can wait when they see someone approaching from the other side. Pavement can locally be narrower (for example 1+3+1=5m), slowing down the cars or just wider (for example 3+6+3=12m) to make more speed or to give children and pedestrians more space on the sidewalks. A roadway of 6m width, has two 'lanes' for both directions. You can remove one locally. You can halve the sidewalks locally as well, but do not remove at one side one of them unnecessarily, otherwise pedestrians have to cross the road. If you do not have to give way to large cars or speeds higher than 30km/h the lane can get the minimum width of 2.30m. For even lower velocities without large vehicles the pavement is suitable for mixed use with pedestrians, say 1.90+0.60≅2.50m.

3.4.10 Space for speed

For higher design velocities you should take more margin for swinging. For normal cars at 30km/h you need 2.25m per lane, and 0.30m extra is no luxury. But at 50km/h you need 2.75m per lane, and at 70km/h 3.25m.[b] Along walls or obstacles, drivers keep even more distance (obstacle fright) to prevent damage.

Drivers also keep distance to cars ahead. The higher the velocity, the more distance they will keep. Above 30km/h that growing distance even decreases the capacity of the road (*Fig. 529*)![122]
That means, to keep the same capacity you need more lanes.

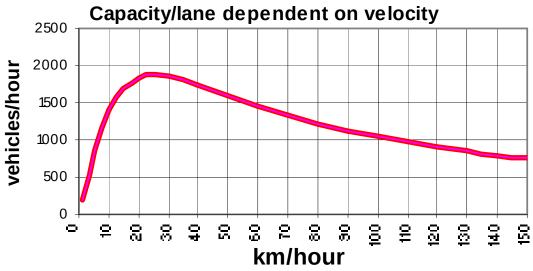


Fig. 529 A higher speed decreases the capacity of the road[c]

As you can see, roads designed for more than 2 000 cars per hour in one direction (that is approximately 20 000 per day[123]) need at least more than one lane per direction.[124]

---

[a] Simple quick profile drawings can be generated by Excel with a worksheet *http://team.bk.tudelft.nl/Databases/Databases.htm* > *Wegprofielen maken met excel .xls*

[b] ASVV …

[c] *http://team.bk.tudelft.nl/Databases* > Hoe de capaciteit van wegen afneemt bij hogere rijsnelheid

Moreover, at 50km/h you have to give separate way to cyclists along the road and at 70km/h at crossings as well if you accept the Dutch appointments 'Duurzaam Veilig" (see *Fig. 575*).

3.4.11 Roads of a higher level

If you leave your home to go for a ride, you start on a 'residential street' (some 20m wide) via a larger 'neighbourhood road' (say 30m) reaching an even larger 'district road' (say 40m) and so on.
On the average every third road of each level you can make a turn to a road of a higher level (see *Fig. 530*, do not take it too serious, it is a rule of thumb)[a]. The question arises at which mutual absolute distance you have to draw them in urban design. To keep it simple, we take 30m for the smallest residential paths, 100m for residential streets, 300m for neighbourhood roads, and 1000m for district roads (*Fig. 530*).

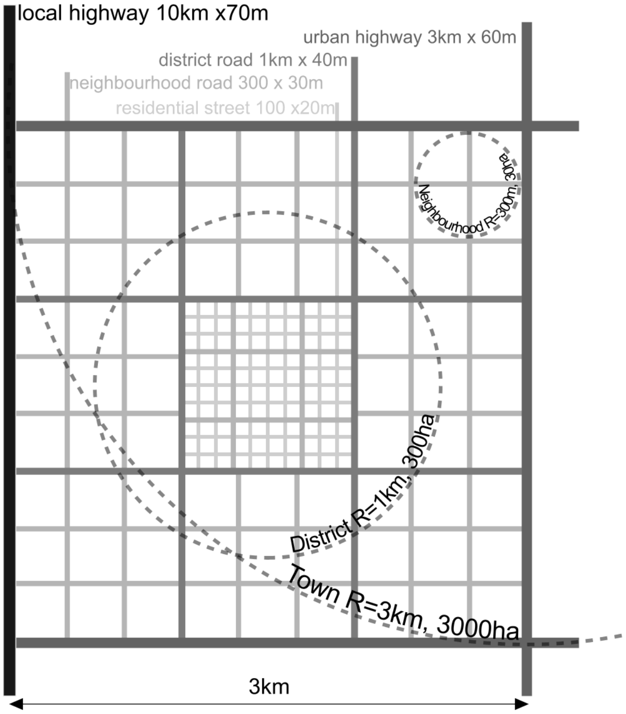


Fig. 530 Four orders in a network hierarchy

3.4.12 Urban islands in a network

Public pavement for traffic and parking is expensive. It has to be paid by lots a municipality can sell, surrounded by that public space (municipal land development). The housing allotments below, include a substantial area of expensive parking spaces as well. They are made by the computer programme Standaardverkaveling.exe.[b] Starting points are:

1. centre lines of surrounding roads on a multiple of 30m (preliminary main grid);
2. roadways everywhere 6m wide, not needed everywhere, but including a reservation for wider roads of higher level in the network elsewhere;

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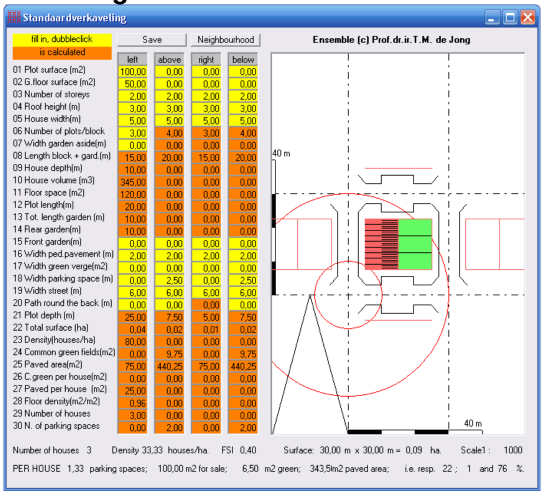
[a] Nes, R. v. and N. J. v. d. Zijpp (2000). Scale-factor 3 for hierarchical road networks: a natural phenomenon? (Delft) Trail Research School Delft University of Technology.

[b] Try it yourself, the programme is downloadable from *http://team.bk.tudelft.nl* > Publications 2003

3. parking standard everywhere more than 1 parking place per dwelling along the road, starting at least 5m from road corners, only drawn along roads North and South (indicated as ‘N’ and ‘S’[a]) in the drawing of the urban island (an urban ensemble completely surrounded by roads);
4. sidewalks seldom smaller than 2m wide;
5. no front gardens yet;
6. dwellings 5x10m, 2 floors high with roof timbers of 3m on lots of 100m2 housing 2.25 inhabitants in rows not exceeding 40m to avoid extra dilatation;
7. path around the back 1m wide;
8. green areas are drawn East and South filling up the main 30m grid. They show the space saved by design operations, but can be used to enlarge the lots for sale as well, diminishing public space (pavement + green).

These starting points can be changed easily in Standaardverkaveling.exe. However, for the time being they are kept constant below to study the change in allotment performance by design transformations.

Mirroring the smallest urban island



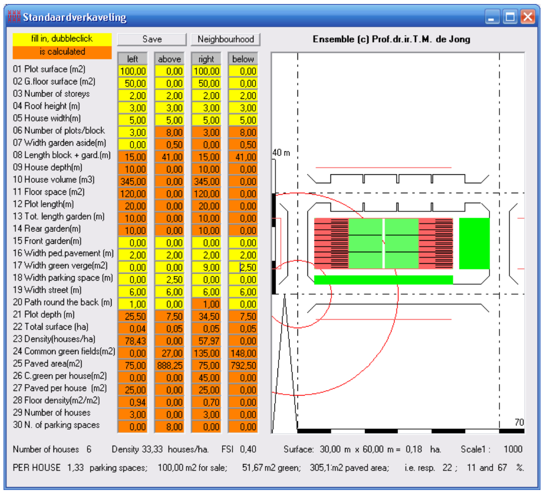
Ensemble (c) Prof.dr.ir.T.M. de Jong

	left	above	right	below
01 Plot surface (m2)	100,00	0,00	0,00	0,00
02 G.floor surface (m2)	50,00	0,00	0,00	0,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	3,00	4,00	3,00	4,00
07 Width garden aside(m)	0,00	0,00	0,00	0,00
08 Length block + gard.(m)	15,00	20,00	15,00	20,00
09 House depth(m)	10,00	0,00	0,00	0,00
10 House volume (m3)	345,00	0,00	0,00	0,00
11 Floor space (m2)	120,00	0,00	0,00	0,00
12 Plot length(m)	20,00	0,00	0,00	0,00
13 Tot. length garden (m)	10,00	0,00	0,00	0,00
14 Rear garden(m)	10,00	0,00	0,00	0,00
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	2,00	2,00	2,00
17 Width green verge(m2)	0,00	0,00	0,00	0,00
18 Width parking space (m)	0,00	2,50	0,00	2,50
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	0,00	0,00	0,00	0,00
21 Plot depth (m)	25,00	7,50	5,00	7,50
22 Total surface (ha)	0,04	0,02	0,01	0,02
23 Density(houses/ha)	80,00	0,00	0,00	0,00
24 Common green fields(m2)	0,00	9,75	0,00	9,75
25 Paved area(m2)	75,00	440,25	75,00	440,25
26 C.green per house(m2)	0,00	0,00	0,00	0,00
27 Paved per house (m2)	25,00	0,00	0,00	0,00
28 Floor density(m2/m2)	0,96	0,00	0,00	0,00
29 Number of houses	3,00	0,00	0,00	0,00
30 N. of parking spaces	0,00	2,00	0,00	2,00

Number of houses 3 Density 33,33 houses/ha. FSI 0,40 Surface: 30,00 m x 30,00 m = 0,09 ha. Scale1 : 1000

PER HOUSE 1,33 parking spaces; 100,00 m2 for sale; 6,50 m2 green; 343,5lm2 paved area; i.e. resp. 22 ; 1 and 76 %.

Fig. 531 30x30m



Ensemble (c) Prof.dr.ir.T.M. de Jong

	left	above	right	below
01 Plot surface (m2)	100,00	0,00	100,00	0,00
02 G.floor surface (m2)	50,00	0,00	50,00	0,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	3,00	8,00	3,00	8,00
07 Width garden aside(m)	0,00	0,50	0,00	0,50
08 Length block + gard.(m)	15,00	41,00	15,00	41,00
09 House depth(m)	10,00	0,00	10,00	0,00
10 House volume (m3)	345,00	0,00	345,00	0,00
11 Floor space (m2)	120,00	0,00	120,00	0,00
12 Plot length(m)	20,00	0,00	20,00	0,00
13 Tot. length garden (m)	10,00	0,00	10,00	0,00
14 Rear garden(m)	10,00	0,00	10,00	0,00
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	2,00	2,00	2,00
17 Width green verge(m2)	0,00	0,00	9,00	2,50
18 Width parking space (m)	0,00	2,50	0,00	0,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	1,00	0,00	1,00	0,00
21 Plot depth (m)	25,50	7,50	34,50	7,50
22 Total surface (ha)	0,04	0,05	0,05	0,05
23 Density(houses/ha)	78,43	0,00	57,97	0,00
24 Common green fields(m2)	0,00	27,00	135,00	148,00
25 Paved area(m2)	75,00	888,25	75,00	792,50
26 C.green per house(m2)	0,00	0,00	45,00	0,00
27 Paved per house (m2)	25,00	0,00	25,00	0,00
28 Floor density(m2/m2)	0,94	0,00	0,70	0,00
29 Number of houses	3,00	0,00	3,00	0,00
30 N. of parking spaces	0,00	8,00	0,00	0,00

Number of houses 6 Density 33,33 houses/ha. FSI 0,40 Surface: 30,00 m x 60,00 m = 0,18 ha. Scale1 : 1000

PER HOUSE 1,33 parking spaces; 100,00 m2 for sale; 51,67 m2 green; 305,1:m2 paved area; i.e. resp. 22 ; 11 and 67 %.

Fig. 532 30x60m W-E mirroring

The picture shows an urban island with three houses with gardens surrounded by sidewalks and streets. North and South of the island there are parking lots for 2 cars each. The allotment is mirrored at the other side of the street.

The smallest urban island taken in consideration here has a grid measure of 30x30m. The consequence of small urban islands is an excessive surface of public pavement (here 76%!), leaving relatively little for sale (here maximally 22%) paying for that public space.[125]

The effect of a first design transformation, W-E mirroring, elongates the urban island reducing public pavement (here into 67%). The gained surface produces a green margin of 9m drawn East and 2.50m drawn South. Now, at that length, one side with parking places is enough to reach more than 1 parking place per dwelling.

The shadow of the N side is best suitable for parking. Now, W and E roads are used for entrance to houses at both sides and back gardens get more privacy. The lots for sale differentiate in morning~ and evening sun lovers.

In *Fig. 532* greenery is drawn East to get an idea of road profiles and crossings without greenery in the corner left below in the drawing, where circles are drawn with a radius of 10 and 30m. For children in the afternoon and in the summer evening green area can better be designed in the West as well to have sunny playgrounds. That does not change the counted figures left and below of the drawing.

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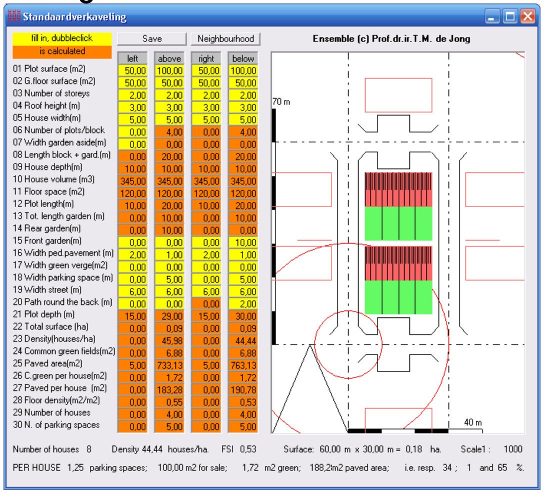
[a] The North an South sides of an urban island are best suitable for parking for two reasons. Their surface enlarges the North-South distance between outer walls of dwellings, giving more acces to sunlight, and the shadow of North walls is welcome to parked cars.

Taking sun into account



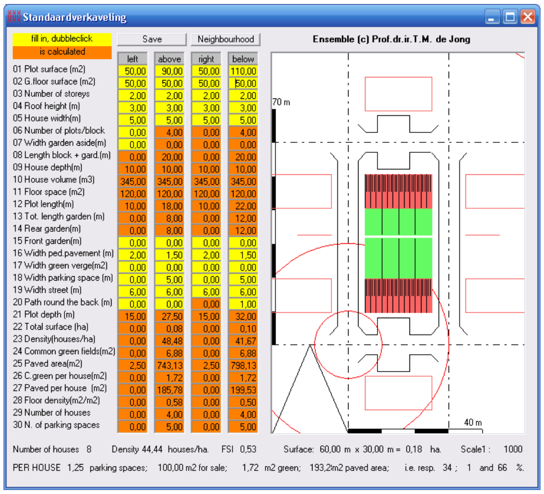
	left	above	right	below
01 Plot surface (m2)	50,00	100,00	50,00	100,00
02 G.floor surface (m2)	50,00	50,00	50,00	50,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	0,00	4,00	0,00	4,00
07 Width garden aside(m)	0,00	0,00	0,00	0,00
08 Length block + gard.(m)	0,00	20,00	0,00	20,00
09 House depth(m)	10,00	10,00	10,00	10,00
10 House volume (m3)	345,00	345,00	345,00	345,00
11 Floor space (m2)	120,00	120,00	120,00	120,00
12 Plot length(m)	10,00	20,00	10,00	20,00
13 Tot. length garden (m)	0,00	10,00	0,00	10,00
14 Rear garden(m)	0,00	10,00	0,00	0,00
15 Front garden(m)	0,00	0,00	0,00	10,00
16 Width ped.pavement (m)	2,00	1,00	2,00	1,00
17 Width green verge(m2)	0,00	0,00	0,00	0,00
18 Width parking space (m)	0,00	5,00	0,00	5,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	0,00	0,00	0,00	2,00
21 Plot depth (m)	15,00	29,00	15,00	30,00
22 Total surface (ha)	0,00	0,09	0,00	0,09
23 Density(houses/ha)	0,00	45,98	0,00	44,44
24 Common green fields(m2)	0,00	6,88	0,00	6,88
25 Paved area(m2)	5,00	733,13	5,00	763,13
26 C.green per house(m2)	0,00	1,72	0,00	1,72
27 Paved per house (m2)	0,00	183,28	0,00	190,78
28 Floor density(m2/m2)	0,00	0,55	0,00	0,53
29 Number of houses	0,00	4,00	0,00	4,00
30 N. of parking spaces	0,00	5,00	0,00	5,00

Number of houses 8 Density 44,44 houses/ha. FSI 0,53 Surface: 60,00 m x 30,00 m = 0,18 ha. Scale1 : 1000

PER HOUSE 1,25 parking spaces; 100,00 m2 for sale; 1,72 m2 green; 188,21m2 paved area; i.e. resp. 34 ; 1 and 65 %.

Fig. 533 60x30m N-S Turning and multiplying

N-S turning and repeating gives both blocks South gardens. Now, the short sides of the urban island are used for parking, forcing cross-parking to reach >1 parking places per dwelling. The path round the back is enlarged at the expense of sidewalks to give proper front access to the Southern block.



	left	above	right	below
01 Plot surface (m2)	50,00	90,00	50,00	110,00
02 G.floor surface (m2)	50,00	50,00	50,00	50,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	0,00	4,00	0,00	4,00
07 Width garden aside(m)	0,00	0,00	0,00	0,00
08 Length block + gard.(m)	0,00	20,00	0,00	20,00
09 House depth(m)	10,00	10,00	10,00	10,00
10 House volume (m3)	345,00	345,00	345,00	345,00
11 Floor space (m2)	120,00	120,00	120,00	120,00
12 Plot length(m)	10,00	18,00	10,00	22,00
13 Tot. length garden (m)	0,00	8,00	0,00	12,00
14 Rear garden(m)	0,00	8,00	0,00	12,00
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	1,50	2,00	1,50
17 Width green verge(m2)	0,00	0,00	0,00	0,00
18 Width parking space (m)	0,00	5,00	0,00	5,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	0,00	0,00	0,00	1,00
21 Plot depth (m)	15,00	27,50	15,00	32,00
22 Total surface (ha)	0,00	0,08	0,00	0,10
23 Density(houses/ha)	0,00	48,48	0,00	41,67
24 Common green fields(m2)	0,00	6,88	0,00	6,88
25 Paved area(m2)	2,50	743,13	2,50	798,13
26 C.green per house(m2)	0,00	1,72	0,00	1,72
27 Paved per house (m2)	0,00	185,78	0,00	199,53
28 Floor density(m2/m2)	0,00	0,58	0,00	0,50
29 Number of houses	0,00	4,00	0,00	4,00
30 N. of parking spaces	0,00	5,00	0,00	5,00

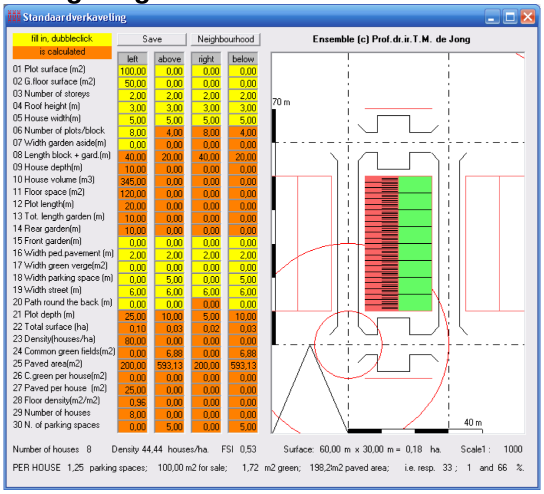
Number of houses 8 Density 44,44 houses/ha. FSI 0,53 Surface: 60,00 m x 30,00 m = 0,18 ha. Scale1 : 1000

PER HOUSE 1,25 parking spaces; 100,00 m2 for sale; 1,72 m2 green; 193,21m2 paved area; i.e. resp. 34 ; 1 and 66 %.

Fig. 534 60x30m N-S mirroring

N-S mirroring introduces North gardens, drawn longer here to get a partly sunny view on the N garden still. It differentiates the lots for sale in size and suggests a different dwelling type for sun lovers with south gardens and artistic life style with Northern light rooms like studios.

Elongating



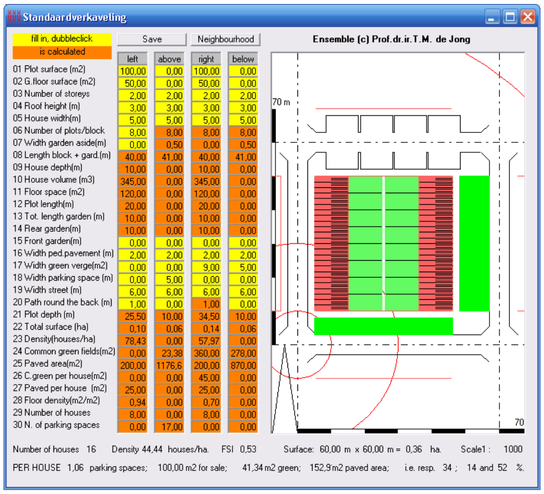
	left	above	right	below
01 Plot surface (m2)	100,00	0,00	0,00	0,00
02 G.floor surface (m2)	50,00	0,00	0,00	0,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	8,00	4,00	8,00	4,00
07 Width garden aside(m)	0,00	0,00	0,00	0,00
08 Length block + gard.(m)	40,00	20,00	40,00	20,00
09 House depth(m)	10,00	0,00	0,00	0,00
10 House volume (m3)	345,00	0,00	0,00	0,00
11 Floor space (m2)	120,00	0,00	0,00	0,00
12 Plot length(m)	20,00	0,00	0,00	0,00
13 Tot. length garden (m)	10,00	0,00	0,00	0,00
14 Rear garden(m)	10,00	0,00	0,00	0,00
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	2,00	2,00	2,00
17 Width green verge(m2)	0,00	0,00	0,00	0,00
18 Width parking space (m)	0,00	5,00	0,00	5,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	0,00	0,00	0,00	0,00
21 Plot depth (m)	25,00	10,00	5,00	10,00
22 Total surface (ha)	0,10	0,03	0,02	0,03
23 Density(houses/ha)	80,00	0,00	0,00	0,00
24 Common green fields(m2)	0,00	6,88	0,00	6,88
25 Paved area(m2)	200,00	593,13	200,00	593,13
26 C.green per house(m2)	0,00	0,00	0,00	0,00
27 Paved per house (m2)	25,00	0,00	0,00	0,00
28 Floor density(m2/m2)	0,96	0,00	0,00	0,00
29 Number of houses	8,00	0,00	0,00	0,00
30 N. of parking spaces	0,00	5,00	0,00	5,00

Number of houses 8 Density 44,44 houses/ha. FSI 0,53 Surface: 60,00 m x 30,00 m = 0,18 ha. Scale1 : 1000

PER HOUSE 1,25 parking spaces; 100,00 m2 for sale; 1,72 m2 green; 198,21m2 paved area; i.e. resp. 33 ; 1 and 66 %.

Fig. 535 60x30m elongating

To reach the same capacity of *Fig. 534* by one sided elongating avoids the path round the back utilizing the side walk, giving back a proper size to the sidewalks N and S. East gardens are suitable for people who like morning sun in the garden and in the sleeping room. Pavement is still 66%.



	left	above	right	below
01 Plot surface (m2)	100,00	0,00	100,00	0,00
02 G.floor surface (m2)	50,00	0,00	50,00	0,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	8,00	8,00	8,00	8,00
07 Width garden aside(m)	0,00	0,50	0,00	0,50
08 Length block + gard.(m)	40,00	41,00	40,00	41,00
09 House depth(m)	10,00	0,00	10,00	0,00
10 House volume (m3)	345,00	0,00	345,00	0,00
11 Floor space (m2)	120,00	0,00	120,00	0,00
12 Plot length(m)	20,00	0,00	20,00	0,00
13 Tot. length garden (m)	10,00	0,00	10,00	0,00
14 Rear garden(m)	10,00	0,00	10,00	0,00
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	2,00	2,00	2,00
17 Width green verge(m2)	0,00	0,00	9,00	5,00
18 Width parking space (m)	0,00	5,00	0,00	0,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	1,00	0,00	1,00	0,00
21 Plot depth (m)	25,50	10,00	34,50	10,00
22 Total surface (ha)	0,10	0,06	0,14	0,06
23 Density(houses/ha)	78,43	0,00	57,97	0,00
24 Common green fields(m2)	0,00	23,38	360,00	278,00
25 Paved area(m2)	200,00	1176,6	200,00	870,00
26 C.green per house(m2)	0,00	0,00	45,00	0,00
27 Paved per house (m2)	25,00	0,00	25,00	0,00
28 Floor density(m2/m2)	0,94	0,00	0,70	0,00
29 Number of houses	8,00	0,00	8,00	0,00
30 N. of parking spaces	0,00	17,00	0,00	0,00

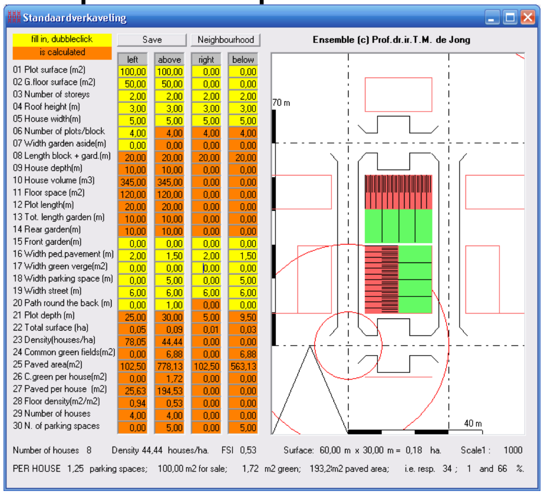
Number of houses 16 Density 44,44 houses/ha. FSI 0,53 Surface: 60,00 m x 60,00 m = 0,36 ha. Scale1 : 1000

PER HOUSE 1,06 parking spaces; 100,00 m2 for sale; 41,34 m2 green; 152,9m2 paved area; i.e. resp. 34 ; 14 and 52 %.

Fig. 536 60x60m mirroring

Mirroring gives evening people a chance as well and both gardens more privacy. It differentiates use and plantation. The enlargement of the urban island again reduces the amount of pavement, now into 52% in favour of the margins possibly used as green area: 9m East and 5m South.

L-shape and U-shape



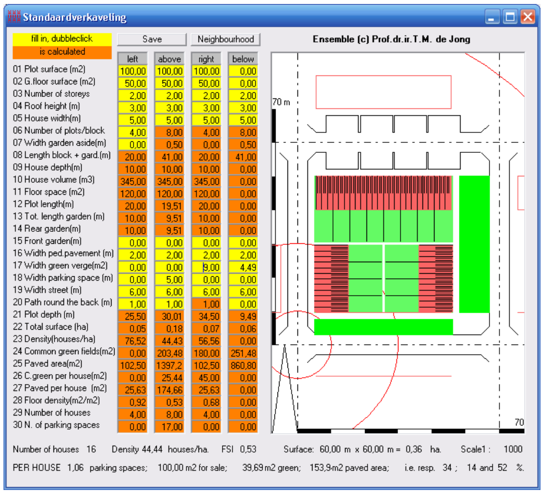
	left	above	right	below
01 Plot surface (m2)	100,00	100,00	0,00	0,00
02 G.floor surface (m2)	50,00	50,00	0,00	0,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	4,00	4,00	4,00	4,00
07 Width garden aside(m)	0,00	0,00	0,00	0,00
08 Length block + gard.(m)	20,00	20,00	20,00	20,00
09 House depth(m)	10,00	10,00	0,00	0,00
10 House volume (m3)	345,00	345,00	0,00	0,00
11 Floor space (m2)	120,00	120,00	0,00	0,00
12 Plot length(m)	20,00	20,00	0,00	0,00
13 Tot. length garden (m)	10,00	10,00	0,00	0,00
14 Rear garden(m)	10,00	10,00	0,00	0,00
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	1,50	2,00	1,50
17 Width green verge(m2)	0,00	0,00	0,00	0,00
18 Width parking space (m)	0,00	5,00	0,00	5,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	0,00	1,00	0,00	0,00
21 Plot depth (m)	25,00	30,00	5,00	9,50
22 Total surface (ha)	0,05	0,09	0,01	0,03
23 Density(houses/ha)	78,05	44,44	0,00	0,00
24 Common green fields(m2)	0,00	6,88	0,00	6,88
25 Paved area(m2)	102,50	778,13	102,50	563,13
26 C.green per house(m2)	0,00	1,72	0,00	0,00
27 Paved per house (m2)	25,63	194,53	0,00	0,00
28 Floor density(m2/m2)	0,94	0,53	0,00	0,00
29 Number of houses	4,00	4,00	0,00	0,00
30 N. of parking spaces	0,00	5,00	0,00	5,00

Number of houses 8 Density 44,44 houses/ha. FSI 0,53 Surface: 60,00 m x 30,00 m = 0,18 ha. Scale1 : 1000

PER HOUSE 1,25 parking spaces; 100,00 m2 for sale; 1,72 m2 green; 193,2m2 paved area; i.e. resp. 34 ; 1 and 66 %.

Fig. 537 60x30m L-shape

Introducing perpendicular blocks provides streetcorners with front entrances in 2 directions. That gives the beginning of an urban look and safety by private control of public space on both roads involved. To improve that effect design solutions for corners, not implemented here, would be nice. Such solutions will struggle with smaller or no gardens in the corner.



	left	above	right	below
01 Plot surface (m2)	100,00	100,00	100,00	0,00
02 G.floor surface (m2)	50,00	50,00	50,00	0,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	4,00	8,00	4,00	8,00
07 Width garden aside(m)	0,00	0,50	0,00	0,50
08 Length block + gard.(m)	20,00	41,00	20,00	41,00
09 House depth(m)	10,00	10,00	10,00	0,00
10 House volume (m3)	345,00	345,00	345,00	0,00
11 Floor space (m2)	120,00	120,00	120,00	0,00
12 Plot length(m)	20,00	19,51	20,00	0,00
13 Tot. length garden (m)	10,00	9,51	10,00	0,00
14 Rear garden(m)	10,00	9,51	10,00	0,00
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	2,00	2,00	2,00
17 Width green verge(m2)	0,00	0,00	9,00	4,49
18 Width parking space (m)	0,00	5,00	0,00	0,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	1,00	1,00	1,00	0,00
21 Plot depth (m)	25,50	30,01	34,50	9,49
22 Total surface (ha)	0,05	0,18	0,07	0,06
23 Density(houses/ha)	76,52	44,43	56,56	0,00
24 Common green fields(m2)	0,00	203,48	180,00	251,48
25 Paved area(m2)	102,50	1397,2	102,50	860,80
26 C.green per house(m2)	0,00	25,44	45,00	0,00
27 Paved per house (m2)	25,63	174,66	25,63	0,00
28 Floor density(m2/m2)	0,92	0,53	0,68	0,00
29 Number of houses	4,00	8,00	4,00	0,00
30 N. of parking spaces	0,00	17,00	0,00	0,00

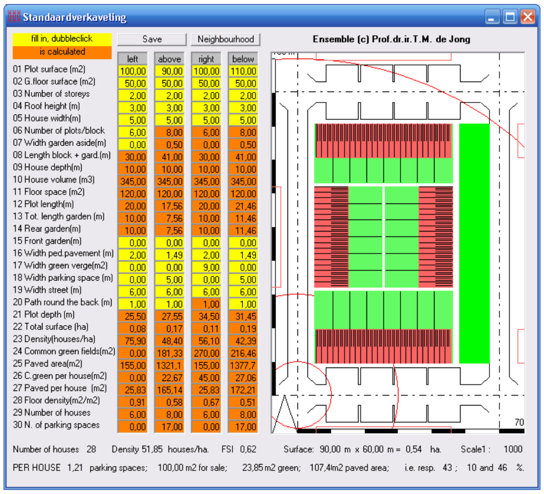
Number of houses 16 Density 44,44 houses/ha. FSI 0,53 Surface: 60,00 m x 60,00 m = 0,36 ha. Scale1 : 1000

PER HOUSE 1,06 parking spaces; 100,00 m2 for sale; 39,69 m2 green; 153,9m2 paved area; i.e. resp. 34 ; 14 and 52 %.

Fig. 538 60x60m U-shape

Mirroring the L-shape produces U-shaped allotments with one open side, here avoiding North gardens. It has the same advantages as previous mirroring transformations, in this case reducing pavement from 66% in *Fig. 537* into 52% and introducing green margins of 9m East and 5m South. S gardens go 0.5m around the back now, giving space for ivy-covered side façades avoiding grafitti.

Closed urban islands



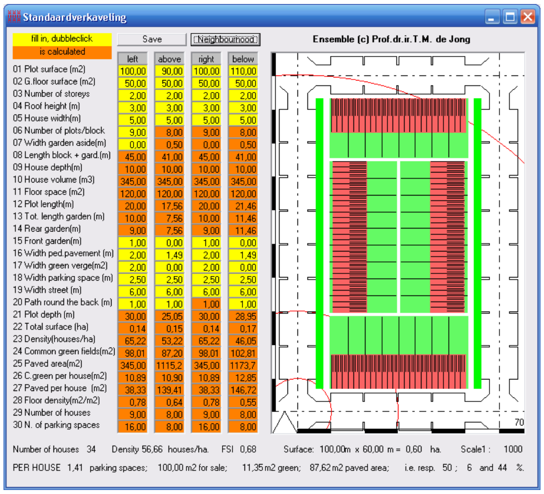
	left	above	right	below
01 Plot surface (m2)	100,00	90,00	100,00	110,00
02 G.floor surface (m2)	50,00	50,00	50,00	50,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	6,00	8,00	6,00	8,00
07 Width garden aside(m)	0,00	0,50	0,00	0,50
08 Length block + gard.(m)	30,00	41,00	30,00	41,00
09 House depth(m)	10,00	10,00	10,00	10,00
10 House volume (m3)	345,00	345,00	345,00	345,00
11 Floor space (m2)	120,00	120,00	120,00	120,00
12 Plot length(m)	20,00	17,56	20,00	21,46
13 Tot. length garden (m)	10,00	7,56	10,00	11,46
14 Rear garden(m)	10,00	7,56	10,00	11,46
15 Front garden(m)	0,00	0,00	0,00	0,00
16 Width ped.pavement (m)	2,00	1,49	2,00	1,49
17 Width green verge(m2)	0,00	0,00	9,00	0,00
18 Width parking space (m)	0,00	5,00	0,00	5,00
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	1,00	1,00	1,00	1,00
21 Plot depth (m)	25,50	27,55	34,50	31,45
22 Total surface (ha)	0,08	0,17	0,11	0,19
23 Density(houses/ha)	75,90	48,40	56,10	42,39
24 Common green fields(m2)	0,00	181,33	270,00	216,46
25 Paved area(m2)	155,00	1321,1	155,00	1377,7
26 C.green per house(m2)	0,00	22,67	45,00	27,06
27 Paved per house (m2)	25,83	165,14	25,83	172,21
28 Floor density(m2/m2)	0,91	0,58	0,67	0,51
29 Number of houses	6,00	8,00	6,00	8,00
30 N. of parking spaces	0,00	17,00	0,00	17,00

Number of houses 28 Density 51,85 houses/ha. FSI 0,62 Surface: 90,00 m x 60,00 m = 0,54 ha. Scale1 : 1000

PER HOUSE 1,21 parking spaces; 100,00 m2 for sale; 23,85 m2 green; 107,4m2 paved area; i.e. resp. 43 ; 10 and 46 %.

Fig. 539 90x60m Closing

Closing the urban island with front entrances on every surrounding street produces a usual allotment type of 90m length, leaving a 9m green margin East to fill the urban grid of multiples by 30m. Limiting parking places to N and S urges cross parking at both sides to have more than 1 parking place per dwelling leaving little space for sidewalks.[126]



	left	above	right	below
01 Plot surface (m2)	100,00	90,00	100,00	110,00
02 G.floor surface (m2)	50,00	50,00	50,00	50,00
03 Number of storeys	2,00	2,00	2,00	2,00
04 Roof height (m)	3,00	3,00	3,00	3,00
05 House width(m)	5,00	5,00	5,00	5,00
06 Number of plots/block	9,00	8,00	9,00	8,00
07 Width garden aside(m)	0,00	0,50	0,00	0,50
08 Length block + gard.(m)	45,00	41,00	45,00	41,00
09 House depth(m)	10,00	10,00	10,00	10,00
10 House volume (m3)	345,00	345,00	345,00	345,00
11 Floor space (m2)	120,00	120,00	120,00	120,00
12 Plot length(m)	20,00	17,56	20,00	21,46
13 Tot. length garden (m)	10,00	7,56	10,00	11,46
14 Rear garden(m)	9,00	7,56	9,00	11,46
15 Front garden(m)	1,00	0,00	1,00	0,00
16 Width ped.pavement (m)	2,00	1,49	2,00	1,49
17 Width green verge(m2)	2,00	0,00	2,00	0,00
18 Width parking space (m)	2,50	2,50	2,50	2,50
19 Width street (m)	6,00	6,00	6,00	6,00
20 Path round the back (m)	1,00	1,00	1,00	1,00
21 Plot depth (m)	30,00	25,05	30,00	28,95
22 Total surface (ha)	0,14	0,15	0,14	0,17
23 Density(houses/ha)	65,22	53,22	65,22	46,05
24 Common green fields(m2)	98,01	87,20	98,01	102,81
25 Paved area(m2)	345,00	1115,2	345,00	1173,7
26 C.green per house(m2)	10,89	10,90	10,89	12,85
27 Paved per house (m2)	38,33	139,41	38,33	146,72
28 Floor density(m2/m2)	0,78	0,64	0,78	0,55
29 Number of houses	9,00	8,00	9,00	8,00
30 N. of parking spaces	16,00	8,00	16,00	8,00

Number of houses 34 Density 56,66 houses/ha. FSI 0,68 Surface: 100,00m x 60,00 m = 0,60 ha. Scale1 : 1000

PER HOUSE 1,41 parking spaces; 100,00 m2 for sale; 11,35 m2 green; 87,62 m2 paved area; i.e. resp. 50 ; 6 and 44 %.

Fig. 540 Elongating and adapting 100x60m

N-S elongating to 100m is easy by adding 2 houses West and East. However, the shortage of parking places then forces parking at all sides. By giving up cross parking N and S, there is space for 6 extra houses in total. The reduction of pavement is 2% only, but the number of parking places is 1.4 per dwelling. This time the green margin is distributed W and E to make trees possible.

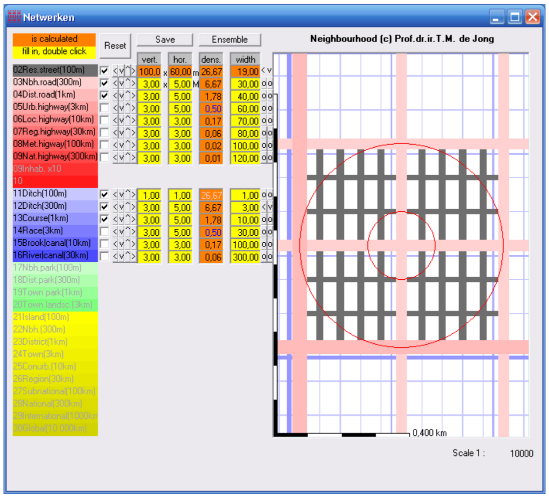
In *Fig. 540* we leave the starting points of page 266 behind and start to look at a higher level. On that level new spaces for mobility are needed. By the way, the elongated blocks of *Fig. 540* exceed 40m and need an extra dilatation, which is expensive.

3.4.13 A neighbourhood

If we multiply the module (**M**) of *Fig. 540* (100x60m) 5 times E-W and 3 times N-S (*Fig. 541*) we reach the mesh width (300mx300m) for neighbourhood roads (30m width of pavement[127]) mentioned at page 266. We now have 15 modules together surrounded by larger neighbourhood roads needing extra space.

Traffic production

These 'neighbourhood islands' we call 'neighbourhood quarters', because 4 of them make a neighbourhood.



		vert.		hor.		dens.	width
02Res.street(100m)	☑	100,0	x	60,00	m	26,67	19,00
03Nbh.road(300m)	☑	3,00	x	5,00	M	6,67	30,00
04Dist.road(1km)	☑	3,00		5,00		1,78	40,00
05Urb.highway(3km)	☐	3,00		5,00		0,50	60,00
06Loc.highway(10km)	☐	3,00		3,00		0,17	70,00
07Reg.highway(30km)	☐	3,00		3,00		0,06	80,00
08Met.higway(100km)	☐	3,00		3,00		0,02	100,00
09Nat.highway(300km)	☐	3,00		3,00		0,01	120,00
09Inhab. x10							
10							
11Ditch(100m)	☑	1,00		1,00		26,67	1,00
12Ditch(300m)	☑	3,00		5,00		6,67	3,00
13Course(1km)	☑	3,00		5,00		1,78	10,00
14Race(3km)	☐	3,00		5,00		0,50	30,00
15Brook|canal(10km)	☐	3,00		3,00		0,17	100,00
16River|canal(30km)	☐	3,00		3,00		0,06	300,00
17Nbh.park(100m)							
18Dist.park(300m)							
19Town park(1km)							
20Town landsc.(3km)							
21Island(100m)							
22Nbh.(300m)							
23District(1km)							
24Town(3km)							
25Conurb.(10km)							
26Region(30km)							
27Subnational(100km)							
28National(300km)							
29International(1000km							
30Global(10 000km)							

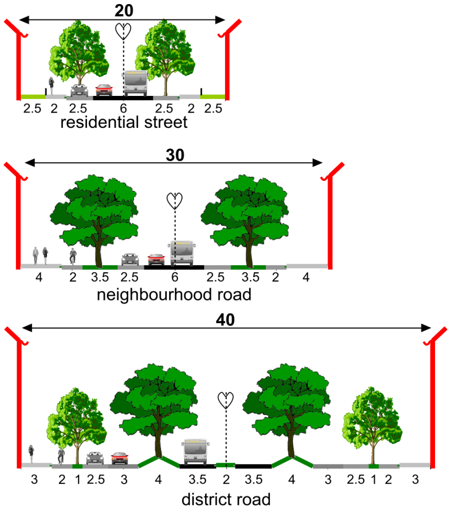


Fig. 541 A neighbourhood, multiplying Fig. 540

Fig. 542 Profiles normalised to 20, 30 and 40m

Suppose every urban island contains some 75 people going out 4 times a day of which 3 by car. Suppose 1/3 of the car trips the driver is accompanied by a passenger, 1 trip is done by walking or cycling.[a] So, a block produces 75x2x2≅300 car movements per day, because they are not only going out, they are coming back as well. That normally means 30 car movements per hour per island. Let them use two of four streets around the block. So, a residential street has some 15 car movements per hour and much more in peak hours. And there are visitors as well.[128]

Space for facilities

The neighbourhood of *Fig. 541* does not only need extra space for pavement of neighbourhood roads, but also for neighbourhood facilities like green, water, a school, shops and offices. Moreover, it has to accommodate facilities of higher level like district roads (40m wide). They produce car movements as well, but in the same time they make part of the modules involved unsuitable as residential area. Moreover, not all modules will reach 56 dwellings per ha or a floor space ratio (FSI) of 68% reached in *Fig. 540*, because many lots are larger than 100m^2. Suppose there are 1000 inhabitants per neighbourhood, it produces 1000x2x2≅4000 car movements per day using half of the neighbourhood roads available. So, a neighbourhood road has some 2000 car movements per day or 200 per hour and much more in peak hours.[129] And there are visitors as well.

---

[a] CBS …

3.4.14 A road hierarchy

Going on like that we can make a table with approximate measures (in reality they will vary around that measure) for any type of road in a hierarchy (*Fig. 543*, do not take it too serious: it is a rule of thumb).

	Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		residential path	**residential street**	**neighbourhood road**	**district road**	**urban highway**	**highway**	**regional highway**	**metropolitan highway**
	directly served area	estate	ensemble	neighbourhood	district	town	conurbation	region	metropolitan region
	m radius | mesh | crossing distance	**30**	**100**	**300**	**1000**	**3000**	**10000**	**30000**	**30000**
	directly served inhabitants	10	100	1000	10000	100000	1000000	3000000	10000000
	number of dwelling layers	1	2	3	4	6	7	8	10
	Profile								
	Left half until median strip								
profile key	**m facade height**	2,75	5,50	8,25	11,00	16,50	19,25	22,00	27,50
	m private use	1,00	2,50						
	🟩								
	m sidewalk	0,50	2,00	4,00	3,00	3,00	3,00	3,00	3,00
	🟩								
	m cycle track1			2,00	2,00	3,00	3,00	3,00	3,00
	🟩			3,50	1,00	1,50		1,75	
	m park1	2,50	2,50	2,50	2,50	2,50	2,50	2,50	2,50
	m parallel road				3,00	3,00	3,00	3,00	3,00
	m park2								
	🟩				2,00	3,00	3,00	3,00	4,50
	m cycle track 2								
	🟩				2,00	3,00	3,00	3,00	4,00
	m hard shoulder					2,50	2,50	2,50	2,00
	m lanes	1,00	3,00	3,00	3,50	6,50	13,00	16,25	26,00
	m park 3								
	m median strip				2,00	4,00	4,00	4,00	4,00
	Right half from median strip mirrored	5,00	10,00	15,00	19,00	28,00	33,00	38,00	48,00
	m total	**10,00**	**20,00**	**30,00**	**40,00**	**60,00**	**70,00**	**80,00**	**100,00**
	m pavement	8,0	15,0	23,0	28,0	41,0	54,0	60,5	79,0
	Physical infrastructure								
	m width between facades	10	20	30	40	60	70	80	100
	km/hour design velocity	10	30	50	70	90	110	130	150
	m minimum lane width	1,75	2,25	2,75	3,25	3,25	3,25	3,25	3,25
	number of lanes	1	2	2	2	4	8	10	16
	Capacity (possible use)								
	vehicles/h capacity per lane	500	1000	1500	2000	2000	2000	2000	2000

Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	residential path	**residential street**	**neighbourhood road**	**district road**	**urban highway**	**highway**	**regional highway**	**metropolitan highway**
directly served area	estate	ensemble	neighbourhood	district	town	conurbation	region	metropolitan region
m radius | mesh | crossing distance	**30**	**100**	**300**	**1000**	**3000**	**10000**	**30000**	**30000**
vehicles/hour capacity	**500**	**2000**	**3000**	**4000**	**8000**	**16000**	**20000**	**32000**
vehicles/24 hour capacity	5000	20000	30000	40000	80000	160000	200000	320000
Use | Intensity								
residential								
directly served inhabitants	10	100	1000	10000	100000	1000000	3000000	10000000
car rides/inhabitant/day	2,00	2,00	2,00	1,00	0,20	0,10	0,05	0,02
%surrounding infrastructure used	50%	50%	50%	50%	50%	50%	50%	50%
light vehicles/24 hour intensity	20	200	2000	10000	20000	100000	150000	200000
cargo								
kg cargo/inhabitant per day	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
kg cargo/vehicle	10	100	1000	1000	1000	1000	1000	1000
cargo vehicles/24 hour intensity	2	2	2	20	200	2000	6000	20000
service								
service visit/inhabitant/day	0,01	0,01	0,01	0,02	0,01	0,00	0,00	0,00
service vehicles/24 hour intensity	0,20	2,00	20	400	2000	2000	6000	20000
total								
vehicles/24 hour intensity	22	204	2022	10420	22200	104000	162000	240000
vehicles/hour intensity	**2**	**20**	**202**	**1042**	**2220**	**10400**	**16200**	**24000**
vehicles/hour peak intensity								
% use by car = intensity/capacity	0,4%	1,0%	7%	26%	28%	65%	81%	75%
dB(A) noise on façade[a]	66	59	62	74	80	84	90	96
% devaluation houseprice by noise[a]	10%	5%	7%	22%	34%	40%	48%	54%

Fig. 543 Approximate characteristics of a road hierarchy as a model

All assumptions of *Fig. 543* are arbitrary and can be changed in the similar spreadsheet 'hierarchy.xls'.[b] This spreadsheet draws the adapted profiles as well. The text below explains the concepts.

Spatial measures

In *Fig. 543* '**m radius**' is a nominal measure (read 300m and think 'something between 100m and 1000m' or 'neighbourhood', with a diameter of approximately 600m) for the area involved. It applies the mesh width of the theoretical network as well, the distance between crossings of roads of the same level (turn distance). '**Directly served inhabitants**' is as elastic as the nominal radius (read 1000 inhabitants and think 'something between 100 and 10 000 inhabitants').

The '**Profile key**' gives a possible division of half the profile including the median strip, summarised without the median strip, supposing the other half is mirrored. So, the total distance between façades is two times half the profile.

---

[a] *calculated according to SRM1*

[b] Downloadable from *http://team.bk.tudelft.nl/Databases/Databases.htm* > *Wegprofielen maken met excel .xls*

Traffic measures

The '**km/hour design velocity**' shows which speed of cars is supposed determining the '**minimum lane width**' of the lanes out of which the roadway is composed. The '**number of lanes**' is determined by the expected number of cars per hour calculated in line '**vehicles/hour intensity**'.
The actual intensity is something else than the capacity, the maximum possible intensity without congestion, for example in peak hours. They are compared in the **% use by car** = intensity/capacity. Above a certain percentage (60%?) you can expect congestion in peak hours.

Non-residential traffic

The **light vehicles/24 hour intensity** is calculated here by multiplying the number of directly served inhabitants, the number of car rides/inhabitant per day and the **%surrounding infrastructure** used as we did already on page 270 for residential and neighbourhood roads. There we mentioned already 'there are visitors as well'. In the neighbourhood it does not count so much, but on roads of higher level cargo transport and service traffic is more important.

How to count that? Here we found a very simple, but perhaps not very reliable way. We estimate the **kg cargo/inhabitant/day** and divide it by an estimated **kg cargo/vehicle** to get the number of **cargo vehicles/24 hour**. In a comparable way the number of **service visits/inhabitant** per day produces the **service vehicles/24 hour intensity**. Summing these lines produces the **number of vehicles/24 hour intensity**, which divided by 10 produces, **vehicles/hour intensity**.

Noise

The **dB(A) noise on façade** depends on many things like intensity and distance to the façade. It is a rough estimate, but it determines **% devaluation of house prices** by noise.[a]

3.4.15 From a model back into a real city

This chapter started by real measures of cars (*Fig. 523*), derived models about a hierarchy of roads with different capacity and intensity (induction from particular into general). We neglected many aspects of urban context. Now, we have to check how reliable these models are, knowing that reality always differs (deduction form general into particular).

Deduction into a special case

A complete survey should take more cases to check the theory. Here we take one case only and we do not check all assumptions (hypotheses). In *Fig. 544 The urban area around Dordrecht*, we find 6 levels of roads. The resolution does not permit to see residential paths (1). But we see residential streets (2, white) , neighbourhood roads (3, yellow), district roads (4, same colour, but somewhat thicker), urban highways (5, purple), highways (6, red), regional highways (7, red and orange). We have drawn circles of nominally 3, 1 and 0.3km around parts we nowadays call city, district and neighbourhood.

Deviation of predicted measures

Let us start with Papendrecht. It has some clear squares of approximately 500x500m neighbourhood roads while our model states 300x300m. Should we adapt our model?

---

[a] It is calculated with a formula given in the thesis of Ruiter, E. P. J. (2004). The Great Canyon. Reclaiming land from urban traffic noise impact zones. (Zoetermeer) Peutz b.v.

Fig. 544 The urban area around Dordrecht[a]

Elsewhere (for example in the central part), there are smaller mesh widths (sometimes 100m). The model fits better the average. Moreover, we appointed: "read 300m and say 'something between 100m and 1000m' ". So, reality deviates within the appointed tolerance of the model. If our model fits the average, we can say: "Papendrecht has a relatively large mesh width for its neighbourhood roads".

Do we count the right hierarchy class?

But perhaps there is more going on. Do some of the drawn residential streets have neighbourhood road characteristics? To decide that, we need to enlarge the detail (*Fig. 545*). No, the map is correct, all streets with the square of neighbourhood and district roads are approximately 20m wide from façade to façade, perfectly according to what we stated in *Fig. 543*. The neighbourhood roads fit the prediction to be some 30m wide as well. However, the district road is not 40m, but 50m wide. There are two possible reasons.

Spatial context driven deviations

There is something more to learn from *Fig. 544* after all. We supposed there would be a district road every 1km, but in Papendrecht we see only one within a radius of 1km (diameter 2km). However, there is interference with the network of rivers clarifying why the second one is not realized. A second one here would not have enough use to legitimate the cost. The river limits its bearing surface. The model supposes a homogeneous topography while reality is heterogeneous. Nevertheless the density of district roads is low comparing to the model, so the remaining one needs more capacity.

Superposition

From Papendrecht we learn also that a district road appearing in a grid of neighbourhood roads can take over a neighbourhood function (superposition, we will discuss that in paragraph 3.4.4). That is another reason to increase its capacity and thereby its width.

---

[a] CDRom de nationale Stratengids van Nederland met kaarten van de Topografische Dienst te Emmen (Den Haag) Citydisc

Fig. 545 A Papendrecht detail

Fig. 546 A central Dordrecht detail

Fig. 547 Dordrecht some 350 years ago[a]

So, we keep the model for the time being, because it keeps us attentive on regularities in the existing urban tissue to be applied in urban design.

The time-dependency of a model

By the way, *Fig. 545* and *Fig. 546* illustrate how much surface can be occupied by non residential functions, as we stated in paragraph 3.4.13. *Fig. 547* shows what we call a city changes in time. Holland's oldest city in the 17th century (Dordrecht) and Amsterdam were very large that time but now we call their surface (R=1km) a district. All other cities in the Atlas of Blaeu[a] from 1652 are even smaller. They had a radius R=300m (walking distance). That is what we now call a neighbourhood. On Bleaus maps you see closed urban islands everywhere with closed corners as well. The urban density was much higher than we are used to nowadays. One of the factors of decreased density is the mobility space we need for cars and their parking lots. The way the urban islands became open allotments in the 20th century is described by Castex and Panerai.[b] What would be the cause?

---

[a] Blaeu, J. (1652). *Toonneel der Steden van Holland - Westvriesland - Utrecht*. (Amsterdam)

[b] Castex, J., J.-C. Panerai, et al., Eds. (1990). *De rationele stad. Van bouwblok tot wooneenheid. Met een nawoord van Henk Engel.* Teksten architectuur (Nijmegen) SUN.

3.4.16 Traffic surface

Ensembles (R=100m)

Fig. 548 and *Fig. 549* show two allotments of 100 dwellings (225 inhabitants) in rows of 10 on 1.8 ha. So, there are 56 dwellings/ha and FSI= 56% while the floor space per two storey dwelling is 100m^2. From total area 62% surface is for sale and 38% is public space including 1 parking place per dwelling and roadway pavement of 3.2m wide.

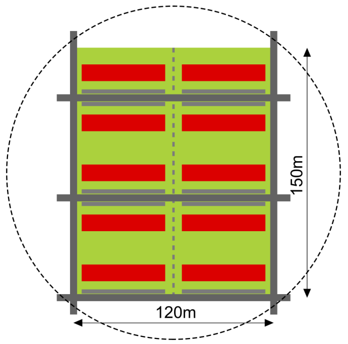


Fig. 548 100 dwellings along residential streets with parking in front of the house: 15% pavement, 23% green area

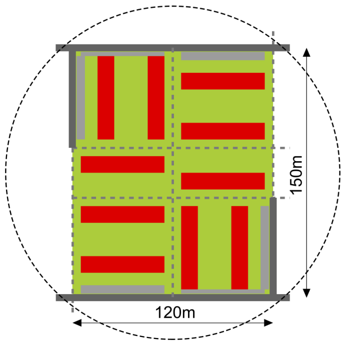


Fig. 549 Reduced pavement by residential paths, parking at 1 minute walk: 10% pavement, 28% green area

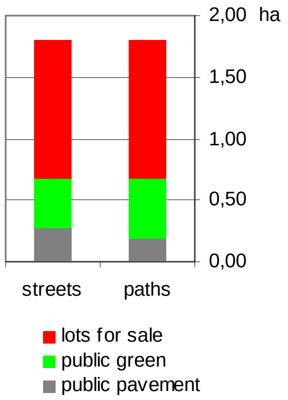


Fig. 550 Reduction of street pavement, increase of green area comparing Fig. 548 and Fig. 549[a]

However, in *Fig. 549* parking is concentrated at the boundaries. People have to walk 1 minute more than in *Fig. 548* to reach their cars, partly living at residential paths, saving 1/3 of pavement![130] That reduces municipal costs (or ground prices and taxes for private persons) substantially. By doing so, there is 1/5 more green area (5% green of total area), resulting in a much greener look without cars. That area could become public green, but it can be sold as well reducing municipal costs again. The disadvantage is, you can not easily come close to your home with luggage, moving vans and other vehicles. And you can not see your car from your home.

---

[a] PPD-ZH(1970)

Neighbourhoods (R=300m)

Multiplying a module like *Fig. 549* by 8 around a centre, produces a neighbourhood of 1800 inhabitants, enough for some facilities like a school (1ha black square in *Fig. 551* to *Fig. 553*), playgrounds, some shops and enterprises or public facilities. By locating parking spaces at the boundaries of the ensembles, at daytime some residential parking space can be used by users of the facilities, avoiding extra facility parking space.

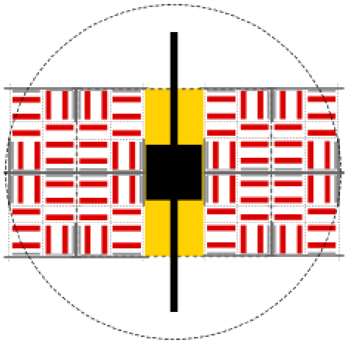


Fig. 551 300m central road

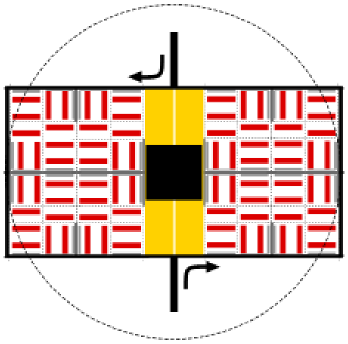


Fig. 552 1800m peripheral one way road substituting 600m residential street

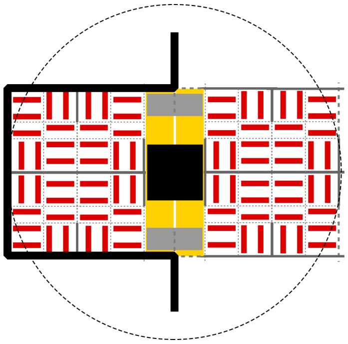
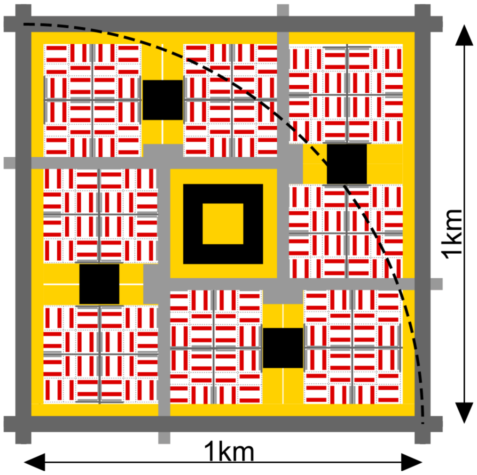


Fig. 553 900m peripheral road substituting 300m residential street, central parking

A central neighbourhood road costs least pavement, but it divides the neighbourhood and the school in two parts (*Fig. 551*). A peripheral road costs much more road length, unless it is part of a grid used for adjacent neighbourhoods as well. A one way solution (*Fig. 552*) may half pavement and barrier effect but causes detours. A one sided peripheral road leaves the other side open to the field and causes long walking distances. Concentrated parking on neighbourhood level could mean a 10 minute walk to your car (*Fig. 553*).[131]
However, these choices are often subordinate to the environment, mostly a district grid (*Fig. 554*).

Districts (R=1km)

Multiplying the module from *Fig. 551* by 4 (7200 inhabitants) the surface fits in a 1x1km grid of district roads (40 wide), leaving open a 30m surrounding margin and a centre (*Fig. 554*) in each district quarter. That centre can be used for additional district green, facilities or housing (4ha black square), utilizing concentrated residential parking in day time. The grid permits to leave out 1200 m neighbourhood streets according to the model of *Fig. 543*, but asks 8x90=720m extra residential roads to give access to all ensembles.[132]



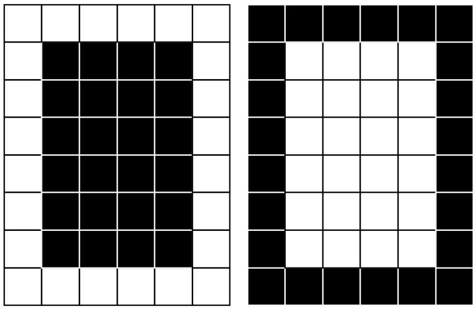


Fig. 554 A small district or district quarter *Fig. 555 Same built-up area optically full or empty*[a]

Fig. 555 shows the optical principle of leaving the centre open, applied in *Fig. 554* on the level of the quarter and on the level of its centre: the same surface left (4x6=24) gives a more spacious effect located in the periphery (6x8-4x6=24 as well: the 'Tummers-De Bruin effect'). A positive side-effect is better accessibility of the built-up area. On an even smaller scale *Fig. 554* shows another principle of central squares: do not make an X-crossing, give access roads along the square a view on larger buildings (here schools). Berlage designing the Mercator square in Amsterdam called it the 'turbine principle'.[133] The resulting T-crossings refer to Camillo Sitte as cited before (*Fig. 508*).

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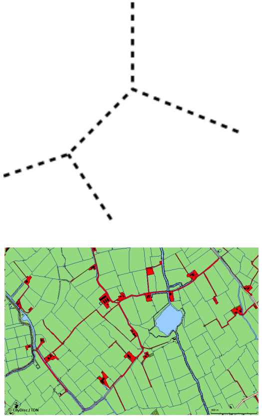
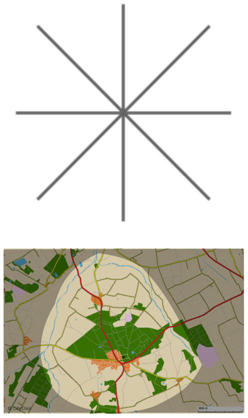
[a] Tummers, L. J. M. and J. M. Tummers-Zuurmond (1997). *Het land in de stad; de stedebouw van de grote agglomeratie*. (Bussum) THOTH.

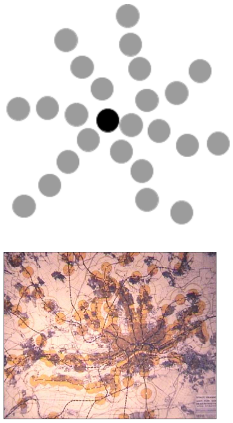
Network types on differrent levels of scale



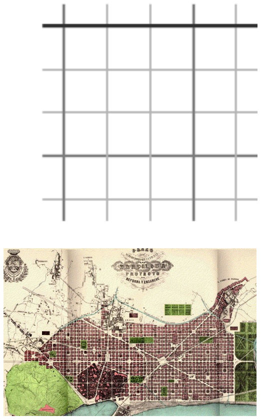
R=1km
Fig. 556 Shortest path for pedestrians



R=3km
Fig. 557 Radial for the market



R=10km
Fig. 558 Stops for public transport



R=0.1-10km
Fig. 559 Grid for car(riages)

Neighbourhoods in a distict

The hexagonal grid proposed by the American traffic expert Buchanan (1963)[a] [134], *Fig. 560* produces neighbourhoods of R=300m suitable in a grid of R=1000m.

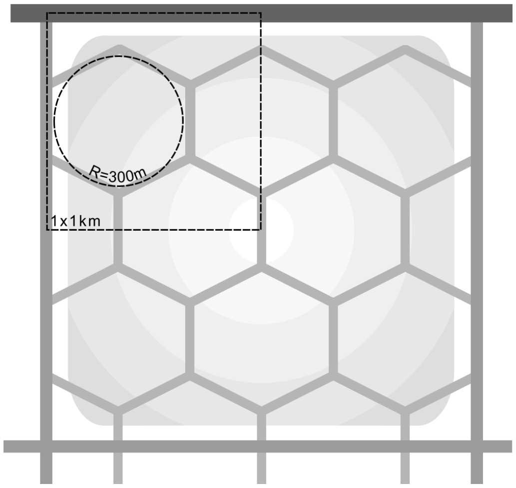


Fig. 560 The Buchanan grid put in a square 2x2km

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[a] Buchanan, C. (1963). *Traffic in Towns. The specially shortened edition of the Buchanan report.* (Harmondsworth, Middlesex, England) Penguin Books.

Ensembles in a conurbarion

Fig. 554 showed how a regular grid of district roads and neighbour streets solves some problems arising if you look at an isolated neighbourhood only.[135] The most famous urban grid is built in Barcelona, designed by Cerdà (1867).[a] He designed urban islands in squares of normally 133x133m (*Fig. 561*).[136]

A neighbourhood contained 25 islands (R=300m!) with bevelled 16m high building blocks making small squares on all crossings (*Fig. 562*).[137] The islands are enclosed by residential streets of 20m wide (*Fig. 563*), neighbourhoods by neighbourhood roads of 30m wide (*Fig. 564*), district (4 neighbourhoods) by district roads of 50m wide with a large median strip (*Fig. 565*).[138] A district had a market.

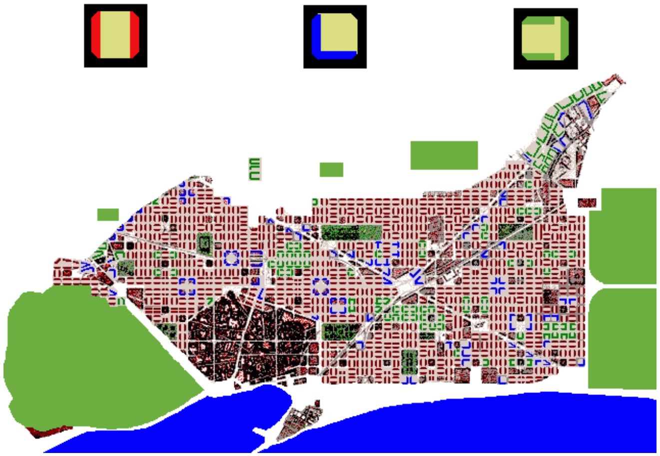

Fig. 561 Plan Cerdà (1867) in Barcelona

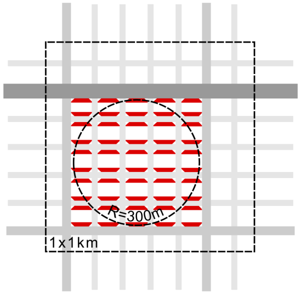

Fig. 562 A Cerdà neighbourhood

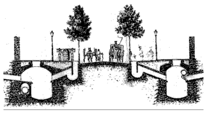

Fig. 563 Streets 20m

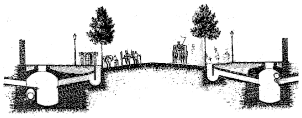

Fig. 564 Roads 30m

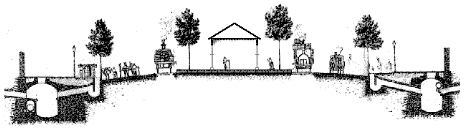

Fig. 565 District roads 50m wide

District quarters

Bach (2006) sums up the advantages of a rectangular grid concerning its flexibility giving next examples here all drawn at the same scale in a square of 1x1km.[139]

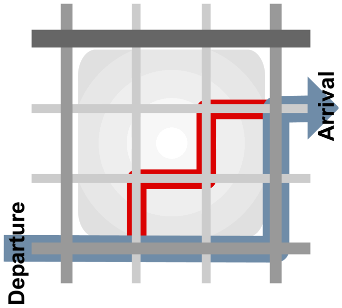

Fig. 566 Making a short cut as long as the detour

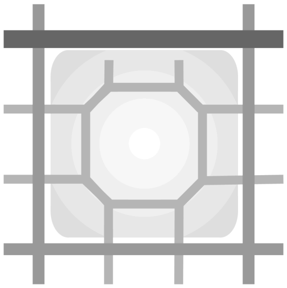

Fig. 567 Easily providing a centre

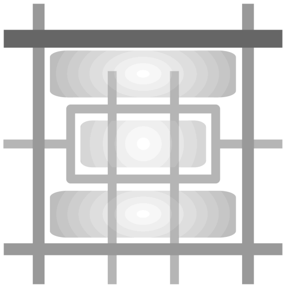

Fig. 568 Easily diminishing access crossings

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[a] Cerdà (1867) *Teoria General de la urbanizacion y aplicacion de sus principios y doctrinas e la reforma y ensanche de Barcelona*, see also for Dutch readers *http://odin.let.rug.nl/~kastud/barca/c/inl.html*

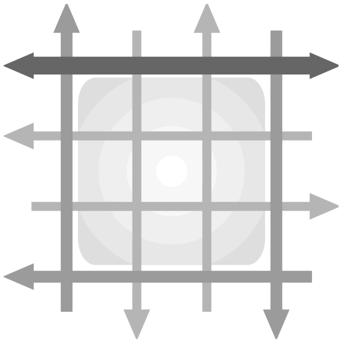

Fig. 569 Easily introducing one way traffic

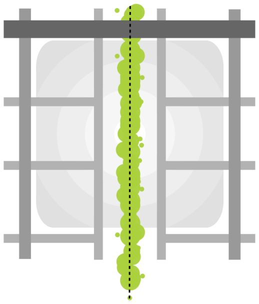

Fig. 570 Easily giving way to other networks like cycle paths

Fig. 571 Easily accepting ongoing green lines

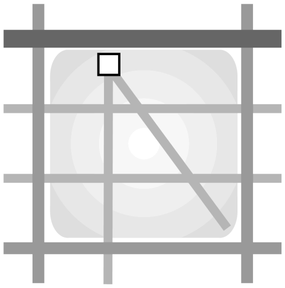

Fig. 572 Exceptions draw special attention

Fig. 573 Easy hinging to other grids

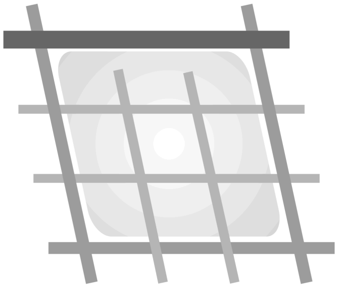

Fig. 574 Crooked grids keep easy orientation

Fig. 575 A grid makes appointments like Dutch Duurzaam Veilig easy to explain[a]

As discussed on page 251 by thought experiment, the content of a crooked grid (*Fig. 574*) is less than a rectangular one, while its outline is the same as the square. So, it will cost more pavement per inhabitant..

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[a] Bach …

From radial into orthogonal in time

According to *Fig. 496* by increasing through traffic towns changed from a spider into a fly in the regional web.[140]

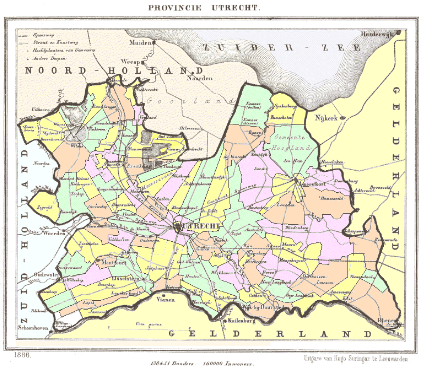


Fig. 576 Utrecht from radials in 1866 …[a]

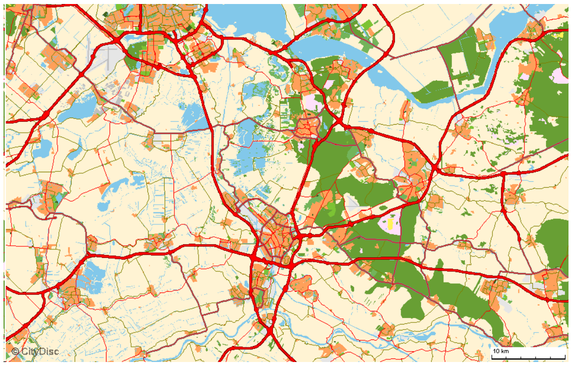
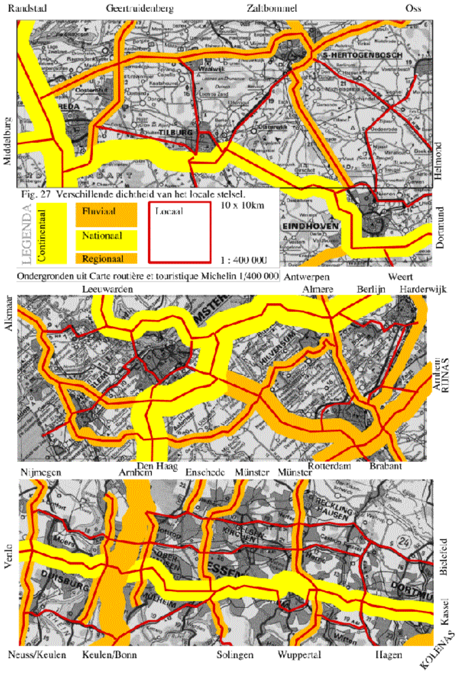
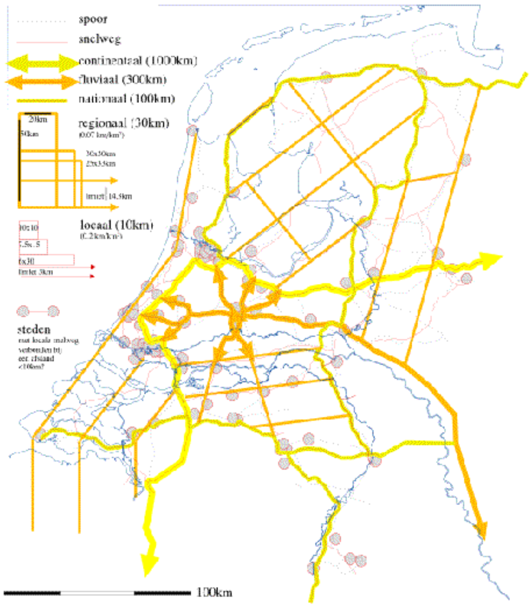


Fig. 577 via tangents into a large-scale grid[b]

Regional networks within a national network



R=30km
Fig. 578 Regional networks



R=100km
Fig. 579 National networks

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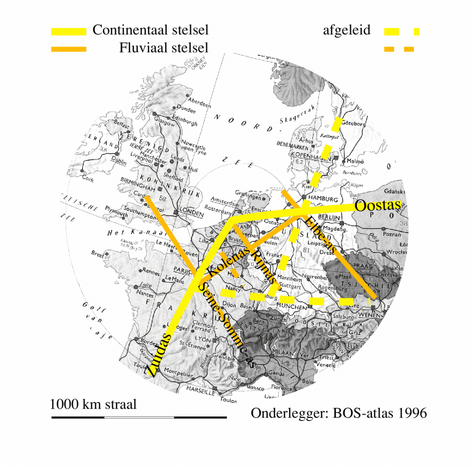
[a] Provincie Utrecht (1866)
[b] CityDisc (2001) Stratengids (Den Haag) CDrom

National networks within an international context

R=300km

Fig. 580 Fluvial networks



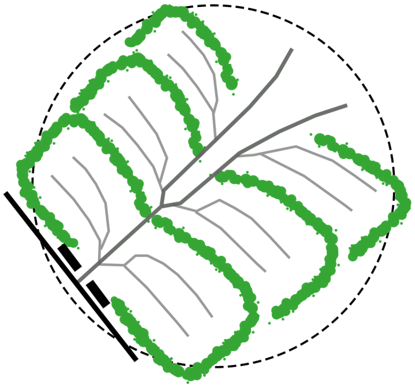
R=1000km

Fig. 581 Continental networks

Slow traffic and public transport

The pedestrian is the basal connector of urban life and all other kinds of its traffic. Not taking care for the pedestrian fragments the residential area, the neighbourhood, the district and the town. It increases casualties promoting the car and these processes strengthen each other. So, care for the pedestrian is the core of urban design. That (p)art of urban design is discussed thoroughly by Bach (2006).[141] So, in this chapter we only summarize some highlights from his work. The cycle increases the velocity reached by human power in flat countries, extending what we call slow traffic, elongating its tracks.

Pedestrians



R=300m

Fig. 582 Reichow: car first

R=300m

Fig. 583 Runcorn: pedestrian first

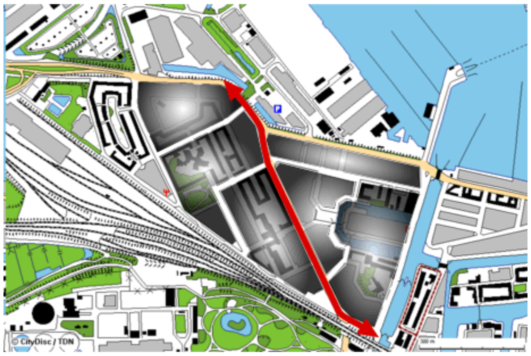


Fig. 584 *Cars dividing a neighbourhood*

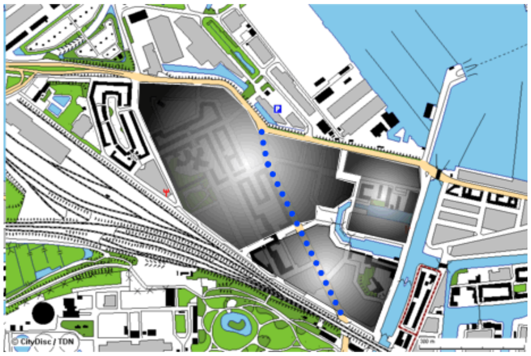


Fig. 585 *Traffic calming*

Cyclists

Cyclists and pedestrians take the shortest way.
So, they introduce radial lines and new crossings in car oriented grids that force detours.[142]

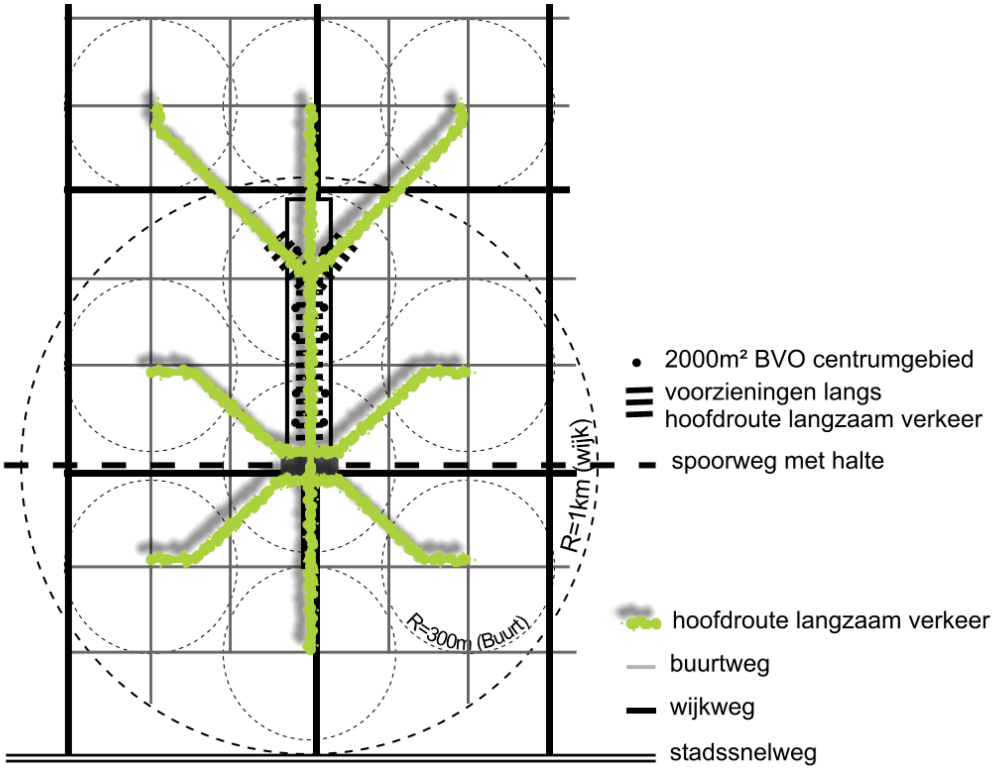


Fig. 586 *Radial with a minimum of crossings*

Busses

At the beginning of the twentieth century the lay-out strategy of public transport lines by busses changed from collecting travellers (*Fig. 587*) into connecting travellers (*Fig. 588*).[143]

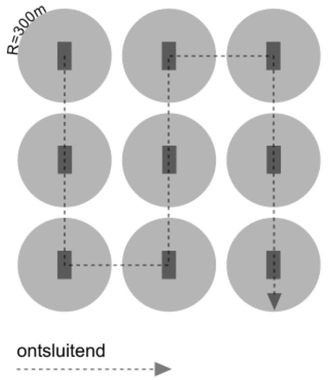


Fig. 587 Collecting travellers

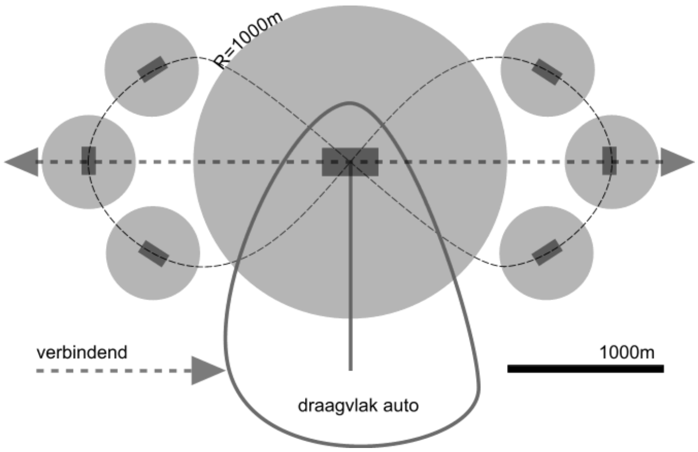


Fig. 588 Connecting travellers

Bus stations

There are two principally different types of bus stations: island type (*Fig. 589*) and herringbone type (*Fig. 590*).

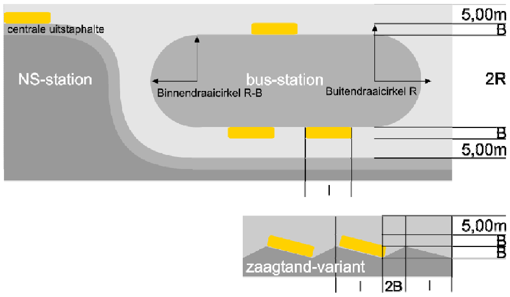


Fig. 589 An island type of central bus station

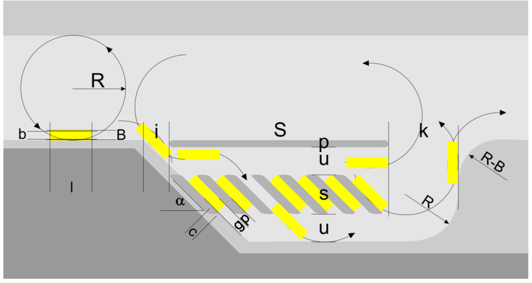


Fig. 590 A herringbone type of central bus station

Bus stops

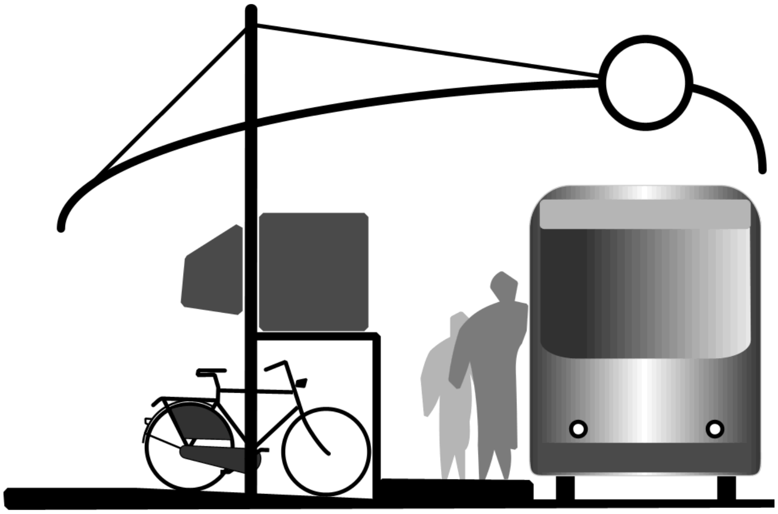


Fig. 591 Bachs (2006) bus stop concerning passengers' demands

Fig. 592 An artists' bus stop

Fig. 593 A Curitiba bus stop

Tramways and metro

		bus	tram	fast tram	(semi)metro	NS-sprinter
	min.	0.0	0.0	0.0	0.0	0.0
km radius served area		**0.3**	**0.3**	**0.5**	**0.6**	**0.8**
	max.	0.4	0.4	0.6	0.8	1.0
	min.	0.3	0.3	0.4	0.7	1.5
km stop distance		**0.4**	**0.4**	**0.6**	**1.1**	**1.8**
	max.	0.5	0.5	0.7	1.4	2.0
	min.	12	12	18	30	40
km/h velocity		**16**	**16**	**22**	**35**	**45**
	max.	20	20	25	40	50
	min.	2	2	4	5	7
km average ride		**4**	**4**	**7**	**10**	**14**
	max.	6	6	10	14	20
minutes ride		**15**	**15**	**20**	**16**	**18**
stops per ride		**10**	**10**	**13**	**9**	**8**
	min.	1000	1667	3333	8000	13333
passengers per hour		**2000**	**3333**	**6667**	**16000**	**26667**
	max.	3000	5000	10000	24000	40000
passengers per stop		**200**	**333**	**524**	**1768**	**3457**

Fig. 594 Some characteristics of urban public transport[144]

Light rail combines all velocities.[145]

From *Fig. 594* you can draw pictures like *Fig. 595*.

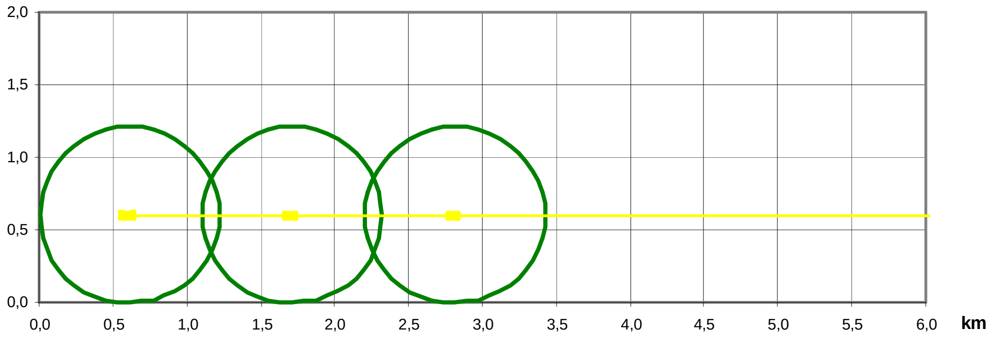


Fig. 595 A metro from Fig. 594with 0.6km radius of served area around a stop and 1.1km stop distance

Supposed you know the line length of *Fig. 595* (for example 10km), you can calculate the number of stops (9+1) and the km^2 served area ($10\pi R^2$ minus overlaps) of all stops together. Supposed you know the number of served inhabitants per hectare (100) and the %inhabitants expected to use metro (14%, see *Fig. 594*) you can calculate the number of passengers per day (15144, *Fig. 596*). That will determine whether the line is exploitable or not.[146]

km line length	10
distance between stops	1.1
number of stops (9+1)	10
km² served area	11
inh./ha	100
number of served inhabitants	110195
14% passengers per day	15144

	inh. / dwelling	dwellings/ ha	m^2 Floor Space /dwelling	%FS (100%·FSI)
for example:	2,3	43	100	43%

Fig. 596 Calculating the profit of the metro line from Fig. 595

Railway-stations

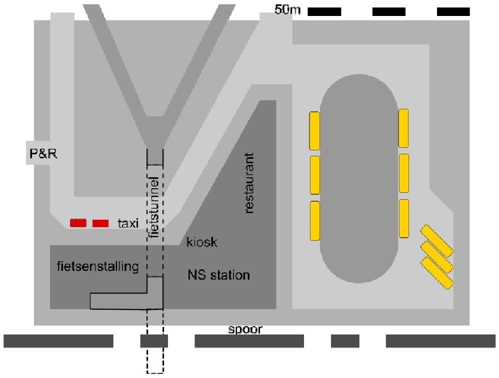


Fig. 597 A railway station accessible for cyclists, pedestrians and busses

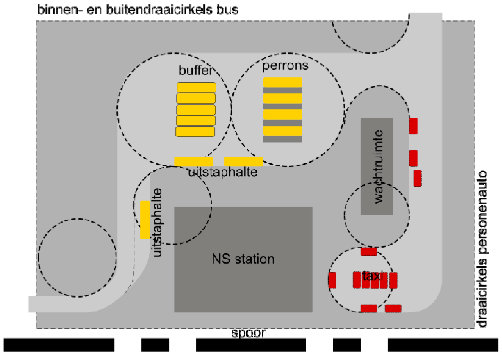


Fig. 598 A railway station for cars based on inner and outer turning circles of busses and cars

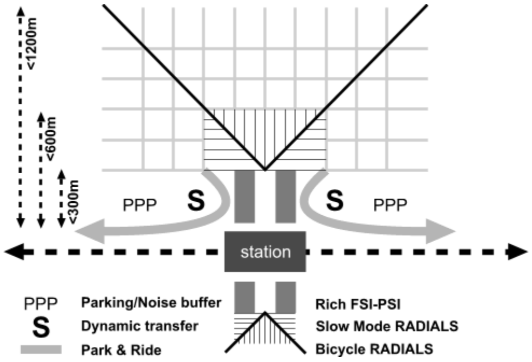


Fig. 599 Approaching the railway station according to Bach (2006)

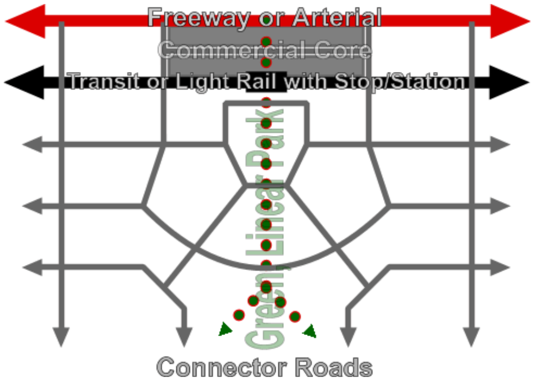


Fig. 600 Approaching the railway station according to Calthorpe

3.4.17 Harbours P.M.

Airports
Seaports
Inland ports

3.5 Other networks: cables and ducts

Increasing use of urban subsoil

Urban development plans are increasingly determined by the urban subsoil.

Problems and requirements associated with groundwater and load bearing capacity can be solved technically (see chapter **Error! Reference source not found. Error! Reference source not found.**, page **Error! Bookmark not defined.**).

In addition, the installation of cables, ducts and drains requires more and more space under the built-up area. As a result, ever stricter requirements have to be met with respect to the relative position of drains, cables and ducts. And don't forget underground storage space, for example for the disposal of glass, paper and other recyclable materials from containers placed in groups in the city. This often makes it difficult to find or make underground space, no matter how much we would like to get rid of these ugly containers by placing them underground.

Additional aboveground facilities

This chapter does not only take a closer look at on the use of underground space in urban areas, but also at space for beam transmitters and other forms of overhead and underground infrastructure.

The branch points and transitions from regional networks to urban networks also play an important part in urban development. Take for example the transition from overhead high-voltage transmission lines via transformers to an underground electricity distribution network. On the other hand a region may have ducts that do not occur in the urban landscape, yet are important for the city.

Regional ducts

On a regional level, ducts generally have a different effect on the use of topsoil than in towns, such as large underground water and gas distribution pipes and underground conveyor pipelines from dock areas to users, for example oil pipelines to the Ruhr region and Antwerp. On a regional scale, however, electricity cables that are underground in cities are aboveground in rural areas, such as the many high-voltage transmission lines across the Netherlands.

Although the spatial use of ducts on a regional scale means fewer restrictions on land use in urban areas, careful consideration must be given to the installation of pipes in the countryside. The ducts and cables in the transition zones from rural to urban areas restrict urban land use and urban developments. Consideration must also be given go maintenance of infrastructure in the country side.

Tunnels

In addition to pipes and ducts, more and more tunnels are being constructed, such as road tunnels and rail tunnels under waterways and rail tunnels to preserve the landscape. Examples that illlustrate the state of art in 2001 are the Rotterdam rail tunnel under the Nieuwe Waterweg, the Betuwe railway line for goods transport (under construction), and the high-speed rail link through the "Green Heart" (also under construction) of the Randstad.

Archaeological artefacts

This chapter elaborates on the different pipelines and their restrictions and limitations.

The installation of underground drains and ducts obviously involves much earth moving. As of 2002, statutory investigations must be carried out into the presence of archaeological artefacts and traces prior to commencement of building activities. Construction companies have a duty to report and to conserve archeological finds. The decision to start digging depends on the importance of the archeological find, as specified under the Malta Convention (1999). This convention has been implemented in the *Nederlandse monumentenwet* (Monuments and Historic Buildings Act)[a]

An archaeological survey was carried out as a pilot project prior to the construction of the Betuwe railway line. During the archaeological survey, important finds were made, from both prehistory and later eras. The finds included the oldest skeleton ever found of a woman (Treintje) in the Netherlands, and finds related to fishing such as a prehistoric boat, fishing nets and fishing gear, as well as Medieval houses and farms.

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[a] The legal side of this Historic Buildings Act is specified in the *Stedenbouwrecht* (laws governing urban development).

Types of ducts and cables

This chapter does not aim at giving a complete list of all ducts and cables that occur on a regional scale. The emphasis is on large distribution networks for gas, electricity and water, as well as telephone networks, data networks, optical fibre networks and pipes to transport raw materials from harbours to processing plants including those in Germany and Belgium.
There are also underground discharge pipes such as sewerage pipes and sewage pressure pipelines. Not all ducts in outlying areas are run underground. High-voltage transmission lines are a good example of overhead use of cables.

In order to supplement drinking water supplies in the densely populated western part of the Netherlands, water from the rivers Rhine and Meuse are pumped to dune areas through pipes. In the dunes the water is filtered and purified into drinking water, and distributed to consumers.
All these ducts and cables have their own requirements for installation which must be met by the surrounding area and the subsoil. This not only concerns subsoil conditions and groundwater, but also topsoil conditions related to land use.
Fig. 602 shows the position of cables and ducts in a street profile outside the built-uparea in accordance with the *Nederlands Normalisatie Instituut* (Netherlands Standardisation Institute).

Space taken up by cables and pipes.

It seems harmless and easy to place obstacles such as ducts and cables underground whenever possible, and from an aesthetic point of view even desirable . Furthermore, underground cables and ducts do not have a dividing and / or barricading effect on the surrounding area as topsoil distribution networks.
Underground installation of cables and ducts, however, has implications for the land above which is kept open (not developed) for maintenance and management purposes. In addition, shrubs and trees are not allowed, as deep roots will affect the ducts and cables. Tree roots, for example, could penetrate sewage drains, causing blockages or subsidence of the soil. Moreover, ducts, cables and drains are not easily reachted and dug up in areas covered with trees, hedges and plants. Depending on the type of cable or duct, a strip of land is reserved on either side which can vary from 1m to 50m.

Risks and costs

The risk of transported material exploding and a standstill of underground transport also plays a role in the decision to keep topsoil free from obstacles.
Sometimes the price tag put on underground pipework is a determining factor in the decision-making process. Think for example of the laying of pipework in subsoil with less load-bearing capacity. Many main sewage drains are supported by piles.
With respect to electricity networks, risk consideration and possible loss of power through conduction are reasons to choose for overhead transport in the countryside across greater distances.
In summary, we can state that extensions, maintenance and management, repairs to cracks and the clearing of blockages in overhead cables and overground pipes are less costly, and that risks of transport are reduced .

In view of these considerations, pipes and cables are laid in open areas as much as possible. The Netherlands Standardization Institute has drawn up standards, the NEN standard[a] for alignment, occupied space, depth and distance between ducts and cables.

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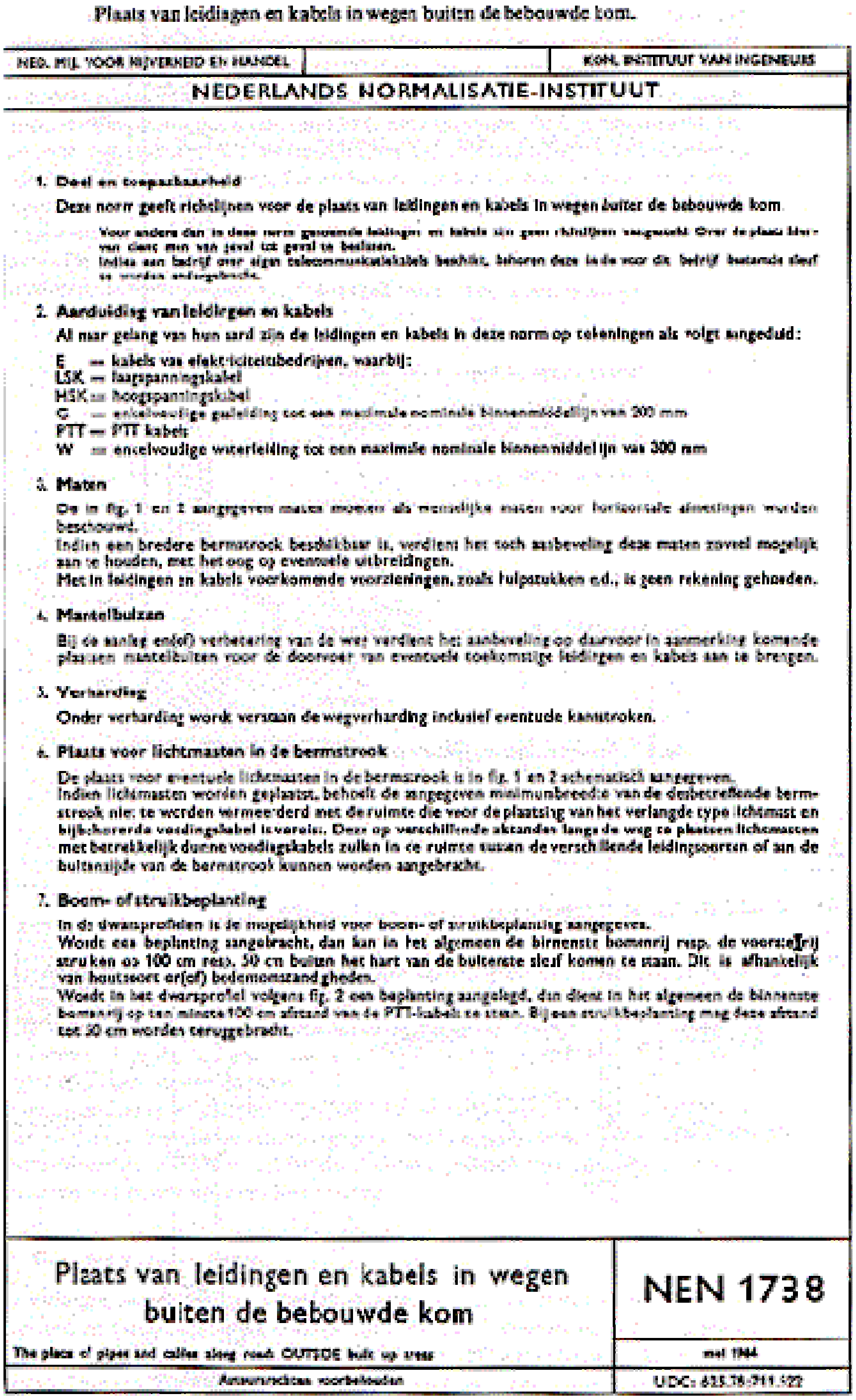
[a] NEN normen zijn te vinden in de zogenaamde normbladen uitgegeven door het Nederlands Normalisatie Instituut.



Plaats van leidingen en kabels in wegen buiten de bebouwde kom.

NED. MIJ. VOOR NIJVERHEID EN HANDEL		KON. INSTITUUT VAN INGENIEURS

NEDERLANDS NORMALISATIE-INSTITUUT

1. Doel en toepasbaarheid

Deze norm geeft richtlijnen voor de plaats van leidingen en kabels in wegen *buiten* de bebouwde kom.

Voor andere dan in deze norm genoemde leidingen en kabels zijn geen richtlijnen aangegeven. Over de plaats hiervan dient men van geval tot geval te beslissen.
Indien een bedrijf over eigen telecommunicatiekabels beschikt, behoren deze in de voor dit bedrijf bestemde sleuf te worden ondergebracht.

2. Aanduiding van leidingen en kabels

Al naar gelang van hun aard zijn de leidingen en kabels in deze norm op tekeningen als volgt aangeduid:

E — kabels van elektriciteitsbedrijven, waarbij:
LSK — laagspanningskabel
HSK — hoogspanningskabel
G — enkelvoudige gasleiding tot een maximale nominale binnenmiddellijn van 300 mm
PTT — PTT kabels
W — enkelvoudige waterleiding tot een maximale nominale binnenmiddellijn van 300 mm

3. Maten

De in fig. 1 en 2 aangegeven maten moeten als minimale maten voor horizontale afmetingen worden beschouwd.
Indien een bredere bermstrook beschikbaar is, verdient het toch aanbeveling deze maten zoveel mogelijk aan te houden, met het oog op eventuele uitbreidingen.
Met in leidingen en kabels voorkomende voorzieningen, zoals hulpstukken e.d., is geen rekening gehouden.

4. Mantelbuizen

Bij de aanleg en(of) verbetering van de weg verdient het aanbeveling op daarvoor in aanmerking komende plaatsen mantelbuizen voor de doorvoer van eventuele toekomstige leidingen en kabels aan te brengen.

5. Verharding

Onder verharding wordt verstaan de wegverharding inclusief eventuele kantstroken.

6. Plaats voor lichtmasten in de bermstrook

De plaats voor eventuele lichtmasten in de bermstrook is in fig. 1 en 2 schematisch aangegeven.
Indien lichtmasten worden geplaatst, behoeft de aangegeven minimumbreedte van de desbetreffende bermstrook niet te worden vermeerderd met de ruimte die voor de plaatsing van het verlangde type lichtmast en bijbehorende voedingskabel is vereist. Deze op verschillende afstanden langs de weg te plaatsen lichtmasten met betrekkelijk dunne voedingskabels zullen in de ruimte tussen de verschillende leidingsoorten of aan de buitenzijde van de bermstrook kunnen worden aangebracht.

7. Boom- of struikbeplanting

In de dwarsprofielen is de mogelijkheid voor boom- of struikbeplanting aangegeven.
Wordt een beplanting aangebracht, dan kan in het algemeen de binnenste bomenrij resp. de voorste rij struiken op 100 cm resp. 50 cm buiten het hart van de buitenste sleuf komen te staan. Dit is afhankelijk van houtsoort en(of) bodemomstandigheden.
Wordt in het dwarsprofiel volgens fig. 2 een beplanting aangelegd, dan dient in het algemeen de binnenste bomenrij op ten minste 100 cm afstand van de PTT-kabels te staan. Bij een struikbeplanting mag deze afstand tot 50 cm worden teruggebracht.

Plaats van leidingen en kabels in wegen buiten de bebouwde kom The place of pipes and cables along roads OUTSIDE built up areas	NEN 1738 mei 1964
Auteursrechten voorbehouden	UDC: 625.76:711.122

Fig. 601 NEN 1738[a]

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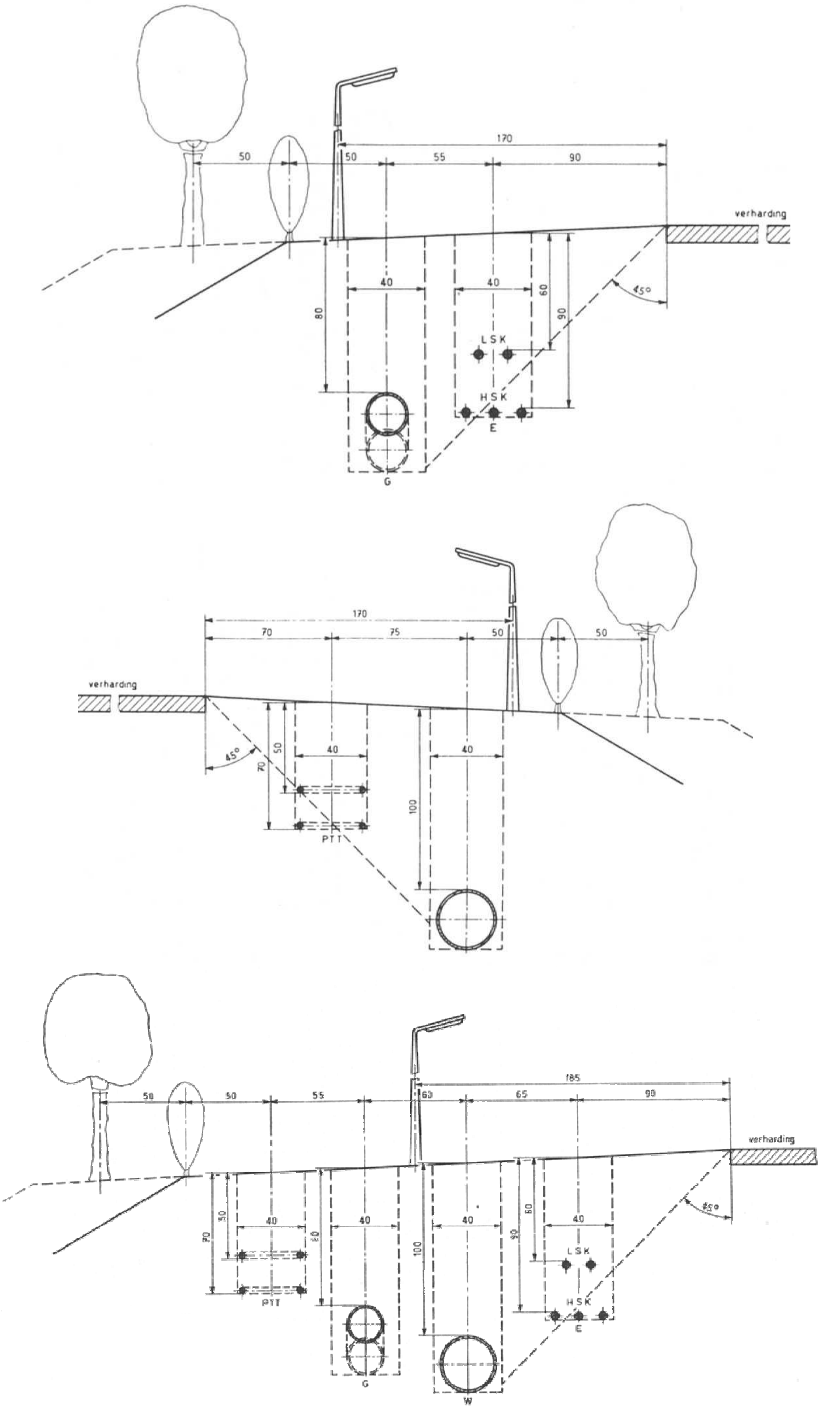
[a] *W.A. Segeren and H. Hengeveld (1991) p. 27*



W.A. Segeren and H. Hengeveld (1991) p. 273

Fig. 602 Position of pipes and cables outside built-up areas

Bundling of pipes not only prevents fragmentation of space and needless use of space, but also reduces the barricading effect within the area.
It is recommended to check new development sites on existing underground ducts and cable and their alignment. Information is available from the provincial authorities.

3.5.1 The electricity network

We assume that there will be no changes to the power supply via electricity networks in the foreseeable future.

Avoiding losses by high voltage

A distinction is made between high-voltage grids with high kilowatt voltages and low-voltage urban distribution networks (220 V).
High-voltage transmission lines have stress levels of 380 kV, 220 kV, 150 kV and 110 kV.
The mains voltage is driven up as high as possible, as high current intensity causes heat loss.
After all: power (watt) = current intensity (ampere) X voltage (volt)
High-voltage transmission lines form an overhead distribution network in the countryside. High voltage is transformed to medium voltage, usually 10kV, in substations that work as distribution centres for urban and industrial areas. In residential areas, the medium voltage in the transformer station is coverted to low voltage (220 V).

High-voltage cables aboveground

In principle, high-voltage grids are aboveground. Areas under high-voltage cables must be kept free of obstacles in connection with swing length of possible break in a cable. This means that building is not allowed under high-voltage lines in areas exceeding 100m. In other words, a land strip of 50m on either side of the high voltage lines must be kept free of permanent obstacles. For further information on the width of a strip of land, see the relevant NEN standards. High-growing vegetation is not allowed either; temporary use of land is allowed for recreational and agricultural purposes and for nature reserves. Apart from the recreational use of land, such as parks or nature reserves, waterways and roads may cross the strip of land below the high-voltage transmission line.
Safety measures prohibit construction under high-voltage transmission lines. People's health must also be taken into consideration. Health aspects primarily concern the problems caused the magnetic fields surrounding high-voltage cables. Another health risk is a higher concentration of copper in areas with high-voltage cable lines. Further research into health risks is recommended.

Comment [T.M.de8]: P.M. zones voor uitzwaailengte bij breuk.

High-voltage cables underground

High-voltage transmission lines are only laid underground if no other solution can be found. The main reason for overhead construction is the loss of power underground because the conductor, the oil insulating layer used as a dielectric, and the earthed cable covering form a condenser, which has a disruptive effect on the phase and causes energy loss in frequently wet soil; air is a better insulator.

Interconnected regional networks

The national electricity network is divided into interconnected regions, allowing instant deployment of another network in the event of cuts and peak loads.
The Netherlands additionally uses electricity from the international European network. For example, during times of massive use of electricity mainly in winter, it comes from the Alpine regions (hydroelectric power stations). Conversely, at low-peak times, the Netherlands supply electricity to the Alpine regions by pumping up the water to help bring to level the storage reservoirs in those regions. Coal or gas-powered plants must always run at a minimum capacity to keep them on stand-by and for technical reasons. Excess capacity can be used to supply other regions in Europe.

Design considerations for the construction of an electricity network

In the Netherlands, high-voltage transmission lines usually terminate at urban boundaries. Via substations, distribution substations and transformers, electricity reaches the meter cupboard in our homes.

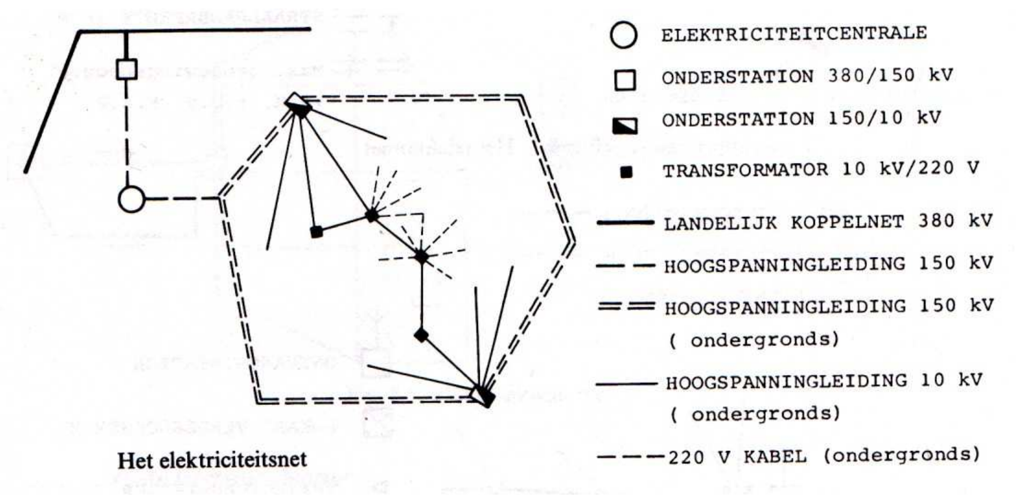


Fig. 603 The electricity network[a]

Design problems can be considered from two angles:

- alignment of new high-voltage transmission lines, and of sites for linking stations and power plants;
- changes to land use for areas around and under existing high-voltage lines

Alignment

Alignments of new pipes must satisfy the abovementioned NEN standards, and take into account future land use and/or land reservation. Adjustments over time are made only in exceptional circumstances. Cost is a key factor in this respect, as are stagnation of transport and possible risks.

Changes to land use

Changes to land use obviously involve major adjustments when an extension of an urban area is concerned. The narrow elongated strips of land beneath high-voltage lines make it difficult to fit in a new residential area.

In connection with safety and health aspects high-voltage lines often determine the boundary lines of an urban extension.

- One possibility is to leave the land under high-voltage lines unbuilt. Temporary land use may be allocated for recreational facilities, unorganised sports events etc.
- A last solution would be to lay the high-voltage cables underground. Compared with overhead installation, the costs of placing them underground is significantly higher. In addition, there will be considerable loss of power and increased maintenance costs. Although there can be no development on the strip, it can be allocated for recreational use. Road construction is allowed, provided that ducts and cables are not “covered” by obstacles. This usually means that pipework and cables are laid in a public green zone, for the alignment area needs to be kept open for safety reasons and maintenance work.
- A final option is the construction of a distribution substation with transformers, from where underground pipes form the distribution networks. Bear in mind that when you select a location for a distribution substation, the switche and compressed air in transformers make them quite noisy.

3.5.2 The gas network

The Netherlands has a national gas network ever since the discovery of natural gas in exploitable quantities. The network is connected to the natural gas extraction in Groningen and the North Sea. One network runs from Groningen and one from Noord Holland, from the pipeline landfall for extraction in the North Sea. Naturally the two networks are interconnected.

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[a] *W.A. Segeren and H. Hengeveld (1991) p. 267*

Urban gas used to be produced from coal. This production was connected to local gas plants and had an urban distribution network. The networks were interconnected to avert calamities in supply and to provide additional gas at peak times. Most rural areas were not connected to a natural gas network. People used bottled gas (butane gas) to cook, while homes were heated with domestic fuel oil or coal.

Like the electricity network, the natural gas network has a distribution system. Gas pressure in rural areas is higher than in towns and cities. In distribution substations at a lower level the gas pressure of 40 bar in the national network is brought down to 25 bar for house service pipes.

Technical Design considerations of the gas distribution network.

The rural natural gas distribution network runs entirely underground. The same restrictions are placed on them as on the national electricity network with regard to obstacles to facilitate maintenance, management and safety, think of the risk of explosions underground.

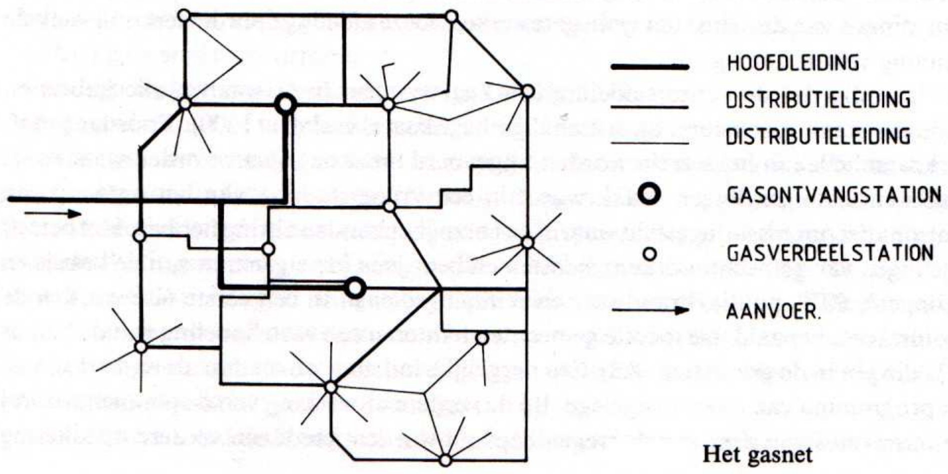

Fig. 604 The gas network[a]

In other words, strips of land with underground pipework must be free of obstacles - buildings and high-growing vegetation. Tree roots can also cause maintenance and connection problems. The width of the strips is significantly narrower than that of the electricity network, it is approximately 10-20 metres (see applicable NEN standards).

3.5.3 Water pipes

Due to the water shortage in a number of water extraction areas[b] water is brought from elsewhere to relieve the shortage in these areas. To supply the western part of the Netherlands with drinking-water, large pipes have been laid from the Rhine to the dunes where the water is infiltrated and purified. There are also water pipes leading from the Biesbos storage reservoirs to water treatment plants in urban conurbations, such as Rotterdam and surroundings. In addition, water extraction areas should also be free of pollution and polluting activities.

The network of water treatment plants to residential areas has a comparable branch system with one or more water mains to supply towns and villages, which branches off at the district and residential levels. To ensure a more reliable supply of water in districts, the pipes are installed in a ring structure.

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[a] *W.A. Segeren and H. Hengeveld (1991) p. 266*

[b] Groundwater is extracted from water-catchment areas through pumping, and used as drinking water following purification. Water-catchment areas are protected against infiltration of contaminating substances such as fertilizers, petrol, etc. As a result, these areas are not suitable for all purposes.

Design considerations for installing rural water pipes.

From a design point of view, the maximum space occupied by rural distribution pipes is at most ten metres, while urban distribution pipes take up less space. Space usage depends on provincial and local acts.

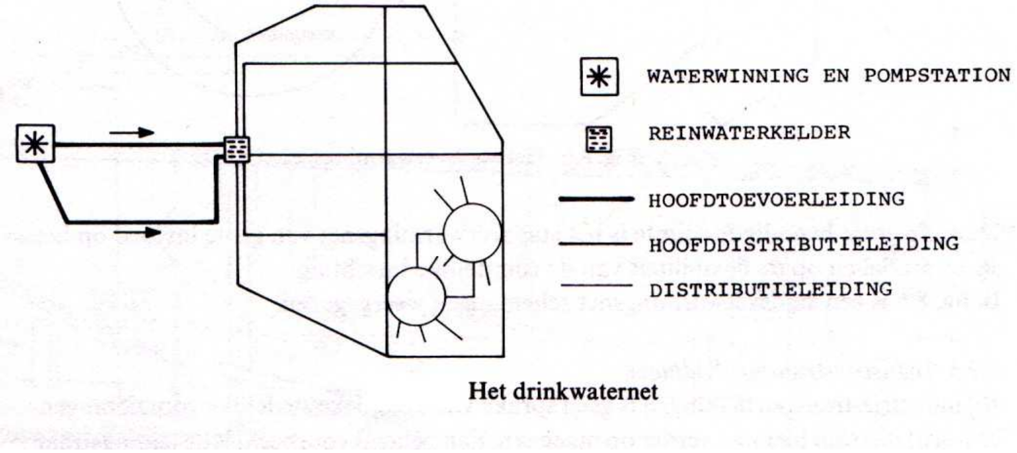

Fig. 605 Drinking-water network[a]

In general, pipes in rural areas are connected to the road network. Vegetation is not desired in view of maintenance purposes. Furthermore, the mains can be affected by roots. The distribution network must be covered by a layer of soil of at least 90 cm, which has to do with the frost limit. In the Netherlands, the fire brigade uses of drinking water to extinguish fires.

3.5.4 Pressure pipelines for sewage water

Wastewater purification plants are usually located in the country. Contaminated water and wastewater is transported through pressure pipelines from the urban areas to water treatment plants. These plants usually have a collection and purification function for a particular region. From the wastewater treatment plants pressure pipelines run to the sea and the big rivers to discharge the purified wastewater. In other cases, purified water is immediately discharged into the storage basin.[b]
Pressure pipelines for sewage water are subject to the same standards that apply to the use of the space above the pipelines. Pipe dimensions depend on the amount of sewage water that passes through them. The option of installing two adjacent narrower drains, in case of reduced discharging capacity is required due to a change in supply, is underused.

Technical considerations for installing pressure pipelines.

Here too, standards apply to pipe maintenance and the prevention of pipeline breakage. NEN standards have been drawn up, sometimes supplemented by local acts.
The space above pressure pipelines is subject to the same design requirements and restrictions concerning use and vegetation as water pipelines. A problem is also caused by the weight of the pipes. Appropriate measures must be taken with respect to soils with less bearing capacity to prevent subsidence of the pipe system. This explains why many sewage systems supported by piles.

3.5.5 The telephone network

Almost the whole telephone network runs underground. Special NEN standards apply to the installation of this network. Per region, the structure of the telephone network consists of an underground cable running from a house to the central exchange, and from there to an underground connection with the nodal point. From the nodal point, a connection is established via beam transmitters to nodal points in other areas.

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[a] *Segeren and Hengeveld 1984 p. 269*

[b] A storage basin is a system of lakes, channels and ditches, where water from lower-down areas is spread out (lifted) and temporarily stored prior to being spread out to outward waters (sea and rivers in direct contact with the sea).

In addition to this underground network, there is also an aboveground network of beam transmitters. These beam transmitters are placed on tall buildings while the transmission paths must be kept free from high-rise.

Current developments in mobile telephone and other connection technologies will certainly influence the spatial use of beam transmitters. A network of lower-scale beam transmitters, masts and receivers has also been developed for the mobile telephone market. Research has shown that this development might be pose health problems.

Developments in telephone satellite connections are bound to play a prominent role in the future.

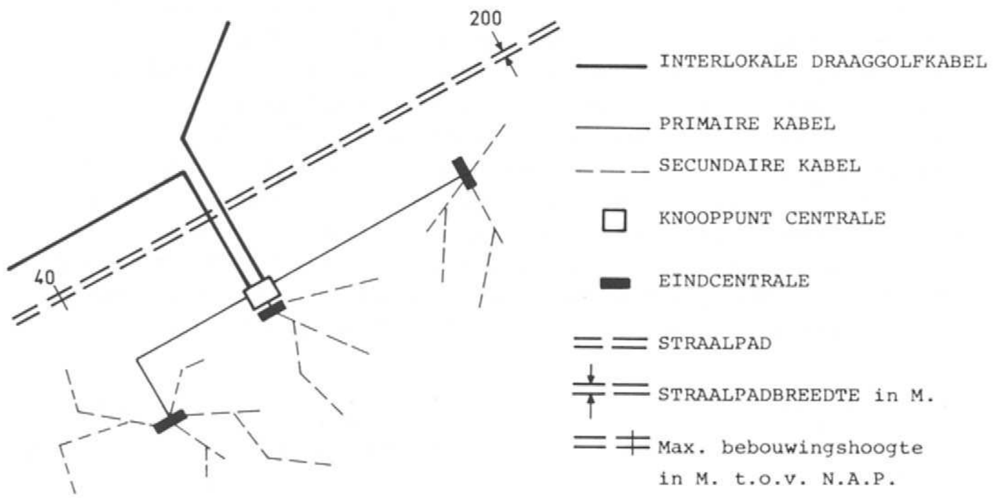

Fig. 606 Telephone network[a]

3.5.6 Radio and television transmitters

In the Netherlands, physical space is also used for transmitting radio and television signals via transmission masts which transmit signals to receivers or aerials. Obstacles can cause interference or distortion.

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[a] W.A. Segeren and H. Hengeveld (1991) p. 268

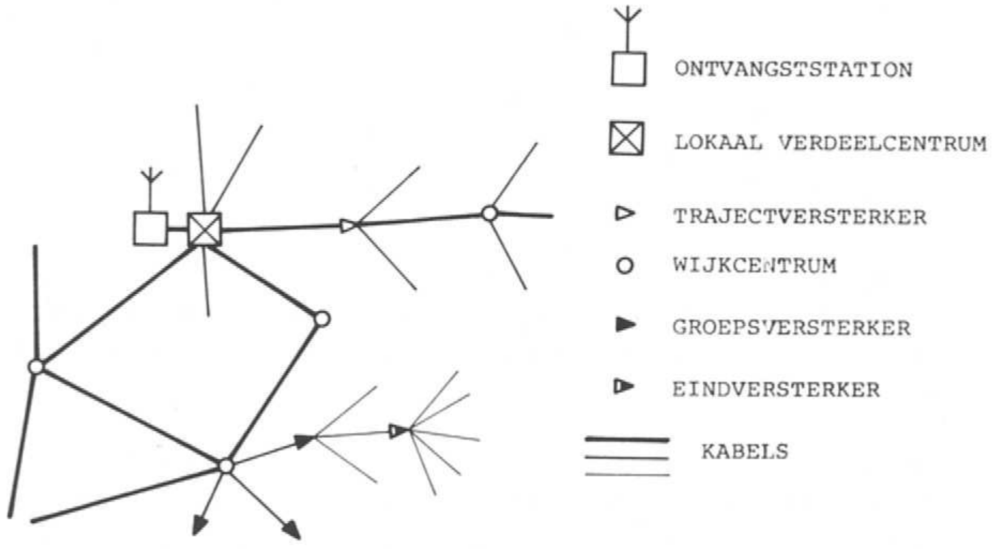

Fig. 607 Central antenna installation[a]

In urban areas, cable networks transmit these signals. The increased use of satellite connections will also result in changes to spatial use.

3.5.7 Network for the transport of raw materials

Underground and overhead pipes are increasingly used to transport raw materials from ports, sea ports or otherwise, to industrial areas. Depending on the materials to be transported, a number of restrictions must be observed. These cover safety measures for the surrounding area, such as buildings and roads, and for transport, for example pressure in gaseous substances, solution / dilution in liquids, suspension etc. Certain substances also carry a risk of explosion: berthing can give static electricity, causing devastating fires, such as oil fires in sea ports.
In general, these pipes connect the port, the unloading quay, to processing plants. Although such pipes primarily run overhead, we can also identify many, and longer, underground pipes, connecting the port of Rotterdam to the Ruhr region and the port of Antwerp for instance. Materials, transported through these underground pipes range from oil products to semi-finished products for industry; this includes secret military pipelines.
The Netherlands has also installed pipes from oil platforms in the North Sea to transport oil products such as gas and oil to processing plants and distribution companies.
In the Netherlands, approximately 20% of raw materials are transported underground through pipelines.

Design considerations of installing pipes for the transport of raw materials.

In terms of design, the use of space and corresponding restrictions governing pipelines is comparable to those of the gas network. However, depending on the material to be transported, additional measures are required.
With regard to the load bearing capacity of the soil, arrangements must be made to prevent sagging and fractures .

3.5.8 Tunnels

Tunnels constitute a special group of pipes.
The best-known tunnels in the Netherlands run under waterways, and are designed for motorised traffic. The oldest tunnel, the Maastunnel in Rotterdam, dates from before the Second World War. Amsterdam has several urban tunnels below the IJ, which connect new districts such as IJburg and Amsterdam Noord with the town centre.

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[a] *Segeren and Hengeveld 1984 p. 268*

A recent development is the construction of tunnels for rail transport. The first one to run beneath a waterway was constructed in Rotterdam, and is a relatively short tunnel. The Schiphol tunnel, which was constructed beneath runways and the airport hall, is another example of a short tunnel. Both train tunnels have underground stations which require a number of additional safety measures. More recent plans include the construction of a tunnel with a railway link for goods transport between Rotterdam and the Ruhr region, and a tunnel for the high-speed railway link (*HSL*) below the Groene Hart region. These underground tunnels cover long distances. In principle, the goods transport railway tunnel requires no ventilation, provided transport is run automatically. On the other hand the HSL tunnel will need to be equipped with ventilation and escape routes.

These tunnels are constructed for a variety of reasons, such as nature conservation, reduction of noise pollution, fragmentation of the landscape, visual considerations etc.

Research has to be carried out into the construction of these tunnels with respect to location and method of construction, and safety of the load carried, both passengers and raw materials. Think of the fires in the Mont Blanc tunnel between France and Italy in 1999 and in 2005, the Tauern tunnel in Austria (2000) and the Gotthard tunnel in Switzerland (2001).

Underground metro networks are currently being constructed in Amsterdam and Rotterdam. In general, these underground systems are subject to the same standards as tunnels. Construction under existing buildings and tunnels in particular will necessitate specific demands as to construction and use. Metro systems must also have adequate escape routes.

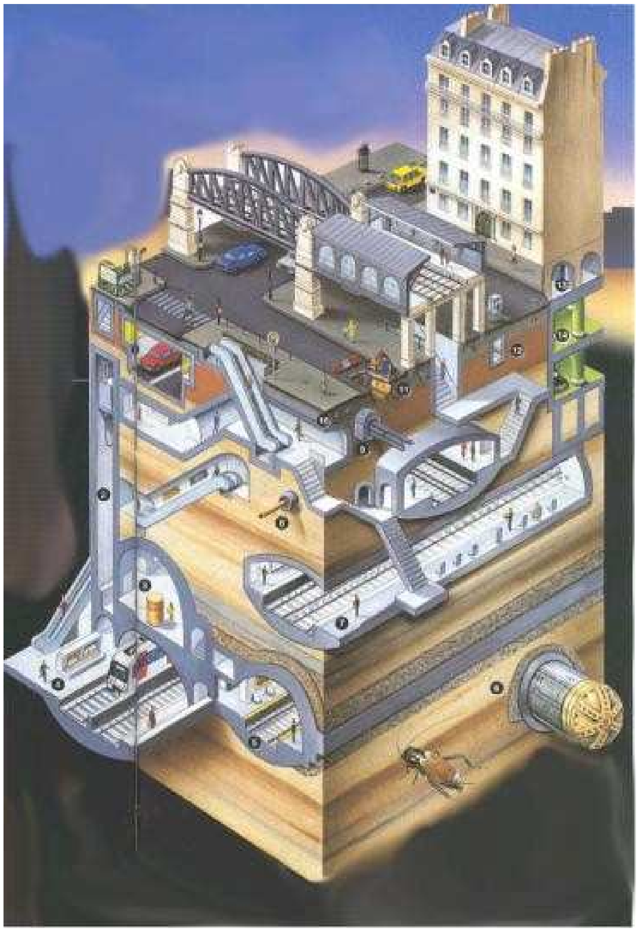

Fig. 608 Tunnels[a]

There are a number of risk factors for tunnels, such as:

- risks arising from soil conditions
- risks arising from method and construction itself and construction material, for example the choice between one or two separate tunnel tubes with one-way traffic, or one tube for freight transport and another for carrying passengers, or as in the Channel Tunnel which uses 'car trains' and 'lorry trains'
- risks arising from how the tunnel is used (calamities!); the reliability of train, lorries and cars and the type of products to be carried. Human errors in the construction and the breaking of traffic rules cannot be ruled out. Management and maintenance of these tunnelsmust be carefully monitored.

Needless to say, use of space depends on tunnel size and length. In principle, few restrictions apply to the use of space above tunnels.

3.5.9 Urban scale

Differences compared with regional scale

In rural areas, electric cables run overhead. In urban areas in the Netherlands they disappear under the ground, after high-voltage is transformed to a medium voltage of 50KV or 10KV. At district level, voltage is decreased once more via a transformer kiosk to 380V (industrial voltage) and 220V (domestic voltage). Transformer noise is caused by switching and compressed air.

In urban areas, gas pipe pressure is adjusted to domestic pressure. This takes place in distribution stations, from where the gas is distributed across a town via underground pipes.

Drinking water is distributed across urban areas via underground pipes.

The sewerage system is treated on page 304, the drainage system on page 304.

The installation of the pipe network of water, gas and sewers has some restrictions. It is obvious that the curves that the tubes make are determined by the flexibility of tubes. The sewage network also needs a fall in order to bring waste from the collecting point to the treatment plant by pumping or under pressure.

Underground conveyor pipelines

Underground conveyor pipelines for materials transported from harbour areas also play a role in urban areas. These pipelines are often bundled in pipe alleys, for which space has been allocated or reserved through decisions at national level. On an urban scale, the layout of this space must meet

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[a] Standaardgidsen (1999)

requirements with regard to safety, accessibility and repair work. In general, this implies that the pipes are installed in public green strips, or incorporated in larger park areas.

Underground transport tunnels

Underground transport tunnels such as metro lines, tram tunnels and car tunnels play an important role in the use of urban areas. Decisions on transport and construction have a major impact on the urban area. Similarly, underground parking garages have a major impact on urban development. Such spaces will need to be designated or combined with the construction of intensively used buildings, such as shopping centres, large apartment buildings and offices.

New developments with respect to the construction of underground bus stations also require space, and will need to be a point of discussion in the planning process. The same applies to underground distribution centres.

Underground storage

On an urban scale, decisions are also taken with regard to small-scale underground material storage, such as the storage of glass, paper and other small-scale domestic waste that is not collected from door-to-door. This underground storage takes up considerable space, and is often difficult to fit in into existing street profiles because of the high density of underground cables, pipes, wires and drains. The containers must be safely reached by users and therefor not be installed just anywhere in a neighbourhood.

The installation of cables and pipes as part of preparing a site for habitation

With regard to planning and constrcution of a new district, the installation of cables and pipes forms part of the process of preparing a site for habitation. The advantage is that it minimises the risk of damage caused by other construction activities. Building activities, however, require their own power and water supply. In effect, this means that these pipes and cables are installed in combination with provisional supply roads prior to the commencement of building activities.

The overall installation of cables and pipes in a new district usually begins with the construction of sewage systems and district heating pipes.

Immediately after completion of the buildings, house service pipes for sewerage and district heating are installed, and the other cables and pipes including connections put in place. Approximately 6 to 13 weeks prior to completion, local municipalities give permission for the installation of underground infrastructures. Negotiations have meanwhile taken place concerning the municipal green areas, as pipes and cables are often located in green zones.

A public works time schedule of the city of Rotterdam

An example of a public works time schedule of the city of Rotterdam is given below:

- No later than 4½ months before completion, plans for making the site “liveable” have to be available. These include specifications and shop drawings of the utilities, which are made once the schemes with the road layout and the green areas are completed.
- Public tendering. This procedure can take up to 6 to 8 weeks.
- Branch pipes are installed 8 weeks before completion.
- Seven weeks before completion, drinking water pipework is installed for legal tests, which may take some time.
- Six to five weeks before completion, the utilities companies can connect up gas pipes and electric cables. Installation of house service connections can commence. Provisional supply pipes are converted to fit the distribution network, or removed.
- Four weeks before completion, house service connections are completed, and telephone and central antenna systems installed.
- The remaining 2 to 3 weeks are used to install discharges and fnish paving.

Main system in the street profile

Distribution networks are planned for urban and rural areas. They include water, gas and electricity, as well as cable networks for telephone and audio-visual appliances including computer networks. Computer cables are primarily fibre optic cables rather than the well-known copper wires.

The choice of district heating with corresponding pipes system is also made on this scale and fitted into the street profile. And don’t forget the wastewater discharge system and the sewage system either as a stand-alone or as a combined system.

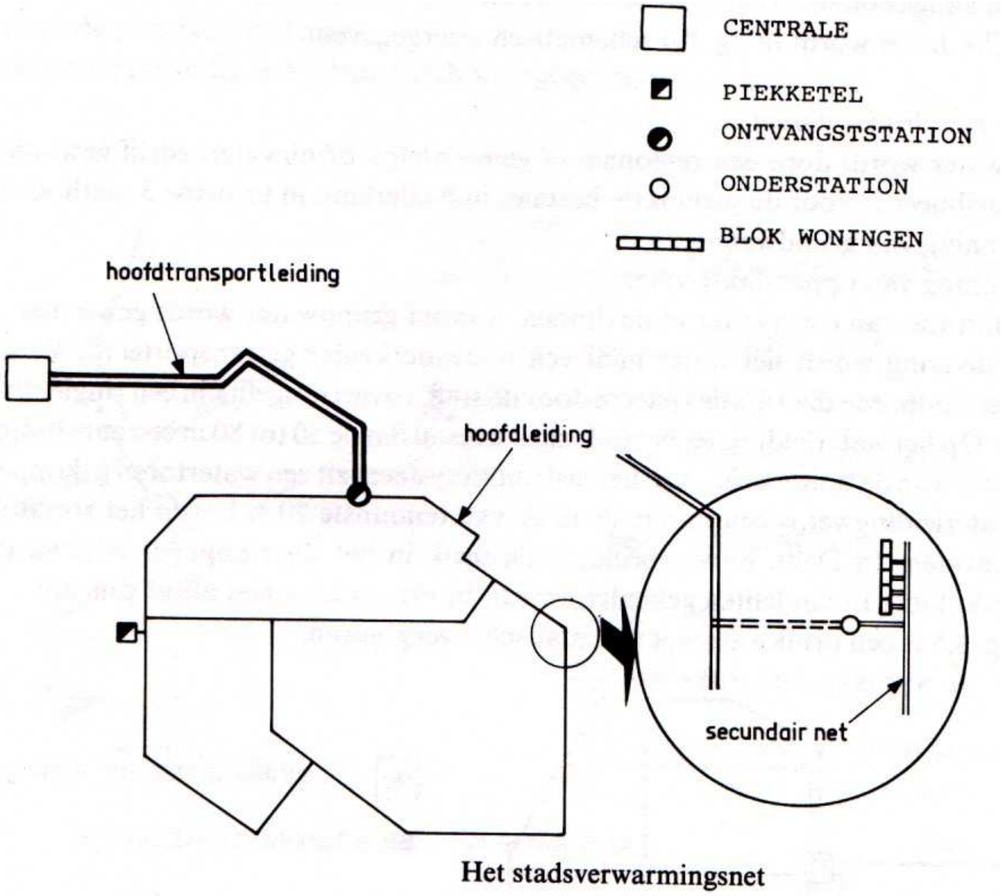

Fig. 609 District heating network[a]

Use of space and relative position

The use of space, the relative position and safety measures of the different networks are laid down in municipal regulations. Although these may differ in terms of depth and pipe combination, the regulations share similar principles. These regulations are available from the local municipality, as are maps containing information on the position of cables and pipes in the street profiles at district and urban level. Most municipalities can provide these maps in digital format. Please note however, that these maps do not specify all pipes, and that not all pipes are registered. This is particularly the case for computer network cables. These have often been installed without specific permits, and are therefore not included on plan drawings. This means most cables cannot be marked out. These networks are usually found at a shallow depth (± 30cm below ground level). *Fig. 610* shows the location of cables and pipes in a street profile of a built-up area as laid down by NEN standards.

Empty shells and combinations

A number of municipalities have begun constructing networks using empty cables (‘empty shells’), which will be use at a future date. The advantage of this method is that streets need not be broken up to install new networks. Another recent development concerns the combination of networks. In Amsterdam, for example, experiments are carried out by installing fibre optic cables in sewage drains. In addition, areas with high groundwater levels need a drainage system. This system consists of canals and ponds, and a closed underground drainage system to collect surplus groundwater, storing it for shorter or longer periods before discharging it.

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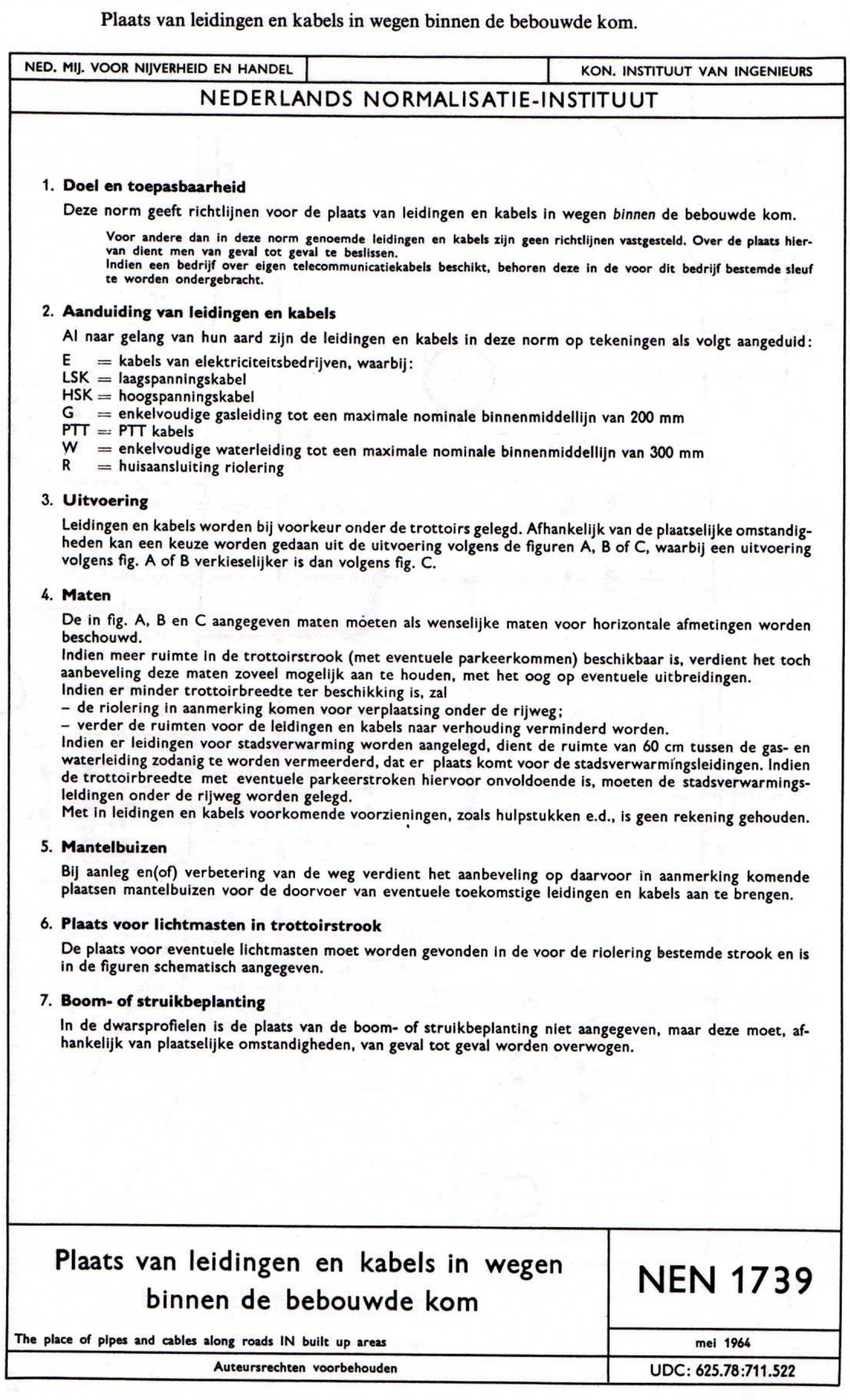
[a] W.A. Segeren and H. Hengeveld (1991) p. 270



Plaats van leidingen en kabels in wegen binnen de bebouwde kom.

NED. MIJ. VOOR NIJVERHEID EN HANDEL		KON. INSTITUUT VAN INGENIEURS

NEDERLANDS NORMALISATIE-INSTITUUT

1. **Doel en toepasbaarheid**

Deze norm geeft richtlijnen voor de plaats van leidingen en kabels in wegen *binnen* de bebouwde kom.

Voor andere dan in deze norm genoemde leidingen en kabels zijn geen richtlijnen vastgesteld. Over de plaats hiervan dient men van geval tot geval te beslissen.
Indien een bedrijf over eigen telecommunicatiekabels beschikt, behoren deze in de voor dit bedrijf bestemde sleuf te worden ondergebracht.

2. **Aanduiding van leidingen en kabels**

Al naar gelang van hun aard zijn de leidingen en kabels in deze norm op tekeningen als volgt aangeduid:

E = kabels van elektriciteitsbedrijven, waarbij:
LSK = laagspanningskabel
HSK = hoogspanningskabel
G = enkelvoudige gasleiding tot een maximale nominale binnenmiddellijn van 200 mm
PTT = PTT kabels
W = enkelvoudige waterleiding tot een maximale nominale binnenmiddellijn van 300 mm
R = huisaansluiting riolering

3. **Uitvoering**

Leidingen en kabels worden bij voorkeur onder de trottoirs gelegd. Afhankelijk van de plaatselijke omstandigheden kan een keuze worden gedaan uit de uitvoering volgens de figuren A, B of C, waarbij een uitvoering volgens fig. A of B verkieselijker is dan volgens fig. C.

4. **Maten**

De in fig. A, B en C aangegeven maten moeten als wenselijke maten voor horizontale afmetingen worden beschouwd.
Indien meer ruimte in de trottoirstrook (met eventuele parkeerkommen) beschikbaar is, verdient het toch aanbeveling deze maten zoveel mogelijk aan te houden, met het oog op eventuele uitbreidingen.
Indien er minder trottoirbreedte ter beschikking is, zal
– de riolering in aanmerking komen voor verplaatsing onder de rijweg;
– verder de ruimten voor de leidingen en kabels naar verhouding verminderd worden.
Indien er leidingen voor stadsverwarming worden aangelegd, dient de ruimte van 60 cm tussen de gas- en waterleiding zodanig te worden vermeerderd, dat er plaats komt voor de stadsverwarmingsleidingen. Indien de trottoirbreedte met eventuele parkeerstroken hiervoor onvoldoende is, moeten de stadsverwarmingsleidingen onder de rijweg worden gelegd.
Met in leidingen en kabels voorkomende voorzieningen, zoals hulpstukken e.d., is geen rekening gehouden.

5. **Mantelbuizen**

Bij aanleg en(of) verbetering van de weg verdient het aanbeveling op daarvoor in aanmerking komende plaatsen mantelbuizen voor de doorvoer van eventuele toekomstige leidingen en kabels aan te brengen.

6. **Plaats voor lichtmasten in trottoirstrook**

De plaats voor eventuele lichtmasten moet worden gevonden in de voor de riolering bestemde strook en is in de figuren schematisch aangegeven.

7. **Boom- of struikbeplanting**

In de dwarsprofielen is de plaats van de boom- of struikbeplanting niet aangegeven, maar deze moet, afhankelijk van plaatselijke omstandigheden, van geval tot geval worden overwogen.

Plaats van leidingen en kabels in wegen binnen de bebouwde kom	**NEN 1739**
The place of pipes and cables along roads IN built up areas	mei 1964
Auteursrechten voorbehouden	UDC: 625.78:711.522

Fig. 610 NEN 1739[a]

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[a] W.A. Segeren and H. Hengeveld (1991) p. 274

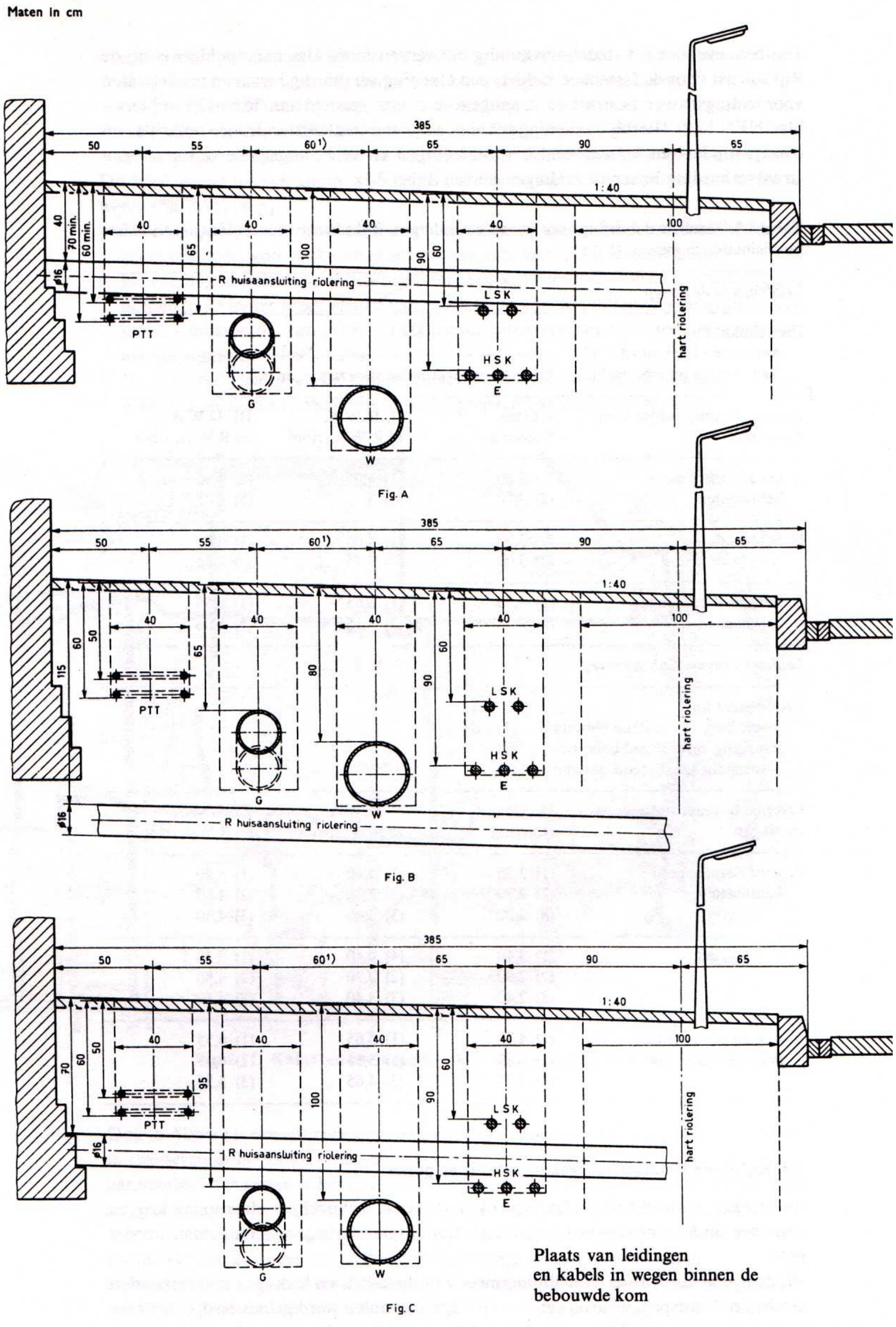

Fig. A

Fig. B

Fig. C

1) Indien er leidingen voor stadsverwarming worden aangelegd, dient de ruimte van 60 cm tussen de gas- en waterleiding zodanig te worden vermeerderd, dat er plaats komt voor de stadsverwarmingsleidingen. Indien de trottoirbreedte met eventuele parkeerstroken hiervoor onvoldoende is, moeten de stadsverwarmingsleidingen onder de rijweg worden gelegd.

Fig. 611 Location of cables and pipes in built-up areas[a]

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[a] W.A. Segeren and H. Hengeveld (1991) p. 275

Drainage

In the first place, drainage systems are meant to make development sites suitable for the construction of houses, and the maintenance of the area in question, i.e. site management. Drainage systems are designed to keep the ground-water table in built-up areas at an appropriate level to prevent water problems with foundations, cellars and pipes, on the other hand these systems are designed to discharge surplus ground water. The groundwater table is artificially kept at a predetermined level by the municipality using pumping stations.

Depth

The minimal depth ranges from several decimetres to approximately 80 cm below ground level. Depth is depends on existing foundations and pipes. Areas with wooden piles foundations, for example, have a different groudwater level: wooden piles must remain submerged to avoid rotting. In later urban areas, however, concrete and other types of foundation are used which are not affected by groundwater. The climate also determines the depth of the groundwater level in urban areas. In times of severe frost, ground saturated with water can freeze to approx. 80 cm below ground level. The frozen ground can cause pipes to burst and holes in the asphalt road surface. In the Netherlands, pipes are therefore always installed deeper than 80 cm below ground level.

Rainwater

In addition to discharging surplus groundwater, the drainage system also serves to discharge rain water and melt water which permeates the subsoil. In built-up areas, excess water from hardened surfaces, such as streets, squares and roofs, is usually discharged via a sewerage system. Underground, the drainage network consists of drainage pipes. Above ground, it made up of ditches, canals and ponds: the ‘open water system’. Water from drainage pipes is either discharged into open waters in urban areas, or transported to drainage pools, also open water, in rural areas. Surplus water in canals, waterways and ponds is discharged from the urban area to open water outside the urban area. From there, the water is carried to the rivers and/or the sea via a system of waterways and pumping stations.

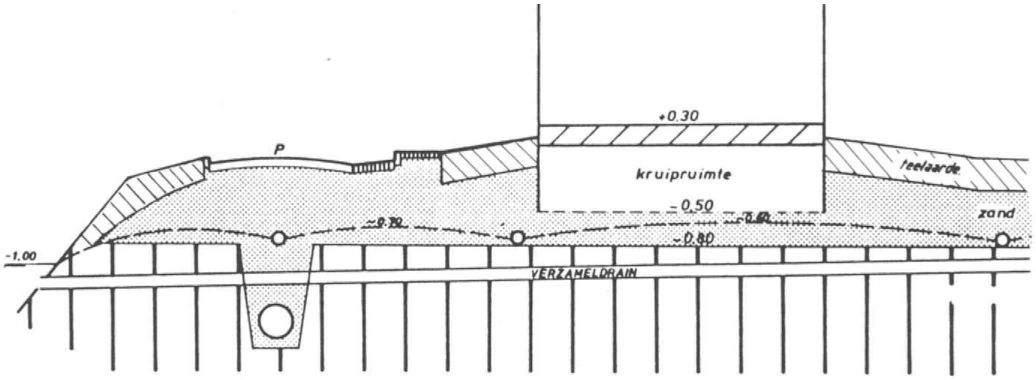

Fig. 612 Urban drainage[a]

Sewage

SewageUp until the early 20th century, domestic and industrial wastewater was usually discharged directly into surface water. In the 19th century, some towns already used various pipe systems to carry this wastewater to areas outside the built-up areas. During the course of the 20th century, sewage systems were gradually installed throughout the Netherlands. Isolated farms and houses are not always connected to the sewage system. Nevertheless, these homes must satisfy wastewater purification requirements. This can be achieved by using individual water treatment methods. Sewage systems are designed to discharge domestic water, industrial water and excess rain water safely in such a way that it does not cause health hazards. Contaminated water is purified until residual water can be safely discharged into open water.

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[a] W.A. Segeren and H. Hengeveld (1991) p. 150

Autarkic systems

This chapter does not discuss buildings that use their own sewage systems to re-use grey water, i.e. rainwater to water the garden, clean buildings, wash cars, take a shower and the re-use of shower water to flush the toilet, or their own purification systems such as helophyte filters. These systems are highlighted in the context of "eco-friendly building".

The common sewage system

A sewage system consists of a collecting system, a transport system and a purification system. Particularly the collecting system is relevant to this book. This system consists of pipes, which collect wastewater and rain water and carry it to the sewage purification or discharge points.

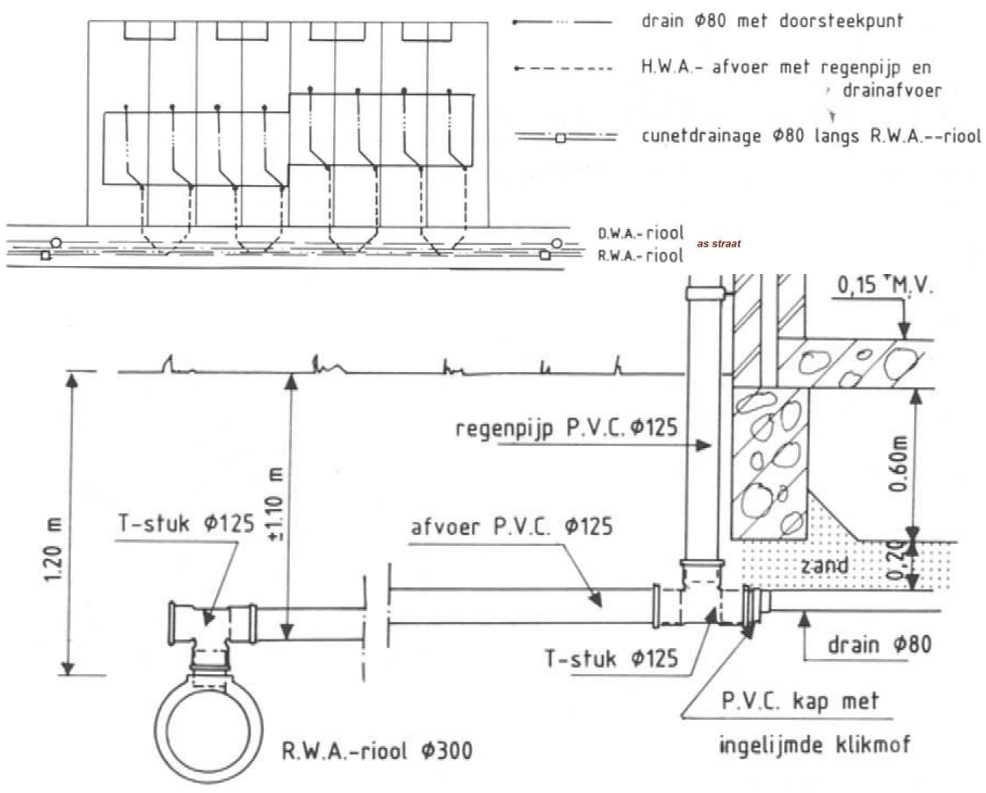

Fig. 613 Building block sewage[a]

We can distinguish the following sewage systems:

- combined systems including various improvements
- separate sewerage systems, stand-alone systems including various improved versions.

The combined system

In this system, all domestic and industrial water and precipitation, rain water and melt water of snow and hail are discharged via one combined system of pipes. Domestic connections and road connections are sloped towards the collecting sewer system. The collecting sewage pipe is drained by a pumping-station. Sewage water is transported to the sewage purification through a pressure pipeline.

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[a] W.A. Segeren and H. Hengeveld (1991) p. 156

The big variable of this system is the amount of rainwater present. Large quantities of rainwater will dilute the dirty sewage water, resulting in less efficient purification. The management of the sewage purification plant is extremely complex due to strong fluctuations in sewage water concentrations and discharge peaks. The dimensions of the system is a problem. It is not economic to adjust the diameter of the pipes to the biggest quantity of sewage water that needs to be discharged. To minimize rainwater dilution and peaks in discharge additional storage capacity is made that is directly connected to the system. If this additional storage proves insufficient, overflows have been constructed to open water. Contaminated water, rainwater and sewage sludge are then discharged onto the surface water. It is obvious that this is the weakest link in the entire process. The overflow system is constructed in such a way, that the predetermined number of annual overflows is not exceeded. In the Netherlands, this has been calculated to be 3 to 10 overflows per year. Approximately 10% of rainwater is carried to surface water via overflows. This system is not the most hygienic or efficient. This is why research has been conducted into possible improvements, which resulted in a new system: a separate sewage system.

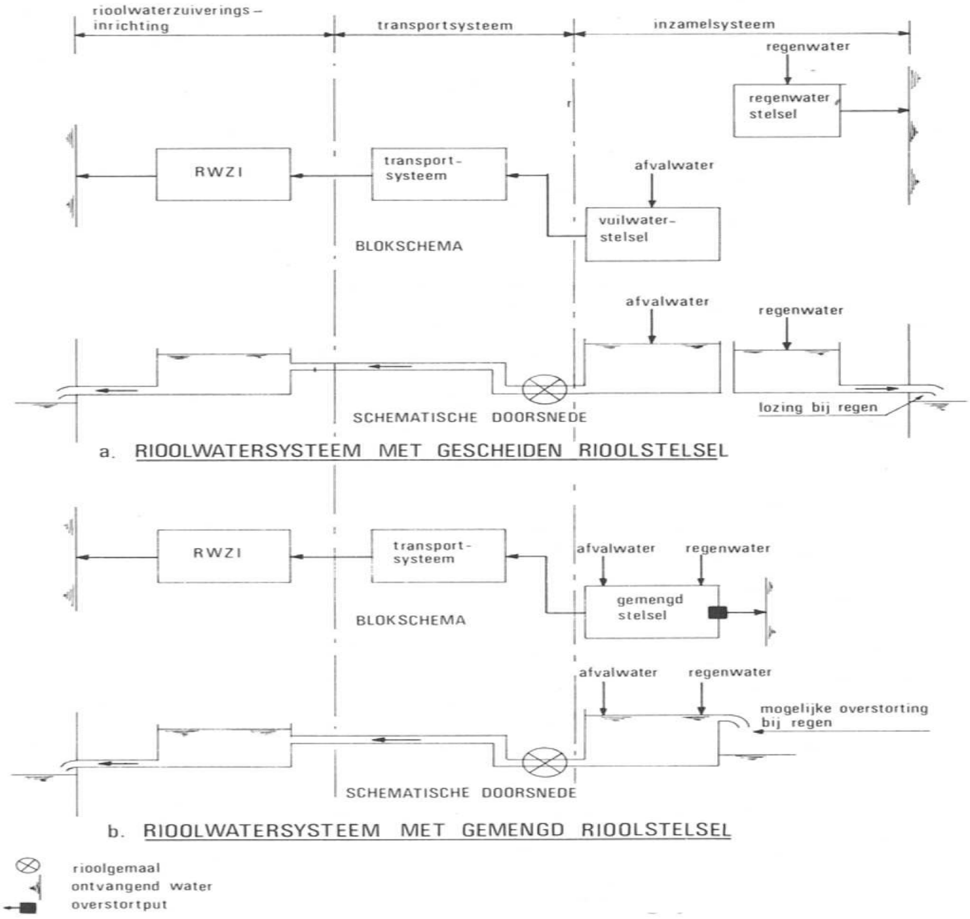

Fig. 614 Sewage systems[a]

The separate sewerage system

In this system, rainwater is separated from domestic and industrial wastewater and discharged via its own pipe system. Rainwater is always discharged directly onto surface water via street inlets. Surface water is also affected by street contamination in the form of spillages of petrol, oil, tyre abrasion and litter. In addition to preventing this kind of pollution, discharge points are equipped with filters to collect

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[a] W.A. Segeren and H. Hengeveld (1991) p. 190

contaminants. The system combines drainage systems installed in the past for site development with rainwater discharge systems.

Domestic and industrial wastewater sewerage is pumped by a sewage pumping-station and discharge to a sewage purification plant. The size of the pipes depends on the average of the highest wastewater production in 24 hours.

Drainage of rainwater is a different story. The amount of annual precipitation, in the form of rain, hail and snow, shows considerable fluctuation. Furthermore, part of the precipitation enters the drainage system, part flows into the soil, part disappears through evapotranspiration and part is absorbed by plants. Water that enters the system is collected and usually discharged directly onto open water in built-up areas. Water from the streets is collected via street inlets and enters the open water via a mud trap and sometimes via helophyte filters.

The choice of a system

It will be clear that the choice of a system depends on the scale of the district or village. The unity of a system is a prerequisite; a system is only as efficient as its weakest link.

The sewage system is determined by discharge quantities. These can be divided into dry weather discharge or wastewater and rain water discharge or precipitation discharge. The required capacity per hour for dry weather discharge is approx. a tenth of the daily discharg. The average water use per person is between 100 l and 150 l. Rain water discharge, on the other hand, fluctutates as the amount of precipitation is spread unevenly over the year. Reduction in precipation water is caused by evapotranspiration, the use of water by plants and water absorption. This reduction of the original amount of precipitation water is known as the runoff coefficient (see *Fig. 615*).

Building type		**Content/ha .**	**Runoff coefficient**
Old city centre	high-density building	350	0.8
Newer districts	closed buildings	250	0.6
	open buildings	150	0.4
	with parks and gardens	100	0.25
Undeveloped, unhardened terrains			0.15
Parks			0.5

Nature of the surface	0.9
Closed road surface	0.9
Clinker paving	0.8
Metalled roads	0.45
Gravel and cinder roads	0.25

Fig. 615 Runoff coefficient[a]

Design considerations for installing cables and pipes in built-up areas.

Built-up areas are intersected with rural cables and pipes. On this level in particular, various NEN standards and municipal regulations apply, causing complications, as the limitations from rural networks stand in the way of urban developments in rural areas. This involves many hours of negotiation to find a solution.

Every municipality in the Netherlands has its own regulations, which can be inspected by municipal services. By and large, they are all identical; regulations prescribe relative position and depth in relation to the surface level. Differences are primarily manifest in load-bearing capacity of soils, and ground-water tables and groundwater levels tolerated by each individual municipality.

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[a] M.R.r. Creemers, J.A.J. Atteveld and e.a. (1983) *PBNA poly-technical pocket book*

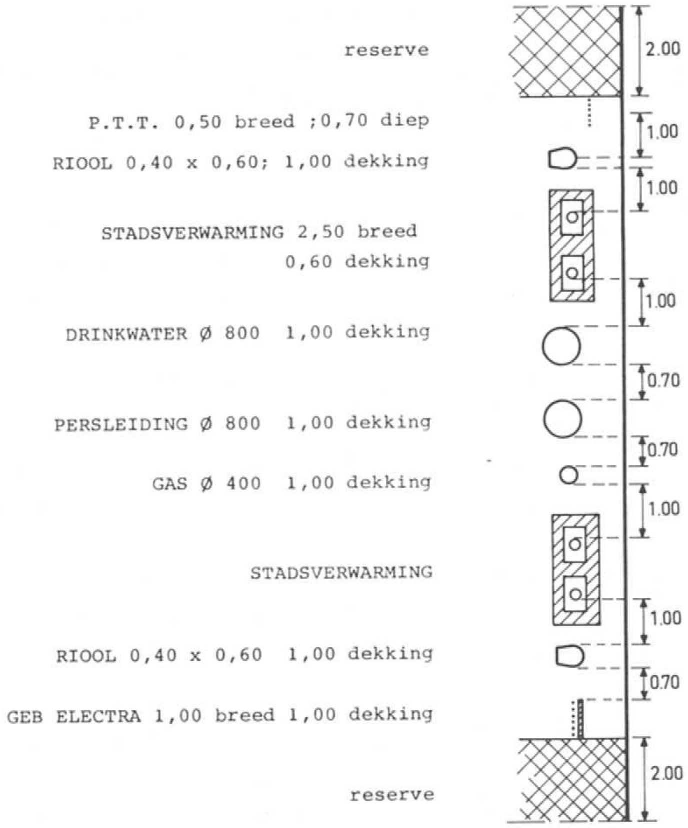

Fig. 616 Standard layout of cables and pipes in Rotterdam, Zevenkamp[a]

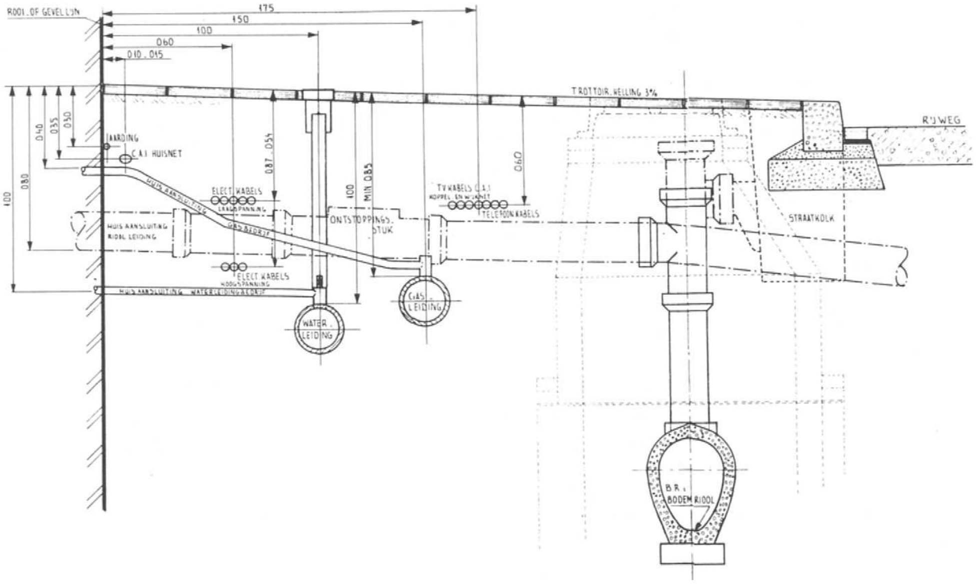

Fig. 617 Standard layout of cables and pipes Den Haag[b]

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[a] W.A. Segeren and H. Hengeveld (1991) p. 271

[b] *W.A. Segeren and H. Hengeveld (1991) p. 271*

Negotiations on the position of cables, pipes and drains

Negotiations on the position of cables, pipes and drains in a new district, and corresponding municipal services, take place during the design phase of an urban development plan. During these negotiations, alternatives and potential design solutions are drawn up, taking into account technical aspects of installation such as house service connections, pipe radius, junctions of pipes, cables and drains, relative influence of the different pipes, and their position in the street profile.

The position in the street profile determines the management and maintenance of pipes and drains, as well as street furnishings such as trees, lighting and street furniture.

Aboveground facilities

The design of public grounds largely depends on the underground infrastructure. “Eco parks” and underground dustbins such as glass and paper containers are often installed near squares or, in any case, near open urban spaces. These should not be obstructed by cables and pipes.

The implementation plan regarding cables, pipes and drains for new districts is laid down at an early stage in the land registry, and is available from the local municipality.

Land registry plans

In principle, the position of all cables and pipes in existing developed areas is laid down in land registry plans, which can be consulted in the event of changes in town planning. The municipality of Rotterdam is a good example: this municipality has stored all relevant data on underground networks digitally. Other municipalities are in an advanced stage in digital processing of data, or are nearing its completion. Nevertheless, there may still be a few surprises in store, as not all installed and obsolete cables or pipes have been laid down, digitally or otherwise. In some cases information may have gone missing. Even computer network cables are not always registered because they are temporary or because contractors do not think it necessary to inform the city council.

Beam transmitters

With the development of a new district urban planners should take account of beam transmitters that require physical space in towns, i.e. height and position of the buildings. A building can form an obstacle for these beam transmitters. Overall beam transmitter systems must be guaranteed in towns for adequate and profitable transmission. This can cause problems in existing built-up areas and thus requires the installation of a more compact network to guarantee adequate transmission range.

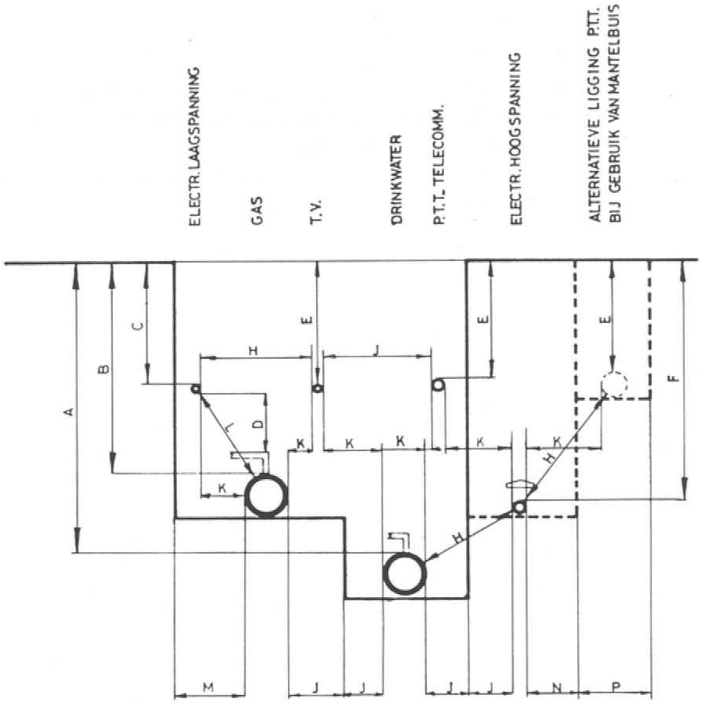
3.5.10 The future.

Combinations

New developments in the field of distribution networks, i.e. pipes, cables and wires, will take place to satisfy future demands for fast communications and connections. For example: a combined system of cable and wire ducts, or a combined system of sewer pipes and fibre optics cables, currently in an experimental stage in Amsterdam. Ducts are a particularly interesting option due to the high degree of accessibility of these pipes. However, the position of these ducts may pose problems: ducts located beneath a building may give rise to private-law cases regarding access to a building. Load-bearing capacity of the soil will need to be taken into consideration, if these ducts are not incorporated into a building. Examples to solve such problems are the communal trenches for cables and pipes used in England, and cable and pipe tunnels in the Netherlands.

The municipality of The Hague is currently installing “empty” pipes through which cables can run to provide extra capacity for new, innovative applications.

The most recent development for communication uses satelites for transmission instead of cables.



LETTER	MAAT
A	900
B	600
C	450
D	150
E	350
F	750
H	300
J	150
K	100
L	200
M	250
N	150
P	250
ALLE MATEN IN MILIMETERS.	

Fig. 618 Communal trenches for cables and pipes[a]

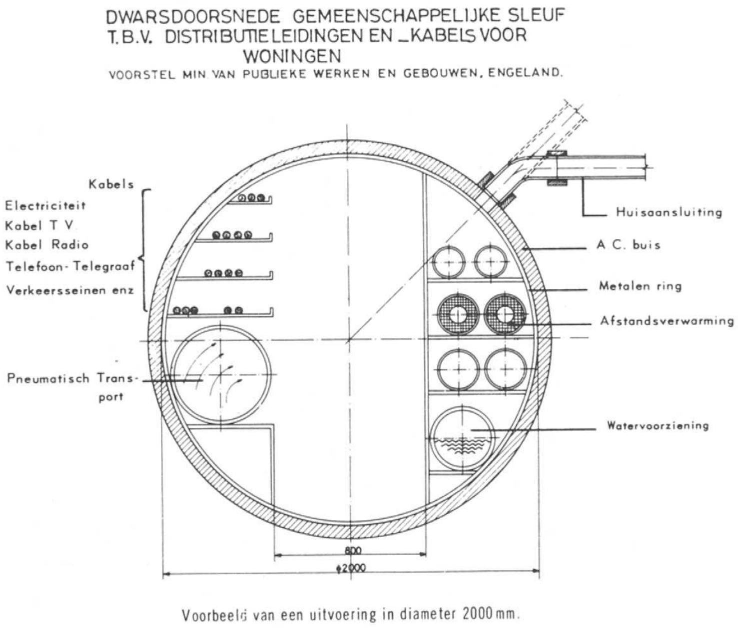


Fig. 619 Cable and pipe tunnel[b]

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[a] W.A. Segeren and H. Hengeveld (1984, 1991) p. 279

[b] W.A. Segeren and H. Hengeveld (1984, 1991) p. 279

4 Earth and site preparation

Contents

4.1 Introduction

The goals of this chapter on earth, ground and soil are:

- To make you aware of the relevance of this knowledge that can give your design approach a 'sense of time and place'
- To give you some background in the scope, viewpoints and approaches in the earth sciences
- To give you some background and insight into the possibilities for applying this knowledge in the design process

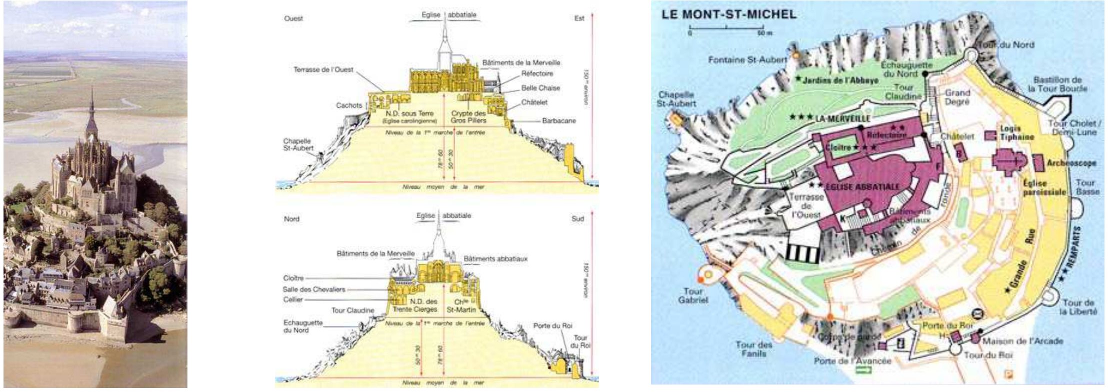

Fig. 620 Urban developement and geology; the Mont Saint - Michel in France. A small settlement around a monastry built on a rock in front of the coast. The settlement and the rock form a magnificent ensemble; the church and steeple enhance architecturally the verticality of the rock amidst the sea water. Walking to the top, no cars are allowed in the city, you experience the elevation. Above you have a splendid view or the surroundings.[a]

In one chapter we cannot give you an introduction to geology, geomorphology or soil science; just see it as a brief glimpse at the magnificent world behind the earth sciences that determines and conditions all urban development to a certain degree. Knowledge and insight into earth sciences can give your design an extra quality and makes you more stable in the preaching, screaming and expression of power of the environmental movements all over the world. It provides you with .firm ground under your feet.

Earth, ground and soil are in most projects the basis on which all construction and planting takes place. First comes the plotting of the contours of the plan by surveyors, then the preparing of the site for construction and .finally the construction and planting itself. Although in earth sciences the material is the most visible, the dominant aspect of earth sciences is time and process. In geology, time and process are the basis for understanding the material. In the context of design and planning, geology plays a role on a large scale and long term; the landscape development in the long run is for a large part determined by the geological conditions of the site. Geomorphology is most important on the structural level, whereas soil science more on the level of element and object.

Holland is very young in geological sense; especially in the west where the dynamic coast landscape still changes. Note that in Holland there is no natural rock; all rock, stone you see is imported. For foreign students; do learn about the geology of your country, it will give you many insights and knowledge you can use in planning and design. Geology is not so visible in the daily environment but is of tremendous importance because of the long term effect and processes.

Terminology and knowledge domains

Earth, ground and soil are related terms but are different in many ways.

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[a] *Guide Vert Normandie, Michelin, 1994*

- Earth[147] is both abstract (the earth) and concrete: what you can put your hands in… Earth is also referring to the planet we are living on.
- Ground[148] is concrete in the sense that it is always substance matter; material
- Rock[149] is a natural aggregate of minerals; it is always hard material. You cannot transform it by hand like ground and earth.
- Soil[150] is the upper layer of the earth, where plants grow. Is abstract; a man-made classi.cation on the basis of explicit criteria. Soil is determining land use for a large part, especially on the regional scale, for agriculture, horticulture and forestry.

4.2 Earth sciences

The central problem of the earth sciences is to understand how our planet works and how it came to be the way it is. The earth sciences comprise three different but related knowledge domains: geology, meteorology and hydrology. In the context of this chapter we take a look at geology and its subdivisions. The other domains have been described in former chapters. Three partial knowledge domains are specifically important in the context of urban design and landscape architecture: geology, geomorphology and soil science. As an example the figures below give an impression of the geology, geomorphology and soil map of Holland[a].

Fig. 621 The geological map of the Netherlands The main geological developments that have formed the country are visible; the river system with the delta, the coastal area with the dunes, the peat in the west and north east and the marine sediments in the north and south west

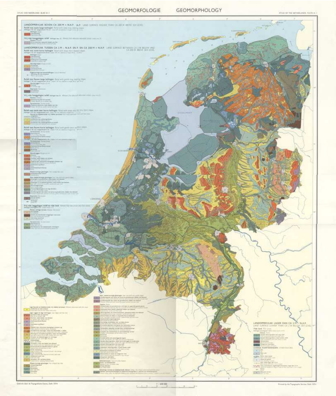

Fig. 622 The geomorphological map of the Netherlands Here the glacial influences are clearly visible in the centre of the country. Glacial ridges formed by the ice.

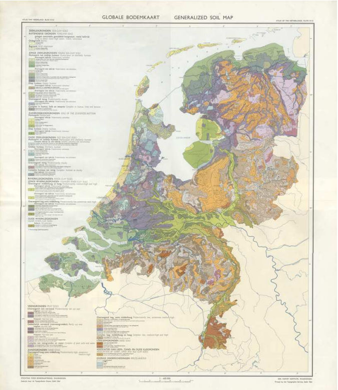

Fig. 623 The soil map of the Netherlands In the west you can see the peat and marine clays. In the east the sandy soils and in also here the river landscape can be clearly distinguished.

4.2.1 Geology

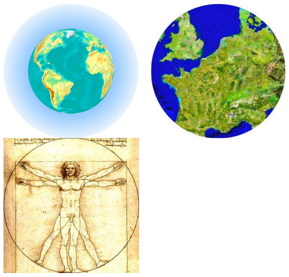

Fig. 624 R: 10 000km>1000km >1m

What is geology?

Study of the earth, its forces, materials and processes[151]. An important part of geology is the study of how earth's materials, structures, processes and organisms have changed over time.

Geologists address major societal issues that involve geologic hazards and disasters, climate variability and change, energy and mineral resources, ecosystem and human health, and ground-water availability.

Concepts and guiding principles of geology

Geologists use three main principles, or concepts, to study earth and its history.

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[a] Atlas, 1977

The first concept, called plate tectonics[152], is the theory that the earth's surface is made up of separate, rigid plates moving and .oating over another, less rigid layer of rock. These plates are made up of the continents and the ocean floor as well as the rigid rock beneath them. Plate tectonics is useful in the field of geology because it can be used to explain a variety of geologic processes, including volcanic activity, earthquakes, and mountain building. The mechanism that drives the earth's crustal plates is still not known, but geologists can use plate tectonics to explain most geologic activity.

The second guiding concept is that many processes that occur on the earth may be described in terms of recycling: the reuse of the same materials in cycles, or repeating series of events. The geological cycle and the hydrological cycle are examples.

The third principle is called uniformitarianism[153]. Uniformitarianism states that the physical and chemical processes that have acted throughout geologic time are the same processes that are observable today. Because of this, geologists can use their knowledge of what is happening on the earth right now to help explain what happened in the past.

Geological time scales; process and time in geology

Geologists have created a geologic time scale to provide a common vocabulary for talking about past events. The practice of determining when past geologic events occurred is called geochronology[154]. The geologic time scale is generally agreed upon and used by scientists around the world, dividing time into eons, eras, periods, and epochs.

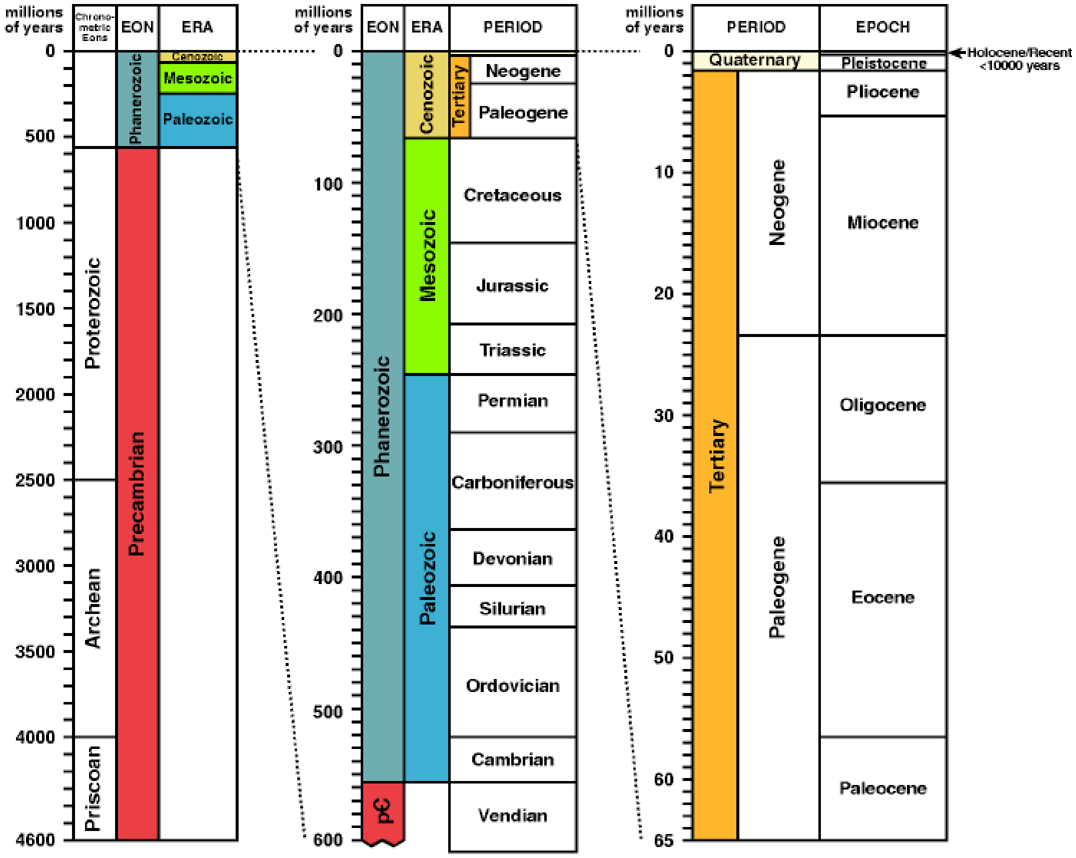

Fig. 625 Geological time intervals[a]

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[a]

These time intervals are not equal in length like the hours in a day. Instead the time intervals are variable in length. This is because geologic time is divided using significant events in the history of the earth.
For example, the boundary between the Triassic and Permian is marked by a global extinction in which a large percentage of earth's plant and animal species were eliminated.[155]
Another example is the boundary between the Precambrian and the Paleozoic which is marked by the first appearance of animals with hard parts.

Eons are the largest intervals of geologic time and are hundreds of millions of years in duration[156]. In the time scale above you can see the Phanerozoic Eon is the most recent eon and began more than 500 million years ago[157]. Eons are divided into smaller time intervals known as eras. In the time scale above you can see that the Phanerozoic is divided into three eras: Cenozoic, Mesozoic and Paleozoic.[158] Very significant events in earth's history are used to determine the boundaries of the eras.

Eras are subdivided into periods. The events that bound the periods are wide-spread in their extent but are not as significant as those which bound the eras. Finer subdivisions of time are possible and the periods of the Cenozoic are frequently subdivided into epochs. Subdivision of periods into epochs can be done only for the most recent portion of the geologic time scale. This is because older rocks have been buried deeply, intensely deformed and severely modified by long-term earth processes. As a result, the history contained within these rocks can not be as clearly interpreted.

Relative Time

Geologists create a relative time scale using rock sequences and the fossils contained within these sequences. The scale they create is based on The 'law of superposition', which states that in a regular series of sedimentary rock strata, or layers, the oldest strata will be at the bottom, and the younger strata will be on top[159].

The three important cycles of the earth as a geological system

The essential fact emerging from earth sciences is that the earth can be viewed as a set of three separate but interconnected cycles:

- the geological cycle of plate tectonics and materials,
- the atmospheric cycle (weather & climate) and
- the hydrological cycle that describes the water movement at large.

The geological cycle

The geological cycle governs the formation and disappearance of solid land. The science of geology contains two central insights.[160]

The first of these, arrived at in the eighteenth century, is that the earth is very old and that its history can be read in the rocks on its surface.

The second insight, gained in the late 1960s, is that the earth has evolved and continues to do so. The continents have not always been where they are now, nor have they always had their present shape and it will also not stay the same in the future. Instead, the surface of the earth has changed constantly, and the continents have moved about, sometimes breaking up into pieces, sometimes coming together again. This view of the earth, called plate tectonics, replaced the old idea of a static and unchanging planet. The study of the rocks and their history is the subject of geology, whereas the study of the forces that drive the activity on the surface is part of the newer field of geophysics.

At the same time that the continents are moving, a smaller-scale geological cycle, involving the formation of rocks and their erosion into sediments and soil, goes on.
It describes the dynamic transitions through geologic time among the three main types of rock: igneous, sedimentary and metamorphic rock.
In river deltas and the eruption of volcanoes, new land surface is added to the earth.
At the same time, the inexorable forces of weather and time break down the mountains.

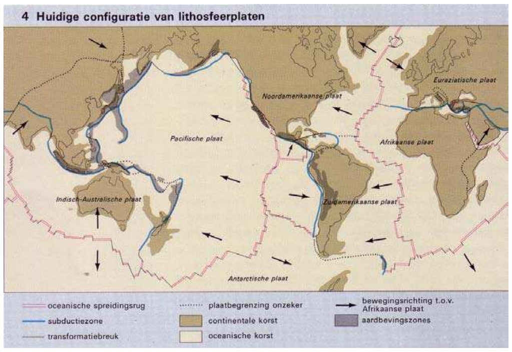

Fig. 626 Plate tectonics[a]

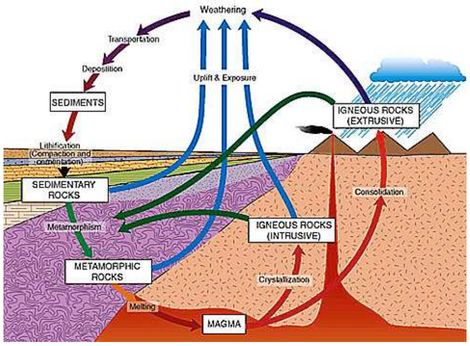

Fig. 627 Formation of rocks[b]

The atmospheric cycle

On the stage set by motion of the continents, the atmospheric cycle operates.

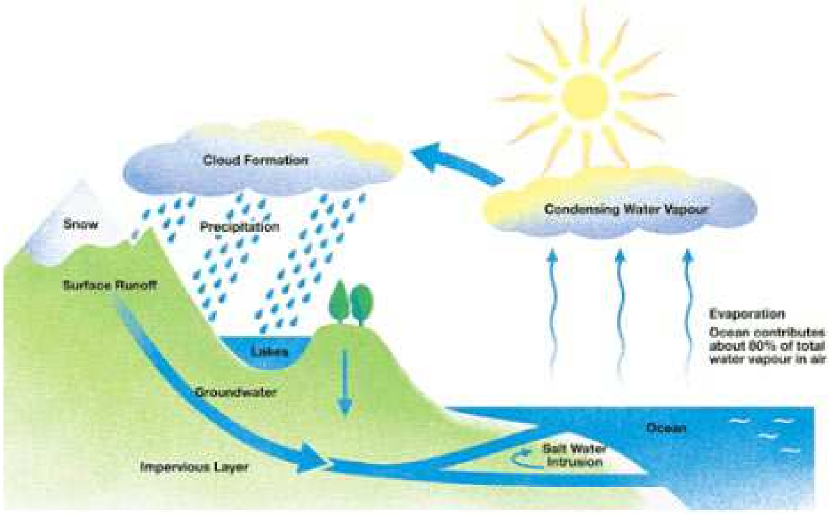

Fig. 628 The atmospheric cycle[c]

Powered by heat from the sun and the earth's rotation, winds move across the surface, carrying weather systems. Rainfall, temperatures, and other day-to-day aspects of our environment change in response to the prevailing winds and the jet streams. These weather patterns and their causes are the subject of the science of meteorology.[161]

Over longer time periods, changes in the earth's orbit or movement of the continents alter the patterns followed by the winds and the temperatures on the earth. Such changes in climate, of which the recurring ice ages are a good example, have had a profound effect on the development of all life on earth including people. Understanding long-term climate development is one of the major research fields in the earth sciences.

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[a]

[b]

[c]

Fig. 629 *R:* 10 000km>*100km* >1m

The hydrological cycle

Intermediate between the slow, majestic changes in the continents and the daily changes in the weather operates the third great cycle — the hydrologic cycle, the cycle of the earth's water, or hydrosphere.

Water evaporates from the surface and returns as rain or snow. Some water is locked up in the polar ice caps, but most resides in the oceans. Perhaps the most poorly understood part of our planet, the oceans act as a great reservoir for many natural and artificial R= 100 km surface= 300 km2 substances.

Their currents help equalise temperatures on the globe, while at the same time they spawn the major storm systems that have such an important effect on human activities.

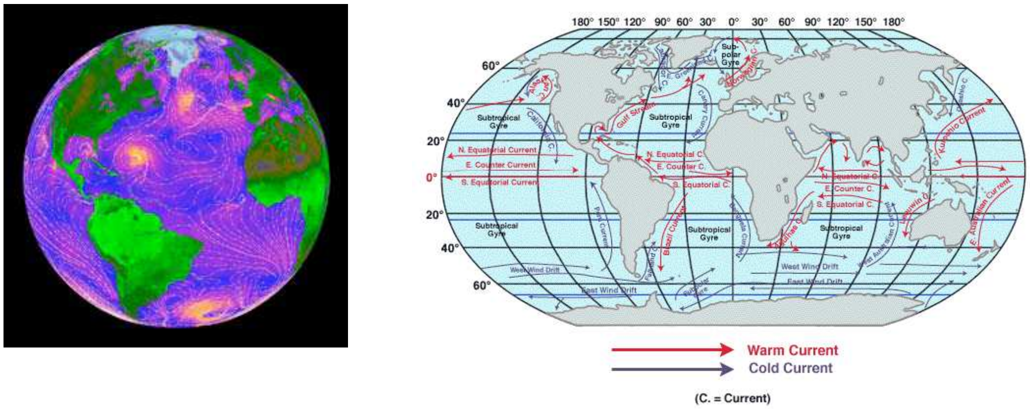

Fig. 630 Currents of the oceans[a]

Geological scale; material and space in geology

In geology we distinguish three main types of rock:

Igneous rocks are formed when molten rock cools, it is found in three major forms:[162]

- Granite is the lightest kind, formed when magma from the earth's mantle rises to the surface. Then cools and cristallises slowly in the earth's crust. By weathering it produces sand and clay stemming from its different cristals.
- Basalt is lava from a volcano that has been spewed out and cooled on the surface.
- Olivine is the heaviest kind, and consequently seldom seen at the surface. Its mining has been proposed as a solution for global warming, because it is slowly binding CO_2.[b]

Sedimentary rocks are formed if weathered or eroded material is deposited on the bottom of rivers, lakes, seas and oceans. Over long periods of time this sediment is buried and compressed. Often plant and animal material is buried along with it and is found as fossils. Coal, limestone and sandstone are sedimentary rocks.[163]

Metamorphic rocks are formed when rock is structurally altered through intense heat and pressure. Marble is produced when limestone is subjected to these stresses.[164]

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[a]

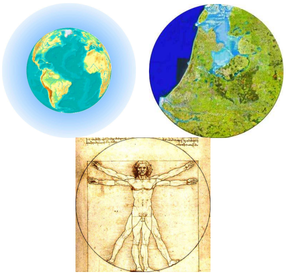
[b] Schuiling (2007)

Space

In order to understand geologic processes and to reconstruct the geologic past, geologists work at different scales — scales that range from microscopic to planetary. In order to work at these spatial scales, they use a number of tools:[165]

- At the microscopic level, traditional tools include the petrographic microscope, used to identify minerals and examine rock textures.
- Some geologic features are very large, and geologists must create detailed maps to observe them completely. Geologists use maps to record basic information, to examine trends, and to understand processes and geologic history. For example, a map may record the locations of historical earthquakes, helping to identify faults.[a]
- On a planetary scale, geologists can map the earth's surface using data from orbiting satellites. Geologists also make maps reconstructing a view of the earth at some time in the past; such maps are called paleo-geographic maps.

4.2.2 Geomorphology



What is geomorphology?

Study of the form of the earth and the forces that are behind that forms; landforms and processes that shaped them. Geomorphology seeks to understand landform history and dynamics, and predict future changes through a combination of field observation, physical experiment, and numerical modeling. Erosion, sedimentation, formation of landforms are issues that are studied in geomorphology.[166]

Fig. 631 *R: 10 000km>100km >1m*

Geomorphology is practiced within geology, geodesy, geography, archeology and civil and environmental engineering.

Concepts, guiding principles in geomorphology

Geomorphology is based on the systems view of geology and is very much process oriented at smaller time scales. It distinguishes three key concepts:[167]

- Landform; an element of the landscape that can be observed in its entirety and has consistence of form
- Landscape; earth surfaces composed of an assemblage of subjectively defined, lesser surfaces including its vegetation and artifacts.
- Geomorphic system; a set of related landforms and processes, usually defined in terms of a dominant agent of geomorphic activity (water, gravity, ice, wind, waves, or organisms)

Process and time in geomorphology

The main geomorphologic processes are:[168]

- epigenous or exogenous processes; these processes occur on the earth's surface, such as weathering, erosion, transport and deposition.
- hypogenous or endogenous processes; these processes are influenced by forces in the earth's crust, such as mountain building, heaving and subsidence, tectonics, volcanism.
- extraterrestrial processes; processes, where landforms are created by "alien" influences, such as an asteroid collision.

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[a] http://neic.usgs.gov/neis/epic/epic_rect.html

Weathering is the disintegration and decay of earth, rock, soils and their elements through exposure to the atmosphere. Water plays a key role in weathering. Weathering takes place at the site; there is no movement involved, in that case we speak of erosion.[169]

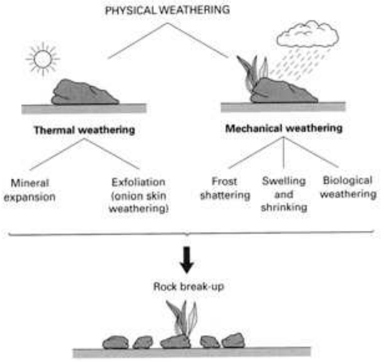

Fig. 1.1 The physical break-up of rocks by thermal and mechanical means.

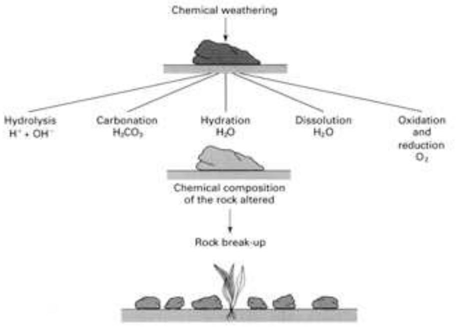

Fig. 1.3 The chemical break-up of rocks by hydrolysis, carbonation, hydration, dissolution, oxidation and reduction. Unlike physical weathering, which simply breaks the rock into smaller and smaller fragments, chemical weathering can also change the physical and chemical properties of the rock.

Fig. 632 Physical weathering

Fig. 633 Chemical waethering[a]

We distinguish three types of weathering:[170]

- Physical or mechanical weathering involves the breakdown of rocks and soils through direct contact with atmospheric conditions such as heat, water, ice and pressure. Mechanical weathering is the cause of the disintegration of rocks. The primary process in mechanical weathering is abrasion (the process by which clasts and other particles are reduced in size)[171].
- Chemical weathering, involves the direct effect of atmospheric chemicals; for example the disintegration by rain water that contains carbonic acid from the atmosphere. Oxidation followed by disintegration is caused by rain water containing oxygen from the air, particularly on ferriferous minerals. Chemical and physical weathering often go hand in hand. For example, cracks exploited by mechanical weathering will increase the surface area exposed to chemical action. Furthermore, the chemical action at minerals in cracks can aid the disintegration process.[172]
- Biological weathering always involves plants and living organisms. Lichens and mosses grow on essentially bare rock surfaces and create a more humid chemical micro-environment. The attachment of these organisms to the rock surface enhances physical as well as chemical breakdown of the surface microlayer of the rock. On a larger scale seedlings sprouting in a crevice and plant roots exert physical pressure as well as providing a pathway for water and chemical infiltration. Burrowing animals and insects disturb the soil layer adjacent to the bedrock surface thus further increasing water and acid infiltration and exposure to oxidation processes.[173]

Most weathering is a combination of three types and takes time. Nearly all weathering involves water, mostly directly like frost, shattering, wetting and drying. That is, weathering is climatically driven and thus the term 'weathering'. Because weather and climate occur at the earth's surface, the intensity of weathering decreases with depth and most of it occur within less than a metre of the surface of soil and rock.

Geomorphology in design

For all design projects the topography and form of the land is a starting point in the beginning of the design process. In Holland it is in most cases relatively easy to oversee the form of the land because of its flatness. In most other countries, it is not so easy to come to grips with the form of the land. You need to analyse and research the contourlines from the topographic map by making sections, analysing slope characteristics and analyse the water system.

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[a]

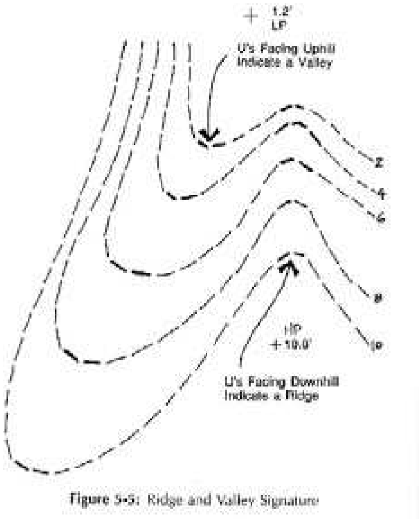

Fig. 634 Ridge and Vally signature

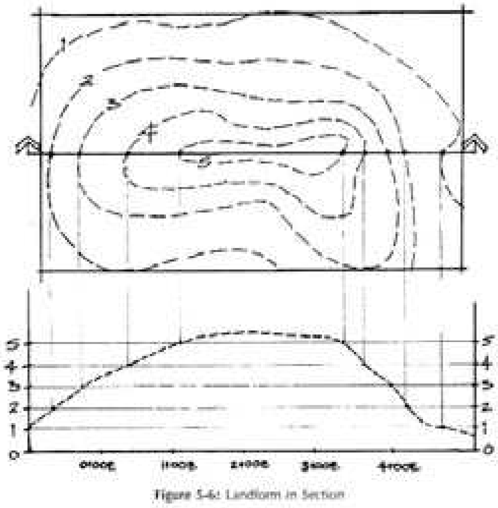

Fig. 635 Land form in section

First some basic principles regarding contour lines. Motloch[a] describes some basis important principles in analysing contour lines and the relief or elevation. First of all reading the contourlines on the topographic maps should first of all give you an idea about valleys and ridges (*Fig. 634*). Secondly you should make a number of sections to see and understand the form of the land as a whole. Making sections from the topographic map is fairly easy and straightforward; see the diagram (*Fig. 635*) Thirdly, the water system should give you some complementary information. If you know how the water runs, you get an idea of what the form of the land is. Even if the water system is changed by man over time, it still gives you information on the form of the land. You always start with the natural system on a large scale to see how the overal structure of the land form is. Then you add the man-made changes and additions like dams in rivers, new waterways, locks and sluices, reservoirs etc.[174]

Formation of land by rivers

The formation of the land by rivers is an important research subject in geomorphology. The development of a river as a whole over time is determined by topography, geological material and climate.[175]

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[a] Motloch (2001)

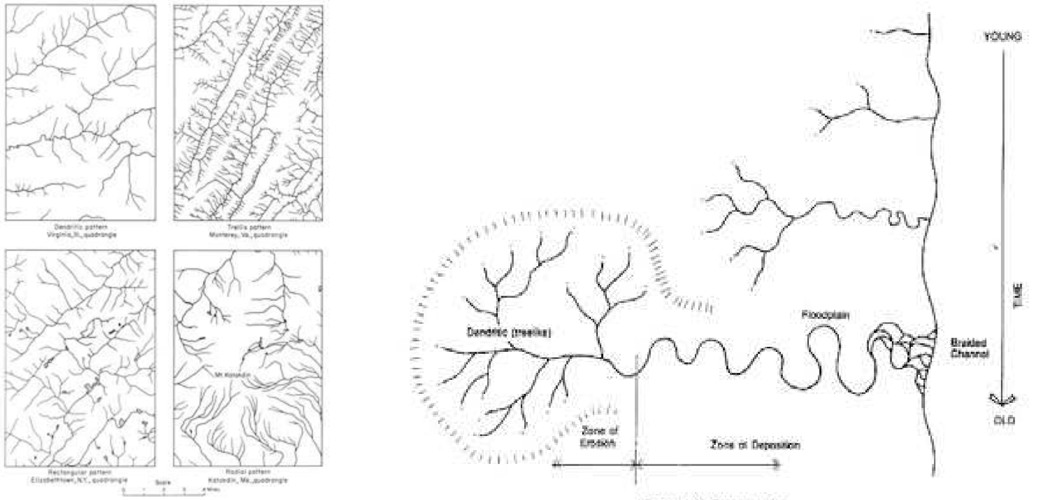

Fig. 5.9 Types of drainage patterns.

Figure 4-9: Stream Aging

Fig. 636 River forms[a]

Fig. 636, shows some basis patterns of rivers; they can be easily derived from a topographic map and give immediately an impression not only about the structure of the watersystem as such but also about the geology. Secondly you need these patterns to define the watershed. Thirdly it gives you an idea where in the riversystem as a whole the area is located; close to the source or close to the sea.[176]

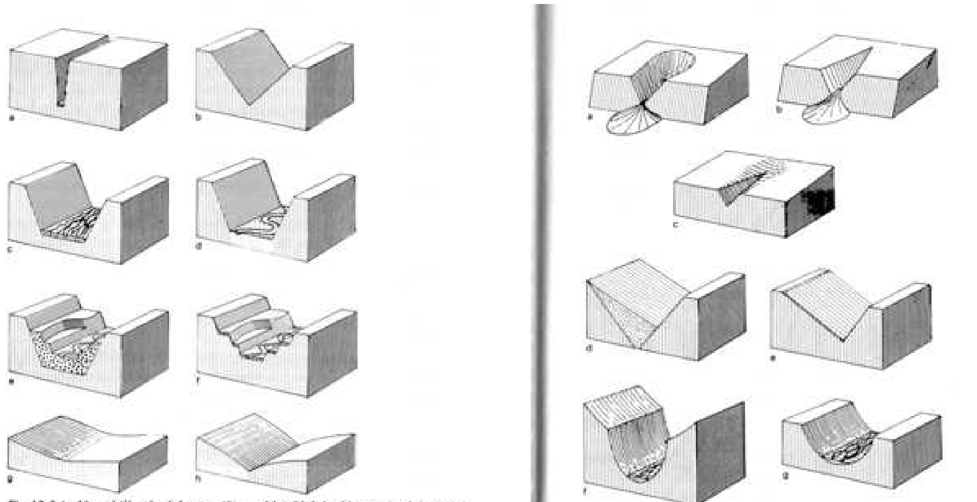

Fig.12.2A. Verschillende daltypen (1). a: kloofdal; b: V-vormig dal; c: dal met vlakke bodem en vlechtende rivier; d: dal met vlakke bodem en een meanderende rivier; e: dal met accumulatieterrassen; f: dal met erosieterrassen; g: 'Flachtal'; h: dal met convexe dalwanden.

Fig.12.2B. Verschillende daltypen (2). a: gully met 'amphitheater'; b: gully met scherp dal-boveneinde; c: gully met delle; d: secundair asymmetrisch dal; e: primair asymmetrisch dal; f: diep trogdal; g: ondiep trogdal.

Fig. 637 Valley forms[b]

Also if you take a closer look at the form of the valley by making a cross section, you can learn about material, landform and formation. *Fig. 637* shows some examples of valley forms, there are many more. It is important that you learn to see basic topographic forms on a regional scale, in this case river valleys.

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[a]

[b]

The IJssel near Doesburg

Taking a closer look at river formation we can distinguish the process of erosion and sedimentation, forming meanders (see *Fig. 638*).

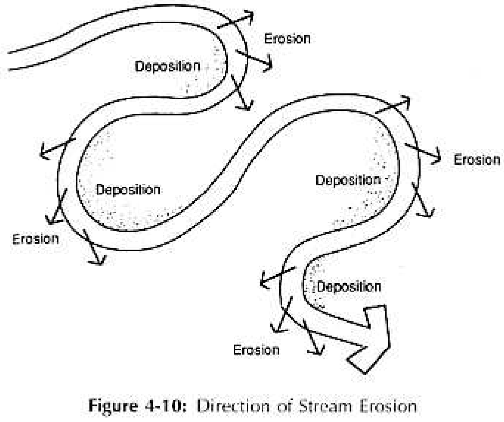


Fig. 638 Direction of stream erosion

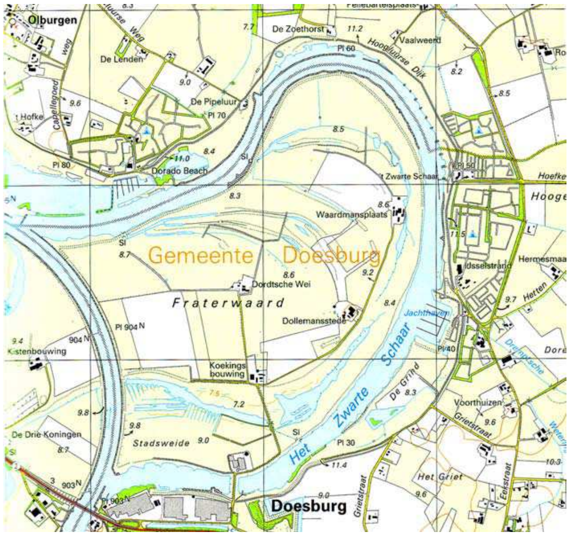


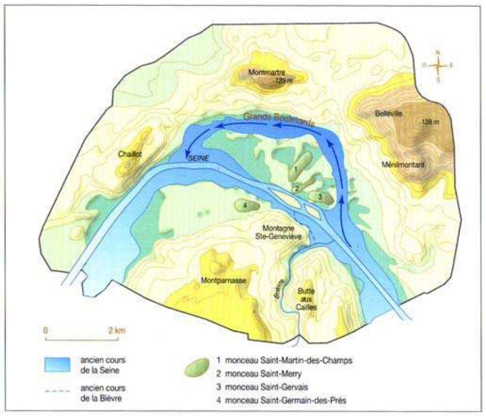
Fig. 639 The river IJssel near Doesburg

Fig. 639 shows a large meander in the river IJssel north of Doesburg. First of all you see on the land the various stages in the development of the meander; the pattern of blue lines shows the subsequent steps in development, from west to east. On the lower left you see a man-made shortcut for river traffic by boat.

The Seine in Paris

Another example of the formation of rivers and river landscapes reflected in the urban landscape of Paris; the former course of the river Seine (see *Fig. 640*) and how that can be read in the present urban pattern (see *Fig. 641*).

► **Restitution de la Seine à l'époque préhistorique.**
Le fleuve décrit une large courbe placée entre le confluent Seine-Marne à l'est et le méandre de Saint-Denis à l'ouest.
Amorcé par la déformation tectonique, le creusement de l'ancêtre de la Seine, lié aux changements climatiques, se poursuivit par saccades. Suivant ces mouvements, le fleuve abandonna ses alluvions qui encombrèrent la vallée désormais perchée.
Alors que la surface alluviale récente était régulièrement recouverte par les grandes crues, le sol alluvial ancien – une plate-forme de gravier située à 7 mètres au-dessus de l'étiage – demeurait insubmersible.
Aujourd'hui on ne distingue plus le support alluvial récent de l'ancien. Cependant, on peut restituer quatre éminences insubmersibles sur lesquelles l'habitat s'est développé en priorité. Un fragment de la plate-forme insubmersible porte par exemple l'abbaye Saint-Germain-des-Prés.



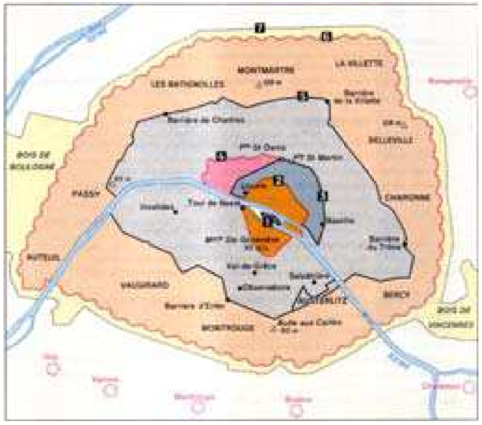


Fig. 640 The former course of the river Seine

Fig. 641 Paris now

In the subsequent stages of urban development of Paris, the former course of the Seine is still visible; see the second extension of the walled city. Also in the name of the quarter 'Le Marais' (The Marsh), that is located in part of this former course of the river Seine, the lower position of the area comes back[a].

Polders

Polders are a special phenomena in the context of geomorphology. It goes without saying that all polders are man - made. There are three types of polders[b]:[177]

- Drained lakes, 'sea bed polders' or in Dutch 'droogmakerijen'
- Marine sediments along the coast that are diked (e.g. the Dollard)
- Diked land in open water like the new IJsselmeer polders in Holland

In the last decades, in Holland no new polders are made anymore. Land is created by making of land above waterlevel. In most cases sand is pumped inside the a ring dike like for instance the 'Maasvlakte' (a recent part of the Port of Rotterdam and the new islands being created for IJburg, a new urban extension in the water east of Amsterdam.

In many delta's all over the world, you can find polders, not only in Holland.

4.2.3 Soil science

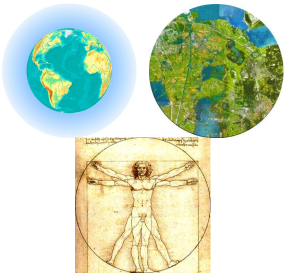


Fig. 642 *R: 10 000km>***10km** *>1m*

What is soil science?

Soil science is the study of soil as a natural resource on the surface of the earth including soil formation, classification and mapping; physical, chemical, biological, and fertility properties of soils; and these properties in relation to the use and management of soils. Soil science explores the nature, properties and use of soil to capture its value and to understand better its critical role as a foundation of life.[178]

People who study soil seek to comprehend fundamental global surface processes on multiple scales that impact ecosystems functioning and environmental health. Soil science is the key factor in food production and is a basis for environmental and natural resource issues such as land use, soil contamination, ground water quality and waste disposal. [179]

Concepts, guiding principles of soil sciences

Soil science studies the upper layer of the earth (±1.5 m) that determines the suitability for plant growth and different types of landuse.[180]

Process and time in soil science

Soils are porous natural bodies composed of inorganic and organic matter. They form by interaction of the earth's crust with atmospheric and biological influences. They are dynamic bodies having properties that reflect the integrated effects of climate (atmosphere) and biotic activity (microorganisms, insects, worms, burrowing animals, plants, etc.) on the unconsolidated remnants of rock at the earth's surface (parent material)[181]. These effects are modified by the topography of the landscape and of course continue to take place with the passage of time. Soils formed in parent materials over decades, centuries, or millennia may be lost due to accelerated erosion over a period of years or a few decades.

Formation of soils is determined by five soil forming factors:[182]

1. Parent material: The primary material from which the soil is formed. Soil parent material could be bedrock, organic material, an old soil surface, or a deposit from water, wind, glaciers, volcanoes, or material moving down a slope.

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[a] Chadych & Leborgne, 1999
[b] Geuze & Feddes, ??

2. Climate: Weathering forces such as heat, rain, ice, snow, wind, sunshine, and other environmental forces, break down parent material and affect how fast or slow soil formation processes go.
3. Organisms: All plants and animals living in or on the soil (including micro-organisms and humans!). The amount of water and nutrients plants need, affects the way soil forms. The way humans use soils affects soil formation. Also, animals living in the soil affect decomposition of waste materials and how soil materials will be moved around in the soil profile. On the soil surface remains of dead plants and animals are worked by micro-organisms and eventually become organic matter that is incorporated into the soil and enriches the soil.[183]
4. Topography: The location of a soil on a landscape can affect how the climatic processes impact it. Soils at the bottom of a hill will get more water than soils on the slopes, and soils on the slopes that directly face the sun will be drier than soils on slopes that do not. Also, mineral accumulations, plant nutrients, type of vegetation, vegetation growth, erosion, and water drainage are dependent on topographic relief.[184]
5. Time: All of the above factors assert themselves over time, often hundreds or thousands of years. Soil profiles continually change from weakly developed to well developed over time.

Soil formation

Fig. 643 R:
10 000km>1m

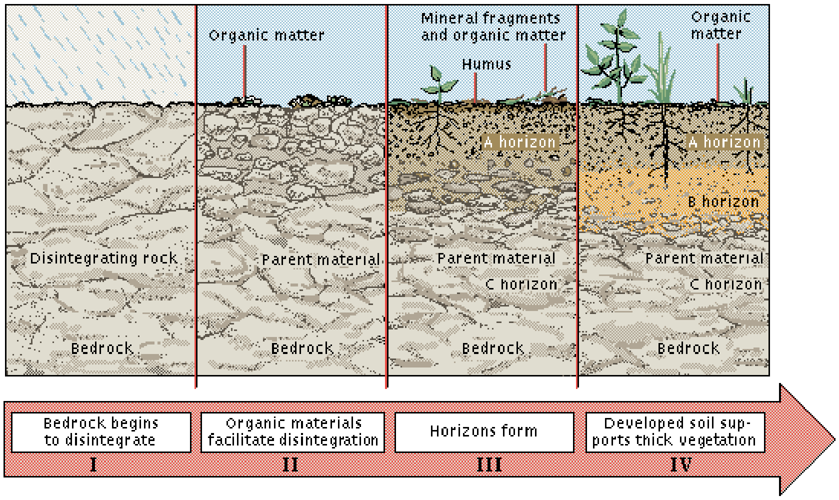

Fig. 644 Soil formation[a]

Soil formation (see *Fig. 644*) is the process by which rocks are broken down into progressively smaller particles and mixed with decaying organic material.[185]

- (I).Bedrock begins to disintegrate as it is subjected to freezing-thawing cycles, rain, and other environmental forces
- (II)The rock breaks down into parent material, which in turn breaks into smaller mineral particles.
- (III).The organisms in an area contribute to soil formation by facilitating the disintegration process as they live and adding organic matter to the system when they die. As soil continues to develop, layers called horizons form. The A horizon, nearest the surface, is usually richer in organic matter, while the lowest layer, the C horizon, contains more minerals and still looks much like the parent material.
- (IV)The soil will eventually reach a point where it can support a thick cover of vegetation and cycle its resources effectively. At this stage, the soil may feature a B horizon, where leached minerals collect. Natural processes that occur on the surface of earth as well as alterations made to earth material over long periods of time form thousands of different soil types.

---

[a]

Structure of the soil layer as a whole is based on the layers that are resulting from the process of soil formation: [186]

0-horizon: leaf litter, organic material;
A-horizon: plough zone, rich in organic matter;
B-horizon: zone of accumulation;
C-horizon: weathering soil, little organic material or life;
R-horizon: unweathered parent material.

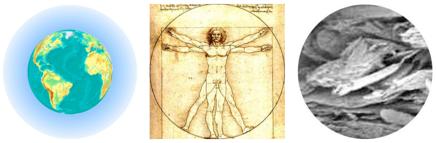

Fig. 645 R: 10 000km>1m>0.001mm=1µ (clay)[a]

Material and space in soil science

In the scope of this chapter, we can only give you an idea of the subject. Thus we have taken as example here, three soil types; sand, clay and peat. We will take a closer look at physical properties, size, form and chemical composition.

Physical structure

Soil structure and soil mechanics are characterised by differences in particle size, structure and texture. Physical qualities are determining the way you can work with different types of ground in construction carrying man-made structures like roads, buildings but also the characteristics for cultivating and labouring the land in agriculture. The chemical characteristics are important for plant growth.

Sand has a 'grainy' structure and Silicium as the basic element
Clay has a 'sticky, gluey' structure containing more minerals.
Peat has a soft structure. It can take up water like a sponge, in that case it expands and gets heavy. Carbon is the basic element.[187]

Particle size

Soil types are classified according to particle size:

(large rock block	
small rock block	
large stone	
small stone)	
coarse gravel	
fine gravel	
coarse sand	2000 - 210 µ
fine sand	210 - 50
loam / silt	50 - 2
clay	< 2

Fig. 646 Fig. 32 Particle sizes

The smaller soil fractions can be determined by assessing their settling velocity in water. The smaller the soil fraction, the slower they settle in water, as their specific surface is bigger. Sand fractions take approx. 1 minute to settle in a normal glass of water, while silt fractions takes approx. 12 hours, and clay fractions even longer.

The surface of the particles per kg of dry matter is 10 m^2 for sand, 100 m^2 for silt and 1000 m^2 for clay. The size of the surface is relevant for the absorbing capacity of soil particles of nutrients on the one hand, and pollution on the other hand.

Sand fractions retain hardly any water or nutrients. Silt fractions retain water reasonably well (but not nutrients) and clay fractions retain both water and nutrients, and these are responsible for soil contamination.

Identifying soil fractions

Soil fraction identification is carried out on the basis of vegetation. For example coltsfoot indicates a high content of soil consisting of particles smaller than 0.016 mm (16µ). By rubbing a quantity of fine grained soil in our palms, we are left with remnants of that soil in the lines of our hands. Loess in a dry state has a similar consistency to flour, while sand is easily identifiable. And so on.[188]

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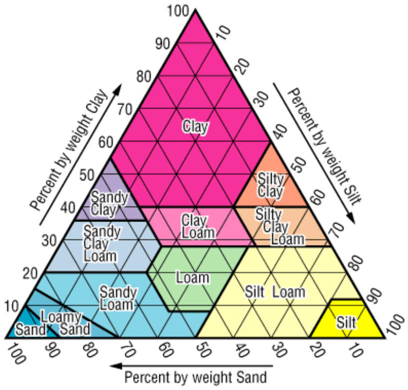
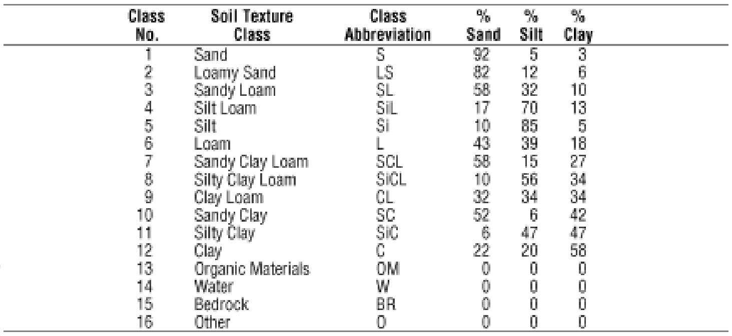
[a] http://www.septicseep.com/images/clay.jpg





Class No.	Soil Texture Class	Class Abbreviation	% Sand	% Silt	% Clay
1	Sand	S	92	5	3
2	Loamy Sand	LS	82	12	6
3	Sandy Loam	SL	58	32	10
4	Silt Loam	SiL	17	70	13
5	Silt	Si	10	85	5
6	Loam	L	43	39	18
7	Sandy Clay Loam	SCL	58	15	27
8	Silty Clay Loam	SiCL	10	56	34
9	Clay Loam	CL	32	34	34
10	Sandy Clay	SC	52	6	42
11	Silty Clay	SiC	6	47	47
12	Clay	C	22	20	58
13	Organic Materials	OM	0	0	0
14	Water	W	0	0	0
15	Bedrock	BR	0	0	0
16	Other	O	0	0	0

Fig. 647 Soil fraction diagram[a]

Ground water saturation

The ground is made up of solid constituents (mineral or organic), soil particles with interjacent pores. These pores can be saturated with air, air and water, and water. The term groundwater zone refers to the state of the water in the ground (pores saturated with water), while capillary fringe refers to pores saturated with air and water, and capillary water zone to zones filled primarily with air. This is the pedologic (pedology is soil science) classification of ground water.[189]

Soil water and ground water

In geology, subterranean water is divided into two groups; water in unsaturated upper zone – soil water - and water in the underlying saturated zone – groundwater.[190]

Soil water only partially fills the voids between the (ground) particles with water, while the other voids are saturated with air. Soil water corresponds with the capillary fringe and capillary water zone. The interface between groundwater and the capillary zone is known as the phreatic level or ground-water table.

Ground water

In general, the term groundwater refers to fresh water, responsible for all biotic processes. The majority of subterranean water, however, is sea water. In the Netherlands in particular, this subterranean sea water plays an important role in coastal areas. It occurs virtually everywhere in the provinces of Holland and Zeeland, and is covered by a layer of fresh ground water. Freshwater has a lower specific gravity than salt water, and as such "floats " on the salt water. Seepage is a vertical groundwater flow; upward movement from the ground water table to the surface under influence of water pressure. The deep polders of Holland and Zeeland (4 to 6m below ground level) contain salt seepage water due to the absence of, or excessively thin layer of, fresh groundwater due to (surface) water removal.[191]

Soil water

The water contained in the upper soil layer –soil water - can be categorised according to moisture content. Even without the supply of (rain) water, soil particles are surrounded by hygroscopically-bound water molecules; an atmospheric humidity of 0 never occurs in nature. An increase in atmospheric humidity leads to an increase in the number of molecules, bound hygroscopically to the soil particles.

Capillary fringe

Under the influence of adhesive forces, soil particles are surrounded by a layer of water due to the inflow of rain water. As the layers surrounding the soil particles thicken, the particles begin to bond, while open, air filled, pores remain. This zone is known as the capillary fringe.

Initially, these pores form a network. However, the increased supply of water eventually causes all pores to fill up with water, allowing water to flow freely between the soil particles. This last zone is

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[a] http://www.soilinfo.psu.edu/index.cgi?soil_data&conus&data_cov&fract&methods

known as the groundwater zone. This zone is easily identifiable in the soil. When digging or drilling a hole, water is accessed at a certain depth, a depth that will eventually be at a constant distance in relation to the ground level. This plane is known as the ground-water table or the phreatic level. The distance to the ground level is known as the groundwater level and is expressed in cm's below ground level. The groundwater beneath the ground-water table moves freely.[192]

Capillary zone

The term 'capillary zone' is also used in pedology. This zone is found in the upper layers of the profile. This zone is also saturated with water by capillary or adhesive forces, but it does not have ground water as its source, nor does it form a connection with ground water. It remained as gravitational water of the downward seeping water following a heavy downpour.

Capillary action of the ground.

Water is primarily retained in the ground by capillary forces (see *Fig. 648*). The capillary action is caused by the affinity between the water molecules (cohesive force) and the affinity of soil particles on the adjoining water molecules (adhesive forces). Water placed in a thin tube in a reservoir with water will rise due to capillary forces. The level of water rise is determined by the thickness of the tube. When the water is rising, the adhesive force between the tube and water is greater than the cohesive force among the water molecules. This phenomenon also occurs in the ground.

The smaller the particles, the more water is retained. The same applies to the pores; the smaller the pores, the greater the water level can rise. In other words, clay ground consisting of minute particles with intermediate narrow pores will be characterised by a high 'piezometric level', compared with sand, which has large particles and pores. This also implies that clay ground will be less easy to drain than sand ground, as clay retains water better than sand.[193]

Capillary levels

Based on laboratory tests and field observations using dipsticks, the following values for capillary piezometric levels above the ground-water table have been determined[a].

Coarse sand	12 - 15 cm
Intermediate coarse sand	40 - 50 cm
Fine sand	90 - 110 cm
Sandy loam	175 - 200 cm
Loam	225 – 250 cm

Due to the capillary action of the ground, the groundwater is pulled into a spherical shape between two ditches; the water level of the ditch acts as the lowest point. That is important for the distance between ditches in agricultural land, since different crops require different groundwater levels (see …).

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[a] Bogomolov (1958)

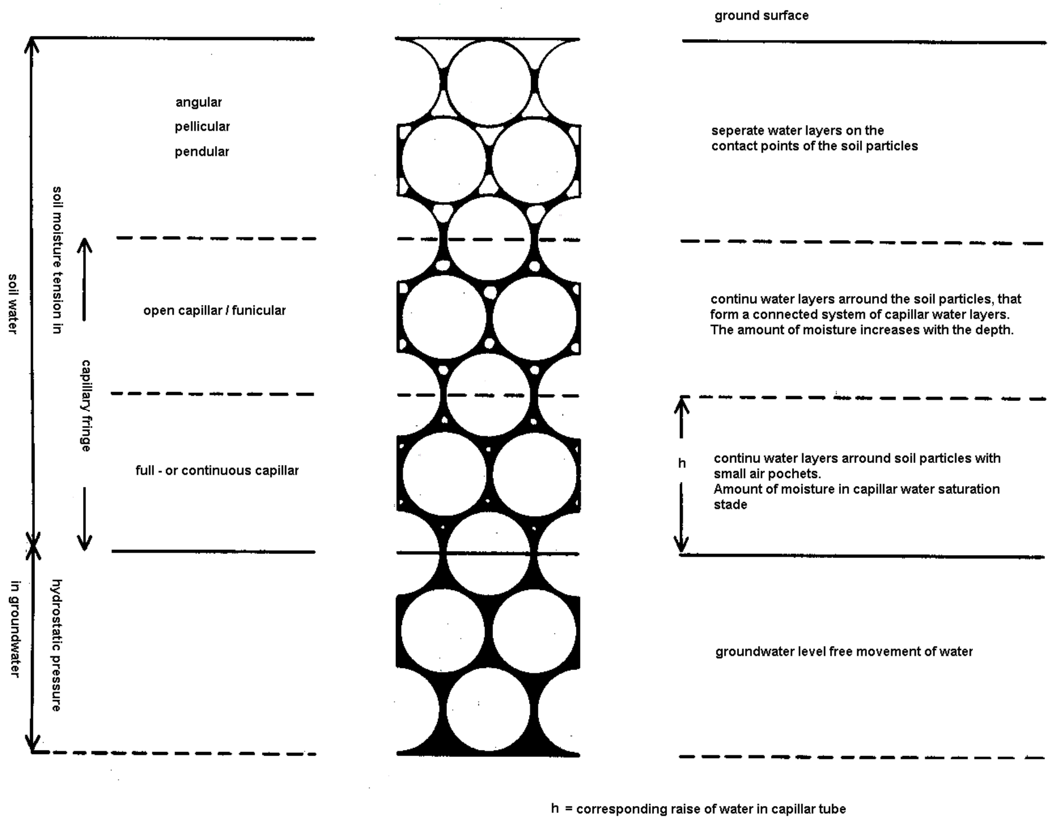

Fig. 648 Capillary action of the soil[a]

Water-table classes.

Groundwater tables are divided into water-table classes, where the highest average groundwater level (HMGL) and lowest mean groundwater level (LMGL) is processed. The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative.[194] The annual natural fluctuation of the groundwater in the Netherlands is measured in tens of centimetres. This movement is characterised by rust stains in the otherwise grey to grey-blue groundmass. This staining is caused by the presence of iron in the soil.

Gt	I	II	III	IV	V	VI	VII
LMGL	-	-	≤40	≥40	≤40	40-80	≥80
HMGL	≤50	50-80	80-120	80-120	≥120	≥120	≥120

Fig. 649 Main subdivision of water-table classes (groundwater level in cms below ground level)

Horizontal groundwater flow

Downward groundwater flows are the result of differences in groundwater levels in an area. Although the general direction of the groundwater flow is known, it will need to be determined for local situations. Flow is dependent on pore space and the size of the pores and, indirectly, particle size. In addition, soil is not an homogenous entity due to stratification in sedimentation, causing big fluctuations in permeability across relatively short distances.

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[a] A.J. Pannekoek (1973) Table p.316

In addition to natural groundwater tables, the Netherlands also has artificial groundwater tables, which are kept at a predetermined level through pumping. Pumping also creates groundwater flows towards the pumping plant.

Vertical groundwater flow

In addition to horizontal groundwater flow, we can also identify a vertical movement of water in the soil. This is known as effluent seepage (Dutch: kwel), where the water ‘surfaces' from the ground-water, and infiltration, characterised by ‘downward movement’ of water. The latter process is a natural phenomenon that occurs under the influence of gravity. This movement takes place in the profile zone above the ground-water table. Technically, this is also the profile zone, where water is temporarily stored.

Seepage

Effluent seepage is caused by water pressure from an elevated area to a low-lying area.
Effluent seepage can occur along hill ridges, when the groundwater level on the hill ridge is higher than the adjoining areas. This causes a subterranean flow in the direction of the lower-lying area. Springs are created in areas where the water issues to the earth’s surface.[195]

Seepage along dykes

A similar phenomenon occurs in areas bordering big rivers, whenever the level of the river water is higher than the neighbouring polders. Water rises to the earth’s surface along the dykes, when the water level of the rivers is higher than that of the land behind the dykes. The pressure of the elevated water produces water movement underneath the (porous) dykes. The seepage water rises to the surface along the dyke. This explains why ditches are constructed alongside dykes to collect and discharge water.

Seepage along the sea

This situation can also occur in the west of the Netherlands, as polders are drained at a greater depth than storage basins and, for that matter, big rivers and the sea. The effluent seepage in this area can be saltwater, freshwater or brackish water, depending on the source of the water from the storage basin or the water pressure from the salt groundwater. Seepage water from the storage basin rises to the earth’s surface near the dyke. Brackish and salt seepage water originating from the brackish/saltwater bell in the subgrade of the west of the Netherlands rises to the earth’s surface in the lowest sections of the polder, where the freshwater layer has thinned as a result of drainage activities, causing salt water to rise to the earth’s surface by pressure in the saltwater bell. This phenomenon gives rise to the opinion that in the long term agriculture in Holland and Zeeland can not survive unless it changes its products.

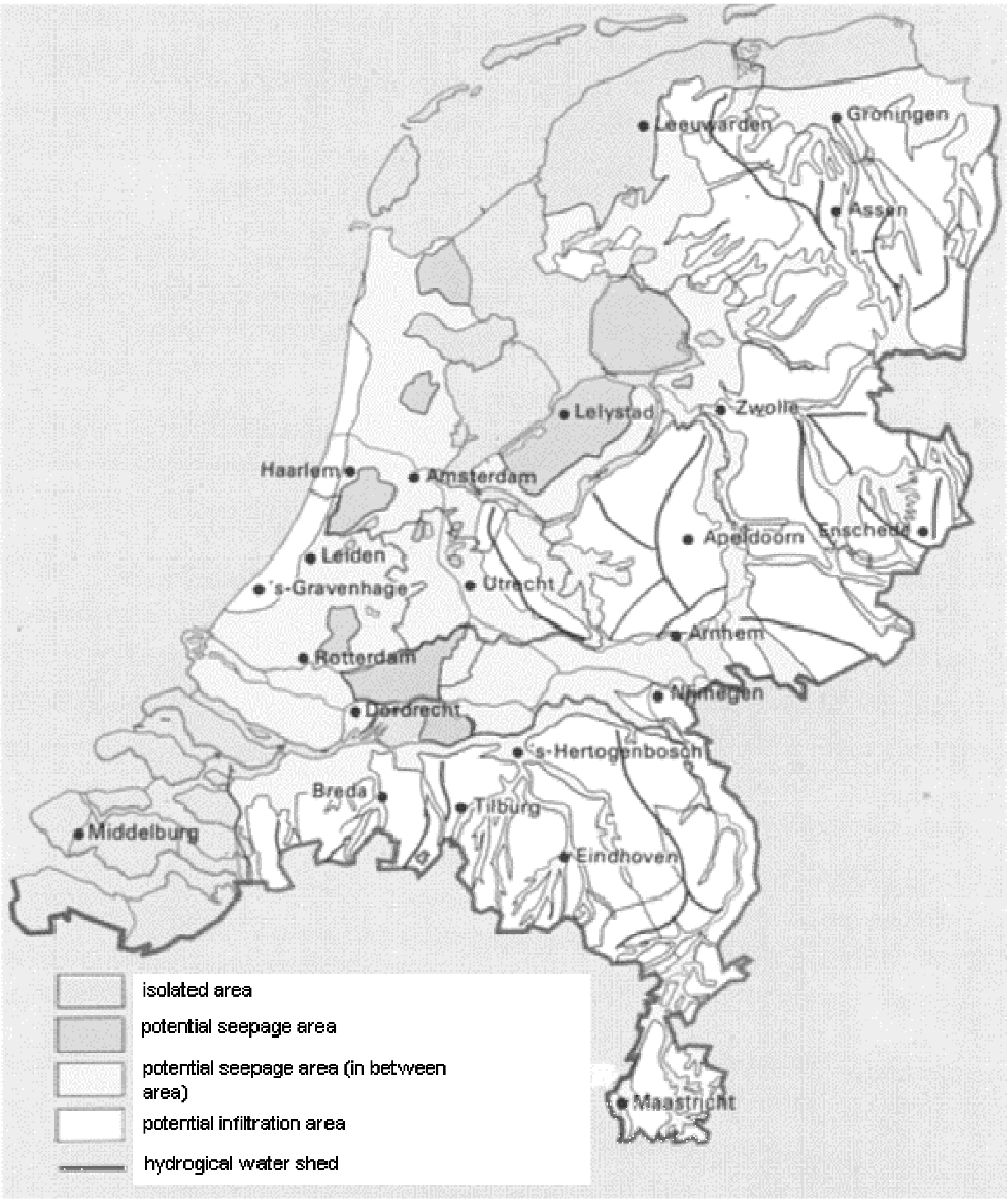

Fig. 650 Potential seepage areas[a]

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[a] Sticht.Wetensch.Atlas_v.Nederland, v.d. Berg, Steur and Brus (1987)

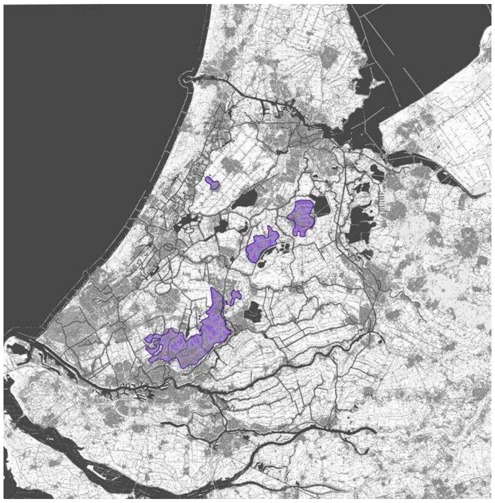

Fig. 651 Deep polders in the Randstad <5m-NAP

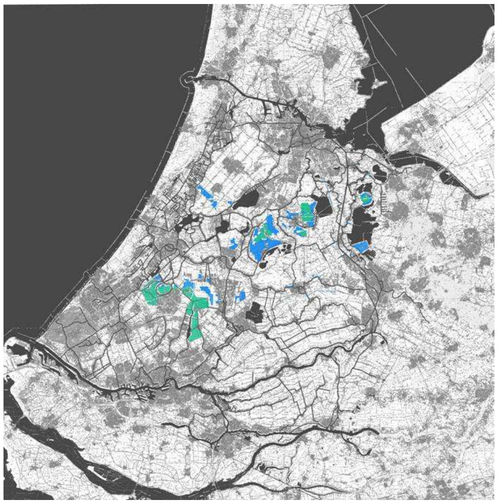

Fig. 652 Seepage areas in The Randstad

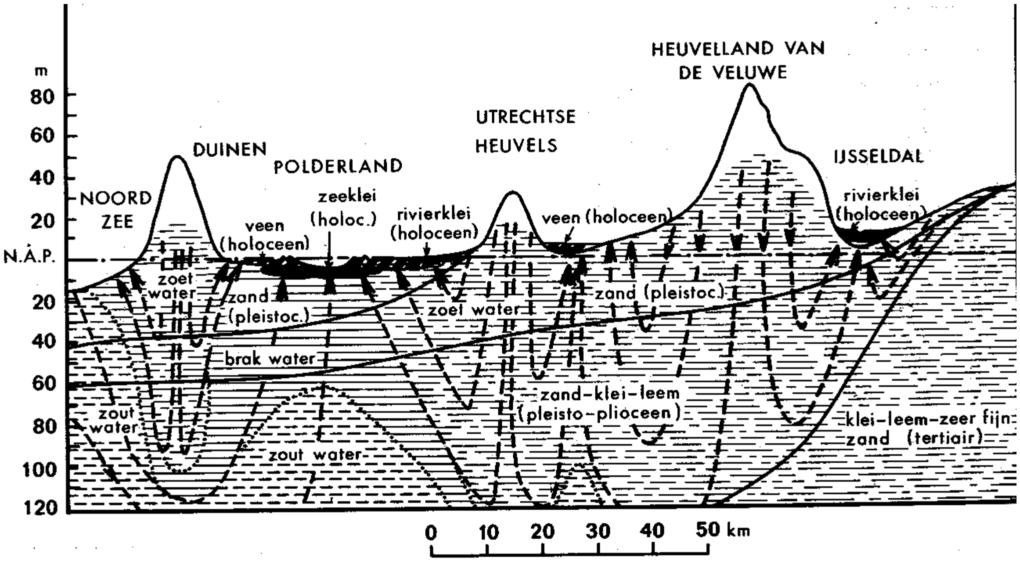

Fig. 653 Schematic hydrogeological cross-section of the Netherlands[a]

Supplemeted with a schematic not quantitave image of the pattern of groundwater **Error! Reference source not found.** shows flowlines for the deeper groundwater flow. The deeper groundwater infiltrates in Overijssel, the Veluwe, the Utrechtse Heuvelrug and the coastal dunes. This causes seepage in the IJsselvallei, the Gelderse Vallei and the polder area of West Netherland.
The exagerated heights (x 350) in the cross-section causes a strongly deformed pattern of flowlines. In reality the horizontal component of the pattern is more pronounced than the vertical component.

Spread of soil contamination

Soil contamination can be spread through the soil by the flow of ground water. If this is to be cleaned up, it is essential to have an insight into the speed and direction of the spread. For further information on this topic, see chapter …, page …

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[a] Commissie-Drinkwatervoorziening-Westen-des-lands (1940)

Land use of sand, clay and peat

These characteristics of soil determine their use:[196]

Sand
Pure sand is not a good basis for plant growth; dunes, deserts are examples. The physical structure is such that sand does drain the water very easily; it infiltrates into the upper layers at a rapid rate. Sandy soils in agriculture have the advantage that they are easy to work and lack of nutrients for plants is not really a problem because of fertilizers nowadays.

Clay
The structure of clay is firm and sometimes 'sticky', especially when it gets wet. Clay soils are in most cases very fertile; they belong to the richest agricultural soils. Young clay soils can be found in delta's and along rivers. In most cases these soils have been in agricultural use for a long time.

Peat
Peat is a very unstable soil; you cannot build on peat, it always needs foundation. For agriculture it is very well suited for growing grass (dairy farming) and horticulture. Peat soils can be found around Delft and the west of Holland in general. When exposed to oxigen, peat reduces (a chemical way of 'burning') thus resulting in shrinking of the soil. To make the peat fit for agricultural use, it has to be drained. The part exposed to oxigen will shrink; a process you can see the results of in all peat areas in Holland.

4.2.4 Chemical compounds

The Earth

Approximately 99% of the Earth's mass is composed by the elements of iron, oxygen, silicon, magnesia, nickel, sulphur, calcium and aluminium (see **Error! Reference source not found.**). The solid core of the Earth is formed by the heaviest elements iron and nickel with a liquid boundary. That makes a difference in rotation possible such as happens if you rotate an egg to determine if it is boiled, but operating like a dynamo causing the magnetic field of the Earth.[197]
A larger proportion of lighter elements and compounds compose its mantle and crust (see **Error! Reference source not found.**).[198]

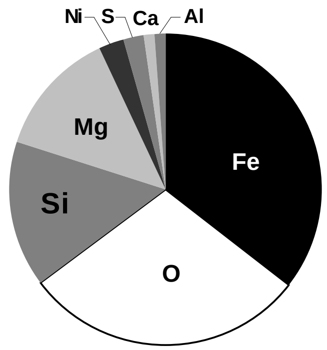

Fig. 654 Contribution of elements composing the Earth by mass (the darker the bigger the atomic mass)

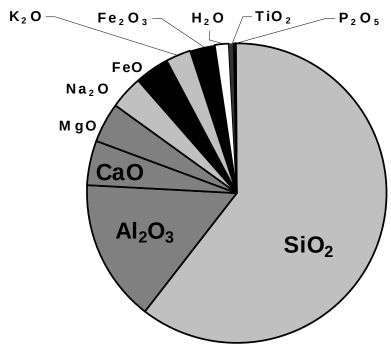

Fig. 655 Contribution of oxides composing the Earth's crust by mass (the darker the bigger the density on the Earth's surface)[a]

Cooling magma

In upward movements from mantle to crust the composition of the residual liquid is changed as a result of crystallisation of the cooling magma.[199] The first minerals to critallise contain a relatively high number of AlO_4-tetrahedrons. Continuous cooling creates minerals with proportionally more SiO_4-tetrahedrons. As a result, the crystallised minerals will prevent each other from adopting their own

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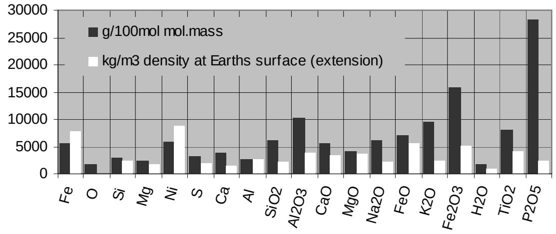
[a] http://nl.wikipedia.org/wiki/Samenstelling_van_de_Aarde

form. This explains the complete absence of beautiful, big crystals in plutonic rock (igneous rock below the surface). That is why rock composition should be analysed with the aid of a microscope.

The Earth's crust

In the crust of the Earth most of elements are combined into oxides with the lightest of the mentioned elements, oxygen (see **Error! Reference source not found.**). The lightest oxide is water. Though its atomic mass is bigger, at the Earth's surface its extended density (mass per volume) is smaller than those of the pure elements (see **Error! Reference source not found.**). These oxides are the main components of rock and raw material for ceramic industry[a]. Because of their colours they are also often used as pigments.[200]



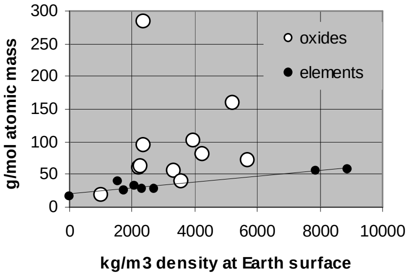


Fig. 656 Molecular mass and density (extension) at the Earth's surface of the most abundant elements and oxides in the Earth's crust

Fig. 657 Lower density at the Earth's surface of most abundant oxides compared to the main elements

Olivine

The heaviest rock is olivine, recently recognised as a possible solution to global warming if exposed to the atmosphere in a granulated form, because it has a natural be it slow reaction with CO_2.[b]

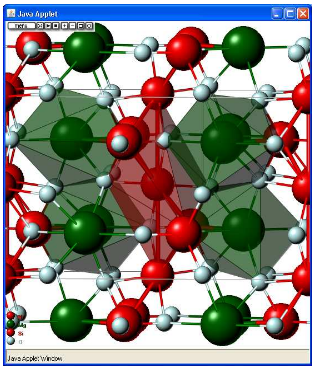


Fig. 658 The crystal grid of olivine

Fig. 659…and its green appearance as a crystal[c]

Composition

Pure oxides are seldom found on their own. They are the basis of many combinations with other elements (see **Error! Reference source not found.**) forming more ore less pure grids (minerals, crystals), on their turn combined into kinds of rocks, mixtures with their own name (see **Error!**

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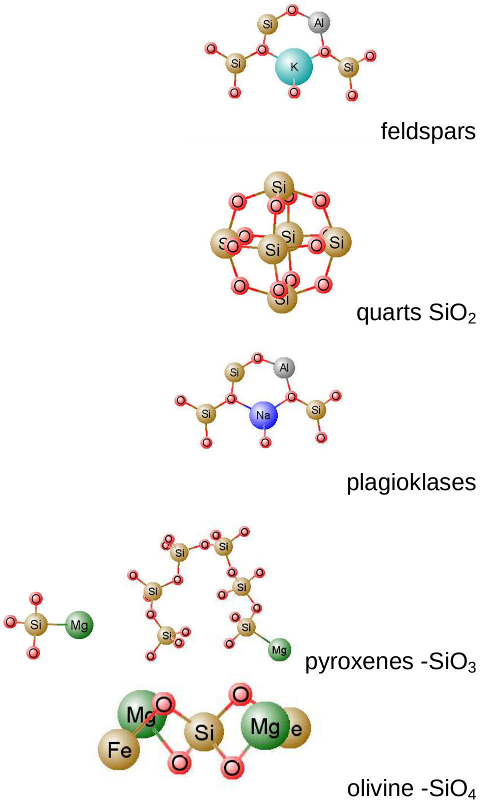
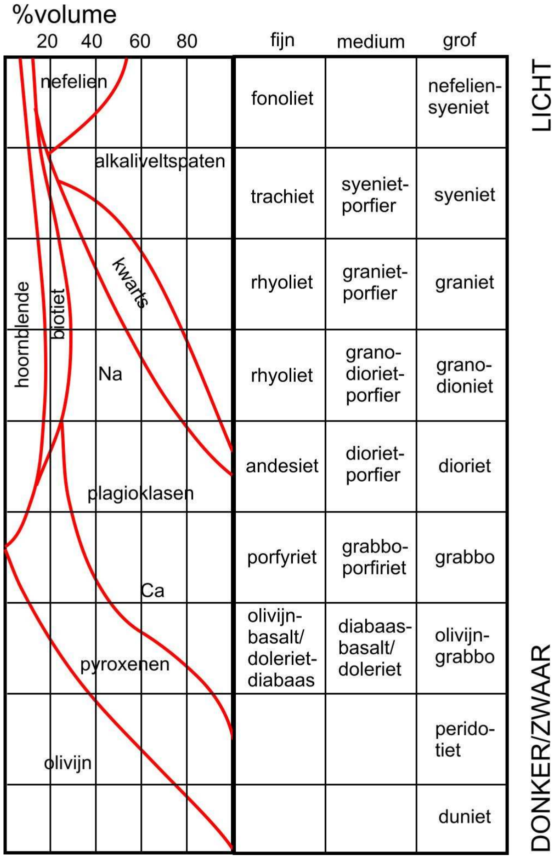
[a] http://ceramic-materials.com/cermat/oxide/na2o.html

[b]

[c] http://www.webmineral.com/data/Olivine.shtml

Reference source not found.). A book on minerals[a] is something else than a book on rocks[b].[201]





fijn	medium	grof
fonoliet		nefelien-syeniet
trachiet	syeniet-porfier	syeniet
rhyoliet	graniet-porfier	graniet
rhyoliet	grano-diorietporfier	grano-dioniet
andesiet	diorietporfier	dioriet
porfyriet	grabbo-porfiriet	grabbo
olivijn-basalt/ doleriet-diabaas	diabaas-basalt/ doleriet	olivijn-grabbo
		perido-tiet
		duniet

Fig. 660 Ideal typical parts of grids.

Fig. 661 Groups of minerals forming types of rocks[c]

As a rule of thumb heavier (mafic[d]) rock such as basalt looks darker than lighter (felsic) rock like granite (see **Error! Reference source not found.**). Heavier, mafic rock is found more abundantly on the bottom of the oceans, where the crust is thinner, while lighter, felsic rock more abundantly on land.[202]

Main minerals of Igneous rock

Out of the huge number of known minerals, only a minority are formed as igneous rock. Igneous rock primarily contains the following minerals:[203]

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[a] Asselborn, Eric; Chiappero, Pierre-Jacques; Galvier, Jacques (2005) *Mineralen* (Königswinter) Könemann, Tandem Verlag GmbH

[b] Bishop, A.C.; Wooley, A.R.; Hamilton, W.R. (1978) *Elseviers stenengids; stenen, mineralen, fossielen* (Amsterdam/Brussel) Elsevier

[c] Bishop, A.C.; Wooley, A.R.; Hamilton, W.R. (1978)

[d] *http://jersey.uoregon.edu/~mstrick/AskGeoMan/geoQuerry11.html*

feldspar	59.5%
amphibole / pyroxene	16.8%
quartz	12.0%
mica	3.8%
other minerals	7.9%

- Feldspars include orthoclase, plagioclase, oligoclase; they consist of the elements SiO_2, Al_2O_3, Ca, Na, K, CaO, Na_2O, K_2O.
- Amphiboles include hornblende, olivine, peridotite; they consist of the elements Mg, Fe, Ca, AlO_4, SiO_4, OH
- Pyroxenes include augite, hyperstone, diopsite; they consist of the same elements as amphiboles, with the exception of OH.
- Micas include biotite and muscovite; they form sheets, which consist primarily of SiO_4-, AlO_4- and FeO_4 tetrahedrons.

To a significant extent, this composition also determines the chemical composition of the soil.

4.3 Engineering

4.3.1 Earth sciences and the urban landscape (P.M.)

Design, planning, construction and maintenance

Engineering of earth and ground

Ground balance; cut and fill

4.3.2 Sustainability (P.M.)

Environmental aspects

The legal aspects of environmental quality of soils

Besluit Bodemkwaliteit in Holland

Landslides and geohazards

Earthquakes

4.3.3 Preparing a site for development

Soils and ground-water tables suitable for residential and industrial areas

Any adjustment or improvement to the soil and ground-water table deemed necessary to enable the construction and design of a residential and industrial area, must be carefully considered during the planning stage, taking into account the technical possibilities and limitations of the ground itself, as well as the groundwater. Not only are these considerations vital to the ecological preconditions associated with sustainable planning, they also underpin the existence conditions of an area, and economically sound planning.

Accomodating the environment

Traditionally, differences in soil properties necessitated a differentiated approach to ground use. Nowadays, economic factors and strategic planning prevail when deciding on future use. No consideration is taken of the management and the preservation of the (newly created) environment. Management can prove so costly and complex, that even minimal cutbacks or setbacks will create serious maintenance and environmental problems.

Sustainable impacts

Any intervention must provide a certain degree of certainty that the newly created situation can be sustained.

Furthermore, any manipulation to the condition of the soil as a result of fill or lowering of the groundwater level, or a combination thereof, will not only affect the actual site, but also the surrounding area. This manipulation can cause significant changes in the patterns of plant growth. In addition, abrupt transitions between different areas will affect the visual and social harmony of an area.

Assessment of existing and future value

The values of the site earmarked for development, land use, cultural-history, vegetation and ecology of the area covered by the plan and the surrounding area must be analysed to enable sound planning and assessments of future use.

4.3.4 Methods for preparing a site

There are two opposing approaches to preparing a site for development:[204]

- technically, any ground can be prepared for development; in other words, the "foundation" does not determine the site to be developed, but rather the demand. This approach does not focus on sustainability of the newly created situation. Effectively, the issue of management is left out of the equation altogether.
- identifying the site to be developed is dependent on the "foundation"; in other words, a site's potential for various functions must be assessed, taking into account installation and management costs. This ‘potential site’ selection is more ecologically sound.

Several preparation methods can be identified. The ultimate choice of method has far-reaching implications in terms of management of the existing situation, as well as the design potentials of the new urban landscape.[205]

Lowering the polder level

To obtain the required drainage, the level of the entire polder polder(site preparation) is lowered via a pumping station. This can prove problematic if only a section of the polder needs to be developed, and will either involve creating a new (smaller) polder inside the existing polder, which is then developed, or adjusting the rest of the polder to the new groundwater table in line with use requirements.
The advantages of this method include ease of execution and savings on embankment sand.
The disadvantages, however, generally outweigh the advantages.
Given its many disadvantages, this method is not applied to peat ground in urban areas.

Sagging

As the water level drops, air will permeate the overburden, causing settlement of the ground (settlement or “sagging" of the ground is caused by the replacement of water by air). Clay and sand grounds are characterised by minimal setting. Peat grounds, on the other hand, are extremely prone to setting due to their high concentration of water (over 90%). In addition, peat oxidation sets in due to the presence of air, resulting in additional loss of volume. As a result of this and the loss of water, 'settlement' occurs, a downward movement of soil that negates the effect of lowering the polder level.

Wooden piled foundations and seepage

The pile heads of old buildings with wooden piled foundations will begin to rot above water. Older trees are also affected by sudden lowering of the groundwater level. Furthermore, deeper polders may be prone to increased effluent seepage from the surrounding, elevated, areas.
These problems are characteristic of many peatland agricultural areas, where levels have been lowered for land development works to increase crop yield. Although at first sight it appears that the existing landscape is being spared, and incorporated in the design of the new neighbourhood, this is not the case.

Raising with sand pumped to the building site

The required dredge spoil is usually derived from a dredge area, from where sand is pumped through pipes to the building site. This method destroys all existing structures of an area. The designer can create his design in a virgin area, and only needs to take account of connections on adjacent neighbourhoods and roads. This is effectively a "tabula rasa" method.
The advantages of this method include the relatively low cost of sand by ‘high-volume dredging’, and the immediate creation of a level building site, making the plan "free" and "flexible". Private and public terrains are gradually lowered and feeder roads are not overtaxed by heavy sand transports, as in the following method.

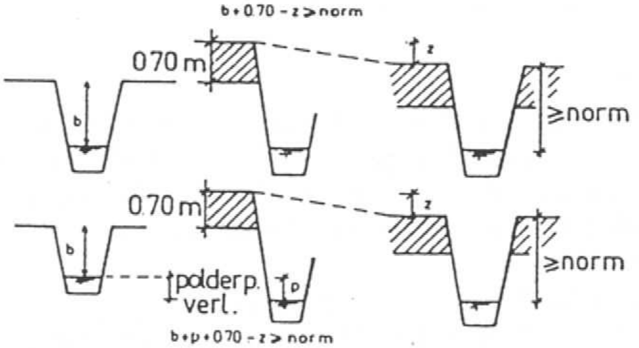

Fig. 662 Raising with sand and lowering polder level[a]

Costs

Cost disadvantages include high pre-investment costs due to the need for extra embankment sand caused by increased subsidence in the early stages. Before actual building can commence, developers will need to wait several years for the subsidence to halt, generating a further cost item.
To minimise these disadvantages, a system of vertical drainage using 'sand piles' is applied – very exceptionally in house construction. Pressurised water is rapidly discharged upwards through the sand piles, causing accelerated subsidence.
Following completion of building activities, the site is subject to all the usual subsidence problems. Another disadvantage is that the existing landscape will disappear completely under a layer of sand, requiring extensive ground consolidation for urban green areas and gardens.

Examples of raising with sand

This method is heavily deployed in the west of the country in large-scale urban expansions.
The post-war urban expansions in Amsterdam West are a well-known example.

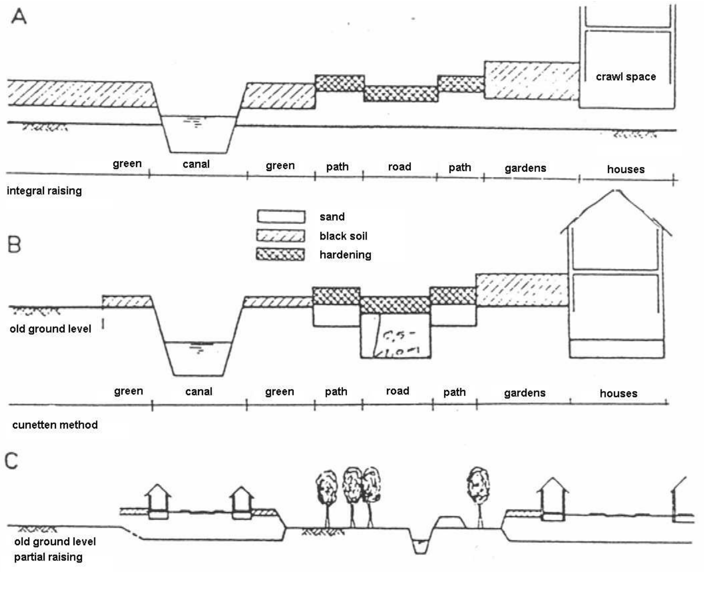

Fig. 663 Raising with sand[b]

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[a]
[b]

Sand delivery per 'axe''

This method is similar to the previous one, the main difference being that embankment sand is delivered by lorry.
The advantage of this method is that it enables a more selective approach, allowing for smaller deliveries and thus phased land reclamation. More consideration can therefore be given to the existing landscape features, which in turn might play a part in the design. This method also allows for the sole raising of those areas that are essential for the construction of roads and pipelines, thus not impacting on other areas.
If the soil is not all too marshy, urban greenery and gardens can be constructed on the original overburden.

The elevated sections are subject to all the previously mentioned disadvantages of subsidence. Nowadays, vertical drainage is applied to these sections. Additional problems include the provisions and costs involved in transporting sand overland.
This method is primarily applied in new residential areas in the North and East of Rotterdam. In general, this involves integrated land reclamation.

Impact of raising with sand on vegetation

Using sand to raise an area has a negative impact on vegetation:

- Embankment sand generally has a low nutrient content. Although this may be ideal for certain types of vegetation, the growth of most trees, as well as lawns and general gardening work depend on the availability of soil with a higher nutrient content.
- Due to its dense packing, embankment sand is not easily permeable for roots. This is particularly true of reclaimed sand. The area is not conducive to tree growth; furthermore, filling a small planting hole with a more suitable soil type will not suffice, as the roots will be contained within the planting hole due to the poor permeability of the surrounding soil.
- The weight of the sand compresses the old top layer, creating a layer with poor water and root permeability. These highly unsuitable plant growth conditions are exacerbated during construction activities, when the ground is further compressed by heavy machinery.

Under-reamed platforms and light-weight fill-material

In this method, mains-connected residences and streets are under-reamed with (concrete) piles. Alternatively, under-reamed living platforms are created. Access roads and parking places are raised with a layer of polystyrene, covered with scoriaceous sand, while urban greenery and gardens are not raised.
The main advantage of ‘living platforms’ is that house building can commence as soon as the platform is complete (in the ‘raising with sand’ method, developers need to wait 5 to 6 years after raising before building can commence). This allows for phased building, thus incorporating existing landscape features. Furthermore, there are no problems with subsidence. The raising of an area using lightweight fill-materials has similar advantages.
The method of light-weight raising has been applied in Capelle a/d IJssel; concrete living platform designs have also been drawn up, such as Piet Blom’s expansion plans for Monnikendam.

Preventing the light-weight construction from floating

To prevent the light-weight construction from floating, excessive groundwater rises must be prevented in the event of heavy rainfall. The preconditions for this method include good drainage and open water storage of at least 6 to 7% of the surface.

Costs

Both methods have one main disadvantage: extortionate costs, roughly twice as high as raising with sand. However, the long-term benefits include far lower maintenance costs. Urban development (sub) plans must be entirely laid down in writing beforehand. Light-weight raising methods are however characterised by slight subsidence in the course of time. Raising increases the weight, thus causing further subsidence.

Living layer

A more recently developed method involves the use of a so-called living layer. This is a layer of 'pure' soil, poured onto the ground (separated by a plastic film). This ground is usually partially polluted, and cannot be purified for a variety of reasons. This method allows developers to build on contaminated ground.

Other forms

As well as the abovementioned methods, an additional option involves floating constructions, as demonstrated for example by Hans Huber's graduation project of his 'Eco Building' in the TU district. For his experimental project in Haarlem, Herman Herzberger designed floating homes that follow the sun's movement. Other development ideas include houseboat parks with their own mains infrastructure.

'Situation-conscious' site selection.

Situation-conscious urban designers tend to prefer an accurate analysis of the soil conditions and water economy, coupled to the issue of preparing a site for development, as an integral part of planning.

Bijhouwer's Kethel

The abovementioned concepts are far from new. As early as 1948, the garden and landscape architect Jan TP Bijhouwer carried out a study into the development potential of the village of Kethel near Schiedam. Soil maps revealed the location of the old village on top of a creek ridge, a sturdy clay ridge, deposited by the flood current of the sea. Bijhouwer projected his development plan on the position of the creek ridges in this area, while he chose the peaty basin between the ridges to design a park. This park was eventually situated here, by selecting suitable vegetation and installing generously sized bodies of water. The development itself partially adhered to his original ideas.

Fig. 664 Bijhouwer, soil map of Kethel and surroundings

Fig. 665 Bijhouwer, development plan of Kethel and surroundings

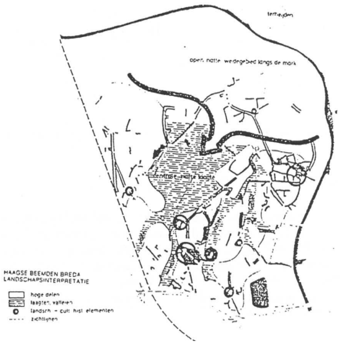

Fig. 666 Maas and Tummers Haagse Beemden

Applications in peaty basins intersected by wide sturdy ridges

In those parts of the Netherlands where smaller peaty basins are intersected by wide sturdy ridges, Bijhouwer's[a] approach is ideal. This is by no means a 'minority concept': in many areas of the Netherlands, peat is intersected by interstream ridges, creek ridges and cover sand ridges, such as The Haagse Beemden, a big expansion district in Breda, designed by the urban developer Leo Tummers and the landscapes architect Frans Maas.[b]

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[a]

[b]

The graduation project of Peter Dauvellier, which touches on the issue of preparing a site for development, compares the approach taken in Kethel to that of the Holy district in Vlaardingen by virtue of their 'universal' approach (integrated reclaiming).

Tanthof in Delft

A separate mention must be made of Tanthof, a district in Delft.
The design of this area has been met with substantial criticism because of its complex, 'drab' layout. This criticism is however primarily targeted at the pattern of building blocks and roads.
The main layout is extremely sensitive to the underlying landscape. One key feature concerns the narrow creek ridge that diagonally intersects the plan, deployed as a green zone with a traffic-calming route, known as the Kethelrugpad. This ridge was far too narrow to allow for concentrated development (as with the Kethel plan). Rather, designers decided to take account of the local soil, loam and clay, to plant ash and elm, slow-growing tree species that will take several years to envelop the district, and will not do as well in the rest of the neighbourhood.

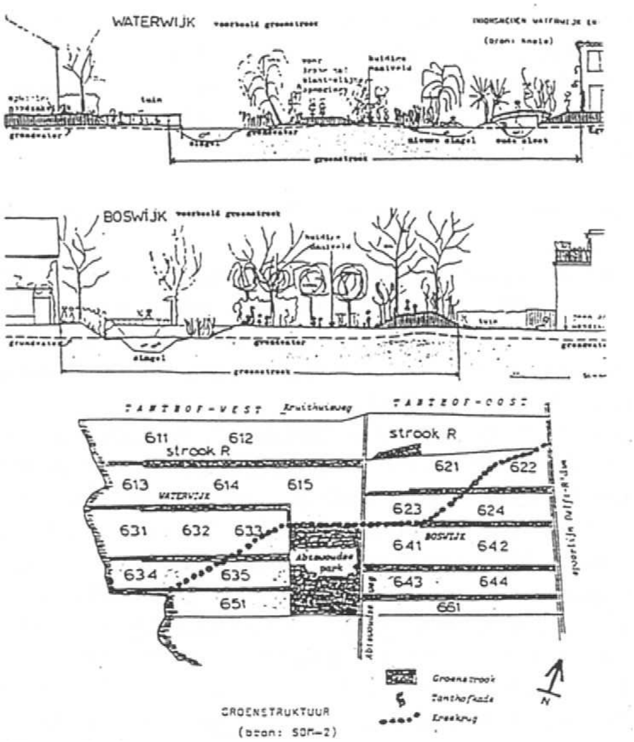

Fig. 667 Tanthof, Delft[a]

In the heart of the district, a park was designed around several old farms, also built on the spurs of creek ridges. A narrow space was left for this park during raising; it forms the transition with the open pasturage of Midden-Delfland.
In this respect, the chief layout is in sharp contrast to the districts of Voorhof and Buitenhof, where the landscape plays no part, and where more 'universal' traits prevail. Unfortunately, the diagonal green zone has been kept extremely narrow, and made ‘spatially subordinate’ at road junctions. The orientation problems of this district are therefore not the result of the design being excessively tailored to the landscape, but rather stem from the fact that the landscape has been given too subordinate a role to play.

Flooding and drainage

Seepage of water underneath houses and boggy gardens are common occurrences in many parts of the Netherlands. This phenomenon is known as flooding, and can be minimised by installing sewers in

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[a]

built-up areas, which discharge water from streets and concreted areas. Unhardened ground will nevertheless continue storing water during groundwater table rises.

What measures can be taken to prevent, eradicate or reduce the risk of flooding?
Sand grounds can be left out of the equation, as dewatering of easily permeable ground is fairly straightforward. Clay and peat grounds pose the biggest dewatering problems, as they do not allow for easy water discharge due to adhesion, retaining the water in narrow pores and corridors.

Existing drainage systems

Prior to being prepared for development, the grounds acted as farmland or as pasturage. To prevent excessive rise of the ground-water table during wet periods, clay and peat areas are equipped with a drainage system in the form of cut trenches and/or drains. In order to maintain the predetermined polder level (water level), excess water is discharged via ditches through a pumping station or drainage sluices.

Paved and ‘unhardened’ urban areas

When preparing a site for development, drainage series are disrupted and ditches filled up, as they do not "suit" the urban development plan, thus given the urban developer sufficient freedom for his design. In a modern townscape, most of the precipitation will eventually be discharged via the sewer system, as urban areas primarily consist of hardened surfaces, so that water can only be discharged artificially. Conversely, the ‘unhardened’ urban areas, the gardens and parks, must have and maintain their storage capability to prevent the risk of flooding.

The rise of the ground-water level can be partially absorbed by underground storage of water (in the crawl spaces of houses) and in sand bodies. This is however not an ideal situation, as water in underground crawl spaces can give rise to unpleasant smells, rising damp, and affect beams, floor heating pipes and cables. Water in sand bodies underneath roads can cause subsidence, affect the load bearing capacity and encourage frost heave.
In most cases, flooding can only be tackled with the aid of a new drainage system, as the "old" system is in many cases unusable for preparing a site for development.

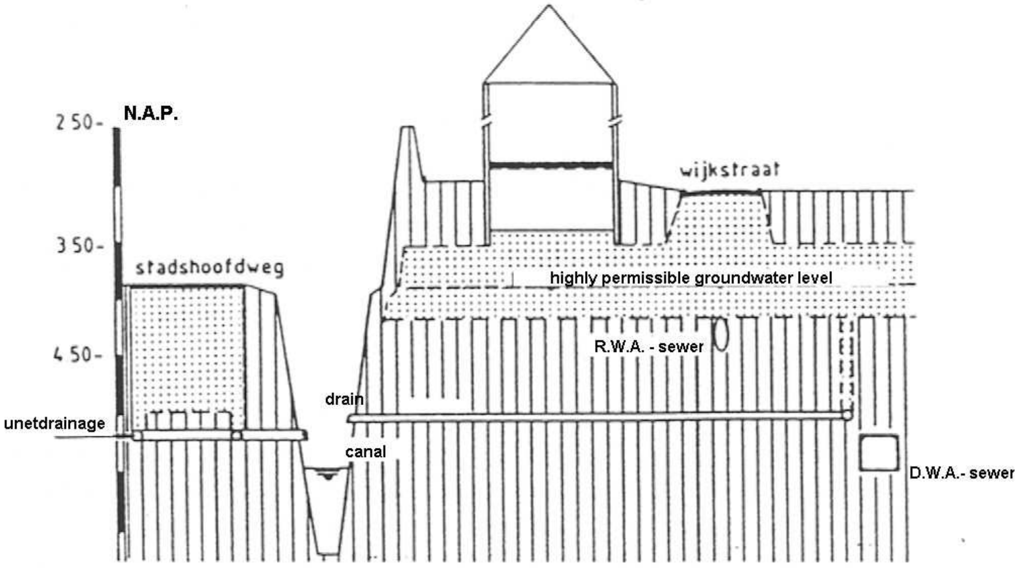

Fig. 668 Water control in urban areas

4.3.5 Urban functions

Urban development and/or destination aspects apply completely different criteria to the ground. Buildings and infrastructure requirements are virtually identical, while planting criteria are far less stringent and highly dependent on use. The designer's standpoint also plays an important role in this respect: vegetation and use adapted to the soil, or vegetation tailored to use.

Criteria applied by all destinations.

Per destination and implementation technique, various 'ground criteria' apply, including:

- load bearing capacity: ability of the ground to support buildings, roads and sewers (static load);
- passableness: load bearing capacity of the ground for carrying people (and machines) and dynamic load;
- relief: altitude variations of the ground;
- dewatering level: the difference between the ditch level and the surface level to be dewatered;
- dewatering: water discharge from the ground to the ditches;
- water retainability: ability of the ground to retain water without groundwater support (i.e. without capillary connection to the groundwater);
- infiltration ability: the amount of water that can penetrate the ground per unit of time;
- closed water storage: additional amount of water that the ground is capable of absorbing in addition to the amount already present (depending on pore space, humidity level and ground-water table);
- open water storage: the amount of water that ditches are capable of absorbing at a certain water level (depending on open water surface area and the water level of the ditch); and
- drainage: discharge of excess water from the ditches to the discharge point.

With regard to drainage:

- for building: foundation frost-proof (frost line 0.6 m below surface level), installing foundation 'in the dry', house service connection of pipes 'in the dry', no water in crawl spaces (if required) – ground water at least 0.2 m below the crawl space floor and groundwater below the foundation installation level due to the risk of cracking to buildings caused by reduced load bearing capacity with increased water levels;
  based on these criteria: ground-water table at least 0.8 m below surface level;
- for roads, parking areas and paths: top of the capillary water below the frost line due to frost heave and thaw during hardening; the substrate must always maintain as constant a bearing capacity as possible;
  based on these criteria: ground-water table 0.7-1.0 m below asphalt;
- for paths: good drainage, resistant to wind and water erosion;
- for pipes (water, gas, sewers): install house service connections 'in the dry'; water pipes and sewers must be frost-resistant; separate sewerage system: hydraulic slope to open water (R.W.D. = rainwater discharge); mixed sewerage system: discharge to emergency spillways; groundwater main sewers may be below the frost line;
  based on these criteria: ground-water table 1.0 m below surface level;
- for electric wires: minimum cover layer 50 cm, situated above groundwater;
- for parks: minimal fluctuating ground-water table, good water retainability of the ground, no hard, impermeable layer prohibiting root growth, favourable global ground-water table, 1 m for trees; this may be less for plants:

pH groundwater:	broadleaf	5
	coniferous	4.5

  N.B. other drainage requirements apply to botanical gardens: keep the situation as natural as possible);
- for sports fields: ground-water table in winter a maximum of 50 cm below surface level due to passableness following rainfall;
- for playing fields and camp sites: quick-drying after rainfall; excessively low water levels affect grass growth in summer

With regard to open water, size and position is determined by:

- civil criteria in relation to dewatering, storage, emergency spillways and overflows
- urban design criteria; ditch levels lower than permissible maximum ground-water table.

With regard to bearing capacity:

- for buildings: Pleistocene sand layer must be sufficiently strong for building foundations (impermeable layers may be perforated when hitting in poles; this may result in effluent seepage); high-rise buildings will almost always have to be founded with piles on Pleistocene substrate; for low-rise buildings, pending sufficient bearing capacity of sand and clay ridges in peat and overflow embankments in clay areas, shallow foundation of these layers is also allowed;
- for roads: dig out sand or earth body above surface level or cunet and fill up with sand; sand body on solid foundation or to spread the load, use sand and clay ridges in the landscape if possible;
- for parks and landscaping: bearing capacity less relevant than drainage criteria.

Buildings

As a general rule, buildings apply the following suitability criteria to the ground:

- With regard to drainage:
  - for building: foundation frost-proof (frost line 0.6 m below surface level), installing foundation 'in the dry', house service connection of pipes 'in the dry', no water in crawl spaces (if required) – ground water at least 0.2 m below the crawl space floor and groundwater below the foundation installation level due to the risk of cracking to buildings caused by reduced load bearing capacity with increased water levels;

    based on these criteria: ground-water table at least 0.8 m below surface level;
- With regard to open water, size and position is determined by:
  - civil criteria in relation to dewatering, storage, emergency spillways and overflows
  - urban design criteria; ditch levels lower than permissible maximum ground-water table.
- With regard to bearing capacity;
  - for buildings: Pleistocene sand layer must be sufficiently strong for building foundations (impermeable layers may be perforated when hitting in poles; this may result in effluent seepage); high-rise buildings will almost always have to be founded with piles on Pleistocene substrate;

    for low-rise buildings, pending sufficient bearing capacity of sand and clay ridges in peat and overflow embankments in clay areas, shallow foundation of these layers is also allowed.

Infrastructure

As a general rule, infrastructures and pipes apply the following suitability criteria to the ground:

With regard to drainage

- for roads, parking areas and paths: top of the capillary water below the frost line due to frost heave and thaw during hardening; the subgrade must always maintain as constant a bearing capacity as possible;
- based on these criteria: ground-water table 0.7-1.0 m below asphalt;
- for paths: good drainage, resistant to wind and water erosion;
- for pipes (water, gas, sewers): install house service connections 'in the dry'; water pipes and sewers must be frost-resistant; separate sewerage system: hydraulic slope to open water (R.W.D. = rainwater discharge); mixed sewerage system: discharge to emergency spillways; groundwater main sewers may be below the frost line;
- based on these criteria: ground-water table 1.0 m below surface level;
- for electric wires: minimum cover layer 50 cm, situated above groundwater;

With regard to open water, size and position is determined by:

- civil criteria in relation to dewatering, storage, emergency spillways and overflows
- urban design criteria; ditch levels lower than permissible maximum ground-water table.

With regard to bearing capacity:

- for roads: dig out sand or earth body above surface level or cunet and fill up with sand; sand body on solid foundation or to spread the load, use sand and clay ridges in the landscape if possible;

Vegetation

As a general rule, vegetation applies the following suitability criteria to the ground:

With regard to drainage

- for parks: minimal fluctuating ground-water table, good water retainability of the ground, no hard, impermeable layer prohibiting root growth, favourable global ground-water table, 1 m for trees; this may be less for plants;

pH groundwater:	broadleaf	5
	coniferous	4.5

  N.B. other drainage requirements apply to botanical gardens: keep the situation as natural as possible);
- for sports fields: ground-water table in winter a maximum of 50 cm below surface level due to passableness following rainfall;
- for playing fields and camp sites: quick-drying after rainfall; excessively low water levels affect grass growth in summer

With regard to open water, size and position is determined by:

- civil criteria in relation to dewatering, storage, emergency spillways and overflows
- design criteria for different vegetation functions such as parks, sports fields etc; ditch levels lower than the maximum permissible ground-water table.

With regard to bearing capacity

- for parks and landscaping: bearing capacity less relevant than drainage criteria.
- passableness or access criteria apply to sports fields.

Industry

Industry criteria governing the ground will generally correspond with criteria applied to buildings in general, and infrastructure. Additional criteria must always be specified.

4.4 Applications for designers

architects

4.4.1 Ground and design P.M.

Different levels of intervention

Ground at the level of element:

materialisation of form

Ground at the level of structure;

organising land use

Ground at the level of process; a strategy

for landscape development

4.4.2 Site analysis P.M.

The form and dynamics of the land

4.4.3 Working with slopes P.M.

4.4.4 Historical examples of design

We have chosen some prototypical plans from history where the working with landform and ground is integrated into the plan and design of the ensemble. We have selected four plans; the Villa d'Este at Tivoli, close to Rome; the Parc de Sceaux at Paris; the Hawkstone Hall and gardens close to Weston-under-Redcastle in the UK; the Parc des Buttes Chaumont in Paris. All four have a different relation with the geological conditions of the site and are from different time periods. All are examples where designers have made use of the geological conditions and have integrated this into their plans. All are public space and can be visited.

Villa d'Este in Tivoli, near Rome

The Villa d'Este was built on a steep slope in Tivoli, a small town south of Rome. It was designed in the 16th century and is an example of a renaissance garden.

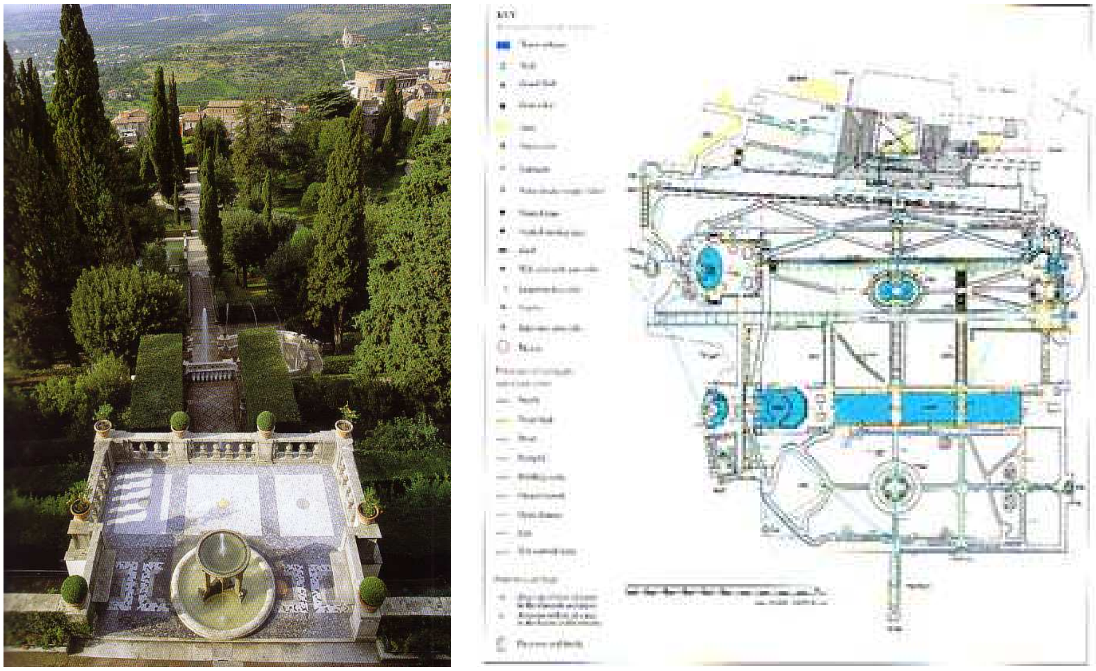

Fig. 669 Villa d'Este in Tivoli[a]

The garden consists of two parts; the very steep slope with the terraces just next to the house and the more .at part further away from the house. House, garden, water, sculpture and site are beautifully integrated into the plan forming a splendid unity that expresses the capacity of using site characteristics

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[a] *Barsi, 2004*

Parc de Sceaux in Paris

Sceaux is a relatively small ensemble compared to the other plans of Le Nôtre.

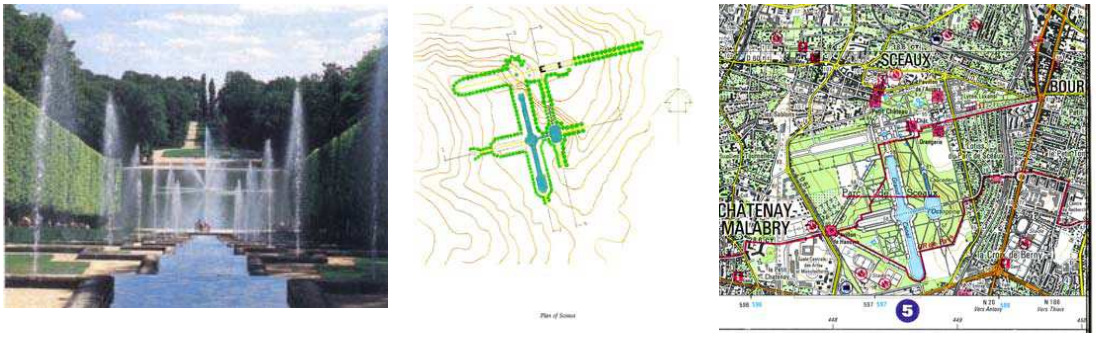

Fig. 670 Parc de Sceaux in Paris[a]

The composition is based on different axial systems. First the main axis that includes the castle. Secondly there are two axes based on water; the grand canal and the cascade both perpendicular to the main axis. Both are perfectly .fitted into the site; they are located in naturally lower areas in the terrain. Le Nôtre made clever use of the site conditions and integrated them into an intriguing composition. The structure gives the composition an effect of surprise; you don't expect the water because you don't see it from the building.

Hawkstone, Shropshire, UK

The plan is a series of interconnected itineraries; it does not have a dedicated groundplan.

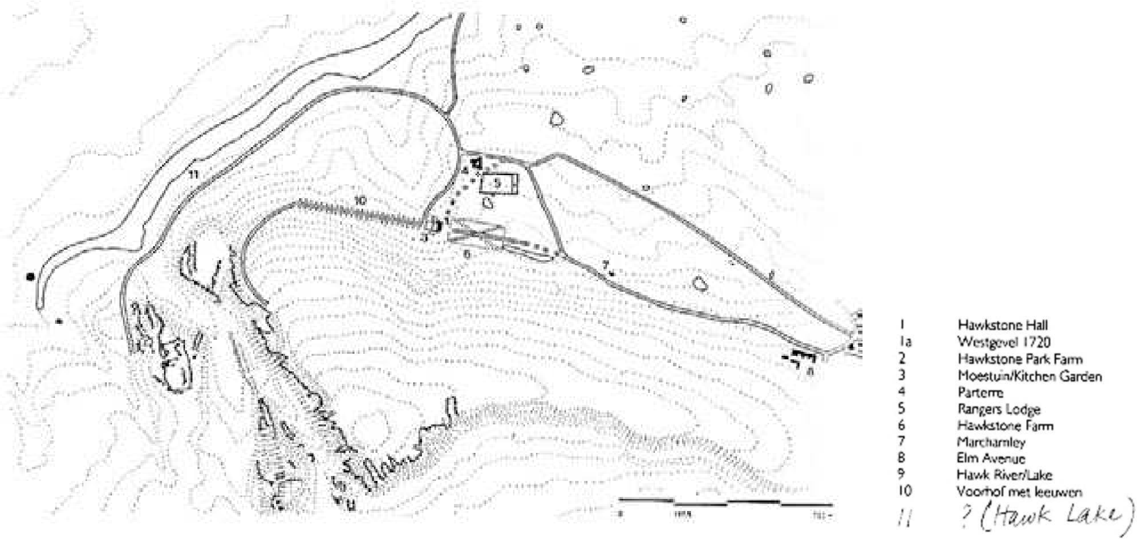

Fig. 671 Hawkstone, Shropshire, UK[b]

It makes a clever use of the exceptional geological conditions of the site; its location on the edge of the plains of Shropshire and the steep side close to the house. The garden is not enclosed but open to the views of the plains and is composed of different walks that make use of the contrast between the steep rock and the open plains.

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[a] *Hazlehurst, 1990; Rostaing, 2001*
[b] *Reh, 1996*

Parc des Buttes Chaumont in Paris

A park in the northeastern part of Paris, not far from Parc de la Villette. It was designed in the 19th century by Haussmann at a former quarry.

Fig. 672

Fig. 673

'Chaumont' refers to chalk. It still contains rocks, the highest being used as viewpoint. It is an early example of 'reuse' of industrial sites, in this case a quarry for chalk. The park gives a special experience because of its urban context; urban nature referring to geological features of the site with a grotto and a waterfall.

5 Life, ecology and nature

Contents

5.1 Natural History

Biodiversity

There are about 1.7 million known species and new species are being discovered every day.[206] It is estimated that one successful new form is created each year, while, under the present conditions, approx. 500 species per year become extinct. Some biologists estimate the real number of existing species as being 10 million, others as many as 80 million, Zoest (1998) reports. Distinguishing species from subspecies (taxonomy) is a constant on-going task. For example, the authoritative Dutch work: *Heukels' Flora* edited by Meijden (1996) has recently been drastically amended to accommodate the new international insights into the organisation, differentiation and nomenclature of the plant kingdom. Viewed from this angle, we live on an unknown planet with a rapidly diminishing biodiversity. Nevertheless, the existing species represent an enormous genetic richness, of which we are hardly aware.

A risk cover for life

Within any one species there are as many variations as there are specimens, and just to make the problems of ecological generalisation even greater, all these specimens live in different contexts and micro environments. To question the meaning of this enormous diversity at the species, genetical and habitat level is typically human, but it is not an ecological question in the scientific sense. All we can do as Pianka (1994) does, is to observe that this biodiversity has arisen due to evolution and that, in the past, when sudden environmental changes took place, it was this that ensured the continuation of life up to the present time. Life has survived all manner of catastrophes because there was always a species, or a specimen of a species, that could survive in the new environment. The extinction of the dinosaurs about 65 million years ago in the darkness, of a kind of nuclear winter, following a meteoric collision with Earth, gave an advantage to night animals, and among them, mammals like ourselves. Biodiversity acts, therefore, as the the risk coverage of life itself suggests Londo (1998).[207]

Plants first

Plant life, which transforms carbon dioxide into food and oxygen for the animal kingdom, is the foundation of this diversity.This forms the basis of the local food chain, down to the smallest scale on the surface of the Earth. Thus, in urban ecology, if one does want to begin with the basement and not the ridge tiles, when reconstructing our *oikos*[a] although for many this is the most interesting (caressible) part of the housekeeping, attention should first be given to botanical diversity.

Dutch plants

Approximately 1,500 of the 250,000 known plant species, worldwide, 3,500 of the 100,000 toadstools and 500 of the 23,000 mosses are found in the Netherlands, in the wild. The science of dividing plants into classes, orders, families and species is known as taxonomy.[208] Taxonomy is based on kinships that can be deduced from evolution. Against that background, plants can be given a name.
Heukels' Flora provides the scientific access to approximately 1,500 Dutch plant species.

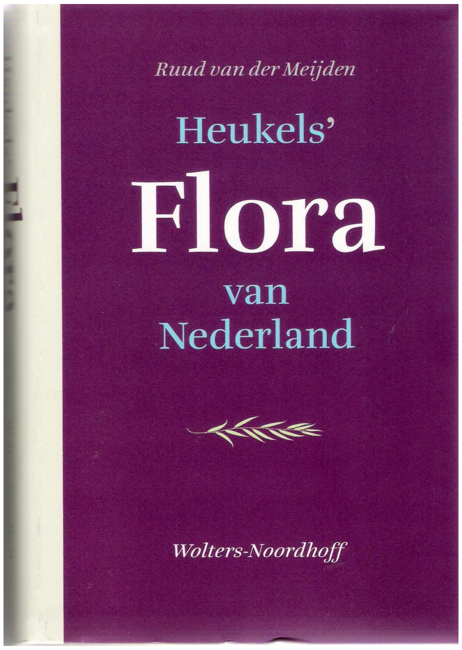

Fig. 674 *Heukels' flora*[b]

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[a] *Oikos* is Greek for 'house'.
[b] Meijden (2005)

Insects are the largest group

To find one's way in this flora, some insight is needed into the genesis of life (see para. 5.1.6). Insects often cooperate closely in the reproduction of higher plants, and of the 1,100,000 known species of insect, approximately 20,000 can be found in the Netherlands. Compared to those, the other groups of creatures are almost negligible: approx. 500 of the 50,000 known vertebrates (30 reptiles, 300 species of birds, 100 mammals).[209]

Counting species or genetic complexity?

The question that comes to the fore here is whether one can compare one-celled life forms with multiple-celled forms that undergo cell differentiation. Although they live independently, their diversity among themselves can be likened to the internal cell diversity of multiple-celled forms. Should we use the number of species as the criterion for biodiversity? The disappointing discovery that human beings do not have very many more genes than species that, so far, have been considered to be much simpler, leads to a similar question, even though it indicates exactly the opposite. As far as the criterion for choosing the number of species is concerned, for the time being, we adhere here to the present mid-way scientific position.

5.1.1 Long-term biotic changes

This history is excellently documented on the bottom floor of the Naturalis Museum.[a] This museum was designed by Fons Verheijen. The design process is described in ‘Ways to study and research’, Jong and Voordt (2002) and is thus worth a visit.

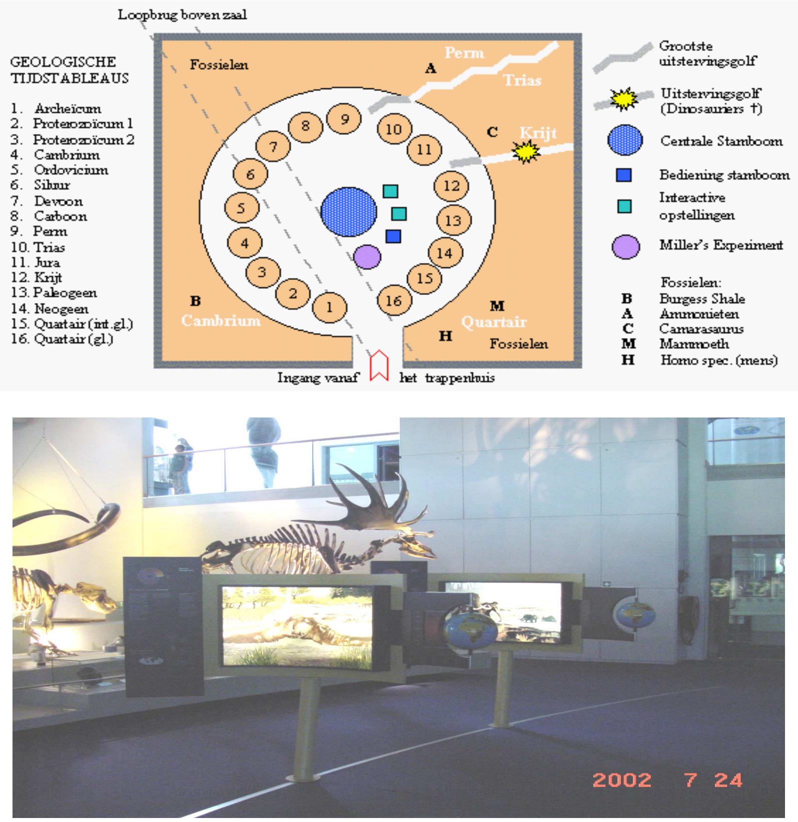

Fig. 675 *Eras at Naturalis*

The oldest forms of life

The oldest forms of life are single-celled marine organisms that later formed themselves into threads of algae. They have produced oxygen from carbon dioxide for more than a billion years.[210] This form of life stagnated when carbon dioxide gases became depleted after the excessive growth that took place during the Carboniferous and Permian eras and carbon ceased to oxidate spontaneously. Fauna took over part of this oxidation process. Carbon dioxide fertilization is still a constant feature of horticulture to cause profuse growth.The increasing amount of CO_2 in the atmosphere, not only leads to a greenhouse-effect, but also to more profuse growth and increased agricultural production. Ecologically, from the point of view of biodiversity, this is not an advantage.

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[a] See *http://website.leidenuniv.nl/~siebersam/*

Revolutions during the last billion years

During the last billion years there have been four important revolutions:[211]

600 million years ago:	Fauna began to adopt chalky skeletons, so that suddenly their historical development can be read in the sediments.
400 million years ago:	Life established a foothold beyond the sea. Mosses and liverworts (*Bryophyta*) brought a green colour to the wet parts of the land (5.1.2).
230 million years ago:	Many animal and plant species suddenly became extinct, marking the end of the Palaeozoic. This made way for the Mesozoic, the Saurian Age. Seed-bearing plants started to develop, which had a completely diploid life cycle. These plants fertilised each other and dispersed diploid seeds (5.1.3).
65 million years ago:	The Cenozoic began with the extinction of the saurians and the advance of mammals (5.1.4).

5.1.2 400 000 000 years ago

Life gained a foothold beyond the sea. Where the land was wet, it became green with mosses and liverworts (*Bryophyta*).These plants can not establish themselves on drier areas because their structures are not sufficiently developed to take in water and store it to use during drought; they have no roots. In addition, they are dependent for reproduction on male gametes that swim.
Early in their development, mosses did not halve their genetic material by means of sex cells, but sometimes duplicated themselves on a part of the female plant. Only then was the duplicated (diploid) genetic material divided and dispersed as single spores that germinated as haploid organisms with a single set of genetic material. Mosses are predominantly haploid. They are not included in *Heukels' Flora.*

The earliest vascular plants

The next step was the appearance of the first staghorn and club-mosses, the horsetails and the ferns (*Pteridophyta*, the first 15 families in *Heukels' Flora*). These were the earliest vascular plants, capable of transporting water internally. They can thus grow higher than the mosses. However, although fully grown ferns can withstand dry conditions because of their vascular system, they still need water to reproduce sexually.[212] This is why the existing *Pteridophyta* are usually to be found in moist, shadowy places and/or why they often reproduce themselves vegetatively.

Flat-stemmed Club-moss | *Giant Horsetail* | *Male-fern*

Meijden (1999)

Fig. 676 *Pteridophyta*[a]

Although small haploid forms do exist, the predominant forms on which all higher plants are modelled are diploid.

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[a] *Meijden (1999)*

5.1.3 230 000 000 years ago

A family tree

Many plant and animal species suddenly became extinct, marking the end of the Palaeozoic. They gave way to the Saurian Age, the Mesozoic. Seed plants began to develop, with a completely diploid life cycle. They fertilised each other and dispersed diploid seeds.
The following appeared, successively:
gymnosperms (families 16-18 in *Heukels' Flora 1996*: the conifers),
angiosperms (families 19-119 in *Heukels' Flora 1996:* most of the flowering plants)
monocotyledons (families 120 to 140, to which lilies and grasses belong)

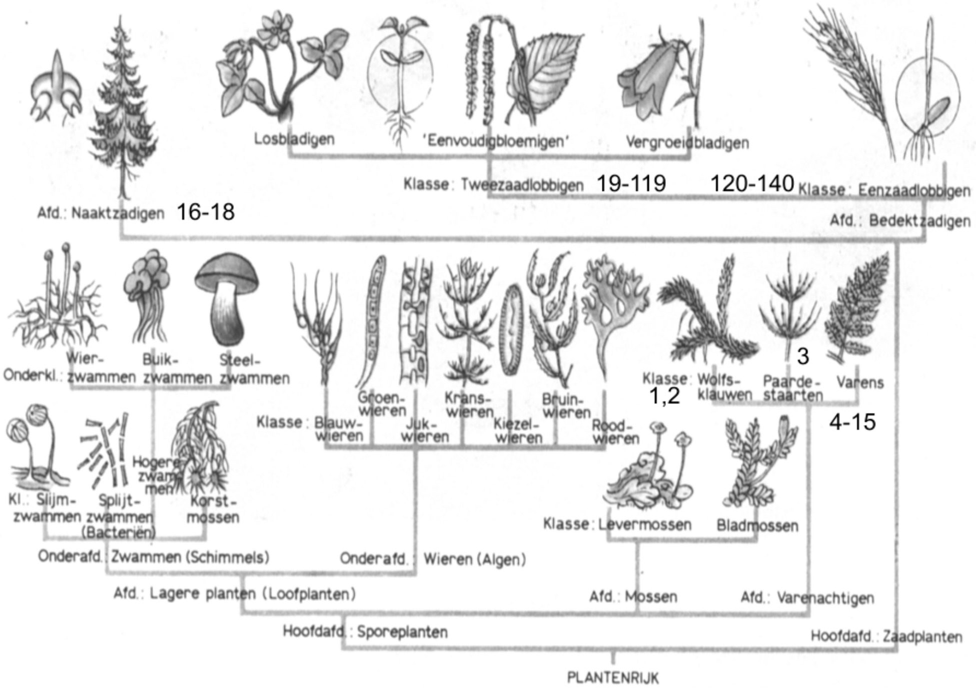

Fig. 677 *Division of the Plant Kingdom*[a]

This scheme gives a didactically simpler division into subclasses than the currently accepted scientific one shown in *Heukels' Flora 1996*. In the mean time DNA-research changed the supposed tree of life again, so the arrangement and name giving of the Heukels' Flora 2005 has changed again substantially.

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[a] Garms (1977) page 2

CD-ROMs

This species specificy is thus focused on the recognisability of these reproductive organs. Species are primarily identified on the basis of these organs. This process is currently simplified by using interactive CD-ROMs (Fig. 678 and Fig. 679).
Knowledge of species gives insight into the constitution of the soils, climatic conditions and growth possibilities. It is probably an important basis to give urban architects a feeling of the *genius loci*.

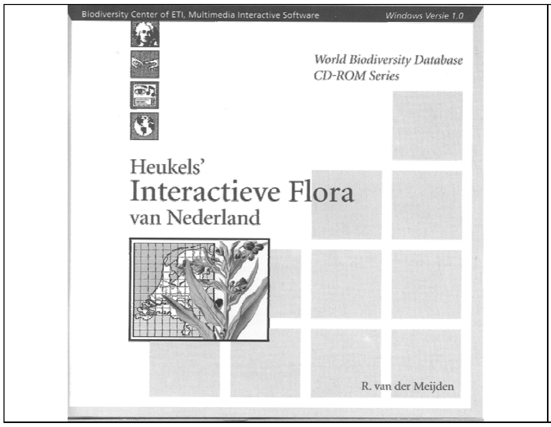

Fig. 678 *An interactive CD-ROM of Heukels' Flora*[a]

Fig. 679 *CD-ROM Marijnissen*[b]

These CD-ROMs give a good picture of different ecological approaches in the Netherlands. The Nijmegen approach (Marijnissen) is less orthodox taxonomically and more accessible for lay people. Another electronic source is CBSs Biobase (see Fig. 807), elaborated on *http://team.bk.tudelft.nl* > Publications 2007 > Life.xls (see 5.1.6).

Taxonomy of plants

According to recent evolutionary insights, plant taxonomy is built up as follows:

Class -da	***Subclass -dae***	Super order *-florae*	Order *-ales*	Family *-ceae*	Genus *-ida*, *ids*

Fig. 680 *The taxonomy of Dutch plant families*

According to accepted interpretations of evolution, the lowest subclass, the *liliidae* (monocotyledons, such as lilies, grasses and orchids), were the most recent to come into existence. However, taxonomy is not a static science; there is still no agreement on the sequence of evolution and subdivision. The families in *Heukels' Flora* of 1990 were still not classified according to the present international standard. In 1996 and 2005 drastic changes were made to the classification system and thereby to the nomenclature, much to the sadness of many.

5.1.4 65 000 000 years ago

The great extinction

The Cenozoic began with the extinction of the saurians and the advance of the mammals. A meteoric impact in the region of the Caribbean caused so much dust to enter the atmosphere that, in the prolonged darkness that followed, plant growth stagnated and the large plant-eaters died out. It was mainly night animals, mammals, for example, that survived.

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[a] Meijden (1999)
[b] Marijnissen and Mol (1998)

5.1.5 Pleistocene

The last 2 million years (the Quaternary or Pleistocene) has been occupied by ice ages (glacials) and warmer interglacials (see page 51).[213] The two most recent glacial periods, the Saalian (Fig. 681) and the Weichselian (Fig. 682), were interrupted by the Eemian interglacial period.[214]

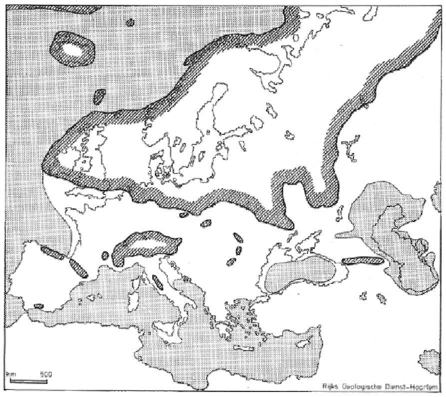


Fig. 681 *Saalian*

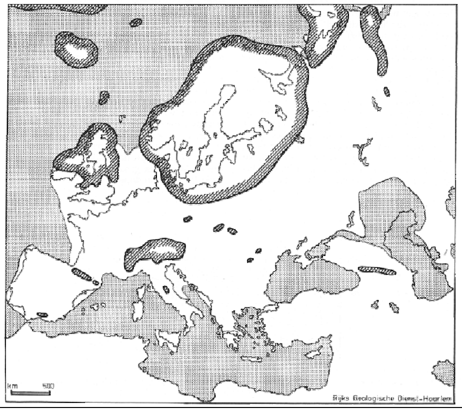


Fig. 682 *Weichselian*

Ice ages in The Netherlands

The higher parts of the Netherlands were formed in particular during the Saalian.[215] The Weichselian did not reach the Dutch area.

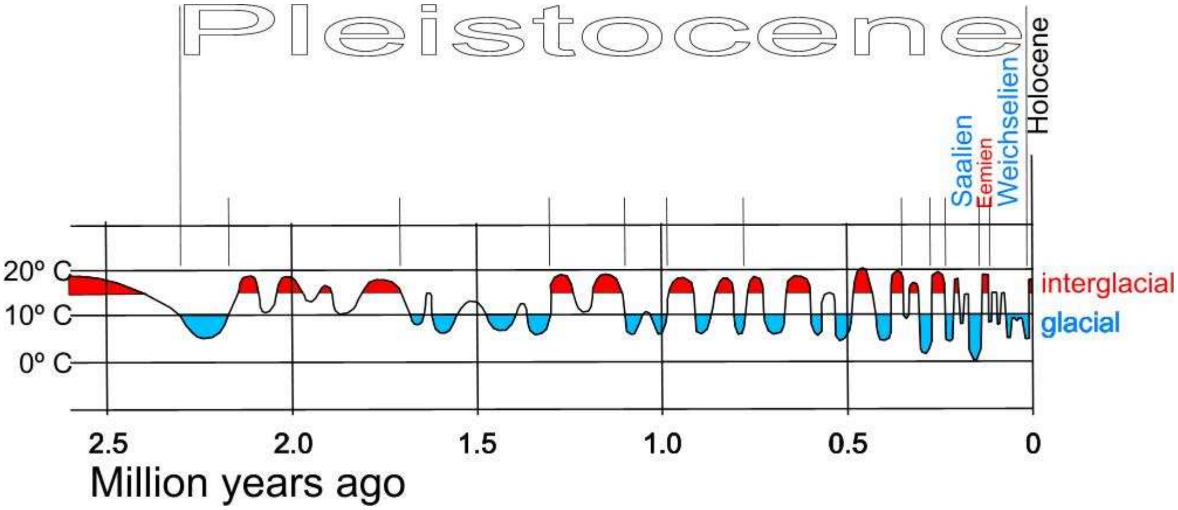
200,000 BC	150,000 BC	70,000 BC	15,000 BC
			
Saalian	Eemian interglacial		Weichselian

Fig. 683 *The two most recent ice ages*

The forming of the Veluwe massif and the *Gelderse Poort* are clearly visible.

Holocene

The lower areas of the Netherlands were shaped from 10,000 BC onwards (Fig. 684).



See *Fig. 73* [a]

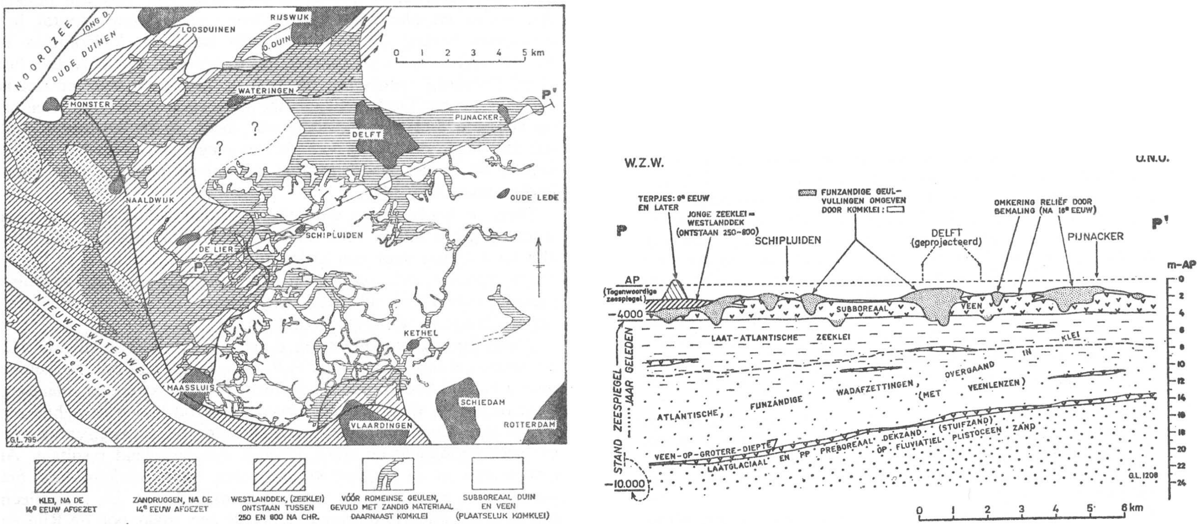


Fig. 684 *Temperature changes and deposits*[b]

For instance, deposits under Delft to a depth of 18 metres beneath New Amsterdam Level (NAP) is Holocene[216]; the Pleistocene extends to a depth of 400 metres[217]

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[a] Sticht.Wetensch.Atlas_v.Nederland (1985) page 13

[b] Faber (1966)

Vegetation changes by temperature

Fig. 685 shows how climatic changes greatly influence the vegetation.

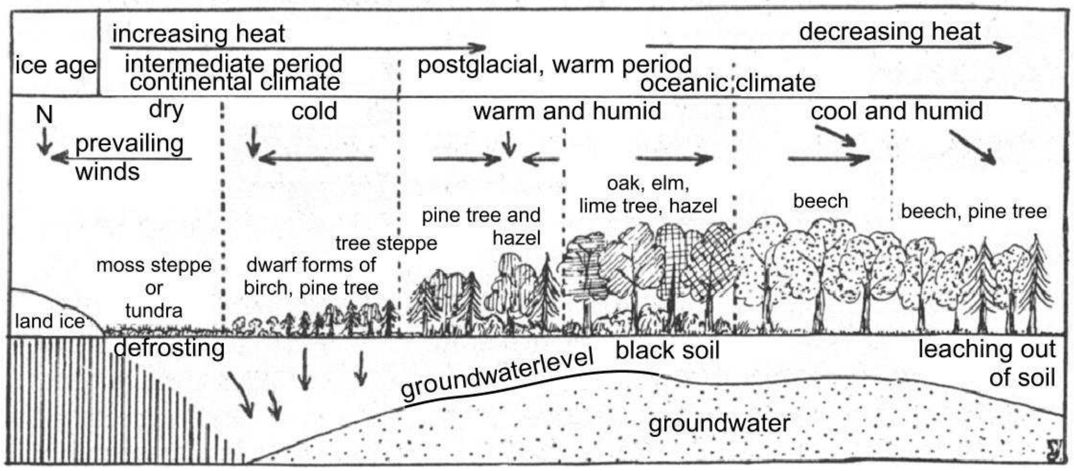

Fig. 685 *The influence of climatic changes on vegetation*[a]

The picture that emerges from pollen dating is one of changing landscapes and habitation (Fig. 686).

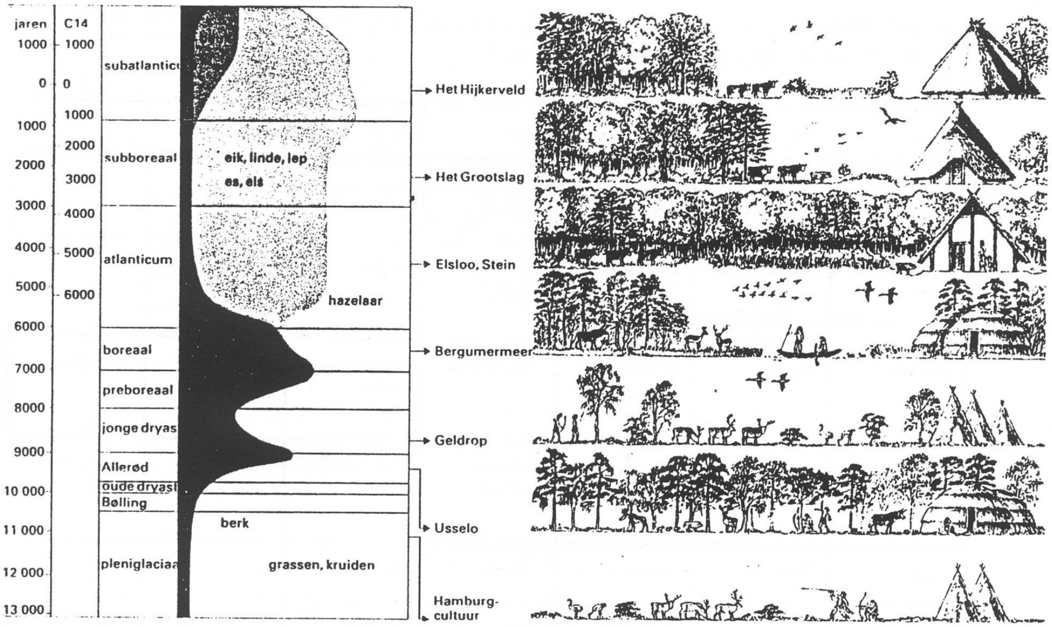

Fig. 686 *Landscape changes since the last ice age*[b]

Paragraph 1.3.1 from page 51 on gives a closer picture of this.

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[a] Visscher (1949)

[b] Bloemers, Kooijmans et al. (1981) page 32

5.1.6 Identifying plants species

Naming

Identifying plants informing you about a biological genius loci (history, soil, water level) of the location and its rarity is a difficult job for laymen. However, on *http://team.bk.tudelft.nl* > Publications 2007 > Life.xls you will find an extract from Duuren (1997) CBS Biobase containing all wild plants of The Netherlands with many characteristics. You can sort this Excel sheet on any characteristic. Fig. 687 shows the first four columns. The sheet is currently sorted on occurrence of urban wild species in the urban area of Zoetermeer. Wild parsnip occurs in nearly any km^2 of the town.

Species number	Scientific name	English name	Dutch name
000922	Pastinaca sativa	Wild Parsnip	Gewone pastinaak
000101	Artemisia vulgaris	Mugwort	Bijvoet
000135	Bellis perennis	Daisy	Madeliefje
000188	Calystegia sepium	Hedge Bindweed	Haagwinde

Fig. 687 *First columns of Biobase extract on Excel sheet*

Primary identification criteria

By next 17 (yellow or grey headed) columns (Fig. 688) you can make your own rough selection to identify plant species quickly. Suppose you find a herb (Growth form = kr) without prickles growing up to your middle flowering in august. Wild parsnip (000922) will appear somewhere in your selection.

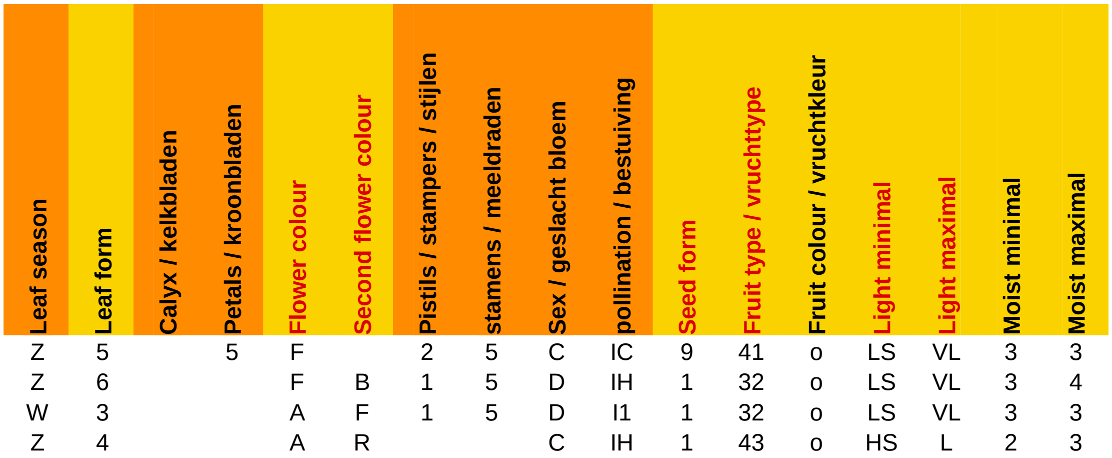
Species number	Growth form	Prickles	Until knee (<50cm, low)	Up to middle (<100 cm)	Above middle (>1m, high)	January	February	March	April	May	June	July	August	September	October	November	December
000922	kr			1								1	1	1			
000101	kr			1	1							1	1	1			
000135	kr		1						1	1	1	1	1	1			
000188	lk				1						1	1	1	1	1	1	1

Fig. 688 *First identifying characteristics of Biobase extract on Excel sheet with rows of* Fig. 687

If you like to identify a tree you should choose 'bo' as growth form. You also can choose grass like (gr); bush or shrub (st); dwarf shrub (dw); woody liana (lh); herby liana (lk) and epiphyte, which is a plant growing on other plants (ep).

Secondary identification criteria

If your selection is still too large you can select further on leaf form and flower colour (Fig. 689).



Leaf season	Leaf form	Calyx / kelkbladen	Petals / kroonbladen	Flower colour	Second flower colour	Pistils / stampers / stijlen	stamens / meeldraden	Sex / geslacht bloem	pollination / bestuiving	Seed form	Fruit type / vruchttype	Fruit colour / vruchtkleur	Light minimal	Light maximal	Moist minimal	Moist maximal
Z	5		5	F		2	5	C	IC	9	41	o	LS	VL	3	3
Z	6			F	B	1	5	D	IH	1	32	o	LS	VL	3	4
W	3			A	F	1	5	D	I1	1	32	o	LS	VL	3	3
Z	4			A	R			C	IH	1	43	o	HS	L	2	3

Fig. 689 Second identifying characteristics *of Biobase extract on Excel sheet with rows of* Fig. 687

Some plants keep their leaves in winter (W), most have leaves in summer only (Z). You can not rely fully on leaf form or flower colour because one plant may have different leaf forms or colours simultaneously. If you doubt you can select two characteristics simultaneously chosing 'or'. Fig. 690 shows used codes for leaf form with proportion of length (L) and width (W), colour, required light and moist.

leaf form	colour	sex	light	moist
1 line L>10W 2 lancet 3W<L<10W 3 elongated 2W<L<3W 4 (nearly) round B<L<2B 5 hand (compound or not) 6 feather 7 compound feather	A = white B = brown C = blue F = yellow G = grey H = colourless M = multicoloured N = back O = without flower P = purple, violet, lila R = red, rose U = orange V = green	A = monoecious B = dioecious C = hermaphrodite D = polygamous E = spore plant	VL = full sun L = light LS = light shadow HS = half shadow S = shadow VS = full shadow	1 = aquatic 2 = wet 3 = moist 4 = dry

Fig. 690 *Codes used in second identifying characteristics from Fig. 689*

The orange or dark grey heads of columns in Fig. 689 are not very useful for identification, they give characteristics to check your selection.

Environmental information derived from plant species

After identifying plant species next 16 columns give interesting information about the environment (Fig. 691). The last row of Fig. 691 shows community type according to Westhoff and Den Held from Fig. 724. The ecotope columns show the code from Fig. 726 *Ecological groups*. Inbetween these columns their classes of tolerance discussed in paragraph 5.2.9 are shown.
The last columns show additional characteristics summed up in Fig. 693.

Food minimal	**Food maximal**	**Acidity**	**Salt minimal**	**Salt maximal**	**Zinc**	**Groundwater**	**Root depth**	**Root depth 2**	**Flow maximum**	**Flow minimum**	**Ecotope 1**	**Ecotope 2**	**Ecotope 3**	**Ecotope tolerance**	**Community Westhoff**
2	3	x				7	3	4	9	9	G47	G48		1	25Ba01
3	3	x				7			9	9	P48	P68	R48	2	17Aa01
2	3	x				9	1	1	9	9	G47	G48		1	25Ba
2	3	x				5	4	4	9	9	R27	R28	R47	2	17B

Fig. 691 *Environmental information derived from plant species*

nutrients	acidity	salinity	dependency ground water	root depth	water flow
1 = poor 2 = moderate 3 = nutricous x = indifferent	1 = acid 2 = moderate 3 = alkaline x = indifferent	0 = fresh 1 = between 2 = brackish 3 = between 4 = salt	1 = hydrofyt 2 = wet freatofyt (obligatory) 3 = moisty freatofyt (obl.) 4 = moisty freatofyt (fac.) 5 = local freatofyt 6 = lime afreatofyt 7 = afreatofyt 8 = salt plant 9 = dune freatofyt	1 = < 10 cm 2 = < 20 cm 3 = < 50 cm 4 = < 100 cm 5 = > 100 cm	0 = unknown 1 = stagnant 2 = slow 3 = streaming 4 = fast 5 = very fast 9 = no sense

Fig. 692 *Codes used for environmental information in columns of Fig. 691*

Additional characteristics per plant species

Column head	**description**
Height belt / hoogtegordel	typical height belt of species
Areal position / areaalligging	position in European dispersion
Use 1 / gebruik 1	agricultural or herbal use
Germinating time / kiemtijd	month when growth starts
Life span / levensduur	1, 2, 3 or more years
Family Heukels' flora	page number in authoritative Dutch flora of Fig. 674 and Fig. 680
Genus Heukels' flora	subdivision of preceding family
Species / soort Heukels' flora	subdivision of preceding genus
UFK_1940	occurrence in The Netherlands in 1940 per 5x5km^2
UFK_1990	occurrence in The Netherlands in 1990 per 5x5km^2
Protection rode lijst	member of Dutch list of rare and declining plant species
Protection Natuurbeschermingswet	protected by Dutch law
Protection EHS doelsoort	target species in Dutch ecological policy (see paragraph 5.5.1)
Protection Bern Convention Protection	protected by European law
European blue list	member of European list of rare and declining plant species
Change in the Netherlands since 1950	Difference between UFK_1940 and UFK_1990
Abundance per 25km2 1980	Number of 5x5km^2 squares species was found in The Netherlands 1980
Abundance per km2 Zoetermeer	Number of 1x1km^2 squares species was found in the urban area of Zoetermeer 2000
Buytenwegh 2002 305723/24	found in the urban area of a 2x1km^2 district of Zoetermeer 2000

Fig. 693 *Additional characteristics per plant species*

For example Fig. 770 used columns Abundance per 25km2 1980 and Abundance per km2 Zoetermeer to compare national and local rarity in a graph.

5.2 Diversity, scale and dispersion

Biodiversity

There are many estimates on biodiversity described much better than I can do by Zoest (1998). We know some 1.7 million well-described species but much more are unknown while some 100 000 species are lost since Linnaeus. The extinction rate is estimated 1000 per year now; the growth in evolution as 1 successful species per year. Though we now know the genome of some, we still do not know how they work let alone we know their mutual relations. Even how our own species works is nearly completely unknown to us, though we already studied 3000 years on this topic. Having some success by medicine, we seldom understand exactly why. Compared with the combinatory explosion of unanswered questions we understand almost nothing, otherwise we could invent species. Possible principals punish researchers admitting that honestly and modestly. Mythmakers win the competition. However, myths may be useful for survival.

Responsability

Every state bears its own responsibility in this multitude of species like a modern Noah. Though The Netherlands occupies less than 0.01% of the earth's surface it entails approximately 35 000 (2%) of the earth's number of known species. Our responsibility is proportional to their global, continental (blue list), national (red list) or local rarity.

The concept of rarity and thus responsibility is scale-sensitive.

Health

Depending on the definition of health[a] I estimate that roughly 80% of the human population is not healthy. There are positive and negative relations between human health and biodiversity. The impact of biodiversity on human health is unknown. Perhaps a small organism in some square kilometres of the remaining rainforests on the long term appears to be a necessary condition for our life by producing tiny quantities of chemical compounds conditioning processes in our body and mind as catalysts. But we do not know. How to calculate the risk of loosing them?

The reverse impact of human health and growth on biodiversity is better known but not certain.

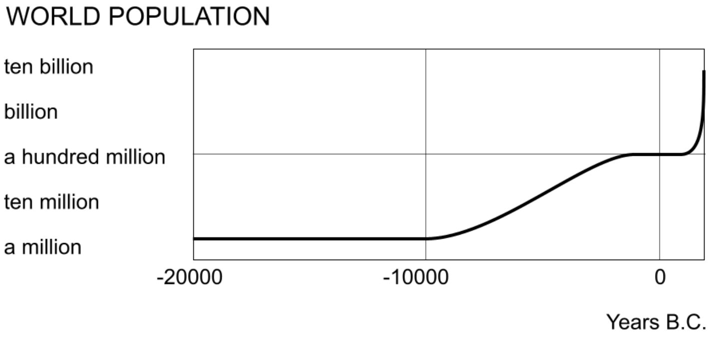


Fig. 694 *Estimated growth of world population*

Health is a scale dependent concept in time. Though world population is not healthy on an individual level, in the long term we are a healthy species growing in numbers exponentially ousting other species, living twice as long as some centuries ago.

And we are not only expanding in number. Per person we need more and more living space in our homes and neighbourhoods. In a wider context we reduced the space we need for agriculture reducing biodiversity in rural areas at the same time.

Intensity of use

However, some 20 years ago Jong (1985) found the *intensity* of urban use in The Netherlands was highest in shops (135 hours/m^2year). After shops came offices, social-cultural facilities, schools, home and garden (48 hours/m^2year).[218] The other hours of the year (counting 8760 hours) in the urban surface may be available for other species depending on the conditions we leave them by design and use (distinguished by time scale). Some species accept or even welcome our presence like that in

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[a] Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948. The Definition has not been amended since 1948. See *http://www.who.int/about/definition/en/*

step vegetation (for example greater plantain, rats, mosquito's, sparrows). Could we welcome more rare species in our towns by creating ecotope cities or as Tjallingii (1996) stresses ecological conditions? How does it interfere with our health?

5.2.1 The importance of diversity for life

Risk-cover for life

Londo (1997) considered diversity as a *risk-cover for life*. In the diversity of life there was always a species to survive or within a species a specimen that survived. Survival of the fittest presupposes diversity from which can be 'chosen' in changed circumstances. Diminishing biodiversity means undermining the resistance against catastrophes. From the 1.7 million species we know, we probably lost some 100 000. So, we not only introduce ecological disasters, but we also undermine the resistance of life against these disasters.

Ecological tolerance

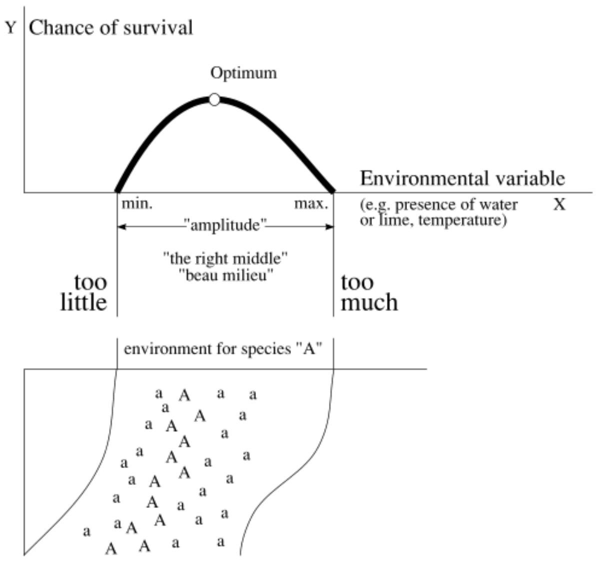

Fig. 695 *Ecological tolerance in theory and reality.*

The curve of *ecological tolerance*[219] relates the chance of survival of a species or ecosystem to any environmental variable, for instance the presence of water. In that special case survival runs between drying out and drowning (Fig. 695).

Imagine the bottom picture as a slope from high and dry to low and wet. Species A will survive best in its optimum. Therefore we see flourishing specimens on the optimum line of moisture (A). Higher or lower there are marginally growing specimens (a). The marginal specimens however are important for survival of the species as a whole.

Suppose for instance long-lasting showers: the lower, too wet standing marginal specimens die, the flourishing specimens become marginal, but the high and dry standing specimens start to flourish! Long-lasting dry weather results in the same in a reversed sense. Levelling the surface and water-supply for agricultural purposes in favour of one useful species means loss of other species and increased risk for the remaining.

But there is a less friendly ecological lesson hidden within this scheme. Marginal specimens are important for survival of the species as a whole. A reservoir of unhealthy specimens favours species. Death regulates life. Health is also spatially scale-sensitive.

5.2.2 The importance of diversity for human living

A realm of exceptions

Biodiversity in mankind is a crucial value in our quality of life. As we are here we are all different and the very last comfort you can give a depressed person is 'But you are unique'. Reading Philp (2001) you should conclude that medicine hardly discovered that uniqueness in the evaluation of medicines. It hinders generalizing science using concepts as average and standard deviation. Dieckmann, Law et al. (2000), Riemsdijk and NOBO (1999) and Jong and Voordt (2002) are aware of that difficulty in ecology, organization theory and design study. Evolutionary ecology (see Pianka, 1994) is only comprehensible considering exceptions outside the limits of a normal test population (3·standard deviation) as Philp (2001) described.

Diversity is also a precondition for trade and communication. If production and consumption would be the same everywhere, there would be no economic life. If we would have all the same perceptions and ideas, there would be no communication. It is an important misconception to believe that communication only helps *bridging* differences. Communication also *produces* diversity by compensating each other and coordinating behaviour by specialization. Diversity is a precondition of freedom of choice, a fundamental right of any human.

Possibilities of choice

The World committee environment and development (1990) of chairwoman Brundtland[220] summarized the environmental challenge by stating sustainability as leaving next generations at least as much possibilities as we found ourselves[a].[221] But what are possibilities? 'Possibilities' is not the same as economic supply. If our parents would have left us the same supplies as they found in their childhood, we would be far from satisfied. 'Possibilities' has to do with freedom of choice and thus variety. Our converging Schumpeter-economy as Krupp (1995) described and converging culture of Fukuyama (1992) leaves no choice. In our search for the alternative we find everywhere in the world the same hotels, the same dinners, the same language. This century, the last 'primitive' cultures are lost and with them an experience of life that no western language can express. After looking at their dancers in the afternoon on our rain forest holyday we find them back in the disco in the evening.

A world without difference

The most extreme consequence of this levelling out would be a world without economy and even communication. If there were no longer any differences in production factors, exchanging goods and services would no longer be necessary. If total worldwide distribution of knowledge and consensus would be the result of our communication age, there would no longer be anything worthwhile to communicate. These thought experiments show clearly that 'difference' is also a hidden presupposition in communication and economy. The question remains on what level of scale self-sufficiency is desired: global, continental, national, local like Steekelenburg (2001) illustrates beautifully in his scenarios.

Quality

Quality can be measured in terms of possibilities of use, experience and expectation for future generations. The way design can sustain a sustainable development in the sense of Brundtland is to produce more ‘choices’ for man, animal and plant. If there were one best solution for all problems of architecture and urban planning, it would be the worst in the sense of choices for future generations! This paradox pleads more for diversity than for uniform solutions. Moreover, if there were a uniform solution, the designer would have no task. Quality is always a function of variation.

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[a] By this committee ‘sustainable development’ was defined as an economic development meeting the needs of the present generation, without endangering next generations in meeting their needs.

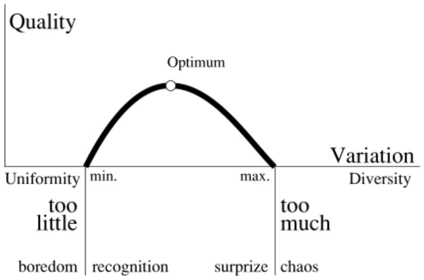

Fig. 696 *Quality = f(Variation)*

Quality of possible experience moves between diversity and uniformity, surprise and recognition. One step too far into both sides brings us in the area of boredom or confusion.

This is a simple conception, already recognized by Birkhoff (1933) and Bense (1954), but why did it not succeed, why is quality always posed as an unsolvable question?
Because the concept of diversity is scale sensitive and so is our experience.

When on one level of scale we experience chaos, in the same time on an other level of scale we could experience boredom.

5.2.3 Scale-sensitive concepts

Confusion of scale

As mentioned in the introduction, rarity, responsibility for rare species and even health are scale sensitive concepts. So is quality. But any discussion on variety and thus variables can fall prey to confusion of scale. That means that even logic and science as forms of communication could be prey to a scale paradox. The paradox of *Achilles and the turtle* is a beautiful example of a scale-paradox in time. The turtle says: 'Achilles cannot outrun me when I get a head start, because when he is where I was at the moment he started I'm already further, when he reaches that point I am again further and so on!' This conclusion is only incorrect by changing the time-scale during the reasoning. Russell (1919) finds something similar on set theory. Russell bans sets containing themselves and reflexive judgements[222] such as 'I lie'. This sentence is not only an object statement, but in the same time a meta-linguistic statement about itself producing a paradox. When I lie I speak the truth and the reverse.

Scale paradox

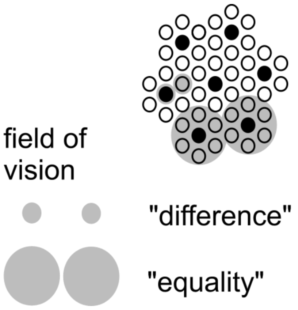

Fig. 697 *The scale paradox*

The *scale paradox*[223] means an important scientific ban on applying conclusions drawn on one level of scale to another without any concern. The picture shows the possibility of changing conclusions on a change of scale by a factor 3. There are 7 decimals between a grain of sand and the earth. That gives approximately 15 possibilities of turning conclusions. In the scale distance between a molecule and a grain of sand applies the same. This ban is violated so many times, that this should be an important criterion on the validity of scientific judgements.

If the scale-paradox influences the concept of diversity, it influences any class stating a difference with the rest.

An example of turning conceptions into their opposite by scale is the duality of aim and means. For the government subsidizing a municipality the subsidy is a means, for the municipality it is an aim. So the conception of means changes in a conception of aim by crossing levels of scale. The turning of '*Zweckbegriff*' into '*Systemrationalität*' discussed by Luhmann (1973) may be a turning conception of the same scale-sensitive character. In growing organizations *integration* on the level of the organization as a whole means often *disintegration* of the subsystems and perhaps a new form of integration in the sub-sub-systems. This scale articulated process is called '*differentiation*'!

Avoiding confusion of scale

In Fig. 697 confusion of scale is already possible by a linear factor 3 difference in level of scale. That is why in spatial planning we articulate orders of size by a factor of approximately 3.

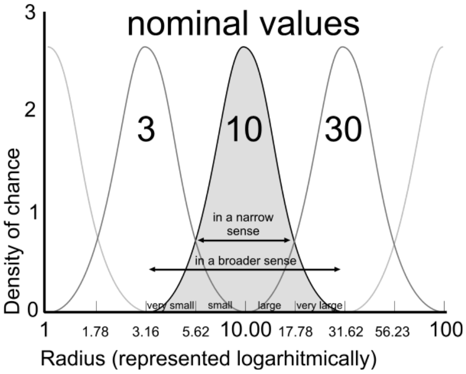

Fig. 698 *Names and boundaries of urban categories*

An element from the nearly logarithmical series {1, 3, 10, 30, 100 …} is the name (nominal value)[224] of an 'elastic' urban category ranging until those of the nearest categories (scale range).
The name giving 'nominal' radius r=10 then is the median of a chance density distribution of the logarithm of radiuses between (rounded off) r=3 and r=30, with a standard deviation of 0.15. We chose a series of radiuses (and not diameters) because an area with a radius of {0.3, 1, 3, 10km} fits well with {neighbourhood, district, quarter, conurbation} or loose {hamlet, village, town, conurbation} in every day parlance.

Then also the system of dry and wet connections could be named in this semi logarithmical sequence according to average mesh widths.

5.2.4 Spatial state of dispersion as a condition of diversity

State of dispersion

Form as a primary object of design supposes state of dispersion.

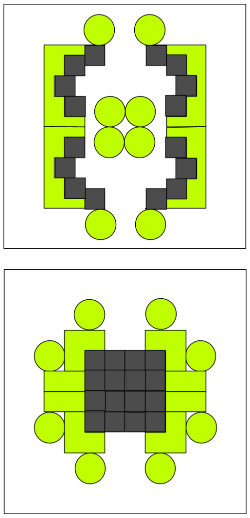

Fig. 699 *States of dispersion r=100m*

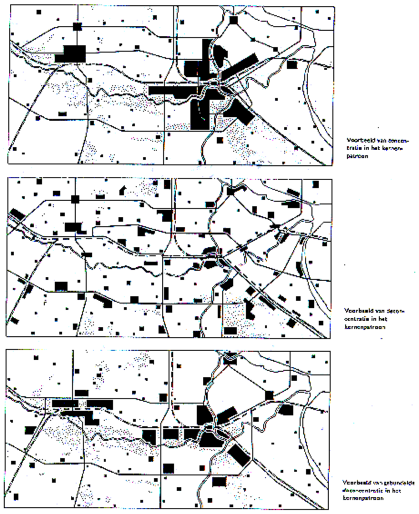

Fig. 700 *Accumulation, Sprawl, Bundled Deconcentration r=30km*[a]

Scale articulation of dispersed states

Scale articulation is especially important distinguishing states of dispersion. State of dispersion is not the same as density. Considering the same density different states of dispersion are possible (Fig. 701) and that is the case on every level of scale again (Fig. 702).

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[a] RPD (1966)

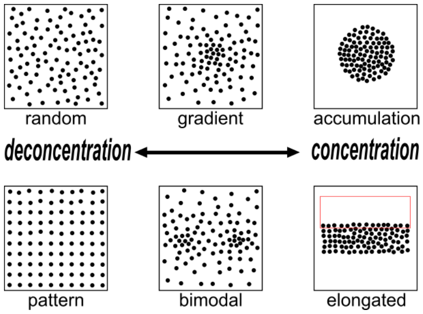

Fig. 701 *States of dispersion in the same density on one level of scale*

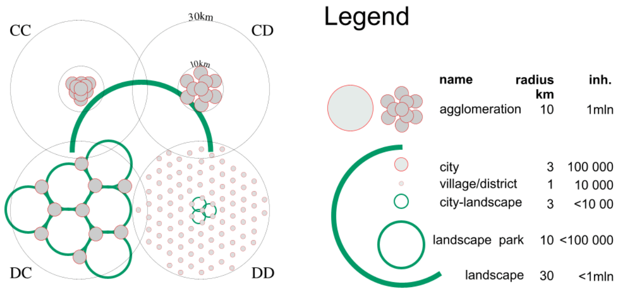

Fig. 702 *One million people in two states of distribution on two levels of scale (accords CC, CD, DC and DD).*

Fig. 701 shows the use of the words concentration (C) and deconcentration (D) for processes into states of more or less accumulation respectively. Applied on design strategies in different levels of scale we speak about ‘accords’ (Fig. 702).

In Fig. 702 the *regional density* is equal in all cases: approx. 300inh./km^2. However, in case CC the built-up area is concentrated on both levels ($C_{30km}C_{10km}$) in a high *conurbation density*: (approx. 6000inh./km^2).[225]

In the case CD people are deconcentrated only within a radius of 10km ($C_{30km}D_{10km}$) into an average conurbation density of approx. 3000 inh./km^2.

In the case $D_{30km}C_{10km}$ the inhabitants are concentrated in towns (concentrations of 3km radius within a radius of 10km), but deconcentrated over the region. This was called ‘Bundeled deconcentration’ in NRO2. The *urban density* remains approx. 3000 inh./km^2.

In the case $D_{30km}D_{10km}$ they are dispersed on both levels.

Urban sprawl

Urban sprawl in a radius of 10km hardly influences the surrounding landscape when the inhabitants are concentrated in a radius of 30 (the two variants above in Fig. 702).

However, the urban sprawl in a radius of 30km breaks up the surrounding landscape in landscape parks. By that condition the sprawl within a radius of 10km is important again: the landscape parks are broken up further into town landscapes. In The Netherlands until 1983 DC was the national strategy (‘Bundled deconcentration’, ‘Gebundelde Deconcentratie’ from NRO2, RPD (1966)), after NRO3, RPD (1983) the policy changed into CC (Compact town’, ‘Compacte Stad’), but turned out in practice as CD and even DD. The result of both strategies was disappointing.

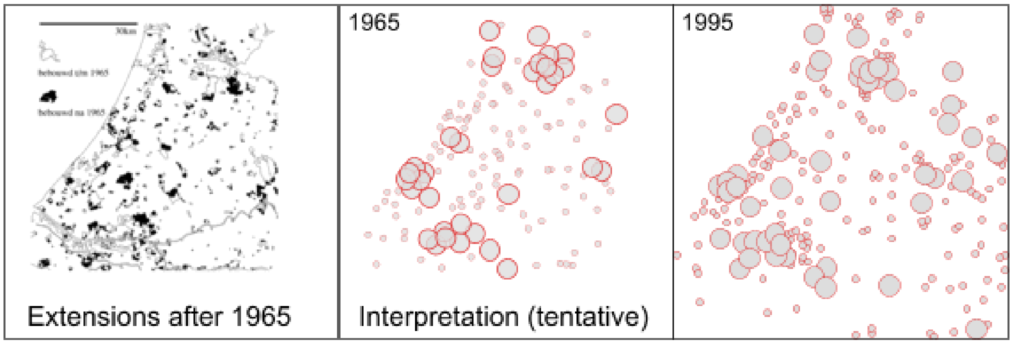

Fig. 703 *Urban sprawl in Randstad, The Netherlands*

Distribution and abundance of organisms

In prominent ecology textbooks there are several definitions of ecology emphasising dispersion or with an increasing awareness of scale (in that case we will speak about spatial distribution):[226]

Andrewartha (1961), cited by Krebs (1994): Ecology is the scientific study of the *distribution and abundance* of organisms.
•Krebs (1994): Ecology is the scientific study of the *interactions* that determine the distribution and abundance of organisms.
•Pianka (1994): Ecology is the study of the *relationships between organisms* and the totality of the *physical and biological factors* affecting them or influenced by them.
•Begon, Harper et al. (1996): Ecology is the scientific study of the interactions that determine the distribution and abundance of *organisms, populations and communities.*

Kolasa and Pickett (1991) seem to be the only ecologists fully aware of scale articulation consequences avoiding confusion of scale.

Time-space scaling

Pianka (1994) stresses relationships in a broader sense than spatial relationships. He adds a scheme stressing scale in space and time, but does not detect any paradox. ‘Community and ecosystem phenomena occur over longer time spans and more vast areas than suborganismal and organismal-level process and entities. (after Anderson (1986) after Osmund et al.)’

Begon, Harper and Townsend (1996) distinguish organisms, populations and communities.

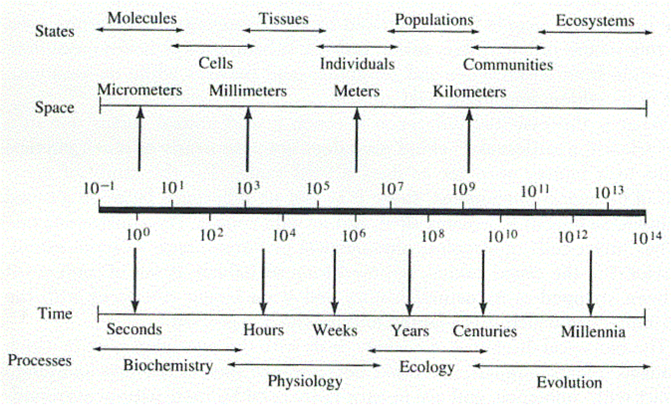

Fig. 704 *Diagrammatic representation of the time-space scaling of various biological phenomena*[a]

That distinction looks like a distinction of scale, but is primarily a distinction between different kinds of ecology:[227]

- autecology concerning populations of one species at a time within their ‘habitat’ and
- synecology concerning the community of different species in the same ‘biotope’.

On the level of organisms one could speak about ‘ecological behaviour’ as for instance Grime, Hodgson et al. (1988) elaborated as plant species bound ‘strategies for survival’ like ‘competitors’, ‘ruderals’ and ‘stress tolerators’ as rôles in a play concerned less predictable than communities reaching a well described ‘climax’.[228]

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[a] Pianka (1994)

5.2.5 300km continental vegetation areas

Global and continental

Ecological typology is scale-sensitive. The subdivision of global life conditions in Fig. 705 distinguishes 'biomen'[229] primarily by temperature and precipitation[230]. This variation is recognisable on a smaller level of scale vertically in mountains. The average temperature and precitipation in the Netherlands are near 10°C and 1000 mm. The natural vegetation in such conditions is moderate deciduous forest, but grassland is not far from these conditions.[231] However, in the low countries of the Netherlands the availability of water is much higher than to be expected from its average precitipation.

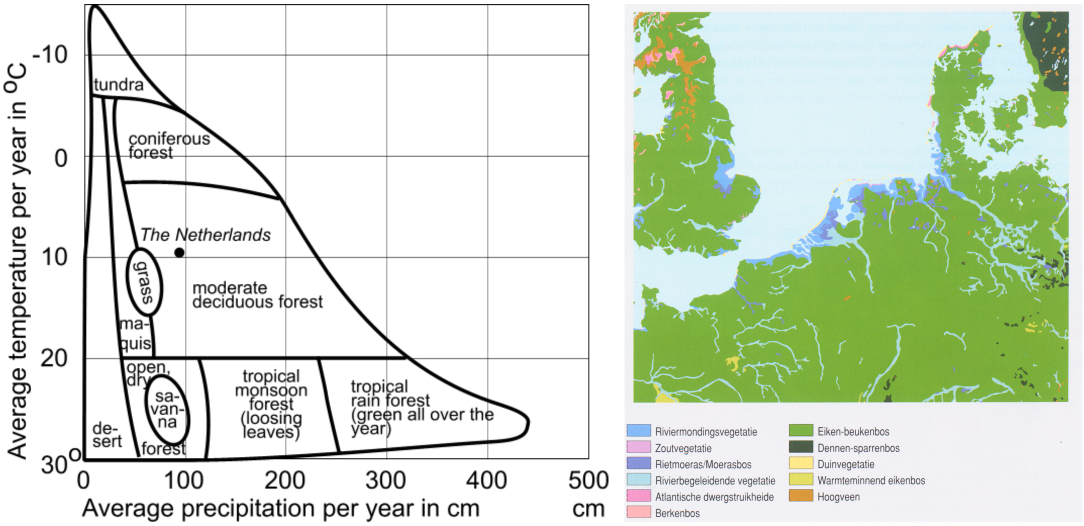

Fig. 705 *Global and continental ecological typology*[a]

On a continental level (r=3 000km) areas of vegetation like estuaries, salt vegetations, reed marsh, river accompanying, Atlantic heather, birch forest, oak-beach forest, pine-spruce forest, dunes, warm oak forest and high moor land are distinguished. On a map types in a typology appear like legend-units in a legend (see Fig. 705). In The Netherlands, Northern Germany and Southern Denmark, the distinction of Fig. 705 (right) corresponds with geological categories like Pleistocene (until 1 000 000 years old) and Holocene (until 10 000 years old).

European level

On a European level of scale different distinctions were made. Fig. 705 gave the most recent one based mainly on forest types and *Fig. 706* an earlier one based on species[232].

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[a] Myers (1985); Bohn, Gollub et al. (2000); Bohn (2001)

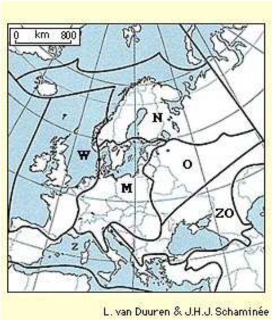	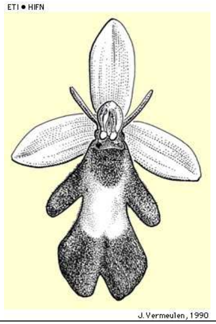	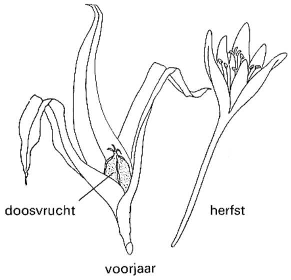	
Western (W), 'Northern' (N), Middle (M), 'Eastern' (O) andSouth-Eastern (ZO) European vegetation areas.	*Vliegenorchis H43*	Herfsttijloos	*Kleine Kaardebol*

Fig. 706 Plants, characteristic for Middle-European vegetation areas (M) in the Netherlands[a]

Mainly West European vegetation in The Netherlands

In The Netherlands the distinction of Fig. 705 (right) corresponded with geological categories like Pleistocene (until 1 000 000 years old) and Holocene (until 10 000 years old).

Fig. 706 distinguishes grounds mainly older than 1 000 000 years in Limburg as 'Middle European vegetation area' (M). Pleistocene and older grounds in South Limburg are nearly fully covered by löss alternating with rock on surface, primarily consisting of chalk, marl and limestone sometimes turning up elsewhere in The Netherlands as well. The rest of The Netherlands as part of 'West European vegetation area' (W) is younger.[233]

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[a] *Mennema, Quene-Boterenbrood et al. (1980) , p. 16;* Meijden (1999); Kelle and Sturm (1980); Meijden (1999)

5.2.6 30km national counties

Holocene and Pleistocene

On a national level in The Netherlands Holocene and Pleistocene are the most enclosing categories approximately separated by the 5m altitude[234], roughly a distinction of clay (with peat and dunes) versus sand (intersected by river clay or locally filled by high moor land). The most urbanised Holocene estuary area, botanically indicated as 'lagoon county' is highly influenced by man and in the same time an internationally rare cultural-natural monument of polders. It is ecologically divided further in many ways representing its dynamic and unpredictable wet ecological diversity.

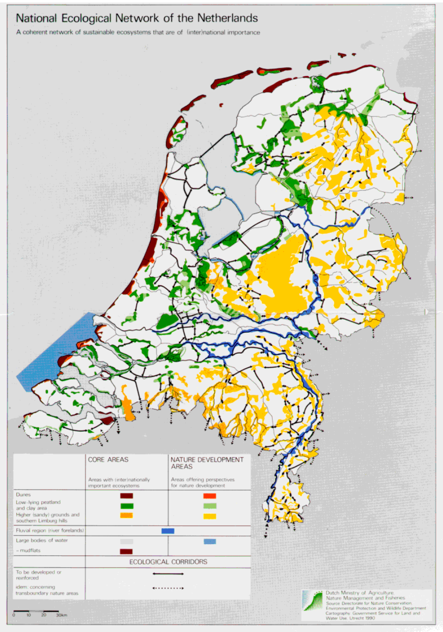

Fig. 707 *Planning Ecological Infrastructure*[a]

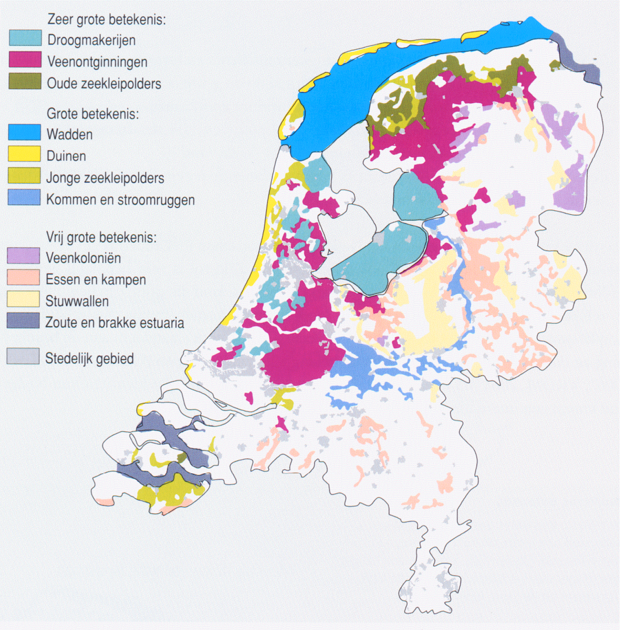

Fig. 708 *International rarity of landscapes*[b]

Based on the synecological typology of Westhoff and Held (1969) and Held (1991), Bal, Beije et al. (1995); Bal, Beije et al. (1995) defined 132[235] (in Bal, Beije et al. (2001) reduced into 92) nature target types of the national ecological infrastructure (EHS). However, Clausman and Held (1984) earlier had proved them to be inadequate for the Holocene Zuid-Holland area. Too many transitional stages between sand, clay and peat, influenced by a historical local diversity of cutting peat and water management produced a variety of nature types nearly equalling the number of grounds itself.

Different plants on Pleistocene and Holocene grounds

Apart from the sandy dunes, the lower Holocene with clay from sea and rivers and low (wet) and high (acid) peat has a very different vegetation compared with the higher and dryer pleistocene covered with coarser sand and gravel.[236] The ecological difference between low Holocene and high Pleistocene is clearly illustrated by dispersion of two species: meadow barley (veldgerst, Fig. 709) and wavy hair-grass (bochtige smele, Fig. 710).

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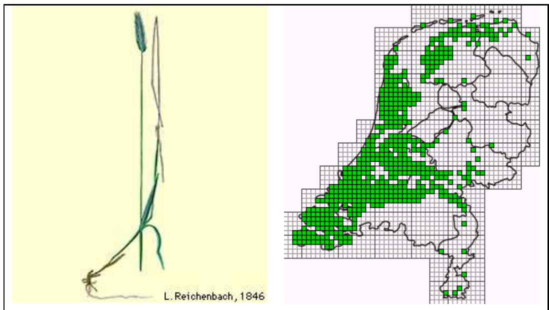
[a] From an earlier version of LNV (2002)

[b] RIVM (2001)



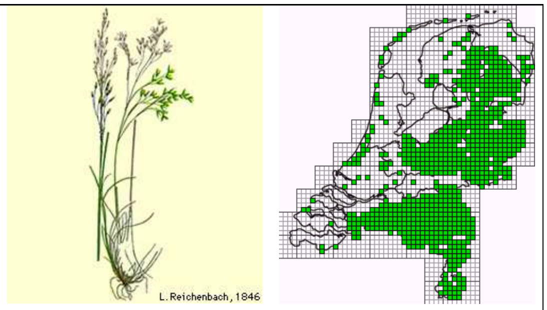
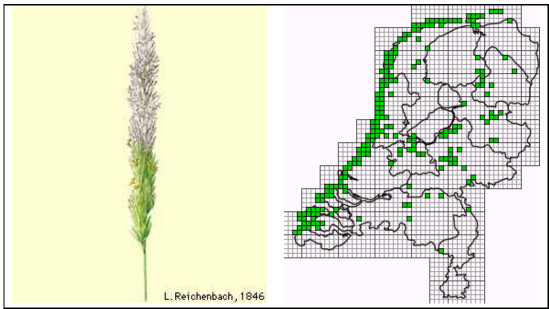


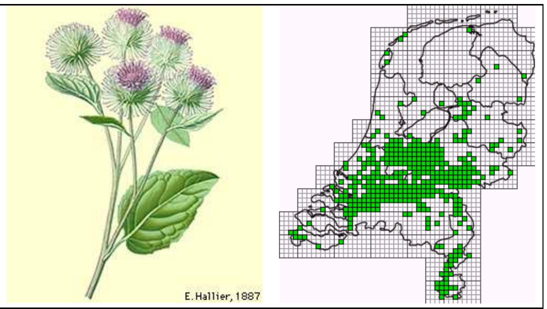
Fig. 709 *Dispersion of meadow barley (veldgerst)*

Fig. 710 *Dispersion of wavy hair-grass (bochtige smele)*[a]

Different plants in dunes and rivers

Holocene is subdivided in dune and river county, illustrated by the dispersion of two other species, marram (helm, Fig. 711) and greater burdock (grote klis, Fig. 712). The remainder is called Haf county with sea clay and peat.[237]





Meijden (1999) and Meijden, Plate et al. (1989) page 44 en 28

Fig. 711 *Dispersion of marram (helm)*

Fig. 712 *Dispersion of greater burdock (grote klis)*

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[a] Meijden (1999) and Meijden, Plate et al. (1989) page 84 en 58

General trees in The Netherlands

General trees in The Netherlands are alder (els), ash (es), sycamore (esdoorn), hawthorn (meidoorn), birch (berk), rowan or whitebeam (lijsterbes).[238]

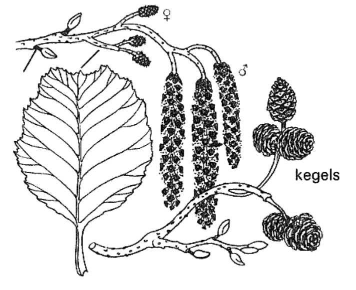
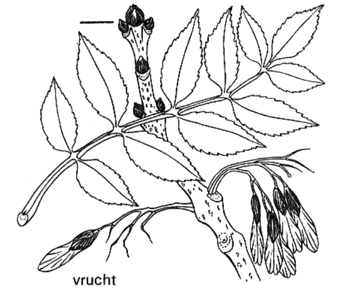
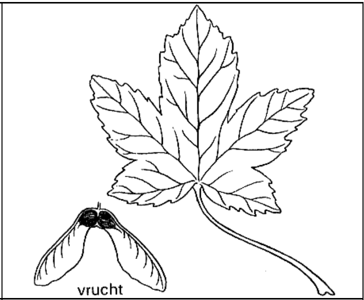
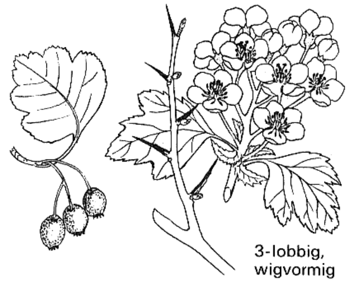
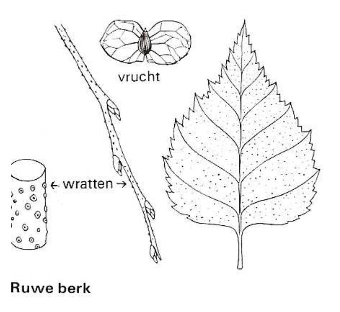
		
Alder (zwarte els)	Ash (es)	Sycamore (gewone esdoorn)
		
Midland hawthorn (tweestijlige meidoorn)	Birch (berk)	rowan or whitebeam (wilde lijsterbes)

Fig. 713 *General trees in The Netherlands*[a]

Trees specific for Holocene and river grounds

Holocene and rivers are characterised by black poplar (zwarte populier), willow (wilg), dogwood (rode kornoelje) (Fig. 714).[239]

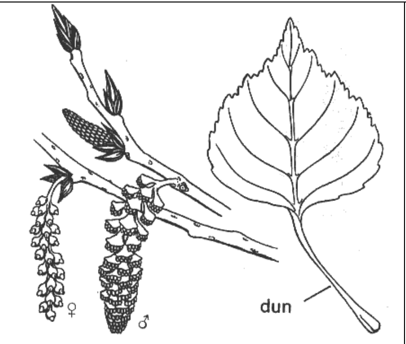
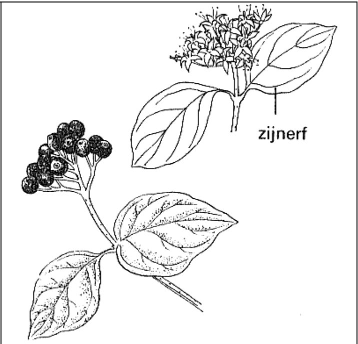
		
Black poplar (zwarte populier)	Crack willow (kraakwilg)	Dogwood (rode kornoelje)

Fig. 714 *Trees of Holocene and rivers in The Netherlands*[b]

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[a] Kelle and Sturm (1980)
[b] Kelle and Sturm (1980)

Trees specific for Pleistocene and dunes

Peistocene and dunes are characterised by scots pine (grove den), red oak (amerikaanse eik), beech (beuk), aspen (ratelpopulier), hazel (hazelaar), holly (hulst), locust tree (robinia pseudo-acacia) and rum cherry or black cherry (amerikaanse vogelkers).[240]

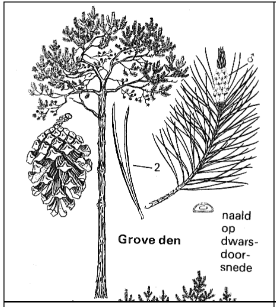
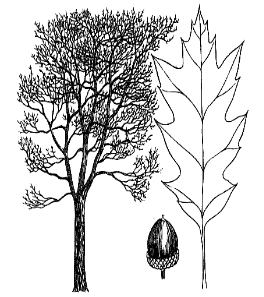
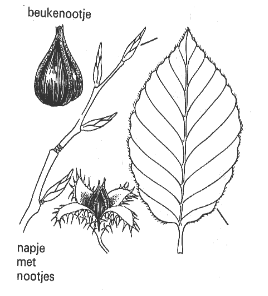
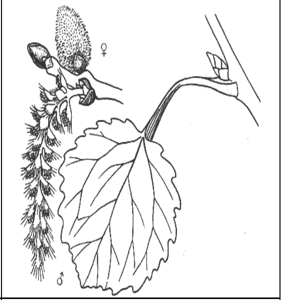
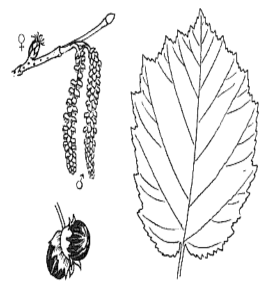
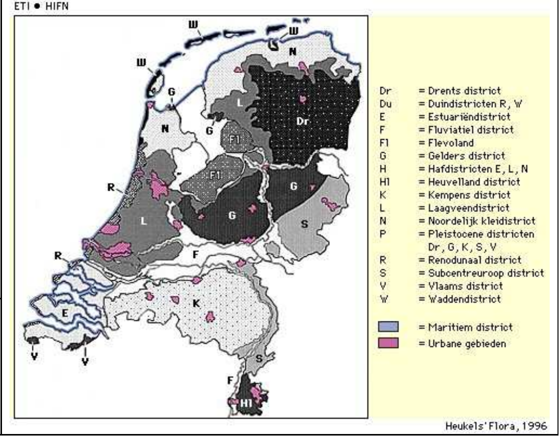
			
scots pine (grove den)	red oak (amerikaanse eik)	beech (beuk)	aspen (ratelpopulier)
			
hazel (hazelaar)	holly (hulst)		

Fig. 715 Trees of Pleistocene and dunes in The Netherlands[a]

Fig. 716 Flora districts according to Van Soest[b]

Further elaboration of ecological counties (districten) (*Fig. 716*) is given by Van Soest (1929/32)[241]

5.2.7 3km Landscape formations

Undisturbed 'definitive' vegetations

Obviously any region in The Netherlands that has got the time for succession of vegetation types gets a more or less 'definitive' vegetation. Coincidences of first establishments are filtered out.
This vegetation is not only dependent on soil, but also on climate, position in respect to sea and ground water level. For example, peat will only remain at high ground water level. In dry conditions it will settle, oxidate to CO_2 en H_2O and disappear leaving a lower mineral surface level.

In this paragraph we will discuss landcape formations and typical forest landscapes that would appear without impact of man at last. Agriculture and the use of fertilizers caused a homogeneous landscape. But the agricultural surface being reduced by economic conditions, an ecologically well-considered choice of vegetation and management could restore regionally characteristic forest, kept open partially by wild grazing cattle. You can consider this paragraph as a guide to planting, because trees occurring naturally in the region will grow better. You can obtain regional knowledge about soils from soil maps 1:50.000 with explanatory discriptions of landscapes.

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[a] Kelle and Sturm (1980)
[b] Meijden (1999)

Natural forest types

Following descriptions are derived from Leeuwen and Kraft (1959). With regard to these elaborations Van Leeuwen's nomenclature is obsolete but simple, useful and clarifying for urbanists and not yet exceeded in that respect.

Forest	**Natural**	**Reclaimed**
	Holocene	
salicion[242]	Willow and poplar forests, often found on *nutricious flooded areas like river forelands*. As coppice wood and wickers, willows are planted on 'grienden'. Temporarily you will find these woods on other nutricious grounds as pioneer vegetation.	Grass land on river forelands and 'grienden'.
alnion incanae[243]	Alder and ash forests with densely shrubs on *clay or sandy nutricious grounds with high and often somewhat changing ground water level or in the neighbourhood of streaming water*. These forests often contain some oaks and poplars as well.	Moisty grass land (meadows) sometimes with hedges (Rubion, alder), pollard willows or poplars.
ulmion[244]	Oak, ash (somtimes elm or maple) forests on *moisty, nutricious sandy and not too heavy clay grounds with ground water level in reach of roots*.	Settlements, horticulture, orchards, fields, grass land, elm lanes, country estates and dune woods.
sambuco-berberidion[245]	Hedges and thickets on *most limy grounds* of Ulmion.	
	Pleistocene	
rubion[246]	Hedges and thickets (hawthorn, sloe, roses, blackberries) on *nutricious, but not expicitly limy grounds*.	Settlements, orchards and fields on rather dry grounds; grass land on more moisty or very limy grounds.
carpinion[247]	Oak, ash (sometimes maple or beech) forests on *nutricious, not too wet loam grounds*. In coppice wood thickets you wil find hazel and hornbeam.	
carpino-berberidion[248]	Hedges and thickets on *most limy grounds* of Carpinion.	
violeto-quercion[249]	Oak (seldom birch or beech) forests or coppice wood on *acid but not extremely poor, ofthen loam containing or somewhat moisty sandy grounds*.	Fields
vaccinio-quercion[250]	Oak (sometimes birch or beech) forests or coppice wood on on *acid extremely poor, sandy (sometimes loamy) grounds*.	Prehistoric (neolithic) settlements, heath often later planted with coniferous wood (drifting sand) or crops (if dry) or meadows (if wet).
	Peat	
betulon pubescentis[251]	Rarefied birch forests on *somwhat dehydrated peat grounds* (very rare).	Digged out or drained and manured meadows sometimes planted as Alnion incanae.
sphagno-alnion.[252]	Birch (sometimes alder) forests with shrubs of alder buckthorn, willows, bog myrthle on *acid peat grounds* (rare).	Bluegrass lands, later usually drained and manured, sometimes planted as Alnion incanae.
irido-alnion.[253]	Alder or willow (mostly coppice wood) in *peat areas with very hing, stagnating not too poor ground water*, usually with rarified shrubs.	Moisty grass land, digged out or drained and manured meadows mostly planted as Alnion incanae.

Fig. 717 *Relation between original natural forest type and reclamated landscape*[a]

Comment [T.M. de9]: Pagina : 468
ZIj komen voor in beekdalen, vochtige laagten in dekzandgebieden en oude duinlandschappen, laaggelegen rivier- en zeekleigronden, niet regelmatig overstroomd buitendijks rivierlandschap, bemeste en iets ontwaterde veengronden.

Comment [T.M. de10]: Pagina: 468
stroomruggronden in het rivierkleigebied, kreekrug- en kwelderwalgronden in het zeekleigebied grensstroken tussen droge, zandige heuvels en vochtige dalen.

Comment [T.M. de11]: Pagina: 468
Vooral in de kalkrijke jonge duinen, ook in Zuid Limburg en hier en daar langs de rivieren, waar de grond kalrijk is.

Comment [T.M. de12]: Pagina: 468
op voedselrijke, maar niet uitgesproken kalkrijke gronden in het rivieren gebied op de leem- en losgronden in Limburg. Vroeger werden ze ook veel gevonden in de oudere zeekleigebieden zoals op Walcheren.

Comment [T.M. de13]: Pagina: 468
in Oost Nederland, Zuid Limburg, Achterhoek, Twente, plaatselijk in het Nijmeegs heuvelland, Veluwezoom, Drente en Noord Brabant.

Comment [T.M. de14]: Pagina: 468
Zij komen voor in Zuid-Limburg.

Comment [T.M. de15]: Pagina: 468
Bovenste deel van hellingen in Zuid-Limburg, grensstrook tussen Ulmoin en Vaccinio-Quercion in geaccidenteerde zandgebieden, hoogste gedeelte van de oude ... [1]

Comment [T.M. de16]: Pagina: 468
Vlakke plateaus in Zuid Limburg, het grootste gedeelte van de pleistocne znadgebieden in Oost en ... [2]

Comment [T.M. de17]: Pagina: 468
iets ontwaterde veenterreinen in Oost en West Nederland. Zeer zeldzaam.

Comment [T.M. de18]: Pagina: 469
Laagste gedeelten met slecht waterafvoer in de pleistocene zandgebieden, voedselrijkere delen van de veengebied ... [3]

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[a] Leeuwen and Kraft (1959)

Ideal typical profiles

The situation of most important soils and corresponding vegetation is represented in ideal typical profiles Fig. 718 to Fig. 721 never appearing in reality. Corresponding forest types have been mostly disappeared since long and replaced by grass and crops. They illustrate mutual arrangements of Dutch original or natural landscapes. Soil maps give more detailed and realistic images.

The Northern coast formation of The Netherlands

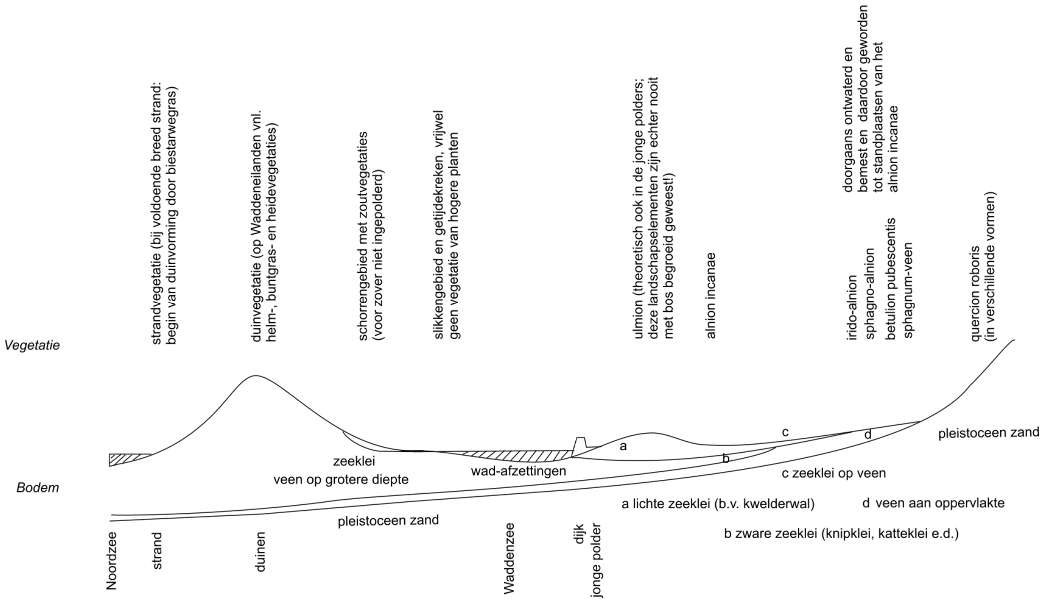

Fig. 718 *Ideal typical coast formation in Northern part of The Netherlands*[a]

Mid-West cost formation of The Netherlands

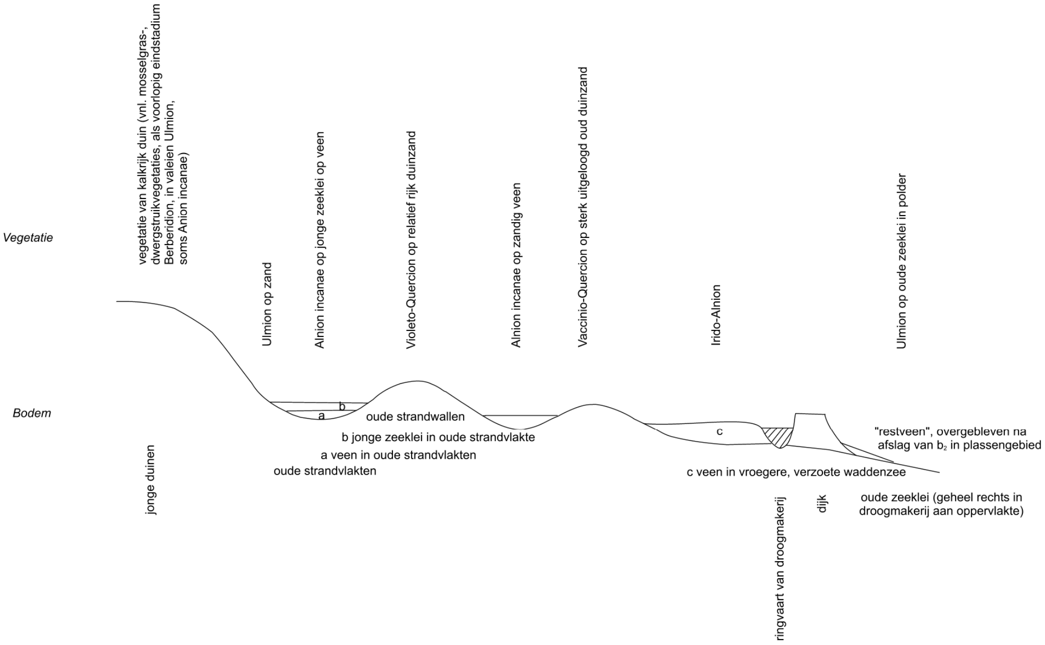

Fig. 719 *Ideal typical coast formation in mid-West of The Netherlands*[a]

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[a] Leeuwen and Kraft (1959)

Peat, river and pleistocene sandy formations

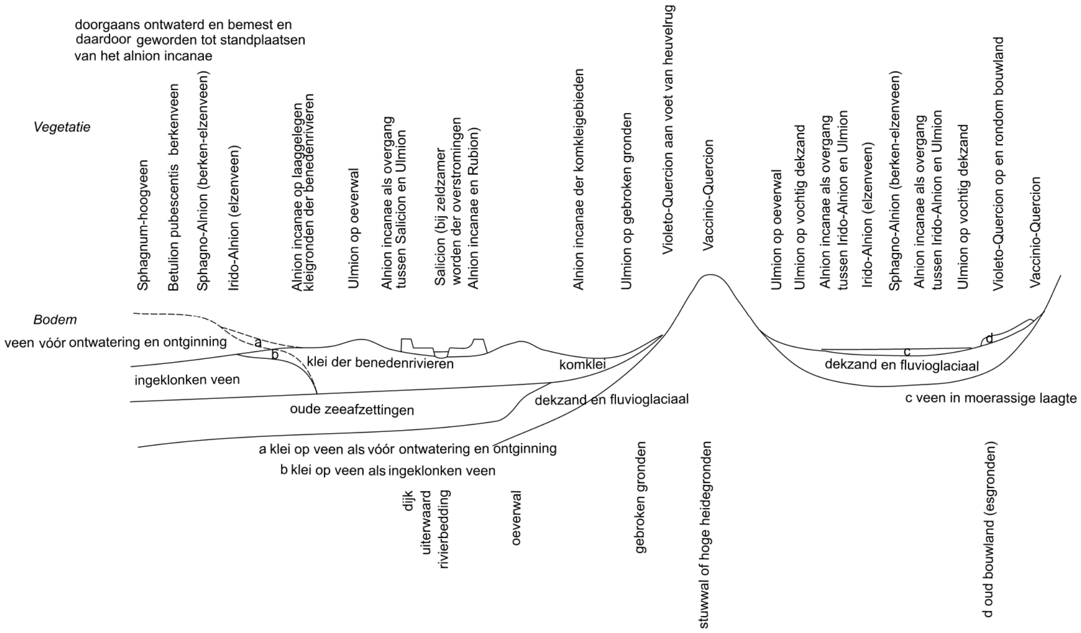

Fig. 720 *Ideal typical peat, river and pleistocene sandy formations*[b]

Growing Peat

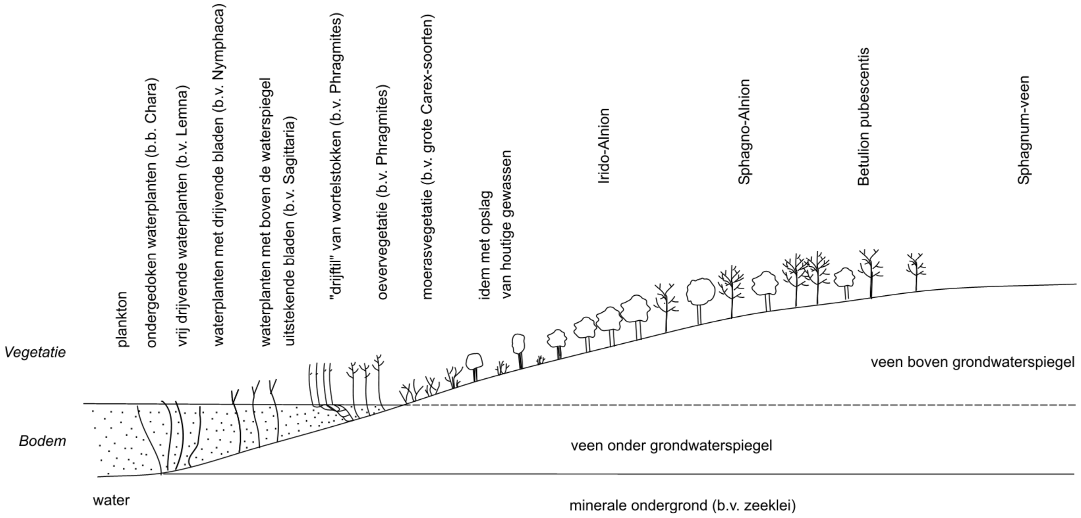

Fig. 721 *Ideal typical 'verlanding' in nutricious environments*[c]

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[a] Leeuwen and Kraft (1959)
[b] Leeuwen and Kraft (1959)
[c] Leeuwen and Kraft (1959)

Clay

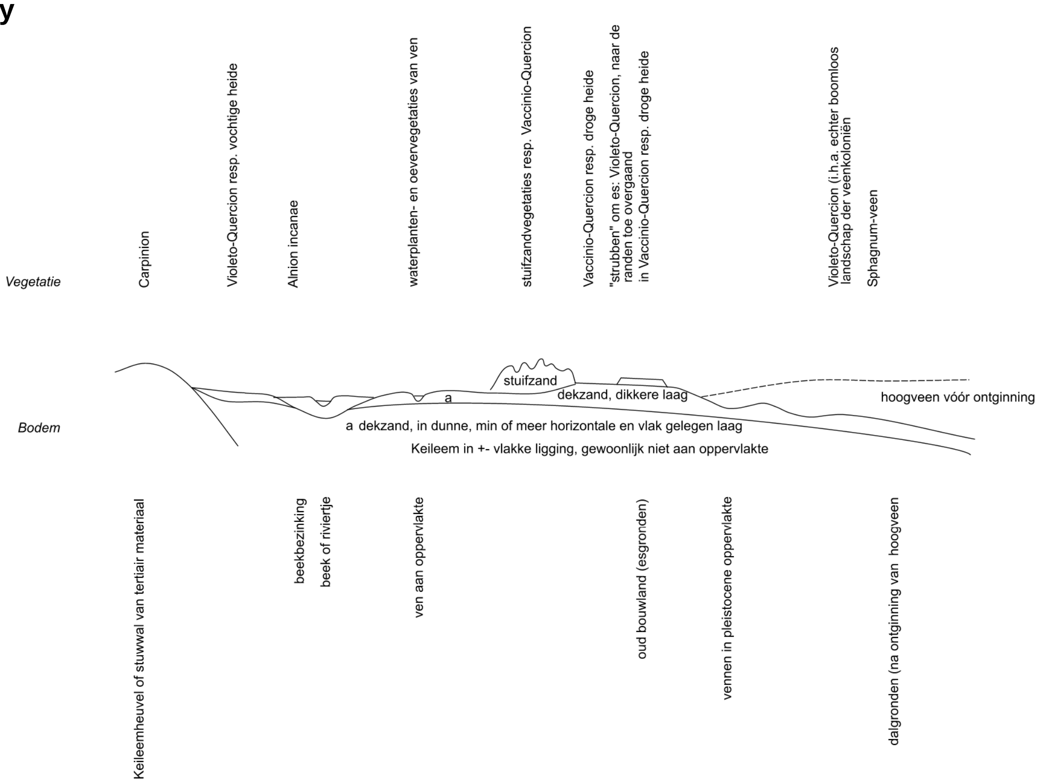

Fig. 722 *Ideal typical boulder clay formation*[a]

South Limburg

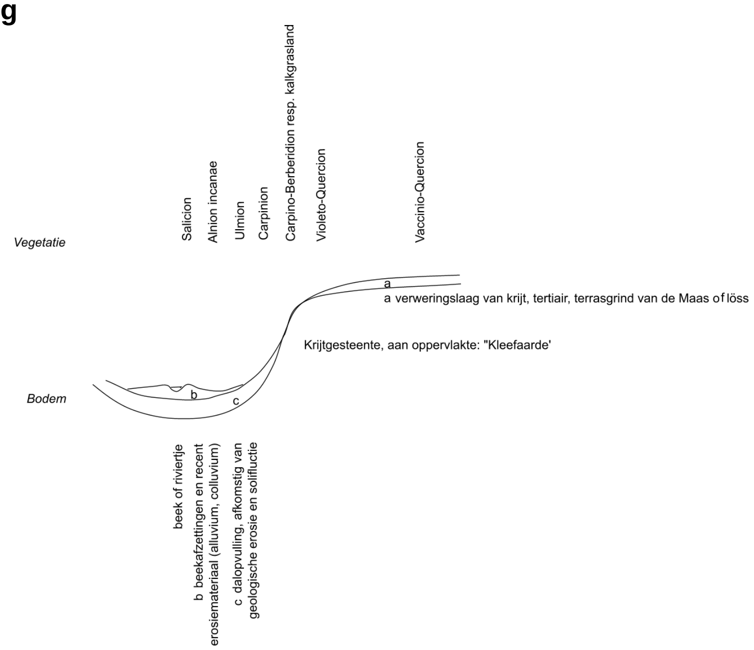

Fig. 723 *Ideal typical formation of South Limburg*[b]

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[a] Leeuwen and Kraft (1959)
[b] Leeuwen and Kraft (1959)

‘Original landscape’ is not the same as the ‘natural landscape’ appearing when human impact would stop, especially when agricultural measures were very radical.

5.2.8 300m local life communities

Succession

Organisms influence eachother. In the beginning competition in fast growing homogeneous pioneer vegetation is dominant. In the next phase of succession different species alternate their use of sun, water and minerals over the year and differentiate them over the area in increasing specialisation. Primarily establishing plants cause a micro climate and soil structure creating conditions for other species. Under these conditions some newcomers get the opportunity to built up reserves and become more competitive than their fast growing predecessors. For exampe, they grow higher catching sunlight from their neighbours or grow deeper surviving dry periods better by their longer roots. In their shadow slow growing specialists settle.

Differentiation and regulation

The differentiating life community prevents large fluctuations of temperature and moist, retains water and nutrients attracting new animals. Specific insects pollinate specific plants and clear up plants weakened by competition in homogeneous vegetation. Birds control insect overloads, disperse seeds. Large grazing animals keep spaces open, predators keep their number limited. Reproductive cycles of every participating organism with its own consumptive, productive and reproductive periods are geared to one another and find for every phase the environmental circumstances they need, or die out. The rise of mutual relations into a climax stage (Fig. 732) requires coordination in space and sychronisation in time. In general it takes time.

Differerent communities in the same biotope

In the same type of biotope different life communities can develop, according to the history of their development. Different (weather) histories after all, change the biotope itself in different ways and select species differently. For example, if papillionaceous flowers with their specialised algae established in an early stage to combine nitrogen in the soil, an other series of succession would follow then when they established later or never. If not, vegetation is dependent on nitrogen manure from outside. And the reverse, if there is an external nitrogen source in the beginning, papillionaceous flowers would not survive competition.

Equal communities in different biotopes

On the other hand the same type of vegetation can disperse over different biotopes as well. So, there is not always a one-to-one relation between biotopes and life communities.
Especially man plants on his fields and gardens species he wants to, regardless the existing biotope accomodating it to his needs. He mostly reduces a mature system into its pioneer stage to get homogeneous highly competing productive crops. Then ecosystems do not reach their climax stage because human dynamic (grazing, mowing, burning and digging) prevents succession into more differentated stages.

A first taxonomy of communities

Mutual relations between species produce recognizable plant communities listed in 38 synecological classes from Westhoff and Held (1975) summarised by Held (1991), subdivided in orders, unions and associations (partly elaborated in Fig. 724)[254]. Classes 32 to 38 elaborate forests more in detail than Fig. 717 did obsoletely but simply. Some scientific names like Salicion (32Aa and 33Aa), Alnion (35Aa) remain the same, other forest types named in paragraph 5.2.7 changed.

code	***class 01-38 ~ea***	**order A-C ~alia**	union a-d ~ion	*associatiion 1-99 ~tum*	***Dutch name class***
01	***Lemnetea***				***Eendekroos-klasse***
02	***Zosteretea***				***Zeegras-klasse***
03	***Ruppietea***				***Ruppia-klasse***
04	***Charetea***				***Kranswieren-klasse***
05	***Potametea***				***Fonteinkruiden-klasse***
………………………………….					
29	***Oxycocco-Sphagnetea***				***Klasse der hoogveenbultgemeenschappen en vochtige heiden***
30	***Nardo-Callunetea***				***Klasse der heiden en borstelgrasanden***
31	***Trifolio-Geranietea sanguinei***				***Marjolein-klasse***
32	***Franguletea***				***Klasse der sporken-wilgenbroekstruwelen***
***32*A**		**Salicetalia auritae**			
***32*A**a			Salicion cinereae		
***32*A**a*1*				*Myricetum gale*	
***32*A**a*2*				*Frangulo-Salicetum auritae*	
***32*A**a*3*				*Alno-Salicetum cinereae*	
***32*A**a*4*				*Salicetum pentandro-cinereae*	
***32*A**a*5*				*Salicetum pentandro-arenariae*	
33	***Salicetea purpureae***				***Klasse der wilgen-vloedstruwelen en bossen***
***33*A**		**Salicetalia purpureae**			
***33*A**a			Salicion albae		
***33*A**a*1*				*Salicetum triandro-viminalis*	
***33*A**a*2*				*Salicetum arenario-purpureae*	
***33*A**a*3*				*Salicetum albo-fragilis*	
34	***Rhamno-Prunetea***				***Klasse der eurosiberische doornstruwelen***
35	***Alnetea glutinosae***				***Klasse der elzenbroekbossen***
***35*A**		**Alnetalia glutinosae**			
***35*A**a			Alnion glutinosae		
***35*A**a*1*				*Carici elongatae-Alnetum*	
***35*A**a*2*				*Carici laevigatae-Alnetum*	
36	***Vaccinio-Piceetea***				***Klasse der naaldbossen***
***36*A**		**Vaccinio-Piceetalia**			
***36*A**a			Dicrano-Pinion		
***36*A**a*1*				*Leucobryo-Pinetum*	
***36*A**a*2*				*Dicrano-Juniperetum*	
***36*A**b			Betulion pubescentis		
***36*A**b*1*				*Betuletum pubescentis*	
37	***Quercetea robori-petraeae***				***Eiken-klasse***
***37*A**		**Quercetalia robori-petreae**			
***37*A**a			Quercion robori-petreae		
***37*A**a*1*				*Querco roboris-Betuletum*	
***37*A**a*2*				*Fago-Quercetum*	
***37*A**a*3*				*Convallario-Quercetum dunense*	
38	***Querco-Fagetea***				***Eiken-beuken-klasse***
***38*A**		**Fagetalia sylvaticae**			
***38*A**a			Alno-Padion		
***38*A**a*1*				*arici remotae-Fraxinetum*	
***38*A**a*2*				*onsortium van Carex remota & Populus nigra*	
***38*A**a*3*				*runo-Fraxinetum*	
***38*A**a*4*				*acrophorbio-Alnetum*	
***38*A**a*5*				*iolo odoratae-Ulmetum*	
***38*A**a*6*				*raxino-Ulmetum*	
***38*A**a*7*				*nthrisco-Fraxinetum*	
***38*A**a*8*				*rataego-Betuletum*	
***38*A**a*98*				*lmion carpinifoliae*	
***38*A**a*99*				*ircaeo-Alnion*	
***38*A**b			Carpinion betuli		
***38*A**b*1*				*Stellario-Carpinetum*	
code	***klasse 01-38 ~ea***	**orde A-C ~alia**	verbond a-d ~ion	*associatie 1-99 ~tum*	***Nederandse naam klasse***

Fig. 724 *Taxonomy of life communities according to Westhoff and Den Held.*

The next taxonomy

However, that taxonomy was adapted again by Schaminee, Stortelder et al. (1995); Schaminee, Weeda et al. (1995); Schaminee, Stortelder et al. (1996); Schaminee, Weeda et al. (1998) . Fig. 725 gives an impression of the first classes only.

	class 01-11 ~ea	**order A-C, DG, RG ~alia**	union a-d ~ion	*association 1-99 ~tum*	*subassociatiion a-b*

01	***Lemnetea minoris***
02	***Ruppietea***
03	***Zosteretea***
04	***Charetea fragilis***
05	***Potametea***
06	***Littorelletea***
07	***Montio-Cardaminetea***
08	***Phragmitetea***
09	***Parvocaricetea***
10	***Scheuchzerietea***
11	***Oxycocco-Sphagnetea***

……………..

	klasse 01-11 ~ea	**orde A-C, DG, RG ~alia**	verbond a-d ~ion	*associatie 1-99 ~tum*	*subassociatie a-b*

Fig. 725 *Taxonomy of life communities according to Schaminee.*

This taxonomy at last was used in nature conservation, simplified in nature target types we will discuss in 5.5.1 more in detail.

5.2.9 30m ecological groups

Based on ideas of Van der Maarel (1971), Runhaar, Groen et al. (1987) divided Dutch plant species in ecological groups (Fig. 726), suitable for estimating impacts of technical measures and ecological potencies.

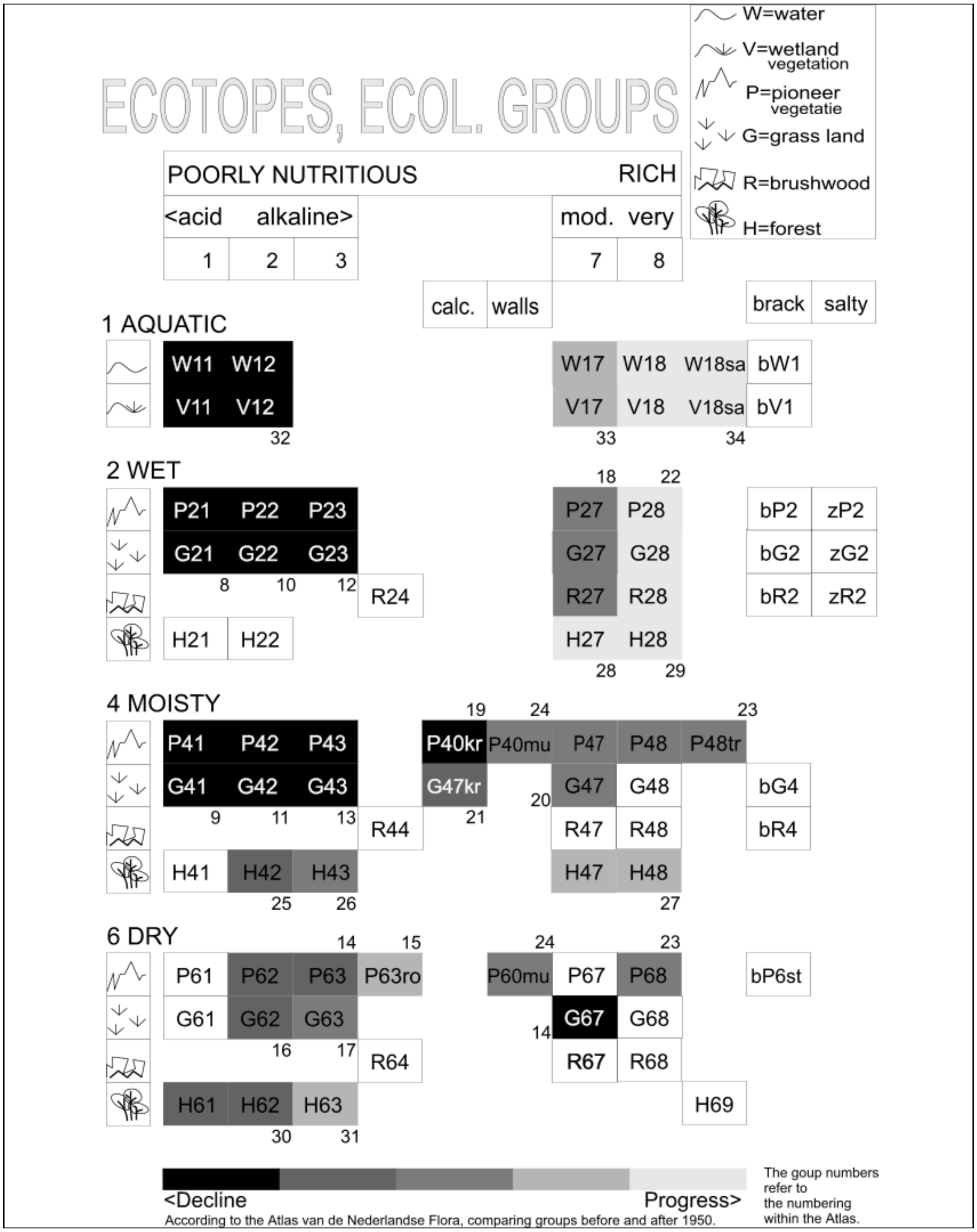

Fig. 726 *Ecological groups*[a]

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[a] *Runhaar, Groen et al. (1987)*

Fig. 726 below shows which ecological groups made progress in the last century and which declined. It is clear that oligotrophe groups declined substantially[255].

Ecological groups classified by directly working conditions

This subdivision restricts itself to conditions directly working on plants like sunlight, moist and acidity. It avoids taking into account underlying causes like soil type and water management complicating this classification. These are important factors estimating the impacts of technical interventions indeed, but they are originating in very different ways from higher levels of scale.[256] For example, salty or brackish groups could not only be caused by surface water but also by seepage. Seepage on its turn can cause very different vegetations dependent on its chemical composition. Keeping classification as close as possible to the plant, the number of subdivisions and their presupposed explanation is limited. Moreover, the difference between ecotope and vegetation fades away and classification concerns both.

A hierarchy in classification

The used characteristics show a certain hierarchy by which a higher characteristic may not have to be subdivided further. For example within salty and brackish environments salt proportion (salinity) is so dominant that no further subdivisions into nutriciousness are necessary. On the other hand lower characteristics like soil spray (st) do not always have to be added to higher characteristics.
Moreover, hierarchy could cause different definitions of lower characteristics depending on current higher characteristics. For example the degree of acidity in water depends strongly on its proportion of bicarbonate (HCO_3^- ions as buffer against acidification). On land other buffers are active. So, by distinguishing land and water vegetations first you can combine both buffer systems in the concept of acidity without losing their distinction but without explanation of causes[257].

Main classification in water, wetland and land vegetations

This classification distinguishes primarily water (W), wetland (V) and land vegetations in freshwater (if heavily loaded by organic pollution marked by ‘sa’, brackish (b) and salty (z) environments). Land vegetations are subdivided further according to succession stages of pioneers (P), grass land (G), brushwood (R), and forest (H), all of them subdivided in wet (2), moisty (4) and dry (6).
Then a distiction is made according to different degrees of nutriciousness from poor (oligotrophe) to rich (eutrophe). Within rich groups acidity does not make much sense, but within poor groups it is essential because it regulates the availability of present nutrients. In acid conditions existing organic material can not be digested by any organism (pickled gherkins, dead bodies in peat).

More sp/ecific indexed vegetations

Other subdivisions are indicated by indexes. Wall vegetations (Fig. 727) like procumbent pearlwort (sagina procumbens, liggende vetmuur), yellow corydalis (pseudofumaria lutea, gele helmbloem) or ivy-leaved toadflax (cymbalaria muralis, muurleeuwebek) get the index ‘mu’. Within moderately nutricious environments pioneer and grass land vegetations can get the index ‘kr’ to indicate lime. Pioneer vegetations can get indexes like ‘st’, ‘ro’ and ‘tr’ to indicate soil spray, digged and treaded soil, often present in towns.

Some examples of coding ecological groups

For example treaded soil is densified and relatively unaccessibe by water and air. Some plants are specialised to such conditions. So, on pathways you will find well known P48tr plants (Fig. 727) like plantain (plantago maior, grote weegbree), shepherd's-purse (*capsella bursa-pastoris*, gewoon herderstasje), knotgrass (*polygonum aviculare*, gewoon varkensgras), annual meadow-grass (*poa annua*, straatgras) or pineapple weed (matricaria discoidea, schijfkamille)[258].

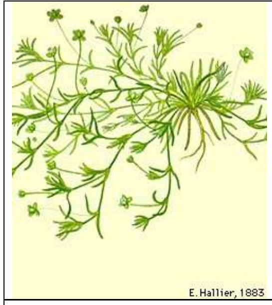			
procumbent pearlwort P40mu	yellow corydalis P40mu	ivy-leaved toadflax P40mu	plantain P48tr
			
shepherd's-purse P48tr	knotgrass P48tr	annual meadow-grass P48tr	pineapple weed P48tr

Fig. 727 *Some wall and tread plants well known in urban areas*[a]

Plants indicating an ecological group

Most plant species appear in different ecological groups simultaneously. Plants appearing in many ecotopes can live in many conditions, they have a wide 'ecological tolerance' and are less appropriate as indicators of specific conditions. Runhaar, Groen et al. (1987) distinguish two classes of tolerance. Class 1 occurs in one or two very related ecotopes only; class 2 occurs in more types. Best indicators live in one ecotope only (class 1), but they are often rare and difficult to recognise by laymen. So, to recognise an ecotope you can best identify several species living together indicating the same ecotope. The wider the tolerance the more species you have to identify to be sure about the ecotope[259]. In the ecotope system a species is classified in as many ecological groups as necessary to explain 2/3 of its presence. If species would be classified to all accidental ecotopes they ever were found the classification would be little specific.

Less specific indicators

To filter out less specific ecological groups taking up a major part of The Netherlands the classification calculates all ecotope types back to the same surface. For example sweet vernal-grass (anthoxanthum odoratum, gewoon reukgras) appears optimally in poor grass lands (G22, G42), but in a lower abundance and coverage also in more nutricious grass lands (G27, G47). However, nutricious grass lands are very common in The Netherlands and poor grass lands are rare. The consequence is sweet vernal-grass occurs most in nutricious grass lands in spite of its preference for poor grass lands. By departing from relative occurrence per ecotope type commonness of nutricious grass lands plays no rôle in classification.

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[a] Meijden (1999)

5.2.10 3m symbiosis and competition

Dependencies

Most animal species are location bound by their dependency on specific plant species. That is why we primarily concentrate on plants. For example the large copper butterfy (lycaena dispar, grote vuurvlinder) feeds only from june until half august on its host plant loosestrife (lythrum purple, kattestaart) and lays its eggs only on its breeding plant a water dock (rumex hydrolapathum, waterzuring) in weak condition (a healthy specimen defends itself against damage by insects). This typical combination is found in The Netherlands in peat counties between Friesland and Overijssel only. So, large copper butterfy is rare in The Netherlands.

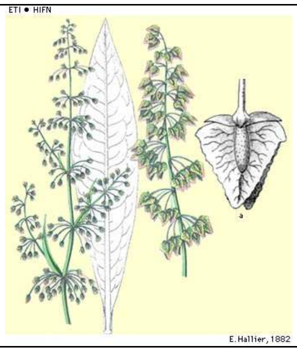	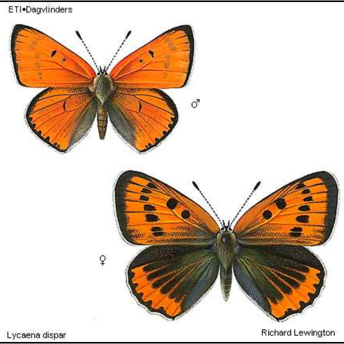	
water dock (waterzuring) V18,V19	*large copper butterfy (grote vuurvlinder)*	*loosestrife (kattestaart) R27,R28, H27,H28,V17*

Fig. 728 *Symbiosis of copper butterfy with breeding and host plant Interactieve ETI CD-ROMs Heukels flora en vlinders*[a]

An other example of specific dependency is a common night butterfly tyria jacobaeae (jakobsvlinder, Fig. 729) laying its eggs on common ragwort (senecio jacobaeae, jakobskruiskruid).

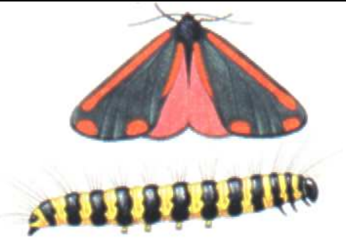	

Fig. 729 *Tyria jacobaeae and its breeding plant common ragwort on the roof of the faculty* [b]

Common ragwort is very poisonous except for Tyria jacobaeae's caterpillar. It stores the poison. So, the caterpillar and the butterfly are poisonous for their enemies.

Rare plants on poor grounds

If presence or digestibility of minerals are a limiting factor, only rare specialists can survive. By manuring exactly these rare species loose competition of common and fast growing species. A nutricion poor environment not only selects rare species but also diminishes defence of plants. Weak plants are better digestible by herbivores and insects. One often recognises rare vegetation by a multitude of insects and their predators like birds.To avoid leakage of catched ions on poor grounds plants build cholesterol in their membranes instead of sitosterol. However, sitosterol makes cell walls stronger and plants less digestible by herbivores (from cow to caterpillar). Where less herbivores

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[a] Meijden (1999); Halder, Wynhoff et al. (2000); Meijden (1999)

[b] Chinery (1988)

survive the ecosystem supports less species.[260] Cows on a richly manured meadow bend as far as they can over the fence to eat grass from a neighbouring unmanured meadow, leaving the manured grass uneaten. A farmer gladly puts an ill cow on an unmanured meadow.

Salt and acid diminish digestibility of minerals leaving space for specialist plants and peculiar ecosystems. Soured forests are rich in parasites. The abundance of great titmouses increased in soured forests though they suffered lack of calcium. Their eggshells became thin[a].

Plants and insects

The relation of every Dutch plant species with animals - particularly insects – is described in Weeda, Westra et al. (1985); Weeda, Westra et al. (1987); Weeda, Westra et al. (1988); Weeda, Westra et al. (1991); Weeda, Westra et al. (1994) . The autoritive Meijden (1996) (see Fig. 674) refers to this publication naming volume and page.

The question how animals recognise ‘their’ plants depends on perception of smell, colour and form. The recognisability of plants for their matchmakers, the insects, culminates in their reproduction organs, their flowers. The question how pistils recognise ‘their’ pollen is a vast area of mircoscopical research. Fertilisation requires coordination in space and synchronisation in time between plant and animal.

Small populations at risk

After the problem of fertilisation the problem of seed dispersion follows. These problems occur on different levels of scale. Topographic, demographic and genetic isolation of populations decreases genetic biodiversity and increases risk of dieing out. On a minimum population area after 50 generations 10% of genetic material may be left, decreasing adaptability and probability of survival. Genetic deterioration becomes a big problem. A minimum population area is not sufficient for conservation of genetic variation and impels making gene banks of threatened species.

Connections between populations

This is an important subject for nature conservation and spatial planning. The Dutch Nature conservation plan LNV (1990) and its succesors stimulate a main ecological infrastructure (EHS, see paragraph 5.5.1) to connect important natural areas by corridors for genetic exchange. This is more important for mammals and reptiles than for birds, insects and plants. However, for mammals and plants narrow corridors are very species-specific. Depending on their lay-out they work for one species and not for other ones. For plants - the basis of any food chain - isolation could even be preferable to avoid invasion of fast growing common species. Rare species often grow and disperse slowly. So, ecological infrastructure will haven little favourable botanical impact and sometimes even negative[261]. For vegetation local diversity is a better investment than connections.

5.2.11 30cm individual strategies for survival

According to Grime, Hodgson et al. (1988) plants have three differerent strategies for survival:[262]

1 growing fast, reproduce and evacuate ("ruderals" like chickweed, *stellaria media,* vogelmuur);
2 develop competition power, then reproduce ("competitors" like rosebay willowherb, chamerion angustifolium, wilgenroosje);
3 endure difficult circumstances other species avoid and reproduce when possible ("stress-tolerators" like cowslip, primula veris, gulden sleutelbloem)

Growing fast or slow

Cickweed can produce seed a fortnight after gemination. It is record-holder of Dutch plants in that respect. The rosebay willowherb goes up fast to compete with other plants, but can weaken by shortage of minerals and fall down. The cowslip is a specialist surviving in circumstances other plants do not.

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[a] "Koolmees zwelgt in verzuurde bossen", Bio Nieuws nr. 5, 22 november 1991.

ruderal
Chickweed (vogelmuur)
P48,P68

competitor
Rosebay willowherb (wilgenroosje)
R47,R67, H47,H62

stress-tolerator
Cowslip (gulden sleutelbloem)
G43,G47kr,H43,H47

Fig. 730 Three strategies for survival according to Grime (1988)[a]

Ruderals are found in newly occupied areas (pioneer stage, see Fig. 732), stress tolerators in developed ecosystems (climax stage) with less minerals.[263] Agricultural activity aims at fast growing crops like ruderals and competitors. So, human impact is often not in favour of stress-tolerators. Stress-tolerators are often protected plants.[264]

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[a] Meijden (1999)

5.3 Ecologies

5.3.1 Generalisation

Generalisation is dangereous, especially if small differences can produce great effects. That is the case in ecology. Biodiversity between species and between specimens within any species is multiplied by the number of contexts they live in. And the physical and social context of any location is different from any other location because every location is unique if only because of its location between the other locations of the Earth's surface. That diversity is a risk cover for life. But there are different differences. Some of them we call 'equality'. Equality is the basis of expectations. The ecological expectations of our common future are gloomy. However, our imagination covers more than expectations, it opens up possible futures as well as probable ones. The modality of possibility requires an other way of reasoning than probability.

In the advanced technology of pattern recognition the emphasis on similarity shifts into a focus on dissimilarity (Pekalska, 2005). Following that track broadens the view into unexpected, improbable possibilities, opened up by difference. Differences are observable at boundaries. So, it's worth the effort to study boundaries rather than homogeneous areas. They determine the areas, not the reverse. Perhaps it produces cross-border insight.

5.3.2 Six kinds of ecology

Besides autecology and synecology we know environmental science emphasising human society and health, cybernetic ecology emphasising space-time relationships, system dynamics ecology stressing abiotic points of departure and chaos ecology stressing unpredictability from minor earlier events. Their approach and terminology differ substantially:

	naming abiotics	**naming biotics**
environmental science	environment	human society
autecology	habitat	population
synecology	biotope	life community
cybernetic ecology	abiotic variation	biotic variation
system dynamics ecology	ecotope	ecological group
chaos ecology	opportunities	individual strategies for survival

Fig. 731 *Ecologies*

The sequence in this summary may reflect a decreasing human centred approach as we ask from urbanists on their way from environmental scientists into designers of biotope cities or even further. In that perspective of urban ecology, it is important to understand the differences to avoid debates that paralysed thinking about nature policy in the Netherlands for years.

Jong (2002) describes in her thesis the strikingly separated Dutch development of the last four categories in Fig. 731 during the 20th century. The clearest controversy - between the 'holistic-vitalistic' synecology and the 'dynamical' systems ecology - represents a beautiful example of spatial dispersion in one species causing scientific diversity. Synecology primarily developed in the Catholic University of Nijmegen (Westhoff) extending to Wageningen University of Agriculture in the higher East of The Netherlands while 'dynamic' ecology originated from the National University of Leiden (Baas Becking, Odum) in the wet lower West area.

System dynamics

System ecology since Odum, E. P. (1971)[a] distinguishes 'ecosystems' containing mass, energy and information within clear cut boundaries. In particular at the boundary of an ecosystem inputs en outputs are observed and measured trough time. The inside is concerned as a 'black box'. Dependend on external conditions these observations and measurements show a 'behaviour' useful to be expected in other situations.[265]

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[a] Odum, E. P. (1971). Fundamentals of ecology. Philadelphia, W.B. Saunders Company.

	PIONEER	CLIMAX
Energy		
Net production	high	low
Food chains	linear	web
Community structure		
Total amount of organic material	small	large
Inorganic nutrients	extrabiotic	interbiotic
Species diversity	low	high
Spatial diversity	low	high
Life characteristics		
Niche specialisation	wide	narrow
Sizes of organisms	small	large
Life cycles	short, simple	long, complex
Nutrient cycles		
Mineral cycles	open	closed
Nutrient exchanges	fast	slow
Reuse	unimportant	substantial
Selection pressure		
Growth strategy	fast	controlled
Production	quantity	quality
Homeostasis		
Symbiosis	undeveloped	developed
Nutrient conservation	small	substantial
Coicidence	high	low
Information	little	much

Fig. 732 *System dynamic stages*[a]

5.3.3 Scale classification

A number of scale classifications summarised by Haccou, Tjallingii et al. (1994), Klijn (1995), Kolasa and Pickett (1991) preceded Fig. 733. Such a classification is required to weigh rarity, replacebility, potential of territory and planned human artifacts. The biological nomenclature is less articulated (factor 10?) than the urbanistic as yet (factor 3), but it proceeds to smaller measures (from 10000km until µ). That is why we fill the gaps by abiotic nomenclature as coincidentally larger frames of smaller biotic components to get comparable urban units (3km radius towns, 1km districts, 300m neighbourhoods and so on). So, we consider the earth to be subdivided in biomen, a continent in areas of vegetation, a geomorphological unit in flora counties, a formation in landscapes, a hydrological unit in communities described by Westhoff and Held (1969) and Meijden (1996), a soil complex ecological groups described by Runhaar, Groen et al. (1987) and Meijden (1996), a soil unit or its structural parts by cooperating or competing organisms. In passing ecologies of different focus get their own level of scale supposed to be optimal for their application. However, this supposition is still arbitrary.

Territorial and taxonomic classification

The synecological classification of communities and the system ecological classification of ecological groups have their own levels of scale but their intention is more taxonomic than territorial. So, biotic components have a larger scale span than the scale classes employed here to be comparable with urbanistic classes of smaller span. Synecological ‘classes’ can take up kilometres, their subdivisions in ‘orders’, ‘unions’ and ‘associations’ can take up metres. An ecological group (see Fig. 726) like P48 (pioneer vegetation on moisty, very nutricious soil) can have a radius of 1km, but a vegetation P40mm (on moisty walls) could be restricted to 100mm. An example of large scale span on species level is known from fungi. Some of them are the largest organisms on Earth, their mycelium extends to hunderds of metres.

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[a] *Odum (1971) page 252*

Ecologies per scale

However, to be able to compare different locations we keep up these names with the supposed modal size (30m for ecological groups) as nominal measure.

nominally	abiotic frame	nominally	biotic components	ecologies
kilometres radius				
10000	earth	3000	biomen	Geography
1000	continent	300	areas of vegetation	
100	geomorphological unit	30	flora-counties	
10	landscape	3	formations	landscape ecology
metres				
1000	hydrological unit, biotope	300	communities	synecology
100	soil complex, ecotope	30	ecological groups	systems ecology
10	soil unit, boundaries	3	symbiosis and competition	cybernetic ecology
millimetres				
1000	soil structure and ~profile	300	individual survival strategies	autecology
100	coarse gravel	30	specialization	biology
10	gravel	3	integration	
1	coarse sand 0,21-2	0.3	differentiation	
micrometres (μ)				
100	fine sand 50-210	30	multi-celled organisms	microbiology
10	silt 2-50	3	single-celled organisms	
1	clay parts < 2	0.3	bacteria	biochemistry
0,1	molecule	0.30	virus	

Fig. 733 *Ecological units*

Fig. 733 is a preliminary and rough attempt to name abiotic and biotic components by scale. Any level of scale has its own nameable diversity and dynamics. It has to be discussed, elaborated and renamed by ecologists more precise. Perhaps different approaches in ecology appear to have their own level of scale, accessible to designers giving measure to the urban context on that scale.

On different levels of urban scale we could need different approaches; for example:

- R=300m Communities in biotopes
- R=30m Ecological groups in ecotopes
- R=3m Symbiosis and competition
- R=30cm Individual survival strategies

5.3.4 Cybernetics

This paragraph[a] discusses the one-sidedness of an emphasis on ecological connections in nature conservation and spatial planning. It traces back the track of Dutch nature conservation thinking, into the typical Dutch ecologist Van Leeuwen stressing separations to restore the balance.

The emphasis on boundaries apart from areas

As a student at the Faculty of Architecture in Delft my favourite lectures were those of architect Aldo van Eijck and ecologist Chris van Leeuwen.

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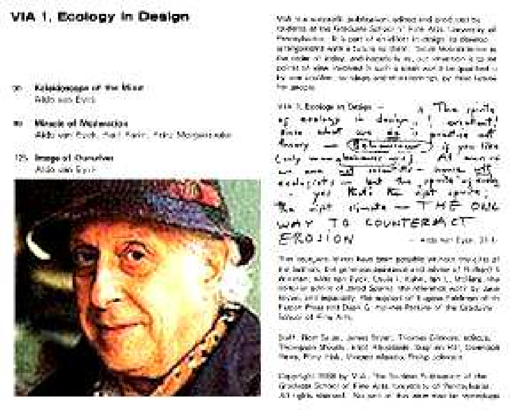
[a] Based on a lecture for the Dutch-Flemish association of ecology NECOV 2005-01



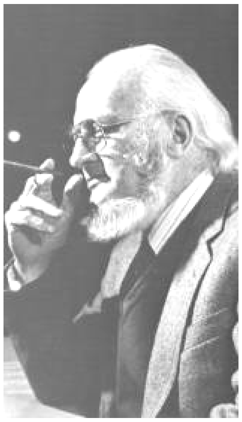


Fig. 734 Aldo van Eyck[a]

Fig. 735 Chris van Leeuwen[b]

Both emphasised the boundaries between spaces instead of the character of the spaces intself. 'The boundary makes the difference; that's where it happens' they argued.
After all, the task of urban and architectural designers is to draw boundaries. Designers cannot do much more than drawing boundaries to make spaces visible and usable.

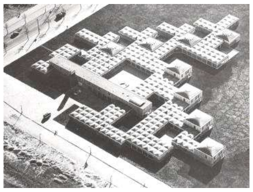


Fig. 736 Van Eyck (1955-1960) Burgerweeshuis (Amsterdam)[c]

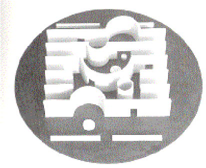


Fig. 737 Van Eyck (1965) Sonsbeek paviljoen (Arnhem)[d]

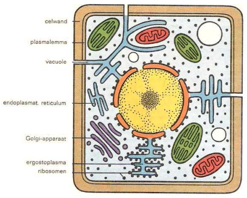


Fig. 738 The cell and its membranes[e]

In the seventies Aldo van Eijck could give a lecture without a break for six hours on only a few images from Mali reporting his experiences of Dogon architecture (A.E.v. Eyck, et al., 1968). The Dogon live at a spectacular landscape boundary. Nobody wanted to miss his rare and fascinating lectures and nobody in the overcrowded classroom was bored for one moment by his humorous and furious criticism of Western culture.

· Inbetween realms

Fig. 739 An entrance as a seat: a 'twin phenomenon' or 'in between realm'

I remember an image showing the entrance of a hut with thick walls. The entrance had the form of a tree or fungus (see *Fig. 739*).·

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[a] *Eyck, 1986*
[b] *Schimmel, 1985*
[c] *Ligtelijn, 1999*
[d] *Ligtelijn, 1999*
[e] *Vogel; Günter; Angermann and Hartmut (1970) page 18*

So, you could sit in this boundary environment without being forced to choose between inside or outside. You got coolness from the shade or warmth from the sun simply by changing position. Van Eijck called such locations not forcing us to choose 'in between-realms' or 'twin phenomena'. He reproached our culture for forcing choices between false alternatives: "Would you like to breathe in or out?".

Van Leeuwen

The emerging environmental awareness of the seventies made the lectures of Van Leeuwen popular as well. Many remember them. Shortly before his death he attended a conference dedicated to his work (D.J. Joustra, et al., 2004), organised by former students in urbanism and architecture.[a] However, the speeches of that conference showed very different applications, (especially in the field of urban renewal) based on vague interpretations contrasting with Van Leeuwens own usual precision.

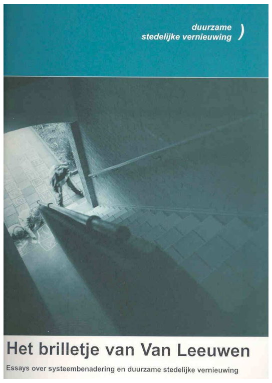

Fig. 740 Conference 2004[b]

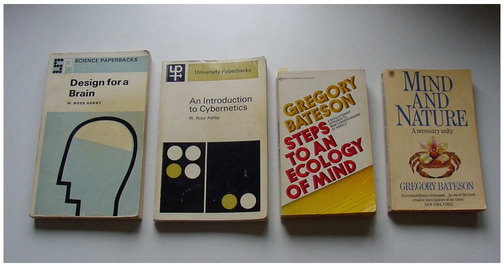

Fig. 741 Van Leeuwens references[c]

He knew the outdoor nature like no one else, but at the same time he was an armchair scholar, writer of many dispersed articles and lecture notes (C.G. van Leeuwen, 1971) surprising colleagues and fascinating designers.

Open-closed theory

His 'open-closed theory' (Leeuwen, 1964) was the subject of dispute with his friend and close colleague Westhoff from the University of Nijmegen at the former national institute of nature conservation (RIN). Westhoff, et al. (1975) developed according to Braun-Blanquet (1964) a Dutch synecological system of life communities now elaborated by his successor (Schaminee, et al., 1995) and translated to nature target types (Bal et al., 2001) applied in the actual policy of the Dutch ecological network (NEN). However, that operational approach now loses foundation in the perspective of climate change.

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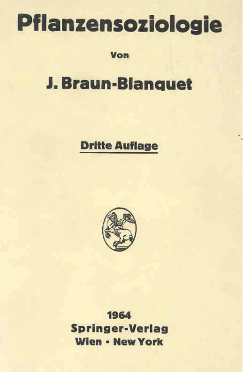
[a] Vries (2008)
[b] *D.J. Joustra, et al., 2004*
[c] *Ross Ashby, 1957, 1965; Bateson, 1980, 1983*



Pflanzensoziologie

Von

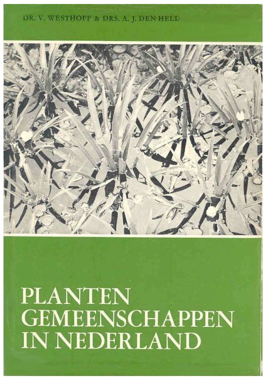
J. Braun-Blanquet

Dritte Auflage

1964
Springer-Verlag
Wien • New York

Source:

Fig. 742 Braun Blanquet[a]

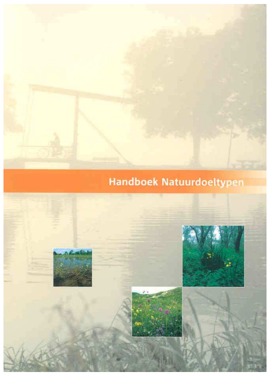


DR. V. WESTHOFF & DRS. A. J. DEN HELD

PLANTEN
GEMEENSCHAPPEN
IN NEDERLAND

Source:

Fig. 743 Westhoff's synecology…[b]



Handboek Natuurdoeltypen

Source:

Fig. 744 …translated into Dutch nature target types[c]

Van Leeuwen made field inventories himself for many years. Based on that experience he emphasised transitions between such supposed life communities rather than determining the communities themselves (Leeuwen, 1965). Precisely there he saw most rare species, especially if such a transition was spun out along a broad strip (gradient) into an infinite range of unnamed particular environments on a smaller scale. There the ecologically most interesting specialists settled.

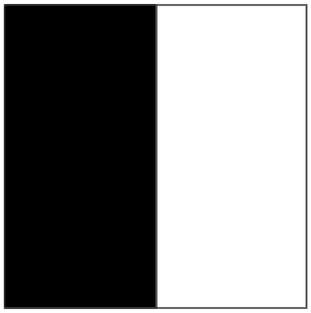


Fig. 745 Limes convergens

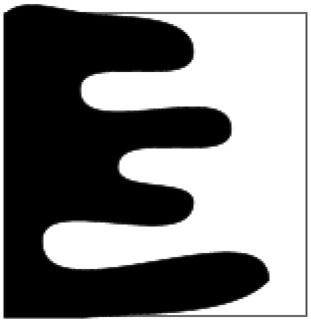


Fig. 746 Boundary rich

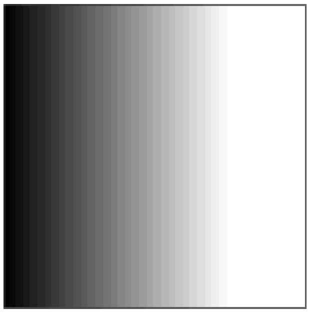


Fig. 747 Limes divergens (gradient)

Van Leeuwen surprised colleagues by predicting the square metre where a specific rare plant species could be found. For example I witnessed him when he was already at an advanced age looking around and indicating the place where the Carex pulicaris ('flea sedge', 'vlozegge') should grow. However, the manager of the area never found that species on his territory. The bystanders went on their knees and found the predicted flea sedge. Van Leeuwen did it intuitively, based on 'phenomenal' field knowledge.

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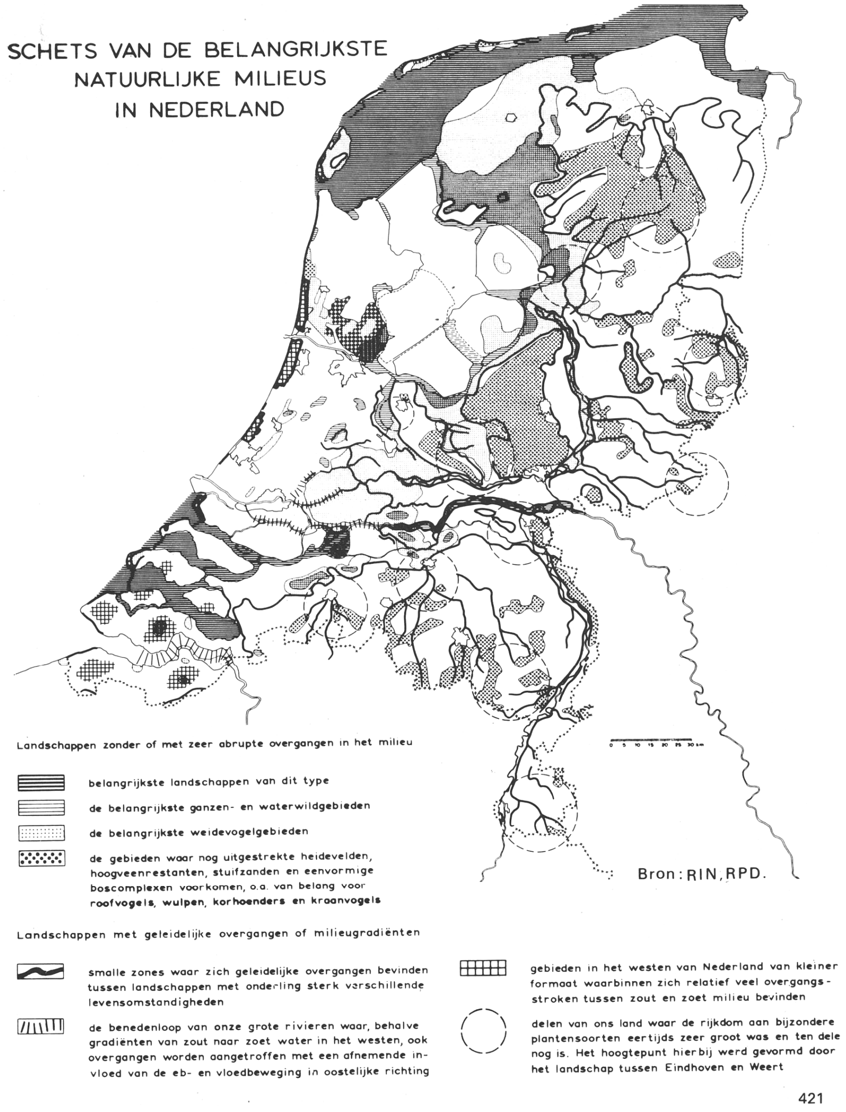
[a] *J. Braun-Blanquet, 1964*
[b] *Westhoff, et al., 1975*
[c] *Bal, et al., 2001*

Gradient map in national planning

This line of thought was the guideline of the Dutch Second National Policy Document on Spatial Planning (RPD, 1966), by which Van Leeuwen's 'Gradient map' was published (see *Fig. 748*).



Bron: RIN, RPD.

Fig. 748 'Gradient map' in the Dutch Second National Policy Document on Spatial Planning[a]

Citing RPD (1966) :'Gradients are narrow zones with gradual intermediate stages between landscapes with mutual strongly different life circumstances. Examples are contact zones between salt and fresh water environments, between relatively dry and wet areas, between poorly and richly nutricious landscapes and slopes in high areas. Within or directly near these gradual zones one finds a great gradation of environmental types in small compass and as a result a large richness of plant and animal species. To this richness belong nearly all rare plant species in our country. Moreover, here are the regions where in the Netherlands natural edge of wood thickets can develop.
Furthermore, the 'conservative' character of these transitional environments is typical. This assures continued existence of species concerned at these locations, subject to not disturbing the transitional environment fully by changes caused by modern agricultural methods.'

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[a] *Leeuwen, Gradientenkaart RPD, 1966*

5.3.5 Regulation theory

Relation theory

However, Van Leeuwen could not record that experience in writings otherwise than by sketching a very theoretical framework known as ‘relation theory’. That theory is dispersed in many articles and elaborated in different separate directions, always surprising by unexpected relations between ‘down to earth’ examples. It led to his being made an honorary doctor of the University of Groningen (1974), but the same University published a doctoral thesis judging that theory to be invalid on mathematical grounds (Sloep, 1983). However, the same critique applied also to other ecological theories not studied by Sloep. Opposite that most readers and certainly listeners got the feeling of a crystal-clear and simple framework, relevant to many questions concerning design, spatial planning, urban renewal and nature conservation. At last Van Leeuwen agreed to name his theoretical framework more precisely ‘regulation theory’, according to his cybernetic references of steering and disturbing.

Spatial and temporal variation

One of the first schemes I remember from Van Leeuwen’s lectures shows some basic notions of that theory (see *Fig. 749*). Firstly it shows the possibility of a negative relation between pattern and process in ecosystems in terms of spatial and temporal variation. So, in general difference correlates to stability (often found near vague boundaries), equality to change (often found near sharp boundaries). However, I realised many years later this rule cannot be applied on any level of scale if you take the scale paradox (see Fig. 825) into account.

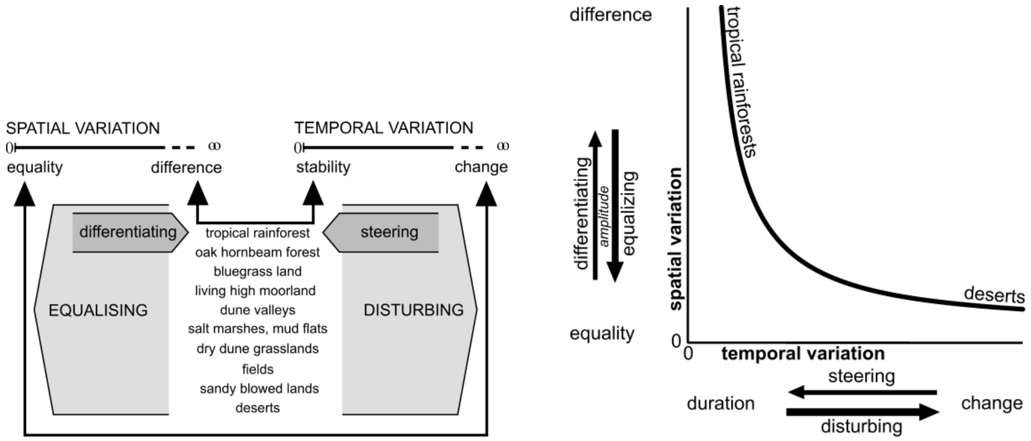

Fig. 749 Spatial and temporal variation in the theories of Van Leeuwen[a]

According to Ross Ashby (1957, 1956) ‘equality’ is not regarded as the opposite of ‘difference’ but as its near-zero-value. After all, any imagined difference can always be made more different by adding attributes of difference (for instance difference of place, distance), but it cannot always be made less different. A difference less than the least difference we can observe or imagine is called ‘equality’. So, ‘difference’ and ‘change’, ‘equality’ and ‘stability’ in the scheme are all taken as values of ‘variation’ (the variable to be distinguished spatially and temporally).

To concern equality as a special kind of difference is contrary to the main presuppositions of usual mathematics, the science of equality (you cannot count different categories) and equations. However, chaos equations like $y_{x+1}=a\cdot y_x-(a\cdot y_x)^2$ where a>3.6 produce chaotic behaviour even different on different computers using different roundings off (see *Fig. 750*).
The same applies to very small differences of initial values in complex models producing very different results.

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[a] *author, derived from the lectures of van Leeuwen in 1972*

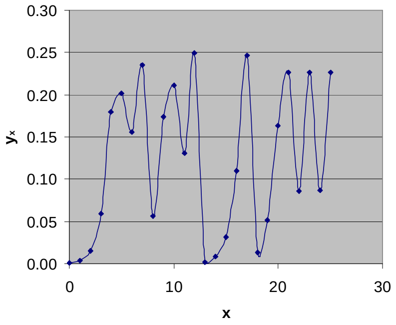

Fig. 750 Chaotic behaviour of $y_{x+1}=a\cdot y_x-(a\cdot y_x)^2$ where $y_0=0.001$ and a = 4

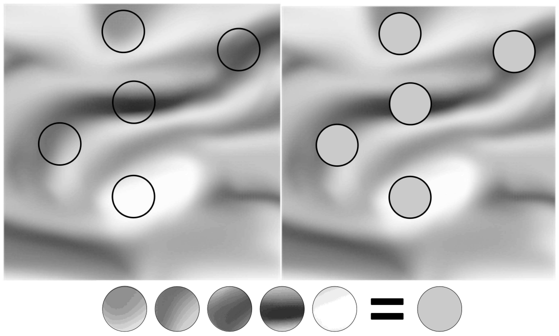

Fig. 751 Reduction to the average

·The main problem is, mathematical treatment of quantities presupposes qualitative categorisation reducing differences to an 'average' (see *Fig. 751*), tacitly supposed in set theory.

Disturbing and steering

Proceeding that way, Van Leeuwen supposed processes of a second order on both pattern ('process on pattern') and process ('process on process') called 'differentiating' and 'steering' with 'equalising' and 'disturbing' as zero-values (see the grey arrows in left *Fig. 749*). Because these processes are changes as well, they are disturbing and equalising by definition. Stopping a process of disturbing is disturbance as well. Suddenly cleaning a ditch or decreasing the number of grazers could deteriorate the condition of the ecosystem unexpectedly. The consequence of this view appeared to be a recommendation not to change the condition too sudden: clean the ditch or decrease the number of grazers slowly according to the adaptation speed of the system.

So according to Van Leeuwen it is easier to break down differences (equalising) then create them (differentiating) and at the same time it is easier to introduce changes (disturbing) than to guarantee duration (steering). This is a simple verbal expression of the second law of thermodynamics in the perspective of cybernetics. Within that interpretation 'life' is represented as a phenomenon climbing up into local diversity and duration at the cost of global disturbance located elsewhere.

5.3.6 Separation and discontinuity

Second order patterns and processes

Regulation theory became more complicated as soon as Van Leeuwen started to look for a second order of *patterns* as well: 'pattern on pattern' ('structure', ranging from 'separation' causing difference, into its zero value 'connection' causing equality) and 'pattern on process' ('dynamics', gradual ('continuity') or sudden ('discontinuity') changes and stops, causing stability or change). Later I realised distinguishing levels of spatial and temporal scales might simplify the argument and put it into perspective. Perhaps the primary supposition about a negative relation between pattern and process is limited to certain levels of scale explaining exceptions. Perhaps concepts like 'pattern on pattern' are simply a question of scale. 'Difference' is a scale sensitive concept after all (see Fig. 825). Moreover, difference, equality, separation and connection are direction-sensitive.

Ligitimate questions

Anyway, many legitimate questions remain. I will summarise some, but not answer them here. The very first question is: "Is this science?". How could you make categories as general as difference and change or separation and connection operational for tests by empirical research? Should you not distinguish different kinds of difference (for example abiotic, biotic differences, differences observed on different levels of scale) to find mutual relations? What causes what? Are the second order variations dominant? Does separation cause difference or the reverse? How could you imagine separation without difference?

Elaborating these questions you come across fundamental epistemologic questions similar to those I know from the debate about academic design (Jong and Voordt, 2002). They go beyond critics like those of Sloep because equality itself is disputed. Consequently the use of categorisation presupposed in any variable is attacked. The very core of that debate in practice is the question how to generalise solutions of context-sensitive problems bound to specific unique locations and contexts. That question applies to ecology as well, confronted with a confusing diversity of species multiplied by a diversity of specimens and contexts. Management theory also struggles with the inapplicability of reduction into the ‘average’ (see *Fig. 751*) from empirical science (Riemsdijk, 1999).

From a designer’s point of view many design decisions in specific contexts cannot be supported by empirical research aiming at generalisation. “That conclusion does not apply to this specific location!” designers complain. Van Leeuwen’s approach offered a terminology directly fitting to design acts par excellence: separating and connecting. It functioned as a great heuristic tool, but many applications fell prey to confusion of scale by lack of scale articulation. Let us now go back to ecological practice.

Meadowland as a fringe laid out

Shortly before his death Van Leeuwen offered me a clarifying example.
Between meadowland and forest in natural circumstances a fringe emerges through herbivore grazing (see *Fig. 752* and *Fig. 753*).

These animals mow with their long necks over the boundary of their reach without treading or manuring (floating head). By doing so, they create prototypes of meadowland. In meadowland (a fringe laid out) without manuring, mowed without treading of note (‘hooiland’, an alternative etymology of ‘Holland’) you find species like Serratula Tinctoria (‘saw-wort’, ‘zaagtand’) not to be found elsewhere. Species rich steppe grasslands like in the Ukraine and Russia are comparable with meadowlands. Why are there species rich (hundreds per m^2) and species poor (one per ha) grasslands? Instability of a specific temporal scale between dry and wet, cold and warm, fresh and salt seems to be the most important factor.
Such an instability reinforces itself: a dense, solid soil emerges with Plantago Major (the tread plant ‘common plantain’, ‘weegbree’). Water remains there, but also flows away easily.

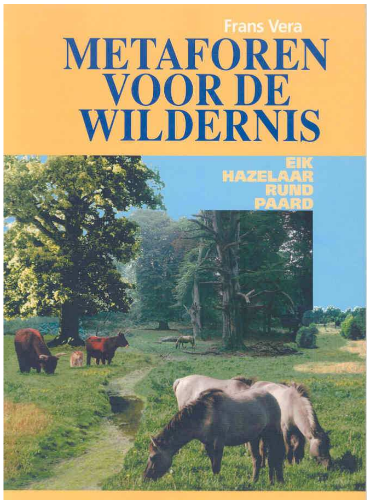

Fig. 752 Metaphors of wilderness[a]

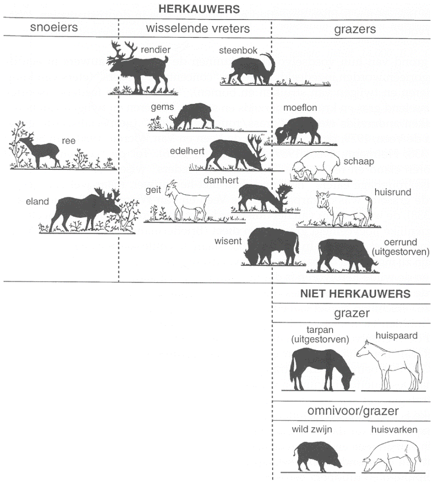

Fig. 753 Pruners, alternating grubbers, grazers[b]

That is why even more powerful alternations between wet and dry, cold and warm arise, which cannot to be endured by many plant species. In Moscow dryness is locally suppressed by the fire brigade, again reinforcing disturbance and condensation of the soil. However, a slope stabilises. In the Netherlands plantago major never grows on a slope, because the contrast between wet and dry is too small. There, other plant species can survive stabilising the environment even further. The Russian

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[a] *Vera, 1997*
[b] *Vera, 1997*

species rich steppe has, unlike a desert a stable water balance horizontally and vertically. A desert becomes brackish by evaporation and consequently rising water (ascending moist flow). Salinisation by irrigation is a well known phenomenon. So, a linking between wet-dry, cold-warm, salt-fresh alternation arises there, which does not happen in species rich steppes. Against temporal changes there are stable spatial transitions based on selective separation.

5.3.7 Selectors and regulators in the landscape

Connection supposes separation

What I would like to bring to the fore is the importance of inaccesibility, isolation, in this case for large mammals. As the concept of ecological networks (ecologische infrastructuur) started its triumphal progress in the Netherlands (D.de Bruin et al., 1987, 'Plan Ooievaar'; primarily based on separation), connections are primarily emphasised.

Fig. 754 The 'Plan Ooievaar'[a]

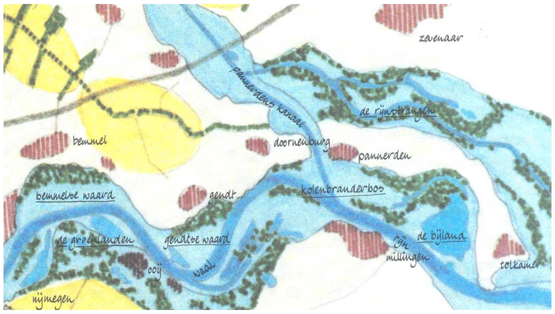

Fig. 755 Separation of nature and agriculture: zoning, selection, regulation, 'ecological networks'[b]

I would like to set against that emphasise for a while one-sidedly, the importance of separations to arrive at the middle (mi-lieu). The concept of 'structure' (litterally 'brickwork') comprises both separation and connection. Exactly their combination produces particular environments where specialists are at ease. Researching that kind of environment could be named 'structure ecology'. In terms of regulation theory both isolation and connection are a value of separation. Connection is solely a zero value of separation. Connection supposes separation, not the reverse. There are no windows without walls. But there is 'difference in separation', always a combination of separation and connection while separation directs connection.

Selectors and regulators

The first notable combination follows on the 'basic paradox of spatial arrangement' as Van Leeuwen named it: the phenomenon of separation perpendicular to connection.

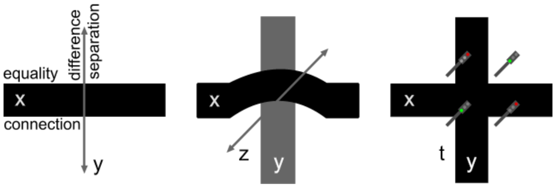

Fig. 756 Basic paradox of spatial arrangement

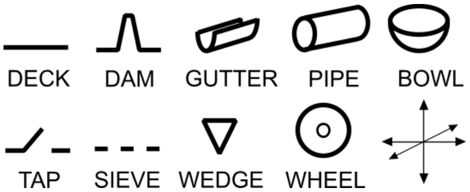

Fig. 757 Selectors[c]

A road is laid out to connect, but perpendicular to that connection it separates. That is painfully felt at crossings. The solution to connecting perpendicularly to the other connection is separating vertically (viaduct) or in time (traffic lights, see *Fig. 756*). However, there are more combinations of separating

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[a] *Bruin et al., 1987*
[b] *Bruin et al., 1987*
[c] *Leeuwen, C.G.v. (1979-1980) Ekologie I en II. Beknopte syllabus*

and connecting. Deck, dam, gutter, pipe and bowl are examples of ‘selectors’ in one, two, three, four and five directions, selectively connecting into the other directions. That direction-sensitive connection quality cannot be imagined without separation into the other directions. Selectors take care not *everything is going anywhere*.

Taps, lids, valves, wedges and wheels are regulators taking care not *everything is always going somewhere*. Living organisms are complex combinations of selectors and regulators known in technology as mechanisms on different levels of scale (see *Fig. 758*, *Fig. 759* and *Fig. 760*).

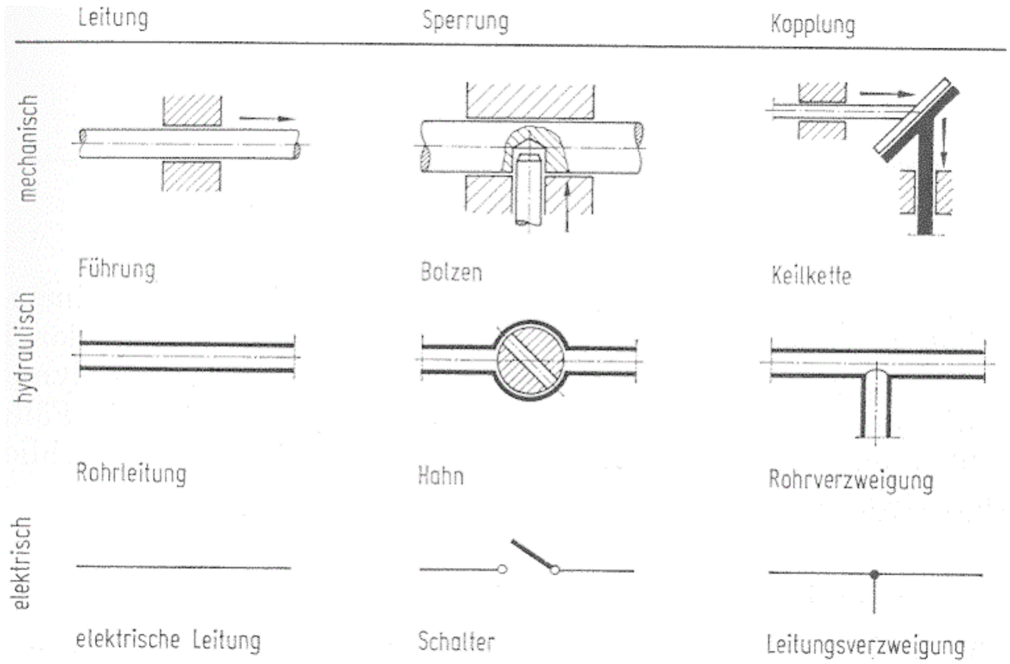

Fig. 758 Mechanical forms of selection and regulation by separating and connecting[a]

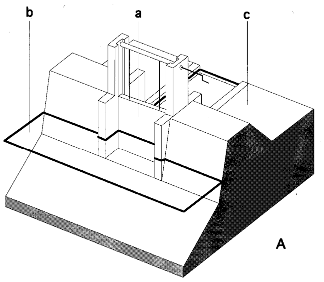

Fig. 759 Sluice closed[b]

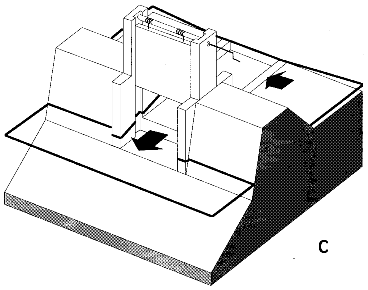

Fig. 760 Sluice open[c]

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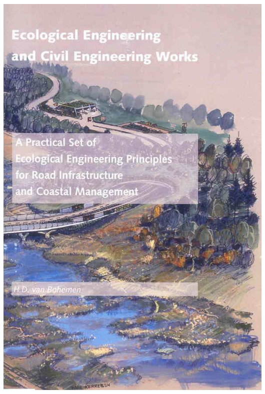
[a] *Rodenacker , 1970*
[b] *Arends, 1994*
[c] *Arends, 1994*

5.3.8 Ecological networks

In the doctoral thesis of Van Bohemen (H.D.v. Bohemen, 2004) strikes that the hundreds of millions (!) spent on ecological connections are hardly judged on their ecological effect.



Ecological Engineering
and Civil Engineering Works

A Practical Set of
Ecological Engineering Principles
for Road Infrastructure
and Coastal Management

H.D. van Bohemen

Fig. 761 Technical ecology[a]

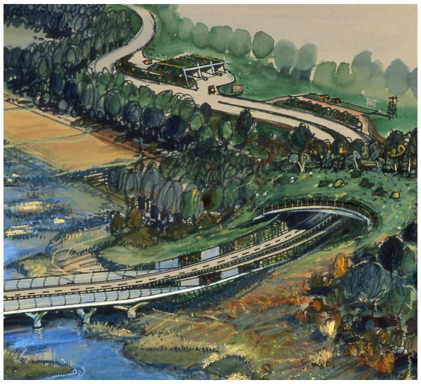


Fig. 762 Ecological connections[b]

The argument is: you have to build a wildlife viaduct before you can measure the effect. That phase is now upon us, but it is recognised that just as in epidemiological research cause and effect are difficult to separate. And then we still focus solely on the effect on populations of some species. Which effect the constructed connections show on other species is even more difficult to determine. The deteriorating effect of positive discrimination is well known from hanging on nesting-boxes: other bird species were ousted, insects died out and the plant species having them as postillions d' amour disappeared.

The impact of connections is sometimes demonstrably negative. Examples include the import of alders from Eartern Europe in the seventies or the connection of the Main-Danube canal. The connection of all parts of the world to each other (globalisation) may be the greatest danger. Connecting genetically different races could cause loss of biodiversity. That leads to the subject fascinating me most: levels of scale. At what level of scale connecting is the best strategy, and at what level of scale separating? The best argument for separating areas is the emergence of subspecies, though it takes a lot of time. A crucial question is: are we in the Netherlands in need of other large mammals than grazers if they have better and more sustainable conditions elsewhere? Could not we create in our wet country much more interesting 'ecological conditions' by separation (Tjallingii, 1996), conditions lacking everywhere else? Holland hooiland!

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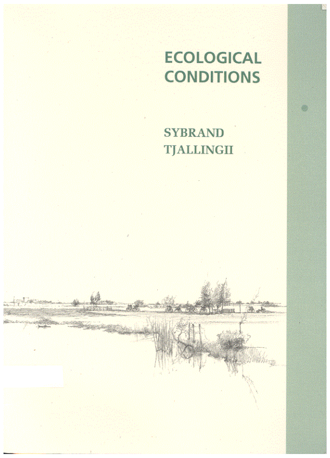
[a] *Bohemen, 2004*
[b] *Bohemen, 2004*


ECOLOGICAL CONDITIONS

SYBRAND TJALLINGII

Fig. 763 Ecological conditions[a]

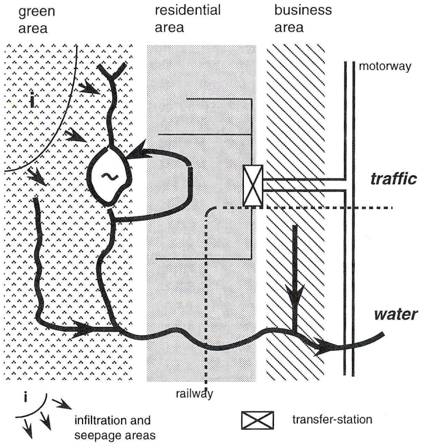
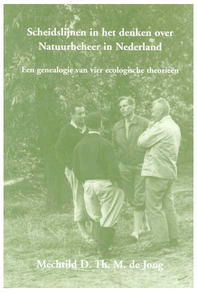


Fig. 764 Separating flows[b]

A more moderate conclusion is that ecology cannot produce general statements, though politicians would like to seduce you that way. That is what I learned from the doctoral thesis of Mechtild de Jong (2002, see *Fig. 765* and *Fig. 766*).

That methodological problem of scientific generalisation in the context-sensitive relations between one and a half million of species from which we know so little, is something shared by ecology with context-sensitive design (Jong and Voordt, 2002) and management sciences.
The problem of the classical empirical ideal to produce generalising statements (out of bits and pieces, to deduce subsequently from these statements conclusions for specific cases) increases if you realise any species comprises differently reacting individuals. That problem increases even more so, if you realise that any individual arrives in a different context. The urbanist or architect knows the problem only too well.
An ecologist is not invited to copy solutions, but to bring a local field of problems into a common solution by a unique concept. That is not solely an ecological network, but a more complete ecological infrastructure.


Scheidslijnen in het denken over Natuurbeheer in Nederland

Een genealogie van vier ecologische theorieën

Mechtild D. Th. M. de Jong

Fig. 765 Separations in Dutch ecological thinking[c]

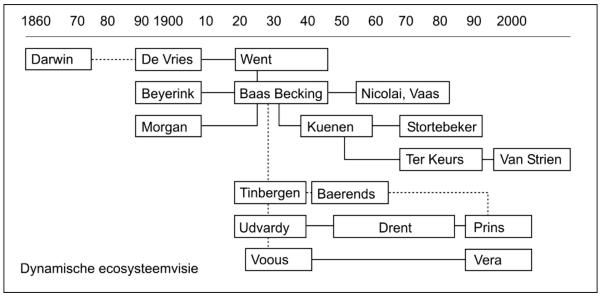


Fig. 766 A genealogy of theories[d]

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[a] *Tjallingii, 1996*
[b] *Tjallingii, 1996*
[c] *Jong, M.D.T.M.d., 2002)*
[d] *Jong, M.D.T.M.d., 2002)*

5.3.9 Urban ecology

Biodiversity in towns

Since 19^{th} century's Dutch hygienic developments in the urban area founded by Cohen (1872) and historically described by Houwaart (1991) - the very source of public housing policy and urban design - biodiversity in spaced towns outruns rural biodiversity.

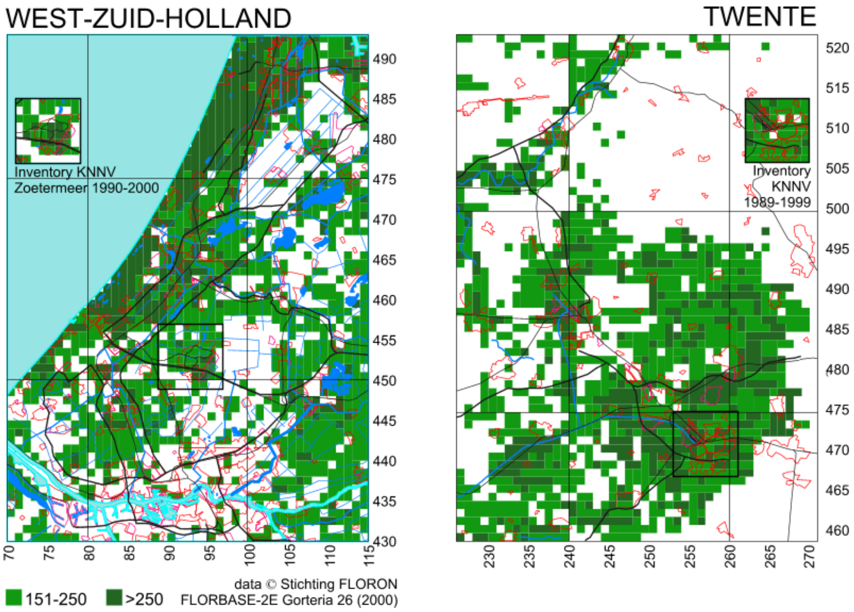


Fig. 767 *Number of wild plant species per km2 in the lower and higher part of The Netherlands*

Fig. 767 shows that some square kilometres in the urban area of Zoetermeer indicated in the left picture have more that 250 wild plant species per km^2. Local observers (like KNNV Zoetermeer, reported by Jong and Vos (1995); Jong and Vos (1998); Jong and Vos (2000); Jong and Vos (2003)) counted even more than national ones (counted by FLORON, reported by Groen, Gorree et al. (1995).

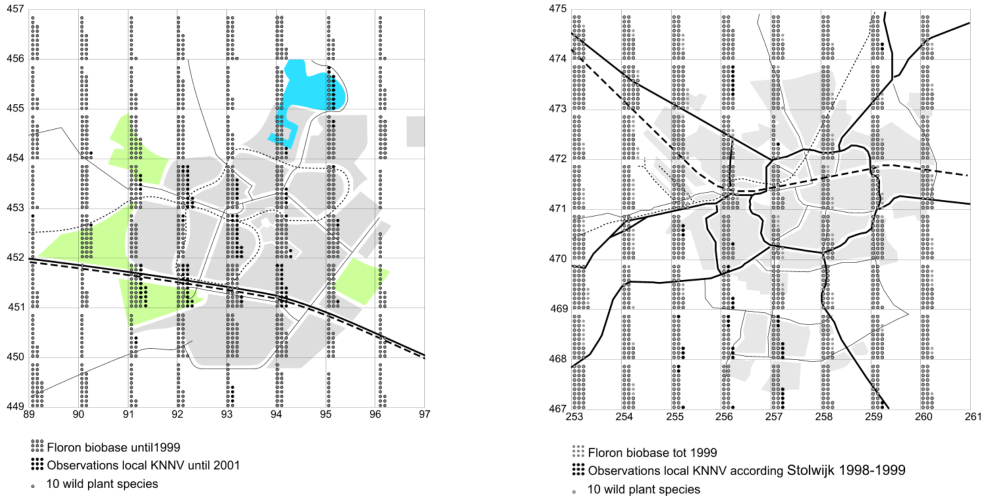
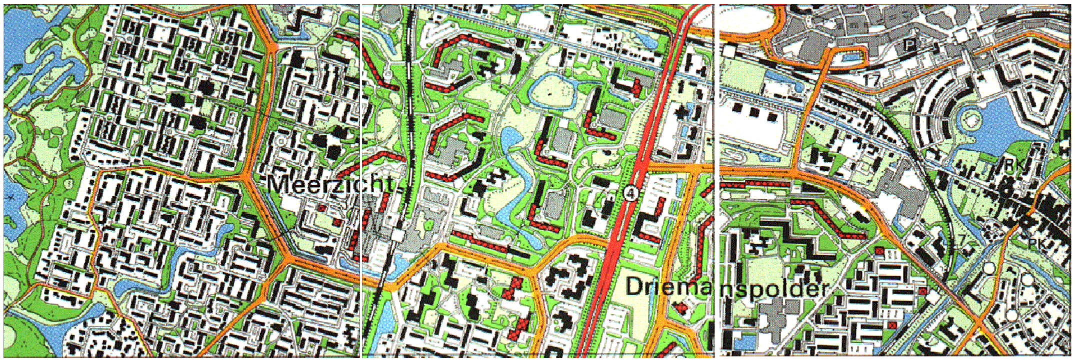


Fig. 768 *Number of plant species per km2 in Zoetermeer and Enschede*[a]

The urban area of Zoetermeer is more in contrast with the rural environment characterised by cattle breeding than Enschede (indicated in the right picture) surrounded by more natural equally rich areas. Fig. 768 shows both in more detail. Here we can see that infrastructure and industrial areas contribute more than we would expect by intuition. Their verges, slopes and rough grounds are less visited and disturbed by man and pet.

Counting species per km^2

The number of species per km2 is added up over several years. So, many species could have been disappeared, they then only show the urban potential. Moreover, some square kilometres could have been observed better than other ones, for example the outskirts.



180 low-rise outskirts

200 high-rise

330 wild plant species centre

Fig. 769 *Number of wild plant species in 3 km^2 of Zoetermeer*

Even when in the centre the plant observations were better than in the outskirts, Fig. 769 warns us for the intuitive view that biodiversity always decreases from the outskirts into the centre. The large number of observed species in the central km^2 could also be explained by urban age, abiotic variation like seepage, drainage, water level or intersection by infrastructure with verges and slopes, less influence of adjacent agriculture and manure of cattle breeding dispersed by water or wind.

So, some of these possible causes could be varied as means of design aiming urban biodiversity.

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[a] Jong (2000)

Rarity in the urban environment

Fig. 770 arranges some 500 urban plant species from the 1500 known in The Netherlands in a sequence of national rarity, naming 50 of them only. Their national presence in % of the 5x5km observation squares is recognisable in the rising line. The spots show the urban presence in % of 1x1km observation squares in Zoetermeer. So, the spots above the line are more common in Zoetermeer than in The Netherlands, the spots below less so.

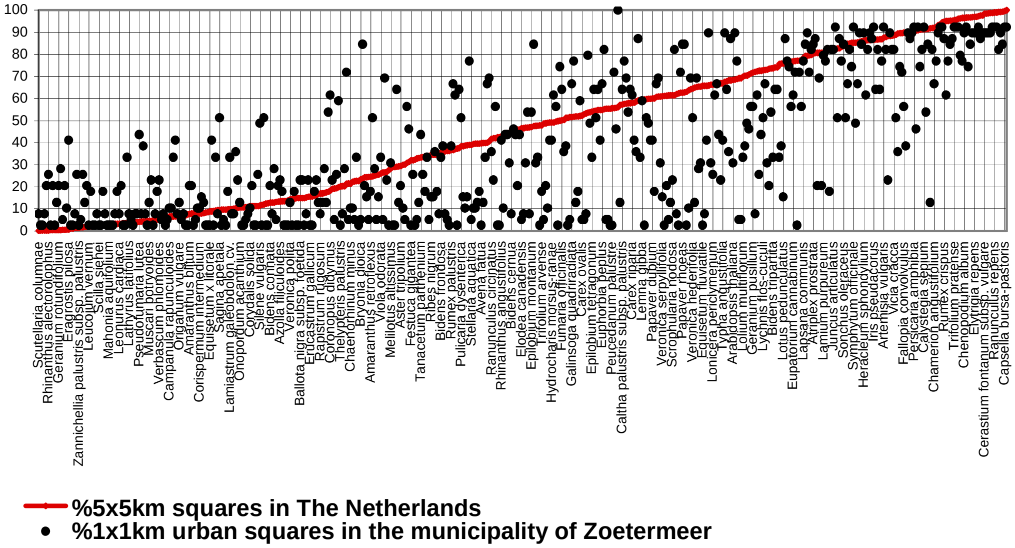


Fig. 770 *Local rarity (100% is very common) of approximately 500 plant species (only partly named) in a sequence of national rarity*

A number of nationally rare plant species in the left side of Fig. 770 evidently found their place in urban ecotopes. In the wake of urban plants and ecotopes rare insects and fungi have been observed in Zoetermeer, but seldom nationally rare vertebrates.

In 1994, it was established for the first time that the biodiversity per km^2 in Amsterdam. By Denters, Ruesink et al. (1994) and Vos (1993; Vos (1996) and Zoetermeer (Vos 1993, 1998) is up to five times higher than in the agrarian surroundings of these cities. In saying this, of course, it should be noted that the richness of species in urban ecosystems differs from that of the classical nature areas.
The agrarian surroundings of Amsterdam and Zoetermeer are not nature areas, but are a series of monocultures closely oriented to economic production. It is no wonder that the large cities show a more diverse range of species. Nevertheless, the potency of the 'urban district' should not be underestimated.

5.3.10 Distribution and abundance of people

Open space in the Netherlands is reduced by 12.5% urban and rural built area for 16 000 000 inhabitants with ample 300 m2 average built area per person. When these inhabitants were concentrated in 16 conurbations of 1 000 000 inhabitants each within 10km radius (see Fig. 702) - regularly dispersed over the country - 10 open large landscapes with a free horizon of 30km radius would be available as open space. They would be accessible within 10km from everybody's house. In empty spaces of that measure bears and eagles could find their habitat and the weekends could be filled by survival journeys we now look for in other countries once a year.

Landscapes (geomorphological units)

However, agriculture and urban sprawl have filled these potentially open landscapes. If we name an area of 30km radius still a landscape as long as there are less than 1 000 000 inhabitants, The Netherlands still have 10 landscapes (see Fig. 771). But not for long, because there are landscapes with nearly 1 000 000 inhabitants and great pressure of urban sprawl. The size of spots in Fig. 771 meets the average urban density in The Netherlands. So, where they overlap the density is higher than average.

Fig. 771 *Built and open space in The Netherlands*

Keeping landscapes open

From Fig. 771 we can conclude that concentration within conurbations (r=10km) does not help much in keeping landscapes open. Regional concentration (r=30km) does. Regional deconcentration breaks landscapes up into landscape parks or urban landscapes like happened in the Green Heart of Randstad (recently named Green Metropolis or Deltametropolis). However, deconcentration within conurbations (r=10km) could help making biotope cities. What kind of biotopes are they?

Possibilities of size

Form, size and structure of components are conditions for the function of open areas though urban functions on their turn can be the historical cause of form and structure. The landscape consultancy H+N+S in Utrecht visualised the functional charge for nature as a function of size and altitude in Fig. 772 .

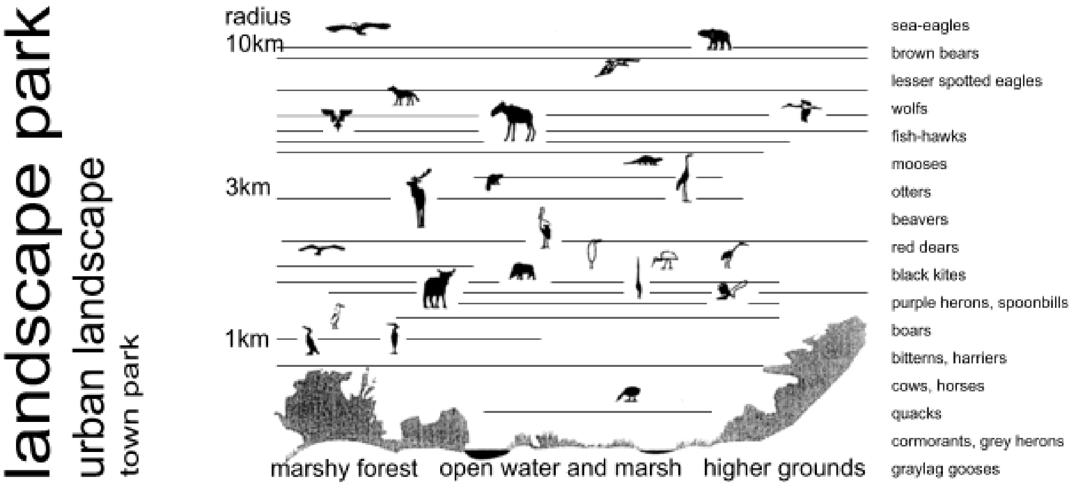


Fig. 772 Possibilities for nature by size and altitude

In Fig. 773 they summarised possibilities of human recreation as well.

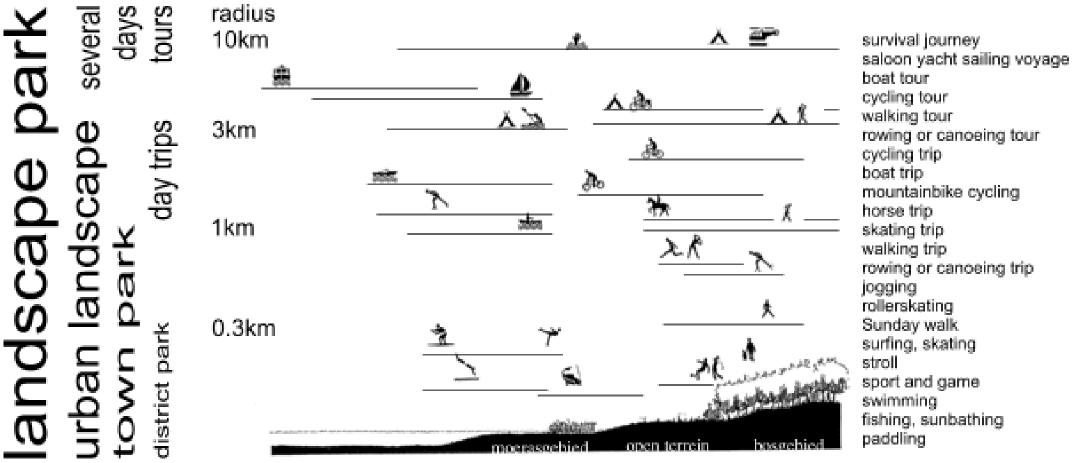


Fig. 773 *Possibilities for recreation by size and altitude*

The smaller the area the less animals could find a habitat, but that is not the case for botanical biodiversity as far as their distribution is not dependent on animals.

Parks, size and distance from residential areas

A crucial space-time dilemma of urban planning is priority for either small open spaces nearby residential areas or remote larger ones with more travel time but a better survival of animal populations and recreational possibilities.

Open area	within	radius
• Landscape	100km	30km
• Landscape park	30km	10km
• Urban landscape	10km	3km
◡ Town park	3km	1km
● District park	1km	300m
∘ Neighbourhood park	300m	100m
· Ensemble green	100m	30m

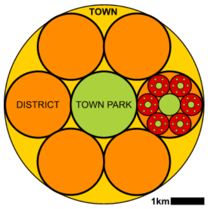


Fig. 774 *Standard green structure*

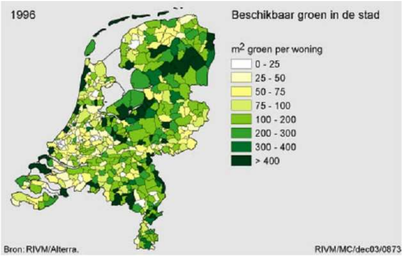
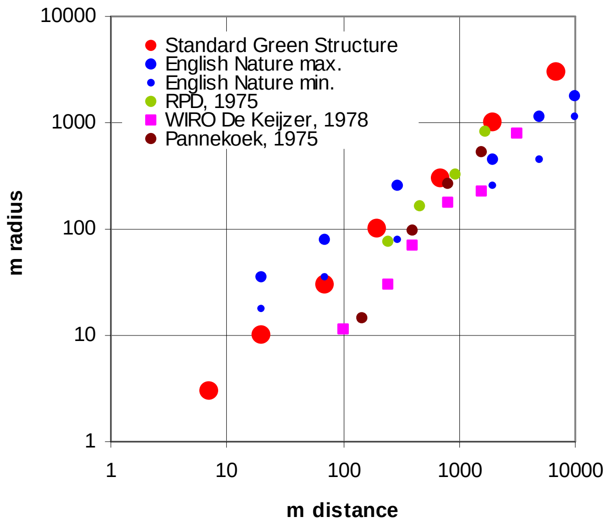


Fig. 775 m^2 Green area per dwelling

If on any level of scale in a town the green area has a size equal to the maximal walking distance (standard green structure, see Fig. 774), then the green area counts 1/10 of the total area. In that case every inhabitant of a town (approximately 30km^2, about 100 000 inhabitants) would have 30m^2 town park. The same applies on a district and neigbourhood level of scale for district parks and neigbourhoodparks. If that reasoning is extended into ensemble green every inhabitant would have have disposal of approximately 70 m^2 public green area. In the Dutch context that is a maximum (see Fig. 775), but it is an easily manageable target standard. Now you can work out how much a town deviates from that standard and which level of scale is favoured.

5.3.11 Comparing and applying standards for green surfaces in urban areas

Both green surfaces in urban areas and their distance to inhabitants can be expressed as a radius. In that case a radius r represents a walking distance *or* an area $a = \pi r^2$, equal to a circular surface of the same size. That representation of surface is more directly imaginable than huge numbers of hectares fastly increasing by a growing scale. A radius grows slower, and by doing so it indicates *orders* of size more easily. *Fig. 776* shows some standards for green surfaces and their distance to the served inhabitants that way. In that figure we can observe that 'English Nature max.' proposes larger green areas at a distance below 1000m and smaller areas further away than what we will explain here as a ‘Standard Green Structure’. Furthermore, we can conclude that all other mentioned (Dutch) standards are below that standard.



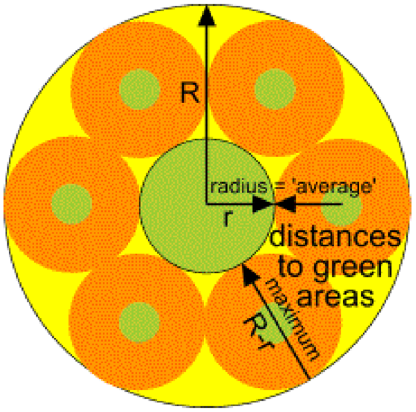


Fig. 776 Some standards for green surfaces in urban areas

Fig. 777 Optimally accessible green surfaces

The figures are calculated in a way explained in this section[a]. Greenery standards expressed in m^2 per inhabitant require suppositions about densities for comparison. These densities are taken from the 'Standard Green Structure' to be explained below.

Nominal orders of size

If in a range of radiuses, you take after 'r' the next radius 'R' ample three times larger (R≈3.16·r), then the next area *A* is ten times larger (A≈10r). It could encompass 7 smaller circles (70%) in closest packing, and a surface proportional to ample 3 circles (30%) as 'tare' (see *Fig. 777*).
If you take an easily nameable range of 'nominal' radiuses = {1, 3, 10, 30, 100, 300, 1 000, 3 000, 10 000, 30 000m}, then the surface increases at average with a factor 10.
In this paper 'nominal' means, that if I *name* a surface '10m', then I will mean something in between 3 and 30m. So, 'nominal measures' are not exact, they are 'elastic' between their neighbours, indicating an *order* of size.

Standard Green Structure

But, greenery standards expressed in m^2 per inhabitant are still incomparable to those expressed in surfaces and distances. Within R they suppose densities, and densities determine the amount of users and the costs of maintenance. I will use a 'Standard Green Structure' to provide densities on different levels of scale for comparison. Green surfaces are optimally accessible if they are located in the centre of the urban areas they serve. In that optimal case the distance from the boundary of an urban area involved (radius R) to the boundary of a central green surface (radius r) is the maximum walking distance R-r (see *Fig. 777*). The 'average' distance is approximately half R-r (depending on different densities within the residential area). If the *average* distance to the green area is the same as its radius, then in this paper we call that distribution of green areas over these levels 'Standard Green Structure' (see *Fig. 778*). Moreover, in *Fig. 778* some common names are added. In this paper they are used to interprate other standards.

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[a] The spreadsheet is downloadable from *http://team.bk.tudelft.nl/* > Publications 2007 > Jong, T.M. de (2007) *Standard Green Structure* (Zoetermeer) *.xls*

nominal green area r m	name	nominal urban area R m	nominal 'average' distance r m	nominal max. distance R-r m
10000	landscape park	30000	10000	20000
3000	urban landscape	10000	3000	7000
1000	town park	3000	1000	2000
300	district park	1000	300	700
100	neighbourhood park	300	100	200
30	small public green	100	30	70
10	common garden	30	10	20
3	private garden	10	3	7

Fig. 778 A Standard Green Structure

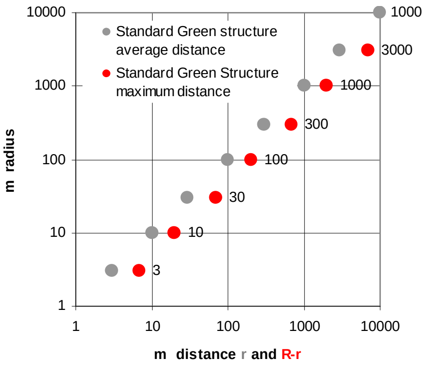


Fig. 779 Shift from average into maximum distance

In Fig. 779 the Standard Green Structure is given in grey. However, most standards are based on the maximum distance. So, for comparison we have to shift the dots half R-r to the right (red dots) as used in *Fig. 776*.

Inhabitants

In this concept of a Standard Green Structure the spatial distribution of green surfaces is determined, but not yet the number of people served. They determine the density or its reciprocal value, the land use in m^2 per inhabitant. However, if a village of 10 000 inhabitants grows into a town of 100 000 inhabitants, it will probably need a town park and if it grows into a conurbation of 1 000 000 inhabitants it will probably need a town park for every township and an urban landscape for the conurbation. That amount of desired untilled land was earlier provided as countryside around the village. In a first approximation that will increase the land use of green surface within the urban area.

Urban R(m)	Green r(m)
30 000	10 000
10 000	3 000
3 000	1 000
1 000	300
300	100
100	30
30	10
10	3

	Ambition	Inhabitants
	countryside	
	countryside	
	countryside	
1	**village**	10 000
6	neighbourhoods	1 667
36	urban islands	278
216	building complexes	46
1 296	buildings	8

	Ambition	Inhabitants
	countryside	
1	**conurbation**	1 000 000
6	townships	166 667
36	districts	27 778
216	neighbourhoods	4 630
1 296	urban islands	772
7 776	building complexes	129
46 656	buildings	21

Fig. 780 Different ambition levels

However, in the same time the price of land will increase and the inhabitants will accept higher residential densities. So, for example a neighbourhood park will be surrounded by higher neighbourhood densities in a conurbation than in a village, resulting in a lower land use per inhabitant. Keeping the average distance to the green area the same as its radius, a higher neighbourhood density applies in a conurbation compared to a village. To determine these densities, we need to suppose different ambition levels for growth. To keep it easy we take 10 000, 100 000, 1 000 000 inhabitants and so on as starting points and divide them according to *Fig. 777* by 6, 6x6, 6x6x6 and so on to derive the number of inhabitants per level (see *Fig. 780*). These starting points can easily be changed by taking percentages applying to densities as well.

Densities

Now you can derive different gross and net densities according to any ambition level dividing the appropriate number of inhabitants by the appropriate urban surface. The density of dwellings is calculated by dividing the density of inhabitants by the average number of inhabitants per dwelling (for example 2.25). The floor/surface ratio (FSI) is calculated by dividing the density of inhabitants by the average floor surface per inhabitant (for example $30m^2$). However, any level of scale has its own gross and net densities. The 'net' of the higher level equals the 'gross' of the lower level (see *Fig. 781*).

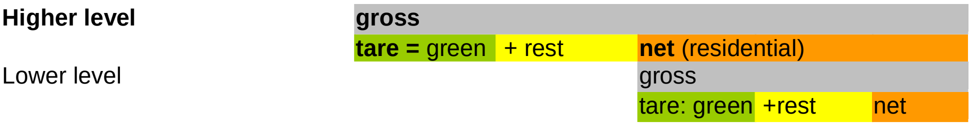


Fig. 781 Net of higher level equals gross of lower level

The difference between gross and net is ‘tare’. Net density concerns the residential part of the total urban area covered by ‘R’. However, on a lower level that residential part contains again non-residential components to be distinguished by the reciprocal value of ‘land use’.

ambition	**density**		**land use**			
	gross	net	gross	- green	- rest =	**net**
	inh/ha	inh/ha	m^2/inh.	m^2/inh.	m2/inh.	
village	32	59	**314**	28	116	170
neighbourhoods	59	88	170	19	38	113
urban islands	88	164	113	10	42	61
building complexes	164	246	61	7	14	41
buildings	246	455	41	4	15	**22**
				68		

Fig. 782 Standard Green Structure densities and land use on the ambition level of a village

Taking a closer look on the resulting land use profile of a village for example (see *Fig. 782*), the tare components can be added, while the gross and net cannot. By adding the green components per inhabitant we find the m^2/inhabitant green area (68m^2). The same calculation for a conurbation (see *Fig. 783*) produces a figure not much different from that of a village because of higher densities on the lower levels of scale (72m^2). The Standard Green Structure has a rather stable use of approximately 70m^2 green area per inhabitant, little dependent on the ambition.

ambition	**density**		**land use**			
	gross	net	gross	- green	- rest =	**net**
	inh/ha	inh/ha	m^2/inh.	m^2/inh.	m2/inh.	
conurbation	32	59	**314**	28	116	170
townships	59	88	170	19	38	113
districts	88	164	113	10	42	61
neighbourhoods	164	246	61	7	14	41
urban islands	246	455	41	4	15	22
building complexes	455	682	22	2	5	15
buildings	682	1263	15	1	5	**8**
				72		

Fig. 783 Standard Green Structure densities and land use on the ambition level of a conurbation

In both cases the gross density on the highest level is the same, because the number of inhabitants increases each level of scale with approximately the same factor 10 as the surfaces of the Standard Green Structure. However, the net residential area on the lowest level (buildings) is different. It equals the m^2 built area per inhabitant. If the average floor surface per inhabitant (for example 30m^2) is nearly four times that figure, the average number of stories has to be 4.

Comparing greenery standards expressed in surface, distance or m^2 per inhabitant

Fig. 784 shows the m^2 green area per inhabitant of different standards distributed over different levels according to levels and densities supposed in the Standard Green Structure. Figures for common and private gardens are added for comparison.

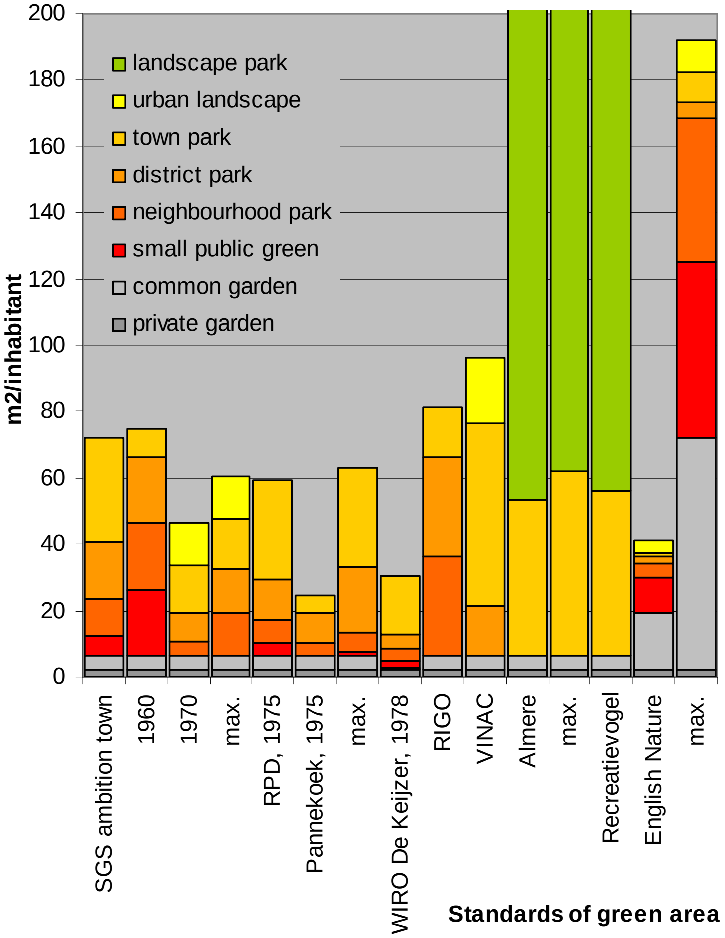


Fig. 784 Standards of green area expressed in m^2 per inhabitant on different levels of scale

If figures are given for the 'urban landscape' (yellow) the ambition is apparently a conurbation with higher densities than a town. However, most standards do have the ambition of a town. So, the Standard Green Structure shown here is calculated with the ambition of a town. To change that, use the spreadsheet mentioned earlier. That sheet shows how densities are calculated for different ambitions. Moreover, it enables you to make your own programme for urban green space according to the identity of the location.

Making a specific programme for urban green space

Given the ambition chosen in an other part of the spreadsheet, the worksheet shows the result of your choices asking radiuses of the urban and green area on two levels of scale (for example town and district, see *Fig. 785*), and the number (1 to 6) of green spaces on the lower level.

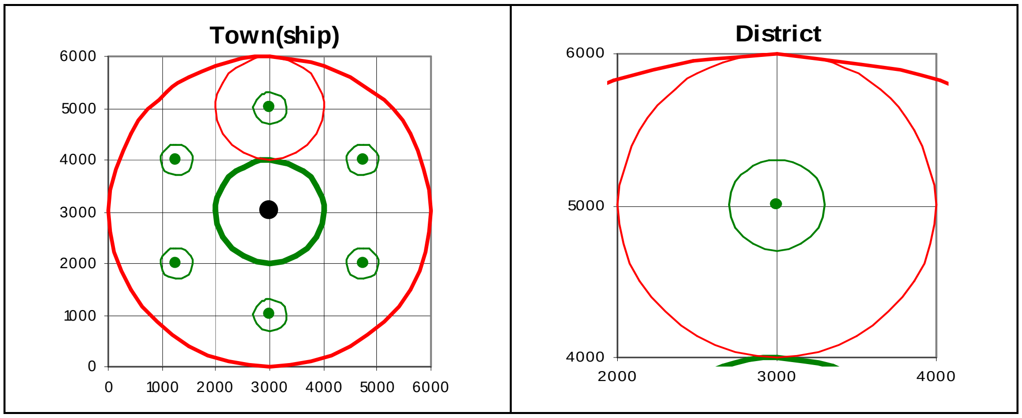
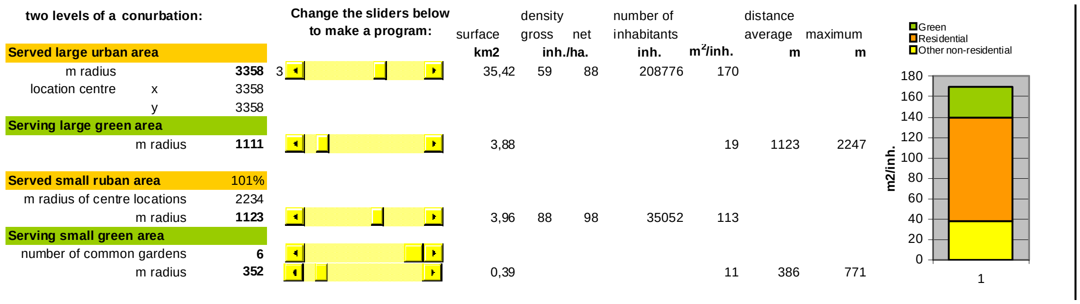


Fig. 785 Two levels of scale represented in a 1000m grid

These choices can be made by five sliders and the spreadsheet informs you directly about the consequences (see *Fig. 786*). On a copy of *Fig. 776* two new green spots show how your programme is in the proportion of the other standards.

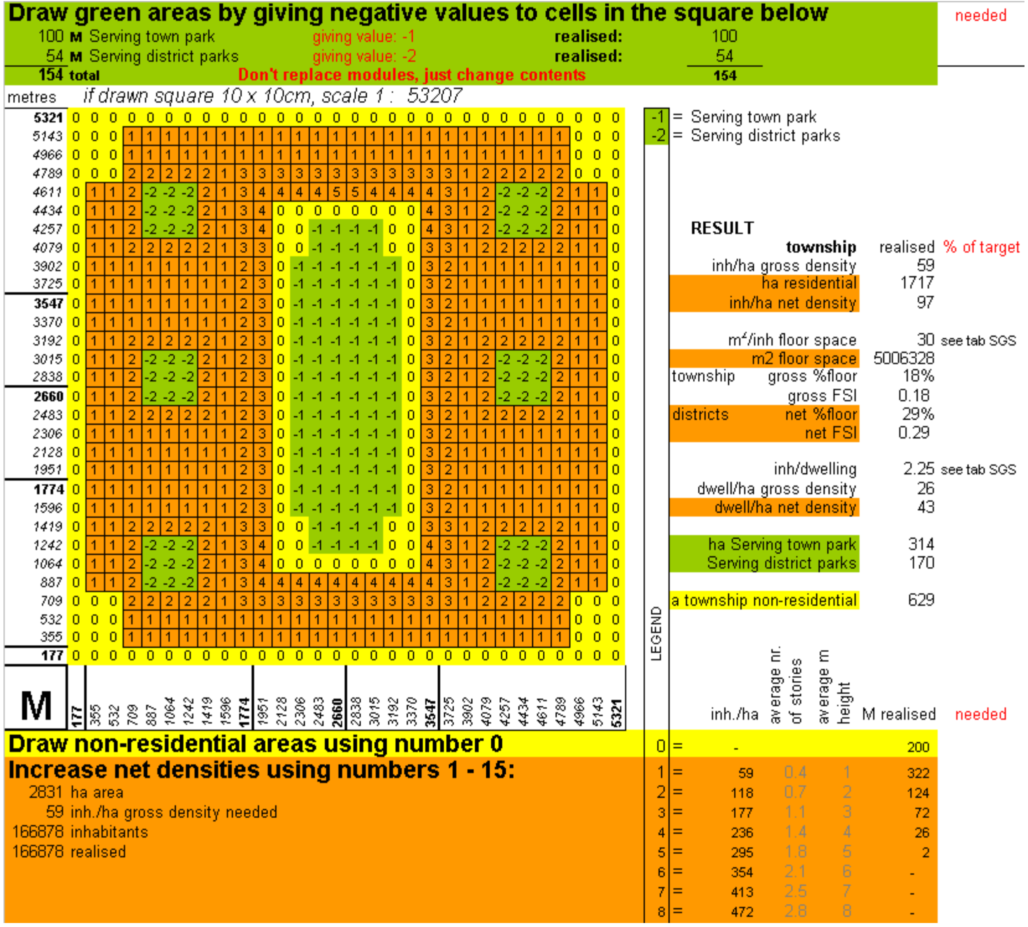


two levels of a conurbation:			Change the sliders below to make a program:	surface km2	density gross inh./ha.	density net inh./ha.	number of inhabitants inh.	m^2/inh.	distance average m	distance maximum m
Served large urban area										
m radius		**3358**	3	35,42	59	88	208776	170		
location centre	x	3358								
	y	3358								
Serving large green area										
m radius		**1111**		3,88				19	1123	2247
Served small ruban area		101%								
m radius of centre locations		2234								
m radius		**1123**		3,96	88	98	35052	113		
Serving small green area										
number of common gardens		**6**								
m radius		**352**		0,39				11	386	771

Fig. 786 Choosing a programme

Distributing green areas according to the programme

The next worksheet shows a square with the same surface of the largest circle you chose divided in 90x90 modules, telling you how much modules you need of each category to fulfill your own programme (see *Fig. 787*).



Draw green areas by giving negative values to cells in the square below

100	**M** Serving town park	giving value: -1	**realised:**	100	needed
54	**M** Serving district parks	giving value: -2	**realised:**	54	
154	**total**	**Don't replace modules, just change contents**		**154**	

metres *if drawn square 10 x 10cm, scale 1 : 53207*

5321	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5143	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
4966	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
4789	0	0	0	2	2	2	2	2	1	3	3	3	3	3	3	3	3	3	3	3	3	1	2	2	2	2	2	0	0	0
4611	0	1	1	2	-2	-2	-2	2	1	3	4	4	4	4	5	5	4	4	4	4	3	1	2	-2	-2	-2	2	1	1	0
4434	0	1	1	2	-2	-2	-2	2	1	3	4	0	0	0	0	0	0	0	0	4	3	1	2	-2	-2	-2	2	1	1	0
4257	0	1	1	2	-2	-2	-2	2	1	3	4	0	0	-1	-1	-1	-1	0	0	4	3	1	2	-2	-2	-2	2	1	1	0
4079	0	1	1	2	2	2	2	2	1	3	3	0	0	-1	-1	-1	-1	0	0	3	3	1	2	2	2	2	2	1	1	0
3902	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
3725	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
3547	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
3370	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
3192	0	1	1	2	2	2	2	2	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	2	2	2	2	2	1	1	0
3015	0	1	1	2	-2	-2	-2	2	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	2	-2	-2	-2	2	1	1	0
2838	0	1	1	2	-2	-2	-2	2	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	2	-2	-2	-2	2	1	1	0
2660	0	1	1	2	-2	-2	-2	2	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	2	-2	-2	-2	2	1	1	0
2483	0	1	1	2	2	2	2	2	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	2	2	2	2	2	1	1	0
2306	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
2128	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
1951	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
1774	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
1596	0	1	1	1	1	1	1	1	1	2	3	0	-1	-1	-1	-1	-1	-1	0	3	2	1	1	1	1	1	1	1	1	0
1419	0	1	1	2	2	2	2	2	1	3	3	0	0	-1	-1	-1	-1	0	0	3	3	1	2	2	2	2	2	1	1	0
1242	0	1	1	2	-2	-2	-2	2	1	3	4	0	0	-1	-1	-1	-1	0	0	4	3	1	2	-2	-2	-2	2	1	1	0
1064	0	1	1	2	-2	-2	-2	2	1	3	4	0	0	0	0	0	0	0	0	4	3	1	2	-2	-2	-2	2	1	1	0
887	0	1	1	2	-2	-2	-2	2	1	3	4	4	4	4	4	4	4	4	4	4	3	1	2	-2	-2	-2	2	1	1	0
709	0	0	0	2	2	2	2	2	1	3	3	3	3	3	3	3	3	3	3	3	3	1	2	2	2	2	2	0	0	0
532	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
355	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
177	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M	**177**	*355*	*532*	*709*	*887*	*1064*	*1242*	*1419*	*1596*	**1774**	*1951*	*2128*	*2306*	*2483*	**2660**	*2838*	*3015*	*3192*	*3370*	**3547**	*3725*	*3902*	*4079*	*4257*	*4434*	*4611*	*4789*	*4966*	*5143*	**5321**

-1 = Serving town park
-2 = Serving district parks

RESULT

township	realised	% of target
inh/ha gross density	59	
ha residential	1717	
inh/ha net density	97	
m²/inh floor space	30	see tab SGS
m2 floor space	5006328	
township gross %floor	18%	
gross FSI	0.18	
districts net %floor	29%	
net FSI	0.29	
inh/dwelling	2.25	see tab SGS
dwell/ha gross density	26	
dwell/ha net density	43	
ha Serving town park	314	
Serving district parks	170	
a township non-residential	629	

LEGEND

Draw non-residential areas using number 0

Increase net densities using numbers 1 - 15:

2831 ha area
59 inh./ha gross density needed
166878 inhabitants
166878 realised

	inh./ha	average nr. of stories	average m height	M realised	needed
0 =	-			200	
1 =	59	0.4	1	322	
2 =	118	0.7	2	124	
3 =	177	1.1	3	72	
4 =	236	1.4	4	26	
5 =	295	1.8	5	2	
6 =	354	2.1	6	-	
7 =	413	2.5	7	-	
8 =	472	2.8	8	-	

Fig. 787 Distributing categories on a field by numbers

The last problem is to increase the net densities of each module to fulfill your programme.

A first visualisation

This exercise is real time accompanied by a rough visualisation (see *Fig. 788*).

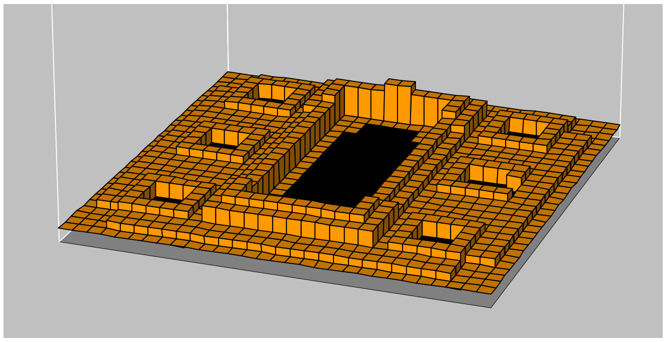


Fig. 788 A first visualisation

This figure does not represent building heights but densities. To get an impression of building heights the vertical exaggeration is estimated depending on the supposed floor surface per inhabitant, the supposed height of a story and the supposed percentage of built-up area within each module.

Connecting or separating

Ecological infrastructure could be important for distribution of animals with a larger feeding ground or reproduction area than the same areas not connected. However its effectiveness is species specific and not convincingly proven. Their surface could be at the expense of larger concentrated areas.

Open area concentrated but isolated The same area connected but deconcentrated

Fig. 789 *The surface dilemma of concentrating or connecting*

Tummers and J.M. (1997) defend central open areas instead of peripheral dispersion.

5.3.12 Urban perspectives

Spatial claims

Claims as mentioned in the 5th National Plan of spatial policy NRO5, VROM (2000) are summarized below left. The expected shrinkage of agriculture surface cannot compensate the growth of other claims to the needed zero on the fixed surface of Deltametropolis. So, many claims will not be satisfied or perhaps be solved in space-saving combinations. From the drawing on page 135 of the mentioned plan one can count the claims in the Deltametropolis. Below right these claims are expressed in km2 and in circles of 1 and 3km occupying the same surface[266].

	Nederland				Deltametropolis		
	1996	claims			claims	km radius	
	km2	low	high		high	*3*	*1*
					km2	*number*	
living	2242	390	850		210	7	3
working	959	320	540		120	4	2
infrastructure	1340	350	600		90	3	1
nature, recr & sport	5439	4770	4770		970	34	2
water	7653	4900	4900		380	13	3
agriculture	23508	-1700	-4750		-1050	-38	7
	41141	**9030**	**6910**		**720**	**23**	**18**

Fig. 790 *Claims derived from the national plan*

Visualising the supposed claims

These circles are drawn at size in the figure below right. So, 10 circles of 3km radius are put together to 1 circle of 10km radius. In the same way one can ’decompose’ any circle in 10 smaller ones to picture more precisely the location, eventually till the picture has reached a photographic halftone appearance with countable spots in different colours (pointillistic representation). This representation for instance shows at a glance the living environments of metropolitan, conurbation or urban centre (1km⊙[a] or 10,000 people surrounded by 30, 10 or 3km urban area), urban outskirts (1km⊙ outside the centre in at least 3km⊙ urban area not bordering on green areas of the same size), green urban areas (such an urban outskirt bordered on at least 1km⊙ green area), village (1km⊙ surrouded by green areas of the same size) or rural (0.3km⊙ or 1.000 people surrouded by green areas of at least 1km⊙) and the number op people enjoying such living environments[267].

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[a] ⊙ means ’radius’ or ’around’

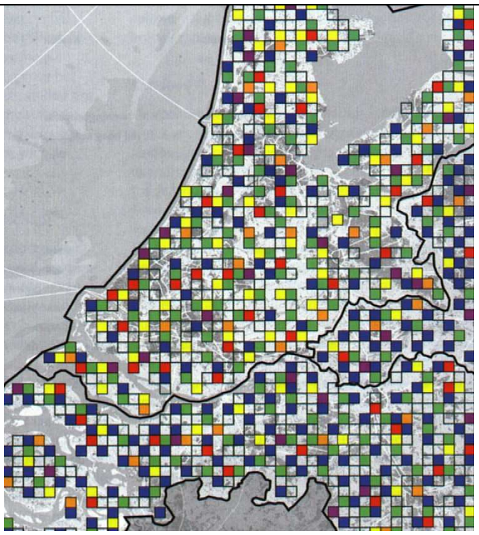

Fig. 791 *Claims dispersed over the surface*[a]

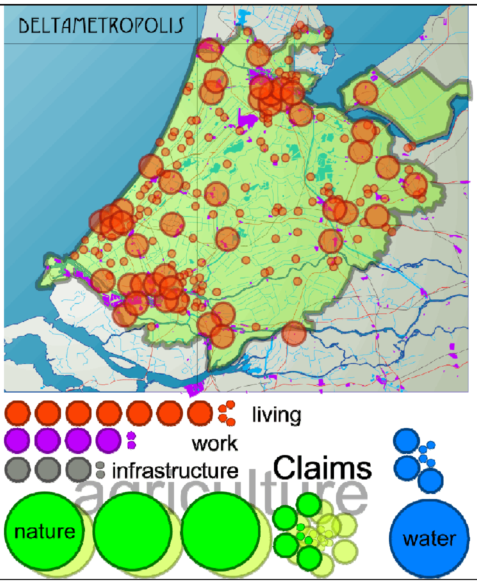

Fig. 792 *The same claims compared with the existing sprawl of cities and villages in Deltametropolis*

Alternatives by design

With the stock of too much paint indicated in the right figure below we can picture many different perspectives of a future Deltametropolis. We necessarily have to omit claims. The perspectives will not only differ in the specific claims they accept or disappoint, but also in the way each colour is concentrated in larger units in favour of their own function or dispersed in smaller ones in favour of synergy with other functions. projects should support this own function or on the other hand synergy.

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[a] VROM (2001) page 135

Claims of nature

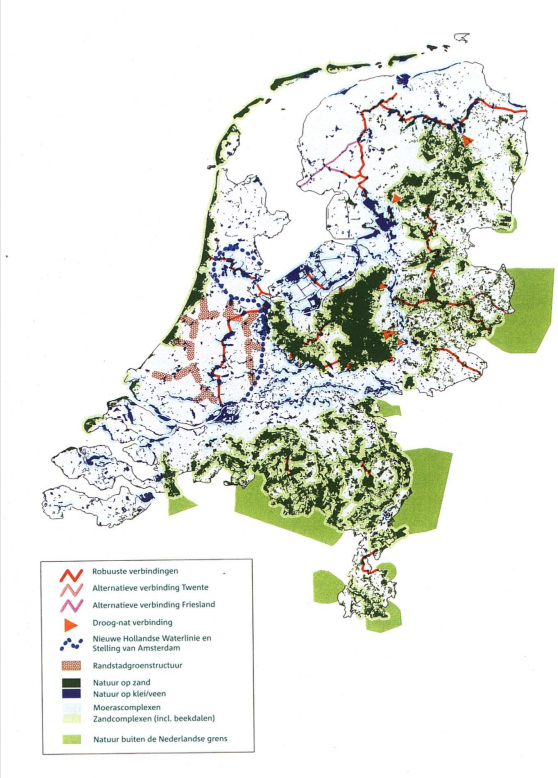

Fig. 793 *Map of the National Plan of Nature Policy*[a]

The National Plan of Nature Policy LNV (2000) publishes on page 25 of its programme the newest version of the accompanying map.

Deltametropolis counts three robust connections[268]:

- randstadgroenstuctuur,
- Nieuwe hollandse waterlinie en stelling van amsterdam, and
- the robust ecological connection between Biesbos and IJmeer.

The biological identity of dispersed natural areas and projects in a large part of Deltametropolis from this programme and their role as aimed nature type (natuurdoeltype) is elaborated by the Province of Zuid-Holland and clearly represented on the Internet *http://home.wanadoo.nl/w.heijligers/Start/ndtkrt1.htm* by W. Heijligers. On the accompanying map one can zoom in to the level of the nature projects[269].

Provincial elaboration and local effect

Perspectives and projects are evaluated in the way urban areas in the Deltametropolis reflect this diversity and biological identity.

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[a] LNV (2000) page 25

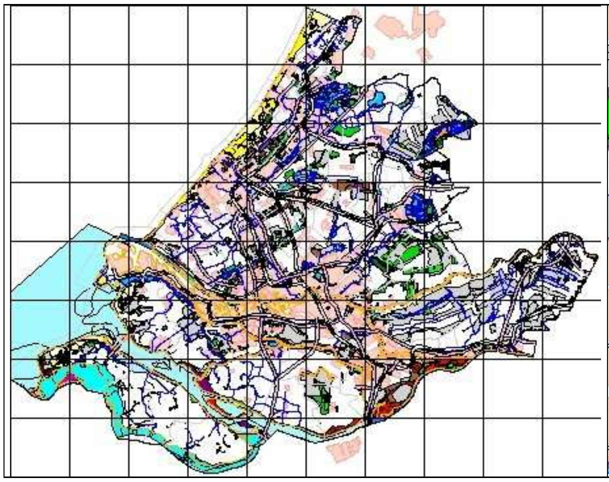

Fig. 794 *Ecological infrastructure in South-Holland*

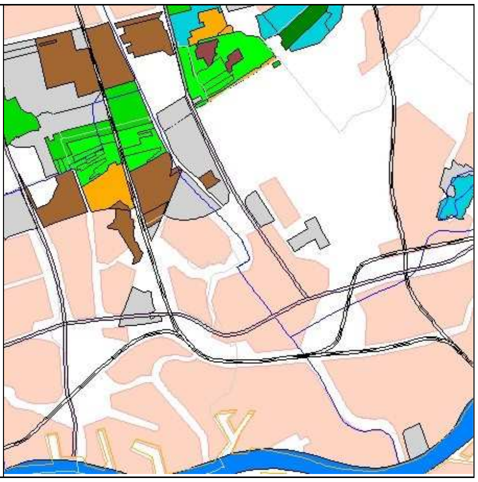

Fig. 795 *Quadrant South-East Delft*[a]

The basic ecological criterion for evaluation is global diversity lo leave possibilities open for future life. Diversity on a high level of scale is operational as rarity (as strong identity) on a lower level[270].

Comparing incomparable values

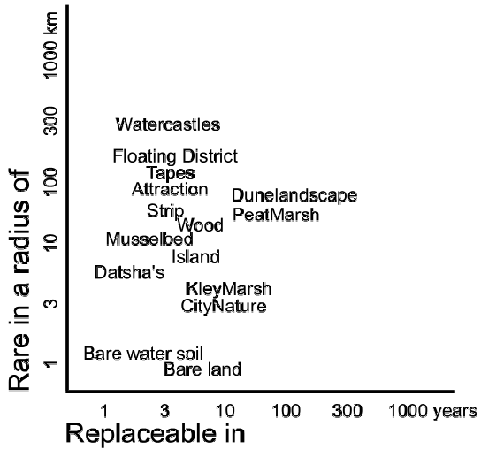

Fig. 796 *Rarity and replacebility of natural and artificial objects*

Perspectives and projects are evaluated on the preservation and production of worldwide (10,000km⊙), European (1000km⊙) and national (100km⊙) rarity of objects[b]. So, rarity can be expressed in km⊙. The second criterion, important for planning and design is replacebility of removed objects, expressed in years. It evaluates the possibility of compensation of rare objects. Once rarity of natural and artificial objects is determined on different levels of scale, they can be evaluated with regard to their replacebility.

In Fig. 796 living areas of 1km⊙ or 0.3km⊙ designed and named by TKA TKA (2001), Hosper Hosper (2001) and H+N+ H+N+S (2001) in Almere (see *Fig. 917*) are located in a diagram for evaluation.

The product of both gives an ecological value for comparison and subsequent evaluation as discussed in 5.4 (see page 429). Natural areas are represented generally more right in the diagram, because they are less replaceble than the mentioned artificial objects.

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[a] *http://home.wanadoo.nl/w.heijligers/Start/ndtkrt1.htm*

[b] The objects can be ecosystems on different size of 100m⊙, 300m⊙, 1km⊙, 3km⊙, 10km⊙, or 30km⊙.

Claims by growth

The urban growth since the industrial revolution culminates, especially in the developing countries where the European hygienic history of towns repeats itself. Restricting ourselves to the present Dutch situation claims on Randstad are bigger than ever and the idea of an open Green Heart fades away by urban sprawl.

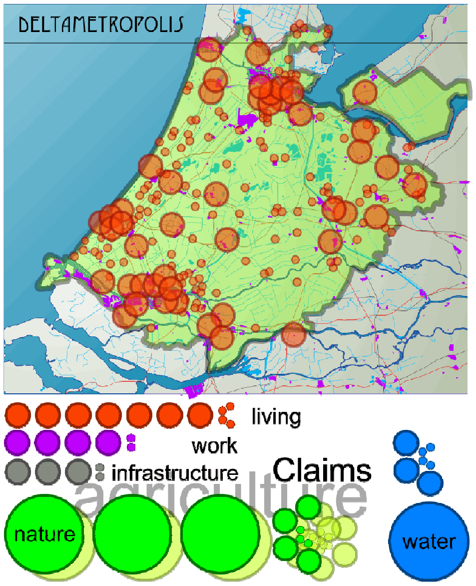


Fig. 797 *Claims on Detametropolis area*

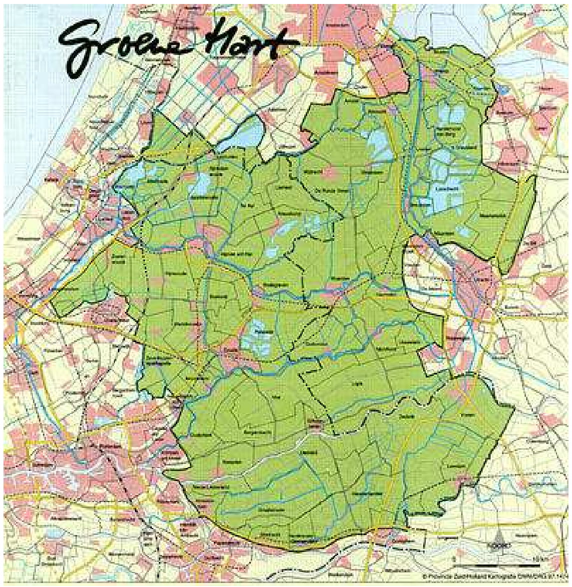


Fig. 798 *The supposed Green Heart*

The 30 years old idea of high density conurbations have not been successful in spite of national strategies like bundled concentration or compact cities. And if so, they would have been not effective (see Fig. 702) in saving surrounding landscape.

Metropolitan ambitions

It is an example of ideas like high tech transportation solutions that have big metropolises as a reference. However, Randstad does not yet reach the capacity of a real metropolis making fast underground systems possible.

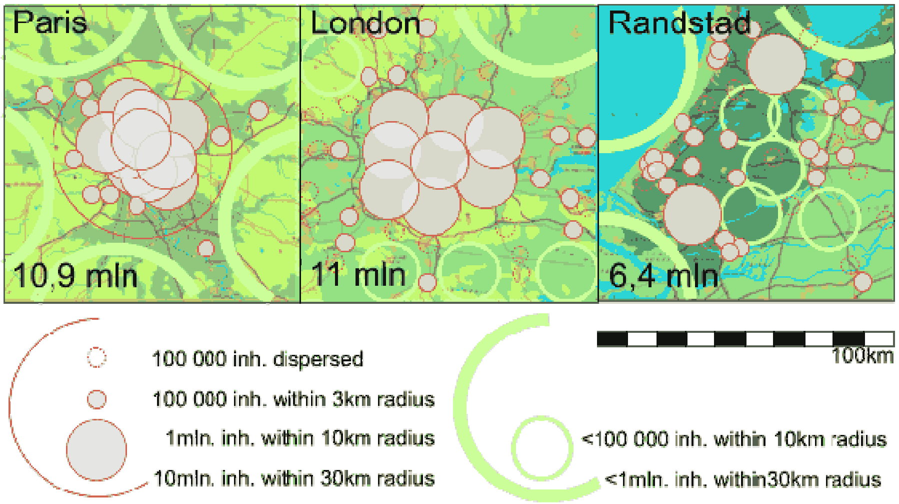
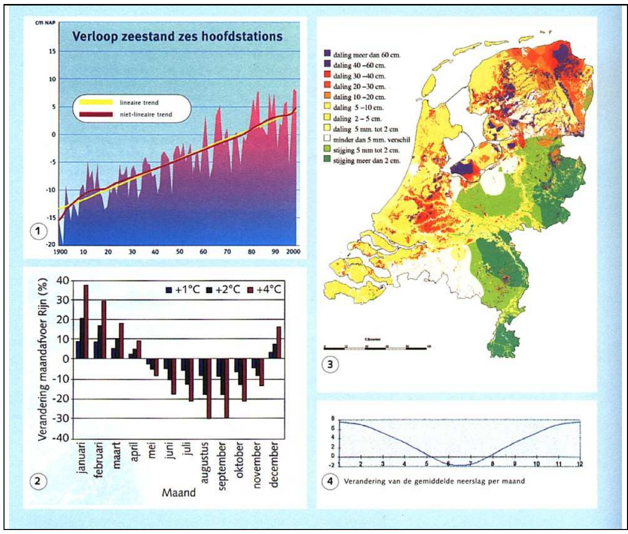


Fig. 799 *The capacity of metropoles*

From an ecological point of view the condition of measure (see paragraph 5.3.3 on page 393) is less important when we concentrate on vegetation rather than on big animals. From a human point of view we should bring nature closer to home (see page 411). That pleads for openness within the conurbation and not for accumulation on every level of scale.

Physical environment and water

The 4th National Plan of Watermanagement Policy V&W (1998; V&W (1998; V&W (1998; V&W (1998) (stressing environment), and its last successor 'Anders omgaan met water' V&W (2000) (stressing security) mark a change from accent on a clean to a secure environment, just as the 4th National Plan of environmental policy NMP4, VROM (2001) compared with its predecessors[271]. Several floodings in The Netherlands and elsewhere in Europe has focused the attention on global warming and watermanagement. The future problems and proposed solutions are summarized in the figures below[272].



In Fig. 800 above most left, global warming, in the figure right the ground descend of the western and northern part of the Netherlands are shown.
Bottom most left, different scenarios of temperature increase, right of it, the expected increase of precipitation in winter and decilne in summer are shown.

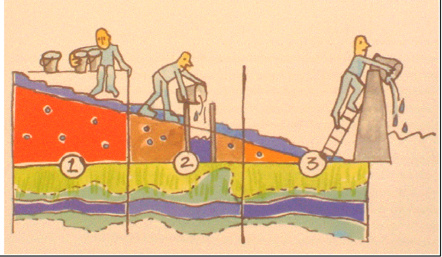


Fig. 800 *Expected problems*[a]

Fig. 801 *Strategies: 1 care, 2 store, 3 drain*

The storage of water requires heavy surface claims. The lowest areas collect water and pollution, so local altitude lines, waterlevels and drain systems fix the possibilities and risks for nature and human living. They have to be listed. Relatively high locations favour both as concurrent functions. Lower areas are more suited for water.
In the short term energy saving by concentration is important to stop global warming, in the long term sunlight will provide enough electric energy to sustain the current worldwide demand several times. The best indicator of a clean environment is the presence of rare nature. Its greatest threat is no longer the city but intensive agriculture.

Operational and conditional steering

The complex world of selectively separating and connecting occurs right down to the smallest scale of biology: the cell and its membranes (see *Fig. 738*). On that interfaces substances are selected and allowed to make connections with each other. The conditions for specific connections are created primarily by separating substancies that should not be connected (preselection). That already begins with the external membrane separating the inner environment from the entropic outside world. That makes less probable processes possible inside. This range of conditions and the endoplasmatic apparatus necessary to create the right conditions for the right connection is often forgotten in understanding the isolated process of connection operationally (monocausally).

The endless range of conditional functions in the environment seem to require another, perhaps typically ecological way of thinking than the single function with one clear product. Such processes are imitated in systems of retorts and pipes being the armamentarium of chemistry (in Dutch: ‘scheikunde’, ‘skill of separation’, not the skill of connection). Madame Curie needed four years to isolate 1/10 gramme of radium from tons of pitchblende. To dissolve sugar in our coffee is a daily activity taking seconds, but separating it afterwards takes much more effort. A heap of manure is easily dispersed, but it takes years to get it out of the ecosystem.

In the same way it is easier to destroy the subtle system of selectors and regulators of a living organism than to rearrange and synthesise it. A violent murder means demolishing separations, starting with those of the skin. Suppose now an ecologically rare location is surrounded by a range of conditional functions we still do not understand completely. Is it wise then to make connections for a few cuddly populations with botanically doubtful functions? Their equalising function in small areas could be that of an elephant in a china cabinet. Other (migrating) animals than grazers do not fit in our small nature reserves, but in vast eutrophic areas elsewhere in the world. There they are needed as mineral transporters comparable with pipelines connecting one sided high productive communities. A much larger number of smaller more rare species of animals needing a smaller area could be supported better by diversification of the botanical foundation. You can wait which superstructure develops thereupon instead of taking the summit of a food web as a target in advance. You should not start building a house with the roof.

5.3.13 Human health in the urban environment

Living in high densities

Being no expert on human health the most extensive overview I know in the joint field of medicine and urbanism is edited by Vogler and Kuhn (1957) some 50 years ago. They discuss many kinds of ‘civilisation damage’ in the urban environment from different medical specialist’s points of view. I never found a reference into this comprehensive work and I can understand it considering its size and age. So, I recoil from reviewing it as well, the more so while I am not read up on more recent medical literature. Apart from the disadvantages of living in high densities Vogler and Kuhn emphasise, its benefits Jacobs (1961) some years later referred to were partly confirmed in a psychological sense.

Crowding

Freedman (1975); Freedman (1977) and Baum (1978) discussed research on crowding and behaviour concluding no other impact of increasing density than intensifying existing negative or positive social-

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[a] V&W (2000)

psychological processes. However, by human biodiversity or social diversity - stage in the lifecycle, income or life style - some people like to live in high densities, others do not. People with children mostly like low densities of quiet suburbs. So, forced to live in high densities the impact could be primarily negative. However, learning to live in high densities with children might turn out positive by discovering advantages, adapting, compensating shortages and accommodating new functions.

Adaptation and compensation

Adapting to an environment and compensating shortages by new accommodations are essential characteristics of life. Life would never have developed without these capacities. The possibility of adaptation and compensation are often forgotten by researchers only interested in forecasting. ‘Arsenic is poisonous’, they predict. The prediction is based on 3x standard deviation from the average (99.7% of the cases) and if arsenic poison would be ever a global problem their solution would be removing the cause only. But in Austria a village population of so called ‘arsenic eaters’ (source unknown) since centuries got used to it. That is the way evolution solved problems by adaptation and compensation increasing diversity, not by global rules reducing diversity. Oxygen was once a global poison, now it is a prerequisite for aerobic life. Adapting, compensating and accommodating are also ways designers study. When low temperature is a problem of living in higher latitudes we compensate (accommodate) by building acclimatised houses. It is unnatural because it disturbs the natural distribution and abundance of homo sapiens. But since we make houses more than 3000 years it appears natural to us. What we call ‘natural’ apparently is time scale sensitive as well.

Regional differences in health

A recent survey into medicine use shows that the most well-to-do sandy region ‘Gooi’ has the lowest use of medicines in The Netherlands (Fig. 802). Insurance companies could decrease their rates for these groups in the same time increasing their wealth (and health). But to which extend Gooi-people owe their health to wealth and life style, to lower housing density, to green area in their direct neighbourhood, dry sandy soil or climate we do not know.

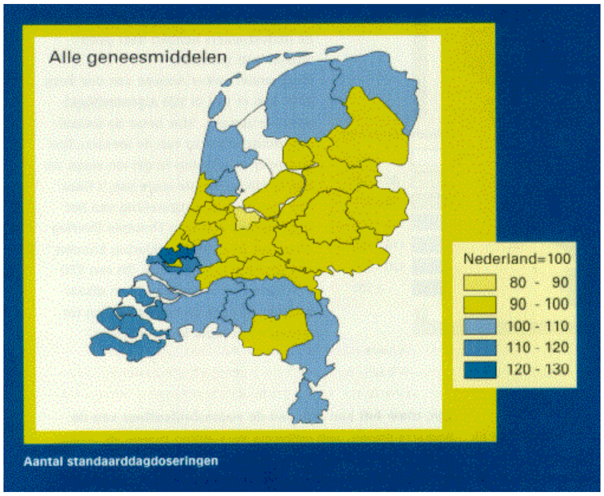

Fig. 802 *Use of medicines*[a]

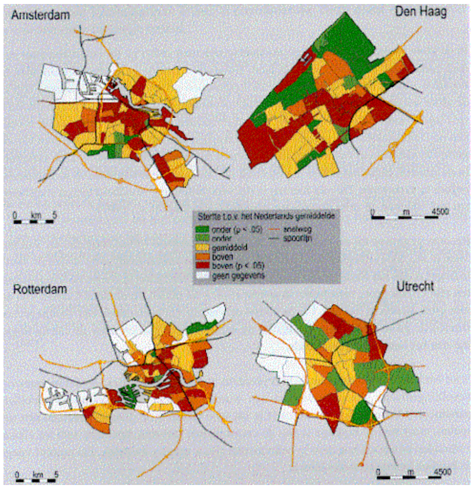

Fig. 803 *Differences in death rates*[b]

Local differences in health

Death rates in the big towns in the nineties were 11% higher than elsewhere in The Netherlands and there are substantial health differences between and within towns (Fig. 803). However, they correlate highly with income differences causing different (un)healthy lifestyles. For example they indicate that in a low-income district the chance to die before the age of 65 is 50% higher than in a high-income

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[a] Batenburg-Eddes and Berg-Jeths (2002)
[b] Garretsen and Raat (1989)

district. And rich people move from low-income wet peat and clay districts into high-income sandy districts leaving a less healthy population behind.

Causes of collective disease

Epidemiological research seldom succeeds in convincingly separating causal physical context factors like the urban environment from other coinciding influences affecting health.
The surveyors did not try to explain either comparing regions of The Netherlands because epidemiological research is one of the most tricky disciplines urging expensive longitudinal research extending decades to be convincing. That is a great pity, because as long as statistical evidence fails an even more tricky branch of statistics wins: risk calculation. Risk calculation seems rational, but often it is also the calculation of fears and myths motivated by little more than sharing them in collective fear.

Contributions by design?

Urban design is not always the most effective solution in environmental problems remaining after the great positive health effect of housing itself. Barton and Tsourou (2000) advise 12 key health objectives for urban planners in the context of WHO healthy city project in which Eindhoven participates: healthy lifestyles, social cohesion, housing quality, access to work, accessibility, local low-input food production, safety, equity, air quality and aesthetics, water and sanitation quality, quality of land and mineral resources, climate stability. Evaluating their effectiveness again would urge expensive longitudinal research extending decades to be scientifically convincing.

Stress

The more we know, the more possible threads we become aware of to be calculated. That raises fear and fear raises stress. Stress is suspect in raising or stimulating diseases like cancer. Fear for cancer is so well-known a medical symptom that it got its own name in medical vocabularies: ‘carcinophobia’. Designers in the wake of this uncertainty already try to make solutions for possible problems. That is their task, but they seldom evaluate the effectiveness and possible side-effects of their solutions.

Avoiding risks may be risky

There is something wrong in the state of medicine. King Average rules the kingdom of exceptions human species comprises, but in the same time exceptional occurrences are magnified by television and newspapers. Television and newspapers bomb us by statistical exceptions, distorting our perception of chance and magnifying impact. Risk is popularly defined by chance x impact. The public shame of few physicians involved intimidates the profession as a whole. And we still know little about our body, our own nature yet. Honest physicians remain silent but that is what frightens more.

Avoiding any risk physicians prescribe too many medicines, order too many physical examinations increasing the costs of medical care, increasing slowly appearing side effects. Avoiding any risk raises new risks on other levels of scale. Always avoiding to catch a cold may result in high susceptibility for flu any time we leave a building or a car. Our hygiene drove life out and nature in exile. Our biological resistance fades, the number of immunity deficiency diseases increases. We do not get injuries enough to become vaccinated by nature itself. We like dangerous holydays to flee from our unnatural and boring safety, but we do not know real danger anymore and fall ill by foreign food.

Costs of care

A secret medical survey I heard of by a medical student in the seventies revealed that half of our diseases at that time were iatrogeneous (caused by physicians). I do not know whether that was true or not and what the present state of medicine is in this respect. That is why I fear the worst case. Insurance companies sell fear. We pay more for safety than for anything else: insurance, police, army, preventing fire, burglary and catching a cold. We fear we can not pay all and we double our work until we die from the impacts of stress. The life time we spend on worry is lost well-being, lost health and life time. Our fear for exceptional possibilities raises new diseases of the mind and we fear them as well. In reality our life is safer than ever, but we do not dare to live with life: the risk to die. Life became strange to us and death as well, we fear the unfamiliar because it could be unhygienic.

Carefree nature

In the mean time numerous other organisms are going their own way, not fearing for anything that is not actual and mostly without any apparent fearing at all. They live from very slow to very fast.

I prefer the slow living plants surrounded by their very fast pairing messengers of life-experience, the insects. Plants are the basis of life's pyramid. Added animal life only selects and regulates like man does as well by harvesting, preserving, mowing and gardening. Sometimes we visit them and walk in something totally else we belong to historically but do not have to understand, something we should not try to plan.

Releasing care

I think it stimulates human health when we bring life close to everybody's home and living, but nobody knows, it is a hypothesis. Berg, Berg et al. (2001) give an excellent overview in their essay about the relation between nature and health concerning history, possible impacts on stress, fear, physical resistance and personal growth. Nature puts the stressing concept of our own importance into a relative perspective of one species between 1 700 000 ones or more. They differ more from us than any people we tend to reject in social conflict. Nature tempers forced choice as architecture should do as well according to Eyck, Parin et al. (1968) .

The challenge of diversity

The intellectual challenge of this century is to handle diversity instead of generalising it by statistical reduction. Generalising research has diminishing returns, on the other hand design is promising, generating study. Evolution and ecological succession is its model. Studying nature heals social disappointment by disappointing presuppositions, prejudices. It stimulates an active form of modesty. The more we know about nature the more we appear to know not, and the more we want to know, to see, to experience. In any town of The Netherlands specialised study groups of nature associations contribute to atlases of birds by Hagemeijer and Blair , Bekhuis, Bijlsma et al. (1988), Beintema, Moedt et al. (1995), butterflies by Tax (1989) and Bink (1992), bats by Limpens, Mostert et al. (1997), amphibians and reptiles by Bohemen, Buizer et al. (1986) , mammals by Broekhuizen, Hoekstra et al. (1992), fishes by Nie (1996), plants by Mennema, Quene-Boterenbrood et al. (1980), Weeda, Schaminée et al. (2000) and mushrooms by Nauta and Vellinga (1995) multiplying our shrinking world of holiday destinations by growing local universes we tended to overlook. In any town nature writes a history of war and peace far more thrilling than television and newspapers could do.
Nature looks for its journalists because it only exists by the grace of those seeing it.

Suggestions concerning spatial human rights

A. Any human has a right on 300m^2 residential area in a radius of 10km, work and services included.
B. Any human has a right on all necessary sources of living within a radius of 30km. These sources have to give access to products of 2000m2 agricultural land per person. This land should be accessible within a radius of 1000km concerning the risk of stagnating logistics.
C. Agriculture has to be located in areas with highest supply of water, minerals and sunlight. Towns and untilled natural areas have to be located in areas with less minerals.
D. Any human has a right on untilled natural ground uninhabited by man within a radius of x from her or his place of residence measuring at least a radius of x/3; x being {0.3, 1, 3 … 100 000 metre}.
E. Dutch cities belong to the most healthy in the world. So, any attention given to health in Dutch cities is distressing in a perspective of the hygienic condition of cities in the second and third world.

5.4 Valuing Nature

'Nature' is treated as a concept in this chapter and thus as part of a culture that values nature (see *Fig. 1012*). This chapter gives some insight into the types of natural area that can be distinguished. It is the task of the (regional, urban architectural or architectonic) designer to choose and, in the appropriate scale size, those combinations of these forms as a key unit, that make a clear, understandable, comprehensive and feasible plan possible.

5.4.1 Assessing biotic values

Biodiversity is the 'risk coverage for life'. The loss of biotopes for human beings, animals and plants is the framework within which the seriousness of the environmental problem is assessed. We will not dispute this here, but describe a method whereby these values can be measured. From these points of departure it is simple to evaluate on various scale and time levels to what extent an element of nature is special or unique and replacable.

Heterogeneity is homogeneity on an other scale

In valuing the Dutch flora and fauna on a European level, we should be petitioning for the whole of the Netherlands to be declared a Wadden area, because, at the European level, that is unique feature of our region. But that would create a very undifferentiated picture of the Netherlands. At the Dutch level, perhaps we ought to collect all the ecotopes of our latitude within our national boundary, but if every country was to do that, then there would be homogeneity at the European level. In other words, the question is: What sort of variation do we want, and at which level?

Rarity in space

As our concern is with the biodiversity of the whole world, our priority must be to assess the uniqueness of our nature within R = 10,000 km (the radius of the Earth is approx. 6,000 km). Uniqueness at the continental level can be read off on the scale against the frequency of occurrence of similar areas within R = 1000 km. At the national level, R = 100 km and at the local level, 10 km. Rarity is also culturally useful because it makes cultural values comparable with ecological ones (Fig. 804). Moreover, rarity has a relation with the economic concept of scarcity determining economic value.

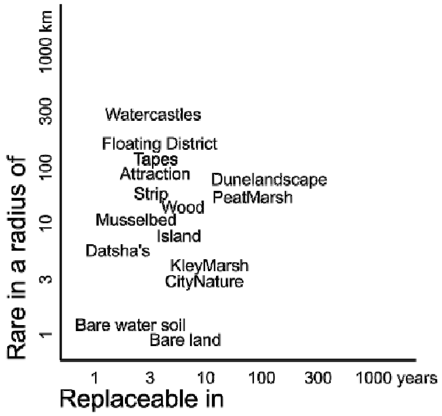

Fig. 804 *Comparing ecological and urban objects*[a]

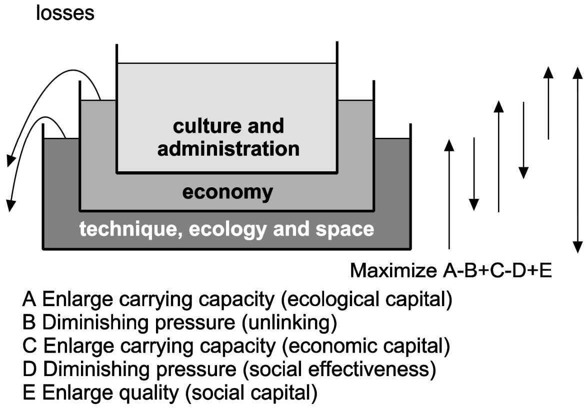

Fig. 805 *Evaluating the incomparable*[b]

Conditional evaluation

Conditionality represented by tanks filled with liquids of different specific gravity clarifies an other possibility evaluating categories of nature and culture (Fig. 805).They could be named as conditional

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[a] Jong (2001)

[b] Jong and Priemus (2002)

evaluation. This figure shows the relation between increasing carrying capacity of ecological and economic capital while diminishing economic and cultural pressure to avoid losses and to find maximal social capital and quality for future generations.

Replacebility in time

A second consideration could be the extent to which destruction of natural areas can be considered to be irreversible. In other words, 'how long would it take for a similar area to revert to its original state: 1,000,000; 10,000; 100; or 10 years?.

Value as a product of rarity and replacebility

If a certain kind of natural area is frequently found within a given radius, and if it can be quickly brought back to its climax state, less value will be placed on this land than when this hardly ever occurs and when it takes a long time to reach the present quality again. In making a valuation, one should thus take the reciprocal value of the product and count up the scores on each scale level. However, very many variants and specifications are possible. This sort of evaluation has been put forward by Joosten et al. (1992) for the Peel and it would be well worthwhile to work it out in depth.

Interestingly enough, this approach has also been found to be useful in establishing the visual quality of the urban architectural and architectonic aspects of an urban renewal plan (De Jong and Ravesloot, 1995).

5.4.2 Measuring rarity

Expressing rarity in kilometres

The local rarity of 'x' communities, ecological groups, populations, formations, ecosystems *or artifacts* can be expressed as the distance 'y' to the nearest x examples in the neighbourhood.

If the criterium for rarity *x* equals 1, then y is the distance to the next example in the neighbourhood (within this radius <y, it can then be considered to be a unique example). From a given x, a radius can thus be deduced (as a frame) outside of which the object is no longer unique or rare. If these turn out to be the only *x* examples in wider surroundings (a broader frame), then the object with *x* examples with that radius as a grain (unit) is rare again in that wider frame.

Rare on one level, common on an other level

Suppose that, within a radius of 30 km, another 10 examples of the same formation$_{3\text{ km}}$ can be found, but, further away, within a radius of 300 km, none at all, then the regional $_{30\text{ km}}$ rarity of these formations$_{3\text{ km}}$ is low, but the subcontinental$_{300\text{ km}}$ rarity of this district$_{30\text{ km}}$ is high. Conversely, regionally, within a radius of 30 km, a formation can be rare, but, it need not be nationally within a radius of 100 km. This does not negate the fact that the nation may have a responsibility continentally for these sorts of formation.

Involving human artifacts in the comparison

The same applies to artefacts. In Delft there is one, for the Netherlands, rare example of profane-Gothic architecture[a]. There are many more examples from this period in Belgium, but, worldwide, they are only found in Europe. The profane-Gothic example in Delft is thus locally rare within a radius of 100 km; subcontinentally it is not rare, but it is again rare, world-wide.

Determination of the grain of comparison

The question is whether people value this profane-Gothic building in itself or the total urban architectural combination of a profane-Gothic building on a Mediaeval canal. In deciding what is rare, people continue to use a coarser grain when comparing one formation with other examples. To liken this to the production of photographic prints, the distance between the framework and the grains (units) (i.e. the resolution) plays a role in determining rarity.

Rarity resolution

If there were no examples of this type of urban architectural combination in Belgium, then one could also talk of subcontinental rarity. The rarity of combinations$_{30\text{ m}}$ within a subcontinental$_{300\text{ km}}$ framework still has a very high 'rarity resolution' of linear 30/300000 = 0.01%.

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[a] The house of the Hoogheemraadschap Delfland on the Oude Delft 167.

For designers, such precision is greater than that needed for a plan, while 10% is enough to reach a decision on a design sketch. An urban architectural design is not rejected because the wrong bricks have been suggested. For biotic components, in order to reach a rarity resolution that is acceptable for making a decision, a grain must be maintained that bears some relation to the frame

The resolution of plant and animal data

If the number of locations where a species is found, on earth or within the Netherlands, is known, a frame, a grain (unit) and therefore a resolution (the ratio between the two) is implicit. In the Netherlands, the grain, the sampling unit, is usually an ‘hour field’ of 5x5 km (with a radius of 3 km), which is the average walking distance per hour. For very many species it is known in which hour field and sometimes even in which square kilometer, topographically, they can be found[a] and also partly to what extent.

The rarity resolution of the hour-field frequency measure

The national rarity of a species is then known as the ‘hour-field frequency’’, the number of hour fields in which the species occurs in the Netherlands. Therefore, it has to do with the quality of the formation For example, for every plant species from different periods, this is fairly well known, so by looking at the development in the hour-field frequency over a number of years it is possible to determine whether a species is threatened within the Netherlands.

The arbitrary boundaries of data

The borders of the Dutch state are arbitrary, because what is measured as rare, nationally, need not be rare regionally or internationally. The rarity resolution of hour-field frequencies in the Netherlands is 3% linear (3 km radius/100 km radius; area-wise it is less than 0.1%: 25 km^2 to 40,000 km^2). In this book we will restrict ourselves to a rough resolution. This can be 10% linear (1% of the area) for nature valuations based on sampling hour fields as large as areas with a radius of 10 km (more than 10 hour fields) in a frame of 100 km (more than 1000 hour fields).

A local policy of rarity

A municipality could, as was considered in Zoetermeer, for example, determine, for its policy on nature, that the accent should be laid mostly on regional and world-wide rarity. If types of ecosystem occur in a municipality that are rare worldwide, then, of course, these deserve to be treated with the greatest urgency. After that, priority is given to things that are regionally rare in preference to national rarities, providing that these occur in abundance elsewhere in the world. In that case, it does not matter whether those things are rare or whether they occur generally in the Netherlands. The aim of municipalities is to create a special identity within their region and not to try to differentiate themselves

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[a]. The plant kingdom is inventorised for the whole country in hour fields. For data, before and after 1950 see Mennema, J., A. J. Quene-Boterenbrood, et al. (1980) *Atlas van de Nederlandse flora. Deel 1. Uitgestorven en zeer zeldzame planten* (Amsterdam) Uitgeverij Kosmos ISBN 90-215-0847-8.. More recent maps/charts of plant species can be found at the FLORON Foundation Meijden, R. v. d. (1999) *Heukels' Interactieve Flora van Nederland* Wolters-Noordhoff BV; Biodiversity Center of ETI; Rijksherbarium; Natuur en Techniek; Kosmos-Z&K Uitgevers. en de synecologische CD-ROM Synbiosis van Alterra (Wageningen). The FLORON Foundation has been inventorising the flora per square km. for a number of years. These consist mostly of European distribution maps/charts. For many other groups of species such as amphibians and reptiles, separate national atlases have been published.Groen, Gorree, et al. (1995) *Florbase; een bestand van de Nederlandse flora periode 1975-1990* (Bilthoven) CML-rapport nr. 91, RIVM ISBN 90-6960-037-4.. From the toadstools there are approximately 400 mapped per hour-field Nauta, M. and E. Vellinga (1995) *Atlas van Nederlandse paddestoelen* (Rotterdam) A.A. Balkema ISBN 90 5410 623 9.. The national dispersion of 107 day butterflies is mapped by Tax, M. H. (1989) *Atlas van de Nederlandse dagvlinders* ('s-Gravenland /Wageningen) Vereniging tot behoud van Natuurmonumenten in Nederland, Vlinderstichting., the European dispersion of much more butterflies by Bink, F. A. (1992) *Ecologische atlas van de dagvlinders van Noordwest-Europa* (Haarlem) Schuyt & Co Uitgevers en Importeurs ISBN 90-6097-318-6.. From 374 bird species mostly per month the national dispersion is described by SOVON Bekhuis, J., R. Bijlsma, et al., Eds. (1988) *Atlas van de Nederlandse Vogels* (Arnhem) Sovon ISBN 90-72121--01-5., for cities like Amsterdam Melchers, M. and R. Daalder (1996) *Sijsjes en Drijfsijsjes De vogels van Amsterdam* (Haarlem) Schuyt & Co ISBN 90-6097-415-8. there are seperate atlases available or inventories like in Zoetermeer Meerendonk, W. W. A. v. (1998) "Vogelwerkgroep Zoetermeer" *Jong, T.M. de; Vos, J; KNNV, Kwartaalbericht* nr 19. Bird guides like Furgeson-Lees, J. and I. Willis (1987) *Tirions Vogelgids* (Baarn) Tirion BV ISBN 90-5121-060-4. contain often European maps of dispersion. For many other species groups like amphibians and reptiles seperate atlases are published like Bohemen, H. D., D. A. G. Buizer, et al., Eds. (1986) *Atlas van de Nederlandse amfibieën en reptielen* (Hoogwoud) KNNV Uitgeverij., vleermuizen Limpens, H., K. Mostert, et al., Eds. (1997) *Atlas van de Nederlandse vleermuizen; Onderzoek naar verspreiding en ecologie* Natuurhistorische Bibliotheek van de KNNV (Utrecht) KNNV Uitgeverij ISBN 90-5001-091-6., vissen Nie, H. W. d., Ed. (1996) *Atlas van de Nederlandse zoetwatervissen* (Doetinchem) Media Publishing Int BV ISBN 90-801413-5-6., weekdieren Gittenberger, E. and A. W. Janssen, Eds. (1998) *De Nederlandse zoetwatermollusken; Recente en fossiele weekdieren uit zoet en brak water* Nederlandse Fauna 2 (Leiden / Utrecht) Nationaal Natuurhistorisch Museum Naturalis, KNNV Uitgeverij & EIS-Nederland ISBN 90-5011-118-1.

from towns outside the region. In simple terms, this can lead to a policy that not only has ecological but also economic significance.

World-wide rarity in The Netherlands

We know that some (sub)species, such as the Zuyder Sea Herring and the small brackish-water jellyfish *Eucheilota Flevensis* became extinct after the closing of the IJsselmeer (Noordhuis (2000). It is known that the core area of the Marsh Fleawort (Weeda, Westra et al. (1991) and the Black-tailed Godwit, a meadow bird (Beintema, Moedt et al. (1995), is in the Netherlands, and that elsewhere they have an uncertain future. Surprisingly, the core area for the Marsh Fleawort is Flevoland, where, after draining the land, it appeared everywhere, spreading rapidly both on land and into the neighbouring waters, but also quickly disappearing again. So we carry a great responsibility when it comes to species like this.

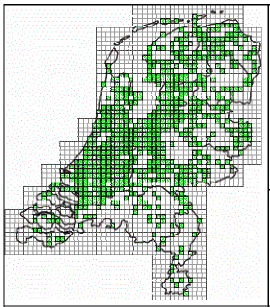
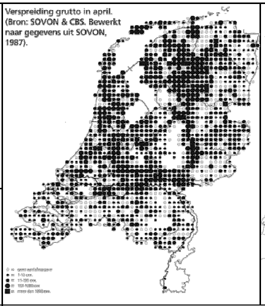
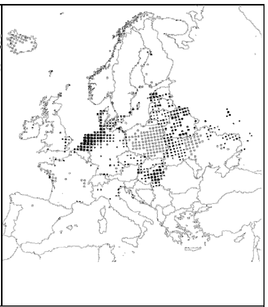
	 29AA02 The association of golden dock (goudzuring) and marsh fleawort (moerasandijvie) in the Oostvaarderplassen		
Marsh fleawort (moerasandijvie) distribution[a]	29 Class bur-marigold (tandzaadklasse)[b]	Black-tailed godwit (grutto) distribution[c]	European distribution[d]

Fig. 806 *The distribution of two Dutch, world-wide rare species*

Responsibility of The Netherlands in numbers

Reading van Duuren (1997) there are only two of the 35,000 species resident within our national boundaries for which we have the responsibility of a Noah. Of the 1,732,000 known species on earth (only a small part of the probable actual number), 35,000 of them are found in the Netherlands. Expressed in another way, 2% of the total number of species on earth are found within an area that is less than 0.008% of the total land surface on earth. Thus the Netherlands is jointly responsible for a much greater number of species than its area would suggest.

Insects and birds

Of these, the largest number of species are insects. In the Netherlands there are about 17,000 species of insect of which approximately 2,200 are butterflies (most of them only flying at nignt), 4,000 *hymenoptera*, 4,500 are *diptera* and 30 other orders of which most of us have never heard. They are one of the most important sources of food for the 366 species of bird found in this country. There is a nation-wide interest in butterflies, but most of them are linked to rare plants that demand species-rich vegetation. Their distribution can be seen from the various butterfly atlases (M.H. Tax 1989; F.A. Bink 1992; van Halder, Inge and Irma Wynhoff et al. 2000). In addition to the 111, mostly threatened, day butterflies in our country, there are also 1,400 moths and small butterflies, as named in CBS's BIOBASE van Duuren (1997) .

Biodiversity

The insects are part of the phylum *arthropoda*so too are many crabs, lobsters, prawns and water insects that are important for birds.The table below shows ordered lists of the most species-rich phyla

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[a] Marijnissen and Mol (1998)

[b] Foto Alterra, IBN-DLO

[c] Beintema, Moedt et al. (1995)

[d] Hagemeijer and Blair

of the 50 phyla that biologists have identified, and they are represented according to how species-rich they are in the Netherlands.

BIOBASE CBS Duuren (1997) Name	Species world-wide	Species in the Netherlands	% in the Netherlands	plants or animals	rough 10% estimate
arthropoda	1130000	21000	2	d	
moulds and fungi	100000	3500	4	p	
‘yellow algae’	9200	2200	24	p	
threadworms or elvers	12500	1700	14	d	
green seaweeds	7000	1600	23	p	
the angiosperms	250000	1400	1	p	
lichens	20000	633	3	p	
mosses	23000	533	2	p	
Chordata	52000	470	1	d	
ringworms	8000	350	4	d	
flatworms	14000	330	2	d	
wheel animals	1800	300	17	d	
molluscs	53000	300	1	d	
eye seaweeds	500	250	50	p	
bacteria	1500	150	10	p	*
blue algae	1500	150	10	p	*
Coelenterata	8000	140	2	d	
virus	1200	120	10	p	*
red seaweeds	3500	78	2	p	

Fig. 807 *Biodiversity according to the CBS Biobase*[a]

5.4.3 The IJsselmeer case

All these plant and animal phyla play both a qualitatively and quantitatively important ecological role for example in the IJsselmeer region. They are not always given the attention they deserve. An exception to this, for example, is the research carried out by the Mycological Research Work Group for the IJsselmeer Polders (Zanen, Ger van and Piet Bremer et al. 2000) on the approx. 1,600 species of fungi (toadstools) that occur in Flevoland. Also important are the ‘yellow algae’ to which the beautiful siliceous sea weeds (*diatoma*) belong, that, world-wide, have created our oil reserves. In the IJsselmeer region they are an important source of food in the spring and autumn if enough silicates have dissolved in the water to enable these organisms to form their skeletons. Elvers and worms are eaten by fish (e.g *tubifex*). The green seaweeds are a summer source of food, especially in the Markermeer, where, because of turbidity, a few of the oldest organisms, blue algae do less well there than in the IJsselmeer. These processes greatly influence the differences in the fish and bird population between the two lakes. An important member of the green algae for the Mute Swans and Gadwall ducks is the Wreath Seaweed, historically the forerunner of the higher plants and vegetables.

Aquatic and land vegetation

Together with the few gymnosperms (mostly conifers) found here, both aquatic and land vegetation in the Netherlands is made up of angiosperms. Most of the Markermeer and IJmeer are devoid of water plants because the transparency of the water is rather poor, also at depth. However, they have become really well-established at the edges, on the foreshores of the sheltered Gouwzee and inside

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[a] Duuren (1997)

the dykes, although, on the outer side of the dykes, they are slowly being pushed out by the just-as-valuable Wreath Seaweed. They are very important for aquatic life and for birds in that they stabilise the lake bed. The vegetation on the new land is still rather homogenous, because most of it is made up of heavy clay that, especially in the areas of salt marsh that are not yet ready for agricultural exploitation, does not mature very quickly.

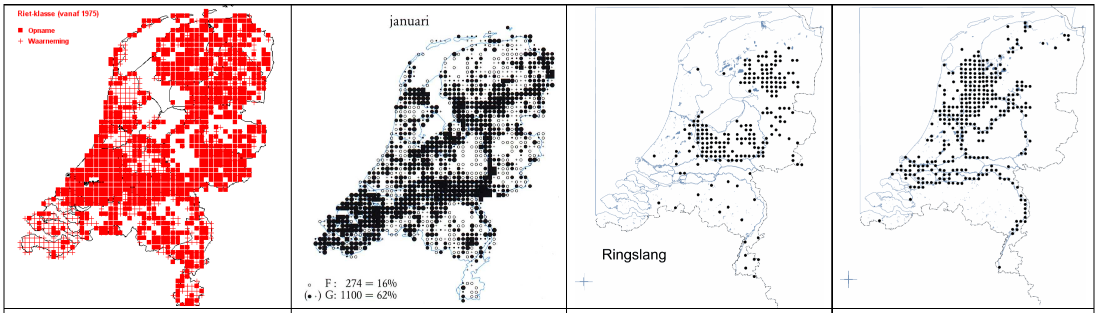
Regionally rare soils

Where the surface soils are sand and loam, as in Pampus-West, an interesting vegetation can develop attracting a rich insect (e.g. butterfly) and bird life. As in all the visionary plans, further research needs to be carried out before these soils are excavated or covered for urban purposes
Dutch vegetation is one of the best researched in the world. Botanically, within the Netherlands, Flevoland is not yet very interesting, but it has great potential, especially along the inner edge of the dykes. Already, in East Flevoland, 50 red-listed (threatened) species are found and summarised by Bremer and Smit (1995) . However, a varied vegetation is in constant competition with productivity which is so valued by the birds of this region. Although clay marsh, as a type of natural area to aim for is doing well there (Bal, D., H.M. Beije et al. 1995), it is an ecological community of few species that only after 20 to 1000 years will grow into a richer peat bog (Londo, G. 1997).

One-sided focus on popular species

Little attention is often given to mosses and lichens. They will play an important role in the new land if peat formation establishes itself. The *Chordata,* the vertebrates, to which we also belong, can look forward all the more to the active interest of nature work-groups. Of course, this applies primarily to birds. We will return to this topic when we deal with rarity in Europe and the Netherlands. There are very many other vertebrates both now and in the future that can play an important role in the value placed on the region's nature.

Using biological atlases to find relations and potentials



08 Reed class (rietklasse)	*Bean goose (rietgans)*	*Grass snake (ringslang)*	*Smelt (spiering)*

Fig. 808 *Maps from various biological atlases*

In the *Atlas of Dutch Amphibians and Reptiles* (Bohemen, H.D., D.A.G. Buizer et al. 1986) and in the *Atlas of Dutch Mammals* (Broekhuizen, S., B. Hoekstra et al. 1992) one can see what the distribution is with an accuracy of 5 km. From this, it is noticeable that colonisation of the new land from the surrounding old land, for example by the grass snake, is still in its initial phase. Constructing foreshores and islands can stimulate this process. The question is whether, having created such habitats, one should either wait until a breeding pair of the creatures in question make the journey to their new habitat, and by chance survive, so that perhaps in 30 years' time the colonisation can begin, or one should actively introduce them there. Within the category 'mammals', a beautifully illustrated atlas is devoted to bats (Limpens, Herman, Kees Mostert et al. 1997).

The role of fish in the nitrate cycle

Fish, as a group are, of course, of utmost importance to the IJssselmeer region, see the *Atlas of Dutch Freshwater Fish* (Nie, Henk W. de 1996), of which some have the status 'protected species'. There are other species that we would rather be rid of (e.g. bream colonisation). The dubious role of the widely occurring bream could well be reversed if an entrepreneur, for example in Almere, would start using this source of food for the production of cattlefood. In the Netherlands, ten times as much manure is produced as household waste. Currently, the protein in cattle food is produced by blue algae in the root tubers of *vleugelbloemigen* (clover, lucerne and other bean wearing plants) on an area three times as large as the Netherlands, in countries in which children die of protein shortages. However, it is more lucrative to feed these soyabeans to our pigs than to use them to cure children of beri-beri.

Fish ponds

The nitrate-rich decomposition product from protein, manure, finds its way into the Randmeren, partly from Gelderland, where the phyla listed above (but not expanded on further here) make them suitable for the Bream. Elsewhere in the world, to recycle this manure, farms have fish ponds for carp and bream. If we were to follow this example, there would be no better location in the Netherlands than the IJsselmeer region. However, this revolutionary breakthrough for nature in the Netherlands is being hindered by the necessity to adapt the fishing laws: sport-fishermen are unwilling to waiver their right to the bream to professional fishermen, who could supply a substantial source of cattle food.

Mollusks and birds

A variety-rich phyla of mollusks (weekdieren), mussels and the like, 1% of which (approx. 300 varieties!) are found in the Netherlands is, among other things, of great importance for the diving ducks in the area. The basis of this is the enormous success of one exotic variety, the Zebra Mussel that appeared in the Netherlands in 1826 from the Caspian Sea and from 1975 onwards, as the waters became richer in nutrients, spread rapidly. Because of its capacity to colonise so quickly, Zebra Mussels are now common in the Netherlands and in Europe. Their appearance in North America in 1989 and has caused problems there (Gittenberger, E. and A.W. Janssen 1998). They can block cooling water and drinking water systems. Nevertheless, this mussel is the favourite, at the moment, of bird-loving Netherlands. A number of details are important in laying out the bed of the Markermeer. Zebra mussels have a life-span of five years. They attach themselves to hard surfaces and the adults seldom move elsewhere. They begin life as one of the millions of eggs released by the female. The larvae move like plankton by means of vibrating hairs until they develop a shell that makes them sink to the bottom. There they actively creep around until they find a hard, protected anchorage where there is not very much light. They can live at depths (to tens of metres deep) much greater than diving ducks can reach. The larvae eat bacteria, blue algae and very small particles of the sediment in the lakes (detritus). As a mussel, they grow the fastest in nutritious, moving water. They filter the water so actively, that they clean the entire IJsselmeer twice a month. The activities of the Water Flea, a species in the lobster family, have a similar cleansing effect. Mussel beds attract many other forms of life.

European rarity of birds

Percentage of the international bird population Tempel and Osieck (1994) 4) Symbol is similar to presence graph Jan.-Dec. V winter birds Wintervogels M whole year, especially in the winter Π whole year N whole year, especially in the spring of s Λ summer, nesting bird			IJMEER	MARKERMEER	GOUWZEE	IJSSELMEER	OOSTV.PLASSEN	LEPELAARSPLASSEN	TOWN
Water	V carnivore	Goosander				4			
	V carnivore	Smew		2	1	2		3	
	V Zebra mussel	Scaup		5		44			
	V fish	White-tailed Eagle or Sea Eagle					n		
	V plants	Barnacle Goose					2		
	V plants	White-fronted Goose					1		
	V plants	Whopper Swan					1		
	M plants	Greylag Goose					41		+
	M plants	Gadwall (duck)		1		3	4		+
	M plants	Pintail (duck)					7		
	M plants	Wigeon (duck)		3		1	1		+
	M plants	Pochard (duck)	6	2		1			+
	M plants	Teal (duck)					13		+
	Π fish	Grebe				4			+
	Π Zebra Mussel	Tufted (duck)	5	4	2	3	1	2	+
	Π plants	Mute Swan				1			+
	Π plants	Coot				1			+
	N plants	Shoveler (duck)					1		+
	Π fish	Caspian Tern	n				n	n	
	Π fish	Black Tern		n		64	1		
reed	V carnivore	Hen-harrier (breeding)					n		+
	N carnivore	Spoonbill (not breeding)					7	1	+
	Λ carnivore	Spoonbill (breeding)					16	2	
	N fish	Bittern (breeding)					n		
	Λ insects	Spotted Crake				n			
grass	N carnivore	Black-tailed Godwit					1		+
	N carnivore	Ruff					n		+
brushwood	N carnivore	Avocet					6		+
	Λ insects	Bluethroat					n		
	Λ insects	Black-winged Stilt/b					n		
	Λ fish	Common Tern				n			+
forest	Λ fish	Cormorant (breeding)					15	7	
	Π fish	Cormorant (not breeding)				8	3	1	+

Fig. 809 *The European responsibility for birds*

Bird and Habitat Directive

For the benefit of the Bird and Habitat Directive, the European importance of the IJsselmeer region for birds is expressed quantitatively as the percentage of their presence in the European population. The threshold value is 1% of that population. Locations below that percentage, but which nationally are one of the five most important locations for that species are indicated with an 'n' in Fig. 809. In the second column, one can see whether the graph of their presence between January and December peaks in the summer (Λ), the winter (V) summer or whether it is a variant between the two.

Seasonal maxima by bird migration

The seasonal maximum outside the dykes for the Black Tern and the Scaup were 64% and 44% of the European population, respectively. These birds seek the open water. Forty-one percent of the Greylag Goose population winters within the dykes of the Oostvaardersplassen or stays there the whole year round. Of the European Cormorants, 34% breed (/b) in the wooded parts of the Oostvaarders- and Lepelaarsplassen or stays (/nb) either there or on the IJsselmeer. Of the spoonbills, 26% either stay or breed inside the dykes. The Tufted Duck population is found on all the lakes in numbers that together comprise 17% of the European population.

Oostvaardersplassen

The Oostvaardersplassen are indicative of how valuable it is to have still water, reed morass, grass fields, brushwood and woods inside the dykes. There are more species of birds here than anywhere else.

Differences between IJsselmeer and Markermeer

The IJsselmeer is the most important stretch of water in Europe, particularly for carnivores, Mute Swans and ducks.

Despite its large surface area, the Markermeer is still not as important as the IJsselmeer, and, on a European level, is mainly important for ducks of the same assortment.

In the IJsselmeer, ten times more fish can be found than in the Markermeer.

Silt is a problem in the Markermeer. It is restrained by the Houtribdijk to prevent it encroaching on the IJsselmeer. The wind draws the silt up from the bed of the Markermeer. This reduces the entry of light, preventing algae from doing their basic work and the waterplants from expanding, except in the protected waters of the Gouwzee. The Zebra Mussels become covered with silt. The numbers of Tufted ducks and Pochards in the Markermeer are decreasing correspondingly.

Map of the Natural Vegetation of Europe

The conclusion is that also the area within the dykes plays a role of international importance. The *Map of the Natural Vegetation of Europe* (Bohn, Udo 2001) compiled by 102 geobotanists from 31 European countries, is a milestone in international ecology. On this map it can be seen how the narrow coastline between Belgium and Denmark offers botanical potentials that are internationally rare. They are indicated as U2 on the map: 'vegetation complexes of dyked morasses with water-loving oak/ash forests and ash/elm forests'. These cover less than 1% of Europe.

Rarity of Dutch woords

Beech woods are typical of the neighbouring countries, as far as the Alps, and further to the north, the coniferous forests appear: 'From Amersfoort until the Urals the landscape is less surprising.' (Constandse, A.K. 1967). Indeed, not all the area is covered with tree species with which we are familiar. It is the long-term potentials that are important. In the succession of overlapping ecosystems, this would be merely the natural and varied final stage (climax) with open areas for special vegetation and fauna, kept open by large grazers (Vera, F. 1997).

The forests of the Flevopolders are largely an early reflection of this end stage, but there are also beech and coniferous forests, not characteristic of the region, that foster the establishment of special vegetation such as internationally rare toadstools (Zanen, Ger van, Piet Bremer et al. 2000). This leads to the question of whether, for the benefit of regional diversity, one should allow clay morass, that is rare internationally, to be cut across here and there by forests that are common elsewhere. However, due to manure infiltration and acidity, the undergrowth in our forests does not develop much further than stinging nettles or Wavy Hair-grass (Dirkse, G.M. 1994).

Continental and national rarity

From the view point of European diversity and rarity, the low areas of the Netherlands should be one large wooded morass. Viewed nationally, this would, of course, be monotonous. Throughout the Netherlands, the natural succession towards a final stage is artificially interrupted everywhere. It is held in various, often productive, intermediate stages for the benefit of nature conservation or agricultural goals. The artificiality of nature in the Netherlands as a whole is the result of the simple fact that, without human intervention, half of our country would be sea floor. What is maintained, can be likened to a picture taken of the river delta at the beginning of history with annually changing waterways and pioneering communities. Since 1000 AD, this landscape has been increasingly stabilised by dykes. Since the end of the Würm Ice Age, around 10,000 years ago, when the North Sea was still dry, the seawater rose and fell periodically through the millennia, but it will now rise faster and higher than ever.

Rarity of urban artifacts

Approx. 10% of this landscape is occupied by warmer urban buildings. The Dutch city — on water, with canals and quays — and built on low land is rare internationally. Currently, in modern cities, due to their more open planning, improved hygiene and/or nature friendly policy, one can find a larger number of wild plant species per km^2 than in many natural areas. This vegetation and its insect fauna are mostly inhabitants of more southern, stoney areas, but they form a gene bank for warmer periods and a refuge within the surrounding agricultural wilderness for living creatures such as bats and birds. Many of the birds named can be seen in towns (Melchers, Martin and Remco Daalder 1996). The Grebe and the fox are discovering the town as a new natural area, while the House Sparrow is disappearing.

Architectural rarity

The daring designs and organisation of Dutch environmental planning and architecture as presented in the prize-winning Dutch pavilion by MVRDV at the world exhibition in Hannover is attracting world-wide interest. A growing fascination can be seen in this pavilion for innovative ways of cooperating with nature. Almere has built up a name for itself in the area of architectonic experiments and has become a showcard for architectural designs, but what it misses is an amphibian aquadistrict and water architecture.

Artificial environment

The now freshwater of the IJsselmeer region is maintained by installations such as dykes and sluices. The policy determining the level of this water (high levels in summer and low levels in winter) contravenes what would happen in nature. Within their own territories, the Dutch Ministeries of Transport and Communications (V&W) and Agriculture, Nature and Food Quality (LNV) have developed into nature and environment ministeries: in construction work and in carrying out agrarian management, working together with nature is high on the agenda. Ministry of Transport and Communications constructions such as earthworks, dykes, roads and their verges have become objects for nature engineering (Aanen,P., W. Alberts et al. 1990). Their contours, layout and management have a demonstrable ecological effect within the cities too.

A paradox of environmental and nature policy on different scales

In the past detergents and nowadays phosphate- and nitrate-rich water from the animal husbandry on the Veluwe reaches the IJsselmeer via the IJssel and the Markermeer via the Randmeren. There, it is transformed by sometimes too rapid growths of, and thereby toxic, algae, grazing, and hunting water-creatures into large quantities of vegetable matter, mussels and fish, which attract large numbers of birds. These birds, that come from far and wide, make this an area not only of international importance, but also a rare area, nationally.

Due to the success of environmental policy (e.g. phosphate-free detergents), less and less nitrate and phosphate is entering the lakes. The reduced availability of these minerals sets an upward limit on food production and allows other, nationally rare, but less productive species to establish themselves. Perhaps the age of migrating birds will be followed by an age of reptiles, amphibians and mammals that, due to the lack of sandy areas and brushwood (foreshores and islands) outside the dykes, have not yet colonised the region. With a view to the future role of the region, it is important to gain insight into the increasing complexity of this system.

National rarity of birds

The table below shows the ecotope of red-listed birds found in the IJsselmeer region (Duuren, L. van 1997). The Red List reflects the national rarity of species. It is a selection made from many other targeted species included in realising a Primary Ecological Structure. The internationally rare species are also represented in this:

		NEST	FOOD	mainly insects
Black Tern	BA	open water	open water	+
Little Grebe	C	open water	open water	+
Garganey duck	C	open water	open water	
Bittern	BD	reed vegetation	reed vegetation	
Sedge Warbler	C	reed vegetation	reed vegetation	+
Savi's Warbler	C	reed vegetation	reed vegetation	+
Spotted Crake	D	reed vegetation	reed vegetation	+
Bearded Tit	DA	reed vegetation	reed vegetation	+
Spoonbill	DA	reed vegetation	reed vegetation	+
Great Reed Warbler	BD	reed vegetation	brushwood	+
Ruff	B	brushwood	grassland	+
Common Tern	C	sandy, open brushwood, pioneer	open water	
Avocet	DA	sandy, open brushwood, pioneer	open water	+
Kentish Plover	BD	sandy, open brushwood, pioneer	sandy, open brushwood, pioneer	
Ringed Plover	D	sandy, open brushwood, pioneer	sandy, open brushwood, pioneer	+
Redshank	C	grasland	grasland	+
Black-tailed Godwit	CA	grasland	grasland	+

B	Very threatened
BA	Very threatened, important internationally
BD	Very threatened, vulnerable
C	Threatened
CA	Threatened, important internationally
D	Vulnerable
DA	Vulnerable, important internationally

Fig. 810 *The national responsibility for birds*

Habitat combinations important for birds

Judged by its feathered visitors, the national rarity of the region can be listed as open water, reed vegetation, brushwood, grasslands and sanctuaries (also on the land of South Flevoland). Sanctuaries are important for birds during the vulnerable moulting period, when their flying capacity and food menu is restricted. For this reason, a favourite moulting place is the lonely Houtribdijk, because it is out of reach of predators and it offers sufficient food. If also used for recreational purposes, then good organisation is required. Wide vistas of open water is also a visual rarity, even though the Zeeland waters are not more than 100 km away. Ecologically, however, large expanses of water are not particularly important (what *is* known is that the Scaup duck is moving away from the coast in indeterminable numbers and that only the Cormorant has a flight range of more than 1 km).

Recreation symbiosis

These waters are mostly important for recreation, for those sailing in the 'brown fleet' of old ships from the historically important harbours in the region. For the real sea sailors, the Waddenzee and the North Sea are nearby.Other sailors like to keep in sight of the shores. When the mast route from the Zeeland waters to the Friesian lake region — the 'Blue Arrow' in the national plan — becomes operational, then the IJmeer will become a junction of shipping lanes. It is questionable whether this recreational pressure will be favourable for moulting and breeding birds. There will be great resistance against high-rise buildings along the shores, and certainly on islands off the coast. A minority of the sailors is against the compartmentalisation caused by islands and foreshores. On the other hand, these supply isolated reed vegetation, brushwood and grasslands, the areas of which are too small for non-swimming predators which would otherwise make bird life impossible. For example, the Spoonbill has been forced out of the Naardermeer by the fox. There is little differentiation in the Markermeer, in this respect. Greater differentiation in land/water transitions would create a more complex system with more species of birds and of other creatures too.

5.4.4 Replaceability

Expressing replaceability in years

Just as rarity can be expressed in kilometres, so can replaceability be expressed in years. A combination of both was first suggested by J.H.J. Joosten and B.P.M. Noorden (1992) as a basic way of valuing an ecosystem. This method has been worked out here and applied for the first time in Almere in order to include human artefacts in the comparison. This basis for comparison is important for many urban architectural and political considerations. It is a consideration of basic qualities in space and time. For example, it is an alternative to earlier attempts to express nature in terms of money or functionality for people (Maarel, E., van de and P.L. Dauvellier 1978; Groot, R.S., de 1992). On the other hand, it might offer the possibility of expressing money in more general ecological definitions of scarcity and production opportunities. The replaceability of an ecosystem or artefacts can be expressed as the number of years needed to recreate that object.

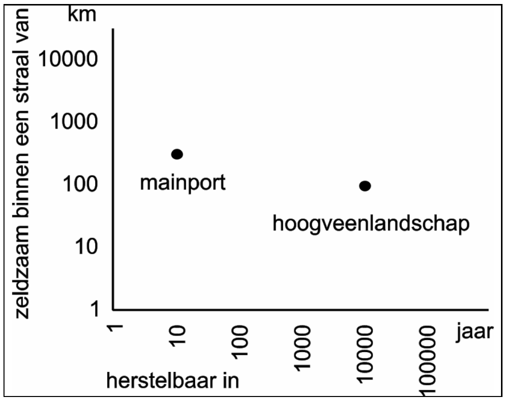


Fig. 811 *Rarity and Replaceability*

Comparing natural and artificial monuments

This figure shows that a main port such as Schiphol and a blanket bog formation such as the Peel (both with an radius of 3km) in a radius of approx. 300 and 100 km, respectively, are rare, but that the time needed to create them is very different. It takes about 10 years to rebuild a main port, but the destruction of blanket bog landscape takes at least thousands of years to reverse. The value of both can be expressed by multiplying both amounts: 3,000 for a main port and 1,000,000 for a blanket bog landscape in our country. The values become more legible by choosing the logarithm (the ‘number of noughts’): 3.5 and 6.

Rarity and replaceability

By viewing rarity in combination with replaceability, a host of methodological queries arise, but they have managerial, cultural, economic, technical, ecological and time–spacial departure points which are urban ecologically relevant. Also even if one doubts the possibility of putting this idea into practice, the mental exercise of thinking through from these points of departure can lead to clarification in various scientific, technical and managerial urban ecologically relevant areas.

5.4.5 Comparability Problems, which categories?

What is replaceable?

Both the IJsselmeer and the Oosterschelde are ecosystems that were formed from a salty sea environment by human intervention during the last century. To what extent can they be compared? This is important for determining their rarity. In determining their replaceability, the question of comparability also plays an important role.

The replaceability of both systems can be initially viewed as being less than or equal to their age, say 30 years. However, one could ask what should be understood by ‘recovery’ in this context.

Supposed expectations on succession

Would their ecosystems experience the same succession if they were now exposed to the sea for a number of years and then shut off from it again? There are a host of examples in which small differences in the initial situation or differences in intermediary situations (e.g., different weather conditions at crucial phases, climatic changes that have started in the meantime, changes in recreational use) can change the direction of the development, to give another result. Are the different outcomes from such possibly different successions comparable and accountable as one group of ecosystems? If one would answer ‘no’, then one would not be able to give meaning to the concept ‘recovery’. In that case, one should, on the grounds of deep ecological insight into succession variants and how to influence them, have access to a sophisticated division of the ecosystem categories that emerge in order to judge exactly whether the outcome of the present succession can be considered to be reconstructable. To have such confidence in ecological predictability is unjustifiable. The far-reaching planning that would be needed to achieve a nature concept exactly is both unnatural and paradoxical, if we want to consider and appreciate ‘nature’ as being outside human planning.

Initial situation

For this reason, one has to harmonise the definition margins of the ecosystem category with the predictability of its, by natural chance directed, existence, and answer ‘yes’ to the question. In the same initial abiotic situation of a large-scale transition from salt to fresh water, one must include in an ecosystem category all outcomes of possible, and within reasonable margins, spontaneous successions.

What is meant by ‘the same initial abiotic situation’? Can this initial situation ever be achieved again? What effects do we have in mind?: total resalination; unexpected overall oil pollution and the resulting death of all life; building to saturation?

For a realistic definition of the replaceability, one has to add the time needed to return to a similar initial situation with the time needed for the succession that follows.

Internal and interdependent comparability

Within one ecosystem, one can talk of an ‘internal comparability’, as being essential for defining its replaceability. For defining rarity, the ‘interdependent comparability’ of a number of ecosystems is necessary. In this way, the rarity of the IJsselmeer region can be relativised by the presence of the Oosterschelde. This consideration is clarified by means of an example.

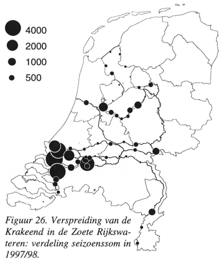
5.4.6 Valuation bases

The death of one is the food of another

Love for an animal or plant species is not always the best stimulus for gaining insight into ecological coherency and perspective. In an ecosystem the death of one is the food of another. Every human intervention in this is a choice, just as building an urban district is a choice. To report on the ecological effects of such a project, a broader insight is required than can be supplied by a few indicator species. Bird, butterfly, plant, toadstool, reptile, mammal and bat work groups are active in almost every town and city. They collect a wealth of information about *their* fascination for the more attractive (caressible) species of the plant or animal kingdom. Full of idealism, thousands of volunteers and hundreds of professional biologists go out and about daily to make inventories. Because of this, atlases are now available showing the distribution not only of categories already named, but also of aquatic plants, molluscs and fish for the Dutch and sometimes European areas or for urban areas, e.g. Amsterdam (Melchers 1991, 1996; Denters 1994), that register their occurrence up to an accuracy of 5 km and sometimes even to 1 km.

Preference for specific species or combinations

From time to time, these distribution maps are amended. There are now already a number of decades that can be compared, so the national or regional presence of animal or plant species can be clearly seen. However, one should realise that there are more and better observers than there were, so that some species might appear to be expanding in numbers, while that might not, in fact, be the case. A recent milestone in Dutch synecology is the overview made of all plant communities, which is also available electronically (Alterra, Synbiosys). Because of this, one can gain a view of succession series and thus the planning for each community. These possibilities will be utilised in the years to come in national and provincial policies on the goal species for the EHS. These atlases have been very useful in writing this book. The example below illustrates how, by referring to different sources, the importance of garland weeds (kranswieren) for the Gadwall duck can be suggested.

<table>
<tr>
<td></td>
<td>
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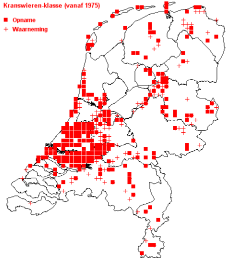
<td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td colspan="2">Gadwall duck (krakeend)[a]</td>
<td colspan="2">04 Garland Weed Class (kranswierenklasse)[b]</td>
</tr>
</table>

Fig. 812 Similarities in distribution situations

Uncertainties

These facts are by far not in a form in which they can be gathered together into a definitive system description. Attempts to do this at national and regional levels by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) and the *RIZA,* among others, are underway. For the time being, the Ministry of LNV is placing an accent on the relationships between vegetation and birds (Schaminée, Joop, and André Jansen 1998, 2001). The presence of certain birds can indeed be an indication of combinations of environmental factors of different scales, because they put different demands on their dynamic fouraging area compared with their peaceful breeding or moulting site. The RIZA has recently produced a more complete description of the IJssel- and Markermeer (Noordhuis, R. 2000), paying attention to the physical and chemical environment, the by many underestimated role of plankton, aquatic plants, fish, water birds, birds that breed in the Netherlands, reptiles, amphibians, mammals, their developments and regional potentials.

An unpredictable young and dynamic ecosystem

From this emerges a dynamic picture of the IJsselmeer region — a young, artificial and unpredictable ecosystem, with the seasonal, annual and decennial coming and going of species, largely in an unclear relationship with each other. Every year, new species are found in the IJsselmeer region, while, at the same time, others disappear. It is difficult to find a reference in the past to make a guess as to where it will go to in the end.

The relation between the large water system outside the dykes and the just as dynamic and increasingly valuable ecosystem on the new land is hardly indicated, because the land, the Oostvaarders- and Lepelaarsplassen, are not included in the area of study of the publication. Nevertheless, it is precisely this relationship that is important when making decisions about whether or not to build outside the dykes.

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[a] IVN Vecht & Plassengebied; Bekhuis, Bijlsma et al. (1988)

[b] W.Kolvoort; Synbiosis, Alterra

5.4.7 Valuing urban nature

A continuing debate

There is no concensus about the way in which urban nature should be valued. This emerged from a debate of biologists in the WLO Work Group for Urban Ecology held on 20 June 2001 at the request of Bram Mabelis, following the publication of his article '*Kwaliteitsmeters voor stadsnatuur*' (Quality gauges for urban nature) in *Levende Natuur* (Issue 6, 2000).

Source: Bram Mabelis' article

During that debate, other publications and methodologies were discussed. From that discussion it appears that potential, time and scale are important concepts in valuing nature. The usefulness of a methodology depends on the balance between politics, design and science. Each of these three has its own character and values.
The texts of different reactions are given below:

IJsbrand Zwart:

Said that, as an employee responsible for ecological policy in Almere, he is trying hard to find a basic ecological map with valuations. Because of the fact that Almere is only 25 years old, the present quality is limited and many facts are missing. The soils (clay and building sand) have nothing special to offer. Describing ecotopes fits in with his intentions to map the nature values of Almere. Due to lack of data, however, it is impossible for him to use species as a gauge. In his opinion, the methodology relies too much on existing facts and qualities, because, in particular, the potentials that are present play an important role.

Henk Timmermans:

Thinking about quality sizes and weights for urban nature demands standardisation on the one hand, and that could be done well by the institutes, and on the other, it must fit in with, and be useful in practice. The latter must be done, and is already partly done, by the municiple services. But they are all trying to 're-invent the wheel'. Therefore, cooperation has to be sought between the various municiple services, the exchange between institutes could be brought up to a higher level and the relationship between research and practice needs to be improved. That is possible in a large project, but non of the participating actors is powerful enough in capital or influential enough to initiate such a project. Would not this be a coordinating task, and thereby a *raison d'être,* for the WLO?

Robbert Snep:

confirms the importance of quality gauges for urban nature. In this, it is important to keep potential and present nature values separate. The present nature value can be determined by making an inventory of nature values and by monitoring target species. The potential nature value is determined by (a)biotic limiting conditions, the spacial positioning (local, regional and national) and the dynamics (management and interference). In working out methods for inventorising and monitoring, as well as determining the potential ecological value, many aspects are not taken into consideration (such as scale level, completeness, trustworthiness, area coverage). A more refined working out of the methods used and (where successful) their standardisation would be desirable.

Taeke de Jong:

Quality gauges for urban nature (Mabelis 2000; Zoest 2001) have managerial, cultural, economic, technical and ecological uses and a function in (time)environmental planning. All the uses earlier listed can be found in this last function. Within environmental planning and urban architecture, each with their own quality criteria (utility, appreciation and durability, in many senses of the word, such as the 'robustness' of the design and the capacity to remain functional in many different situations for many different interested parties), the emphasis does not lie on the actual value of a region, but on its potential value in the future. Essentially, this designer's perspective is essentially of another modality than that of the empiricus. Urban architecture and environmental planning merely create conditions. They cannot bring about or predict utility, appreciation or durability. There is a similar problem in ecology, that of unpredictability due to the lack of many, still unknown and sometimes intangible, causal connections.

The danger of fixing specialists' preferences in valuation maps

For more than 30 years, the urban architectural design profession has been objecting to valuation maps that fix combined values from a particular sector (see, e.g., the debate in the '70s about mapping the environment), because surplus values can only be compiled from partial values. These maps are made using information from different sectors (management, culture, economy, technique, ecology, available capital). A 'sieve analysis' is sometimes applied to all these maps, brought together as layers in a GIS system, to form a stain chart with vetos. Once the vetos have been established, then the role of those sectors in the decision process comes to an end. The urban architectural conceptions that are still allowed to enter this type of 'hinderance chart' or 'limiting condition chart', are often no more than 'left-over options' that produce insufficient or poor living environments. In practice, all these sector charts have their own untraceable assumptions and complicated deliberation systems that are mistrusted in political debate because they cannot be understood in 'simple round words'.

Playing specialists off against one another

In this confusion, the designer takes the opportunity to undermine all these interests with a new concept that offers unforeseen possibilities. In doing this, previous advice is shouted down by reactions from sectors that have kept quiet up to that point and now see a new chance. The agenda is quietly changed in favour of those who are shouting the loudest at the decisive moment. The trick is to be able to play out alternative ecological plans against each other in simple round words or pictures. The valuation chart is used occasionally in this process, but by continually referring to it lessens its power to convince, because the other sectors bring their own valuation chart into the game, whether or not from a hidden agenda. The political game of dice only looks at the side that lies uppermost at the crucial moment.

Improving instead of protecting

Whatever way one measures it, everyone can see that ecological values are going down. It is important to find a method whereby not only registered values are protected and stabilised, but where the value of 'worthless' areas can be increased in the hands of designers so that they are given new chances in changing situations. Ecology can offer vegetative images that stimulate designers' imagination. For me, the aim of urban ecology is to operationalise the design-relevant presuppositions of different ecological valuations in a language that offers a framework for deliberation for designers and politicians, and also for other sectors. My first attempt (Jong 2001) took rarity and replaceability as a point of departure for valuation. These ecologically important variables are compatible with the way of thinking of the urban architectural designer, but they also have an economic meaning. They offer a design-technical and political framework within which other sectors can also be considered.

As urban architectural work and the political trade are both differentiated on the basis of scale (European, national, provincial, regional, municipal), it is a good idea, also in ecology, to differentiate by scale. Each scale range between a given grain (unit) and framework of decision-making has its own style of deliberation.

A grain of valuation

In Mabelis' systematics, two differences can be identified that have many interesting theoretical implications. Mabelis' grain is species-level, and the framework is a referential area such as a park, neighbourhood, district or town. After long hesitation, the grain taken in a variable framework when planning Almere Pampus was the neighbourhood level (radius 300 metres). By including 'species-similar' references in the wider surroundings within the concept of rarity, many problems in establishing an historical place-bound reference can be avoided. Therefore, unlike Mabelis' system, the reference is not internal, but external: Are there similar systems in the (wide) vicinity? These references would change simultaneously and detectably if, for example, climatic change made the historical reference irrelevant. In addition to that, the urban environment is already incomparable with historical references, due to raising (using sand to prepare land for building), draining and a higher average temperature, unless one restricts oneself to those district parks which have a similar water management system as before urbanisation.

Indicator species

I agree with Mabelis' choice to use a number of indicator species, irrespective of their rarity and relationship to each other. If the rarity can be valued at system-level, then valuing it at species-level would lead to double valuation. Mabelis only measures the diversity of indicator species. In itself, it is a valuation choice that can become opaque and evoke discussion when the choice of indicator is made complicated by professional ecologists. My question in Almere was: ‘From what scale and categories does one choose the limits to a system, in order to be able to identify surrounding systems as being comparable?’ I have not found an answer yet. Perhaps it is completely unnecessary to make a systematic choice of category. On the one hand, I am impressed by the enormous number of inventorial data that, due to Schamineé’s efforts, have now been released by Westhoff’s plant community School and built into the nature-target types of the LNV (Schamineé and Jansen 1998, 2001). On the other hand, I am also sensitive to the criticism directed against such preconceived category formation. I am more inclined towards abiotically orientated types of ecotope, because they can be directly influenced by urban architecture, and indicate potentials. However, data and prognoses based on them are less accessible.

Categories and types to compare

New categories are constantly emerging, especially in urban districts, or new spacial constellations are recognised that do not fit into an existing typology. A similar sort of problem already exists within the designers’ profession when you try to set up a building typology, not to mention an urban architectural typology. Every final year student will try to prove that their design does not fit in there, and that it is thus a ‘new type’. In the 1950’s, CBS’s Standard Company Categorisation (SBI) divided companies into the wood industry, steel industry, textile industry, and so forth, but it collapsed as more industries came into being that began to use a combination of all these materials. The statistics from the old company categorisation became incomparable with those of the new one, so that it was no longer possible to make long-term prognoses from this material. The same thing happened with the land-use statistics. Each categorisation is thus a child of its time and carries along with it hidden assumptions. The only aspect that remains is the level of the species. I have to agree with Mabelis there, although taxonomy also turns out to be a dynamic process.

Valuating potentials

I do not know how the ecological valuation charts that van Zoest showed of Amsterdam were made. I am curious to find out, and hope that their valuation systematology is simple enough for designers to have access to their presuppositions. In that case, an interest will also emerge in the ecological potentials of less valuable areas and that is more challenging and more productive than a veto chart of valuable areas. For the time being, in Almere, there is only talk of less valuable areas. Therefore what it comes to here is extending the abiotic potentials. That demands design, ecological design, and the creation of living conditions. When considering nature development, one should perhaps have no other aims in mind than diversity. After all, we value nature mainly in that it *does* lack human influence. In that light, nature-target types are paradoxical. We do not design a house to instigate a certain type of household. We design an *oikos* merely to make different households possible.

5.5 Managing Nature

Many kinds of context

There are many managerial, cultural, economic, technical, ecological and spatial situations (spacial contexts and perspectives in time) that influence ecological success, whatever the plan. They can be incompatible on different scale levels, without interfering with a rich natural habitat. It is thus possible for the aims for nature at the provincial level to be mainly directed towards clay morasses, while at the municipal level, local differences in soil and land use are utilised for much more promising nature development on such tiny local areas that they do not hinder the larger targets. In this way, national societies such as the *Natuurmonumenten* and the ANWB can place the emphasis on recreational values and national infrastructure, while the municipality can prioritise its responsibility for housing.

Contradictions and conflicts solved by scale

Such contradictions are often a question of differences in scale and are therefore not true contradictions. Management may direct on a national level, follow on a regional level and direct again on a local level. Nationally, culture may be focused on tradition, regionally on experimentation and locally on tradition again, or vice versa. The national economy can flourish, be retarded regionally, but within them, there may be successful locations again. In a more physical–technical way one can direct one’s attention nationally to specialising on European nature or economy, while striving locally for function combinations that produce a better overall fulfillment of life. Ecological diversity on a European level can produce homogeneity on a national level and within the NW European building concentration there is enough space left over for national distribution, and, within that, for concentration again, regionally.

Effect analysis supposes expectations about the future context

The number of plausible perspectives on all these levels is so large that, unless founded on a broad scenario, there is no possibility of carrying out an effect analysis that will have any predictive value. National, regional and local nature goals and presuppositions about managerial power, cultural developments, economy, techniques, ecology and space are thereby essential. To arrange these presuppositions scalewise, the following scheme can be applied:

	radius	managerial	cultural	economic	technical	ecological	spacial
global	10000 km	directing	experimental	growth	integration	diversity	distribution
continental	1000 km	following	tranditional	shrink	specialisation	homogneity	accumulation
national	100 km	directing	experimental	growth	integration	diversity	accumulation
regional	30 km	following	traditional	shrink	specialisation	homogoneity	distribution
local	10 km	directing	experimental	growth	integration	diversity	accumulation
urban	3km	directing	experimental	growth	integration	diversity	accumulation
in the district	TKA	directing	traditional	growth	specialisation	diversity	distribution
	Hosper	directing	experimental	growth	integration	diversity	accumulation
	H+N+S	following	experimental	growth	specialisation	diversity	accumulation

Fig. 813 *Presumed perspective*

Hidden suppositions about the future in plans

Urban architectural plans for the same region can differ in perspective. The perspectives of the urban architectural plans of TKA, Hosper and H+N+S differ as to whether the authorities will be directing or following at the district level, whether one would like to live more traditionally or experimentally, or whether there is talk of (de)concentrated specialisation or concentrated integration of functions.
The interpretation given here is arbitrary and on higher scale levels it is uniform for the designs, but the scheme makes one aware of suppressed presuppositions that designers and valuators have with

respect to different levels. These presuppositions differ among the participants in the decision-making process. We can, however, realise them in part, especially at the local level. If these presuppositions are explicit, a guess can also be made of the effects of different plans after further research at the neighbourhood level.

5.5.1 Main Ecological Structure (EHS) and nature-target types

EHS

A main ecological structure (EHS) is established in nature policy that is worked out further for each province.

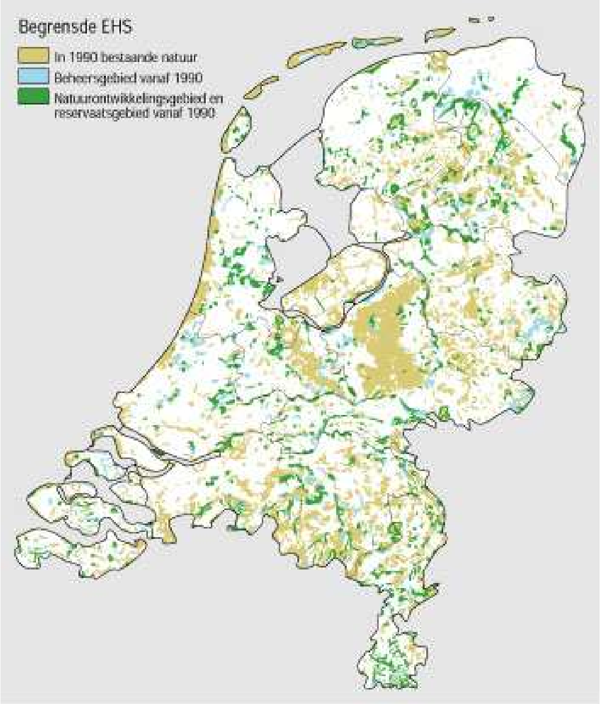

Fig. 814 *The EHS for the Netherlands*[a]

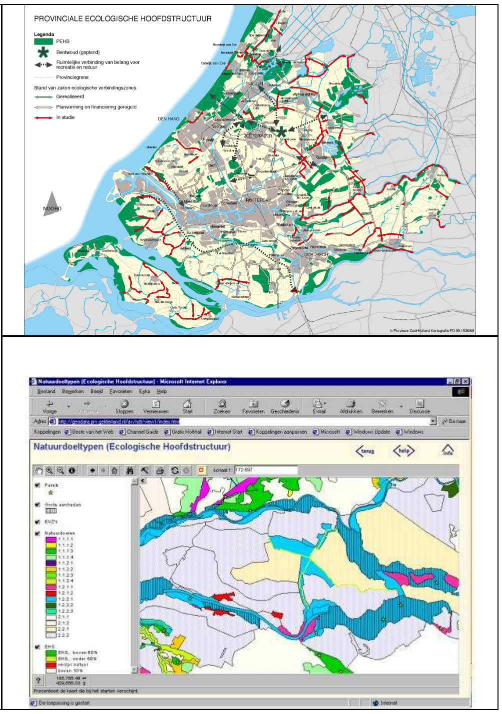

Fig. 815 *The EHS worked out on Internet for the province of South Holland and the Gelderse poort*

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[a] LNV (2000)

Nature target types

Nature conservancy sets certain types of nature as a target for itself, in order to shape the main ecological structure in the Netherlands*.* In Fig. 31 these nature-target types of the IKC/Ministry of *LAVIN* by Bal, Beije et al. (1995); Bal, Beije et al. (1995); Bal, Beije et al. (2001) are linked to an urban architectural scale.

	Main group 1	Main group 2	Main group 3	Main group **4**[1]**)**
Name	almost-naturally	supervised-naturally	half-naturally	multifunctional
Radius	**3km**	**>1km**	**300m**	**100m**
Future picture	global	global	fixed	fixed
1. STRATEGY				
spacial scale	Landscape > thousands of ha.	Landscape > 500 ha.	ecotope/mosaic to approx. 100 ha.	ecotope mostly a few ha.
location	mostly process-determined	process and pattern-determined	process-, pattern- and species-determined	pattern- and species-determined
processes	not directed	directed integrally	directed in detail	directed in detail
patterns	not established	not established	established, perhaps a cyclical succession	established
directing variables	non	process-focused on landscape level	process- and pattern-focused up to ecotope level	process- and especially pattern-focused up to ecotope level
2. LAY-OUT				
nature–technical	only in the beginning phase	only in the beginning phase	perhaps repeated	perhaps repeated
environmentally specialistic	only in the beginning phase	only in the beginning phase	permanent, if necessary	non
Conservancy				
Internal nature conservancy	non	non	partly necessary	necessary
compartmentalising	non	non	possibly in mosaic	possible
shared use	(very) extensive	(very) extensive	(fairly) extensive	characteristic
3. DEVELOPMENT				
succession-stage	mostly diverse stages	diverse stages	a stage/mosaic	a stage
extent of development	on average long	on average long	rather short	short
predictability	on average, limited in the long run	on average, rather limited in the long term	quite large	large

[1]) The characteristics of the types in subgroup 4B (derived multifunctional types), apart from the characteristics associated with shared use, they are the same as those of the types from which they are derived.

Fig. 816 *Overview of nature-target types*[a]

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[a] Bal, Beije et al. (1995)

Nature-target types specified by physical-geographical region

The nature-target types are specified according to physical-geographical region (Fig. 817).

Physical-geographical region		Main group				total
		Landscape scale		ecotope level		
		1	2	3	4	
		3km	>1km	300m	100m	
hl	Hilly land	1	2	12	2	17
hz	Higher sandy soils	2	3	19	2	26
ri	Fluvial area	0	2	12	2	16
lv	Laagveen area	1	3	10	2	16
zk	Marine clay area	0	3	13	2	18
du	Dunes	1	1	16	2	20
az	Estuaries	0	3	8	1	12
gg	Tidal zone	2	2	2	0	6
nz	North Sea	1	0	0	0	1
	Total	8	19	92	13	132

Fig. 817 *Nature-target types per* ***physical–geographical region***[a]

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[a] Bal, Beije et al. (1995)

5.5.2 Nature-target types for the higher sandy soils

The following nature types have been established as targets for the physical-geographical region ‘higher sandy soils’ (e.g. the Veluwe) (Fig. 818).

Fysisch-geografische regio ***Hogere zandgronden***

3km	>1km	300m	100m
hz-1.1: zand-natuurboslandschap	hz-2.2: zandverstuivingslandschap	hz-3.1: laaglandbeek	hz-4.1: akker
hz-1.2: hoogveenlandschap		hz-3.2: zoetwatergemeenschap	
		hz-3.3: rietland en ruigte	
	hz-2.3: boslandschap van bron en beek	hz-3.4: ven	hz-4.2: grasland
		hz-3.5: droog grasland	
		hz-3.6: bloemrijk grasland	
		hz-3.7: vochtig schraalgrasland	
		hz-3.8: open zand	
		hz-3.9: droge heide	
		hz-3.10: vochtige heide en levend hoogveen	
hz-2.1: boslandschap op arme en lemige zandgronden		hz-3.11: struweel, mantel- en zoombegroeiing	hz-48: afgeleide doeltypen uit hoofdgroepen 1-4
		hz-3.12: hakhout	hz-48.3: inheemse bos cultuur
		hz-3.13: bosgemeenschappen van arme zandgrond	hz-48.4: boscultuur met uitheemse soorten
		hz-3.14: bosgemeenschappen van leemgrond	
		hz-3.15: bosgemeenschappen van bron en beek	
		hz-3.16: bosgemeenschappen van hoogveen	
		hz-3.17: middenbos	
		hz-3.18: boombos	
		hz-3.19: park-stinzenbos	

Fig. 818 Nature-target types for the ***higher sandy soils***[a]

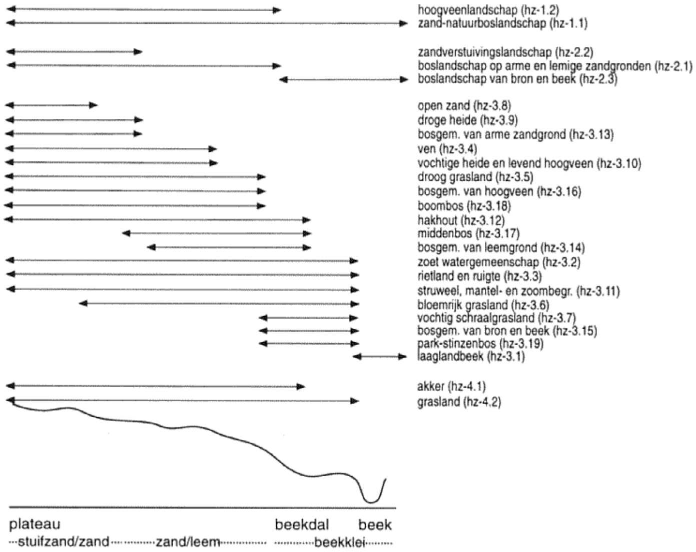

Fig. 819 *Nature-target types for* ***higher sandy soils in local profile***[b]

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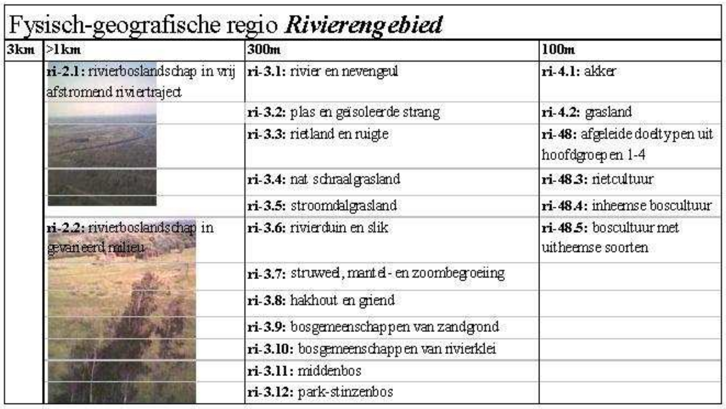
[a] Bal, Beije et al. (1995)

[b] Bal, Beije et al. (1995)

5.5.3 Nature-target types in fluvial areas

For The Fluvial Area, the following nature types have been established as targets (Fig. 820).



Fysisch-geografische regio ***Rivierengebied***

3km	>1km	300m	100m
	ri-2.1: rivierboslandschap in vrij afstromend riviertraject	**ri-3.1:** rivier en nevengeul	**ri-4.1:** akker
		ri-3.2: plas en geïsoleerde strang	**ri-4.2:** grasland
		ri-3.3: rietland en ruigte	**ri-48:** afgeleide doeltypen uit hoofdgroepen 1-4
		ri-3.4: nat schraalgrasland	**ri-48.3:** rietcultuur
		ri-3.5: stroomdalgrasland	**ri-48.4:** inheemse boscultuur
	ri-2.2: rivierboslandschap in gevarieerd milieu	**ri-3.6:** rivierduin en slik	**ri-48.5:** boscultuur met uitheemse soorten
		ri-3.7: struweel, mantel- en zoombegroeiing	
		ri-3.8: hakhout en griend	
		ri-3.9: bosgemeenschappen van zandgrond	
		ri-3.10: bosgemeenschappen van rivierklei	
		ri-3.11: middenbos	
		ri-3.12: park-stinzenbos	

Fig. 820 *Nature-target types for **The Fluvial Area***[a]

300m

ri-3.1: rivier en nevengeul
ri-3.2: plas en geïsoleerde strang
ri-3.3: rietland en ruigte
ri-3.4: nat schraalgrasland

ri-3.5: stroomdalgrasland
ri-3.6: rivierduin en slik
ri-3.7: struweel, mantel- en zoombegroeiing
ri-3.8: hakhout en griend

ri-3.9: bosgemeenschappen van zandgrond
ri-3.10: bosgemeenschappen van rivierklei
ri-3.11: middenbos
ri-3.12: park-stinzenbos

Fig. 821 *Nature-target types for **The Fluvial Area — 300m***[b]

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[a] Bal, Beije et al. (1995)
[b] Bal, Beije et al. (1995)

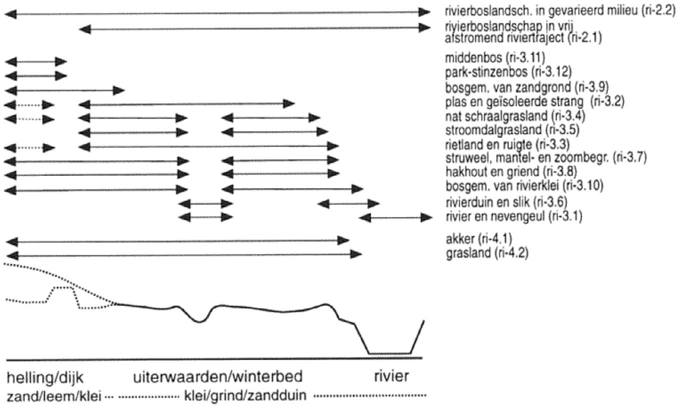

Fig. 822 *Nature-target types for* ***The Fluvial Area in local profile***[a]

5.5.4 Nature-target types for the Marine-clay areas

For the Marine-clay areas, the following nature types have been established as targets (Fig. 823).

<table>
<tr><th>3km</th><th>>1km</th><th>300m</th><th>100m</th></tr>
<tr><td rowspan="2"></td><td rowspan="2">zk-2.1: clay–primeval morass (including freshwater tidal landscape)
zk-2.2: wooded landscape on clay
zk-2.3: low fen morass</td><td rowspan="2">zk-3.1: freshwater community
zk-3.2: brackish water community
zk-3.3: salt and brackish brushwood and landscape
zk-3.4: reedland and brushwood
zk-3.5 wet infertile grassland
zk-3.6: grassland rich in flowering plants
zk-3.7: peat heath
zk-3.8 thicket, mantle and seam growth
zk-3.9: felling wood and osiers</td><td>zk-4.1: food-crop field
zk-4.2: grassland
zk-4B: target types from the main groups 1-4
zk-4B.3 reed culture
zk-4B.4: indigenous woodland culture
zk-4B.5: woodland culture with foreign species</td></tr>
<tr><td>zk-3.10: woodland communities on Marine clay
zk-3.11: woodland communities on peat-on-clay
zk-3.12 middle woodland
zk-3.13: park-<i>stinzen</i> woodland</td></tr>
</table>

Fig. 823 *Nature-target types in* ***Marine-clay areas***[b]

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[a] Bal, Beije et al. (1995)
[b] Bal, Beije et al. (1995)

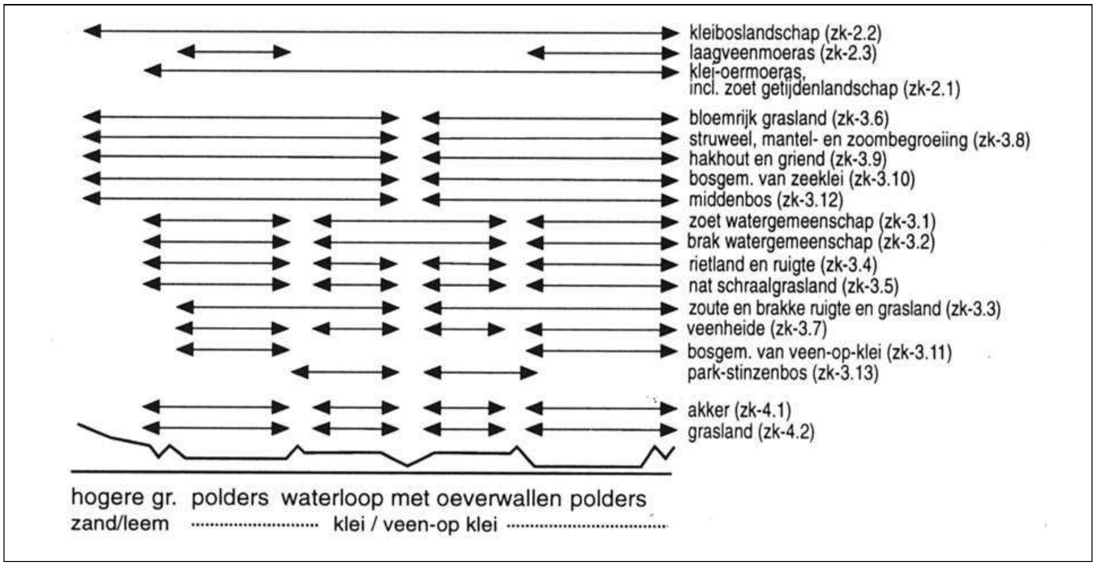

Fig. 824 *Profile of nature-target types in Marine-clay areas*[a]

5.5.5 Urban nature

The relation between abiotic factors in urban areas and diversity of plant species is examined on 8 levels of scale. Hypotheses on the abiotic origin of this diversity, especially within cities, are listed on each level of scale. They are supported by examples from the cities of Zoetermeer and partially Enschede.

Regions

If one compares regions (of a 30 km. radius) with each other, other differences come to light than when, for example, one compares groups of buildings (‘ensembles’ with a radius of 30 m). Travelling through an urbanised landscape, on average, one sees, for example, that within 30 m. the extent to which land is being trodden on and exposed to sunlight varies, but variations in ground and water management are often only evident at distances greater than 30 km. Which differences in abiotic situations can, for each scale level anew, explain the differences in richness of species? This question is largely unanswerable, but for urban architects and civil technicians it is crucially important, because these disciplines, certainly in new situations, literally set the conditions of these variables. In the case of high-lying wet and dry areas, should one bring about change every 100 km. or every 10 m? Should one open up or drain water every 100m or every 1000m? This produces — depending on the existing context — an entirely different diversity in the initial abiotic situations. In addition, when one realises that one can do that differently in one direction or another, that results in an infinite number of design alternatives. Which of these alternatives produces the most extensive ecological richness?

Towns

Towns are stonier, 1 to 3℃ warmer, and are nowaday s cleaner, than their agrarian surroundings. They are, thanks to the 19th century hygienists (see Houwaart, E.S. 1991), cleaner and more spacious than a century ago. Urban environments are dynamic (there are few places that have not been turned upside down at least once during the last 25 years), but, viewed abiotically, they are also varied. For botanical diversity, the important abiotic differences (in combinations of minerals, moisture, exposure to sunlight, mowing management, disruption, treading on (extent of), (surface) hardening (by constructing roads, heat capacity) are greater per square km. than in agrarian areas and are often also greater than in nature reserves. On what scale level should these variations be explained and utilised?

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[a] Bal, Beije et al. (1995)

Hypotheses for design on different levels of scaele

For the time being, we will choose the following points of departure (hypotheses):

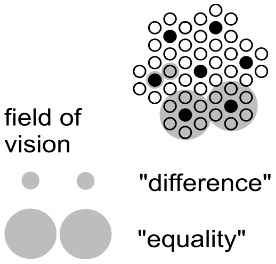
Variation effective for the vegetation	R =	
the height, ground	30km	
ground ('floor' or 'bottom' if you're talking about a lake, canal, valley, etc, i.e. a surface), water management	10km	
seepage, drainage, water level, opening up waterways in towns and cities	3km	
urban architectural planning	1km	
dividing land into lots (distributing green areas)	300m	
(surface) hardening (by constructing roads), treading on (the extent of), manuring by pets, minerals	100m	
difference in height, mowing management, disruption	30m	
exposure to sunlight	10m	
One must interpret the radius between adjoining radii, flexibly. The last four scale-levels cannot, as yet, be observed in grid squares of one kilometre.		

Fig. 825 *Hypothetical working variations per scale-level in urban-nature subsoils*[a]

Fig. 826 Scale paradox

Scale paradox

The scale paradox in urban architecture (see *Fig. 826* and Jong, T.M., de 1995) teaches us that conclusions must be drawn from the same scale-level (the smallest grain considered and the largest frame) as that on which the premises were based. For example, in the above figure, if every time one takes into consideration one small circle and its surroundings, then one notices differences, while, on the contrary, when repeatedly comparing small groups of seven with their surroundings (see also Kolasa, J. and Pickett, S.A. 1991) one should conclude that they are alike. The paradoxical notion 'homogenous mixture' indicates this dilemma exactly: at a certain scale level it is homogenous and at a lower abstraction level it is heterogeneous. The notion 'bundled deconcentration' is another example. For such notions, an immediate question can be raised: 'On which scale is the one and on which scale the other?'. In addition, this figure shows that confusing concepts like these are already possible where there is a factor 3 linear difference in scale level. There is a 7-decimal linear difference between a grain of sand and the earth, and so there are more than 14 confusing concepts lurking in the background.

Scale articulated view on image and ecology

With this in mind, in Amsterdam, we have made an image quality plan that attempts to find an optimum in tolerance between surprise and recognition at each scale level (in their extreme form, between chaos and order) as the sensory working of variation (Jong, T.M. de, and Ravesloot, C.M. 1995). Diversity in ecology is also sensitive at scale-level as both cause and effect, or rather as abiotic condition and biotic effect. The crucial rarity of species, biotopes, plant communities, ecosystems, landscapes, plant–geographical districts is just as dependent on scale (globally, continentally and nationally, etc. rare). For example, in Zoetermeer, a policy line was established at some point that one should concentrate on globally (within a radius of 10,000 km) and regionally (within a radius of 30 km) rare species (and thus not on nationally rare species). Insight into this demands a (as yet not available) differentiated and long-term overview of combinations of species and their ability to recover within 1, 10, 100 years, etc. (rarity in time). It thereby becomes possible to deliberate rationally between different urban functions (a main port is rare within 300 km and can recover within 10 years; a peat landscape is rare within 300 km and can recover within a 1000 years). As there are too few facts available, we do not deal with rarity and recoverability any further in this article. A scale-based view of diversity is a condition, and a good first step in the direction of, such a scale-based view of rarity.

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[a] JONG (2000)

5.5.6 Differences in diversity between and within regions

Zoetermeer and Enschede (approx. the same size) are situated in areas that differ greatly in richness of species. The urban areas of Zoetermeer and Enschede differ little in diversity (not counting combinations of species). This complies with Denters's (1999) references that indicate that urban flora differ very much ... from those in the immediate neighbourhood, whereas striking similarities can be found between the flora of various towns ...'. When one views these towns as a whole, at regional level, the age of the town does not have much influence on the diversity. The influence of soils (clay and sand, respectively) should also not be exaggerated because in preparing low-lying land for building, sand is used as a material to raise the level of the ground. In fact, in Zoetermeer, that has not happened very much. Except for relief that is related to infrastructure, in principal, the clay bottom has here only been partially raised to approx. 40 cm using soil from within the urban, excavated from new water features and building pits, thus creating a closed soil balance. Waterways can be encountered approx. every 400 m. The entire urban area here will be drained more or less to the same extent, to 1m. below ground level.

Differences in diversity at urban level

In both Enschede and Zoetermeer there are large differences within the town in richness of species (see Fig. 768). In both towns, the number of wild plant species per square kilometre are shown in dots representing 10 species, such as is more precisely inventorised by Floron and by local observers (municipality and KNNV). Fig. 768 shows three widely differing one-kilometre grid squares in urban architecture, extending from the district Meerzicht (left) to the old village (right) in Zoetermeer. The numbers of species found also differ significantly. In the 1970's, Meerzicht was the third newly built district, following the high-rise districts Palenstein and Driemanspolder that dominate the view from the motorway. From there onwards, high-rise buildings were renounced in the newer, more northerly districts.

Centre and periphery

New perifery districts in Enschede score relatively high; old central districts, just as, for example in The Hague, score relatively low. In Zoetermeer almost everything is new. What is noticably different in Zoetermeer compared with Enschede is that the richness in species decreases from the middle to the edge in many cross-sections. The largest number of species is to be found in the middle of the town, in the old village. During the last 30 years, the town has grown round this centre, first westwards and then in a clockwise direction. The edges of town are sometimes less accessible and admissible for observers. Eutrophication from the rural surroundings can play a role. There have been fewer disturbances in the old village in recent years than elsewhere in the town.

Infrastructure

Apart from this, the centre is a concentration of old high water courses and new, relief-rich infrastructure such as the fast train and the urban motorways, with scarcely trodden-on verges. Both contribute to the richness of the local species. Unexpectedly, in both towns, a concentration of infrastructure appears to foster more species. Industrial premises also score well.

The high, dry, chalk-rich railway line, along which vegetation is regularly removed, produces, in between the maintenence clearances, and for some one-kilometre grid squares, an extraordinary pioneer environment that thereby contributes to the local richness of species. The banks of this looped-shaped fast train line have the largest range of variations of exposure to sunlight imaginable. The only documented example of ecological infrastructure at work along the fast train line, following its opening in 1977, is the advance, in 1984, of the Cinnabar moth via a long yellow ribbon of Ragwort from the dunes near The Hague (van Wely,1993).

Waterways

Waterways in the northern part of Zoetermeer are suffering more and more from seepage containing phosphate and iron, made turbid by algae. They were originally maintained by vegetation-unfriendly dredgers, but this activity has been restricted in recent years to that of keeping the flow of water open at essential bottlenecks in the water system. Old water courses, sometimes with water levels raised as much as 4m, that have been left undisturbed by the urban architect, have clearer water, without any seepage and their banks are rich in species, sometimes with rare flora. At the water's edge, the rough banks of ponds encircled with reeds, although picturesque, are influenced by seepage, and so contribute relatively little to the richness of species.

Mowing habits

Whether removing mown vegetation from the sides of motorways has contributed to the increase in species from 200 to 222 over the entire motorway network between 1982 and 1988 (Vos, 1990) is difficult to prove. It is possible that increases in shade and leaf-fall from planted vegetation and manuring by pets from raised paths has worked against the desired empoverishment of these areas. Moist grasslands that are rich in food are mown twice a year, and drier or wetter grasslands only once.

Smaller scale differences in initial abiotic situations

The urban architectural variation at district level (within a radius of 1 km) appears to influence the richness of species, but can be disrupted by local elements such as the fast train line. The variation in richness of minerals, moisture, sunlight, hardening of soil surfaces and disruption is effective at this scale level, but, for urban architectural ends, can only be evaluated by means of inventories which have a smaller resolution than the usual square kilometre. The 'mean-field assumption' (Dieckmann, C.S. 2000) used in current statistical ecological research is insufficient for that. For example, due to detailed planning, mowing management can vary within a radius of 30 m. Schools could be brought in for such labour-intensive inventories. For the urban nature type 'nature in the living environment', a start has been made to inventorise abiotic factors within a radius of 100m (Breems, S.C. 2000).

Conclusions

For a truly ecological urban architectural design, it is necessary to conduct scale-based ecological research in towns, in which differences in species richness and rarity within a radius of 1 km and 300, 100, 30 and 10 m are explained separately. To help balance a solution against other functions, it is desirable to establish a measure of recoverability (e.g. within 1, 10, 100 ...years). In opposition to current urban ecological opinions, arguments can be put forward about the observed, sometimes negative, influences of seepage, the unexpected positive influence of business zoning and traffic infrastructure, and the limited influence of the subsoil, pond verges and the age of buildings on botanical diversity. Herewith, is also, for example, the much defended strategy of the two networks (traffic infrastructure and water) refuted in its scaleless form.

6 Living, human density and environment

Contents

6.1 Adaptation and Accommodation

6.1.1 Human population

Adaptation and accomodation

This chapter deals with the adaptation of the human species to its habitat (adaptation), and the adjustment of the human habitat to the species (accommodation, technique).
The unmatched growth of human population is due to its faculty of toolmaking and consequently, its accomodating capacity. That accomodating capacity happens to be the object of architecture and urban design.

Architecture and urban design as a part of ecology

So, the chapter approaches architecture and urban design as human ecology, a part of aut-ecology[273], necessary to understand the distribution and abundance of this particular species and its remarkable artefacts on Global, European, national, regional and local levels. Syn-ecologically it is interesting to see how this species recently developed into a plague, ousting other species and changing the environment (environmental ecology). From a viewpoint of systems ecology its potential to survive on any level of scale in space and time could be studied, taking global resources into account. Cybernetic ecology could prove helpful for design and chaos ecology for management.

History as a laboratory

However, this chapter starts with a historical approach, because history is a kind of laboratory unveiling suppositions of our existence we are inclined to forget.

Anthropogenesis

For millions of years, human characteristics have been tuned to the natural environment in which people had to survive (adaptation). Therefore, it is useful to acquaint oneself with this ‘reference’ environment as such, and, now and then, to allow this nature to be the tutor of architectural (and mechanical engineering) forms. Even in the most advanced studies into the development of autonomous robots, the mechanics of insects are attentively observed. Also in the other development that is thought to be important for the future — biotechnology — nature is often ‘the tutor of art’ (‘Natura Artis Magistra’).

Human habitat

In the history of human origins (anthropogenesis)[a] , human adaptation and environmental determination have played a major role. Different human-like animals such as *australopithicus* developed and later became extinct. Approximately 2 million years ago, due to climatic and environmental changes in Africa, *homo habilis* with larger brains than its predecessors exchanged a forest habitat for savanna starting to eat meat.[274] This species’ apparent use of tools has often served as a criterium to demarcate humanity: the capacity to oversee a series of acts of which only the first (e.g. the making of tools) can be carried out immediately.[275] The use of language or fire as tools both suppose such an ability. Subsequently, *homo erectus* developed with many variants. Thirty thousand years ago only two species remained, *homo neandertaliensis* and *homo sapiens.* The neandertalers existed at least 500 000 years, but became extinct, leaving *homo sapiens* with a common ancestor in Africa approximately 150 000 years ago as the sole human survivor.

Arboral pre-adaptations?

The origin of the human race, preceding *homo habilis*, should have produced a number of ergonomically interesting ‘aboreal pre-adaptations’ (adaptations to the former forest environment), such as the ability to grasp with the hands, stereoscopic vision, upright posture, the production of a limited number of offspring at each pregnancy, a lengthy up-bringing of the offspring, etc.[276] The tropical rain forest is then by no means as frightening as is it is made out to be. It is a fantastic experience to cut a path for oneself through this twilit environment: it feels as though one is returning

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[a] De opvattingen over de antropogenese zijn jaar in jaar uit sterk in beweging. De hier uitééngezette opvatting is ontleend aan het wat oudere maar voor ons doel vrij volledige boek van Harrison, G. A., J. S. Weiner, et al. (1964) *Human Biology* (Oxford) The Clarendon PressHarrison, G. A., J. S. Weiner, et al. (1970) *Biologie van de mens* (Utrecht/Antwerpen) Het Spectrum N.V..

home after 6 million years. All the senses are stimulated in a changing, yet balanced, way. One can seldom see further than 100 metres ahead and is constantly obliged to focus the eyes on objects both nearby and further away. Moreover, it is an environment similar to a Gothic cathedral: full of vertical light-seeking pilasters, in which, occasionally, the sun festively forces its way to the bottom. This demands continuous attentiveness, but, on the other hand, the senses seldom become overloaded.[277]

Savanna adaptations?

The 20tth century witnessed the clearance of the last primitive forest peoples and their culture and habitat. Nevertheless, a cultural-ecological study of these communities that are so closely linked with our reference environment could be of importance for future urban design.

The transition from forest dwelling to life on the flat savanna lands must have made the eyes lazy, but the hands and the head more diligent. Particularly in between these environments people seek cover and build their own protective shelters.

6.1.2 Habitat, density and economy

With the help of technical resources, the human species nowadays can maintain and organise itself to suit its own wishes in every biotope (accommodation). In general, such accommodation results in pioneer, grassland and brushwood vegetations. Sometimes, mankind changes the dominance relationships in the landscape to such an extent that, in places, the old situation remains protected (nature conservation) or new successions are allowed to come into being (nature development).

Habitat and density

Different populations live in different densities (Fig. 827)[278].

HABITAT	% total land area on earth	% total world population	inhabitants per km^2
Dry lands and deserts	18	4	10
Tropical forest/ shrub crops	15	28	60
Grassland areas	21	12	20
Semi-forested areas	7	39	190
Mediterranean shrub overgrowth	1	4	130
Temperate to cold area	10	1	3
Arctic/tundra area	16	<1	1
Living area in the mountains	12	12	30

Fig. 827 *Population densities in different habitats 1970*[a]

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[a] Harrison, Weiner et al. (1964); Harrison, Weiner et al. (1970)

Habitat and economy

Each habitat has resulted in different forms of economic household management (Fig. 828). In mediterranean scrub and tropical grasslands (savannahs) all types of economy have been found.[279]

	Food-gatherers	Hunters	Pastorales	Nomads	Simple cultivators	Advanced cultivators
Equatorial forests	Siamang	Pygmies, Melanesians			Amazone, Nw.-Guinea	Indonesia, Java
Tropical forest and scrub	Grand Chaco indians	the Bantu	the Bemba		Indo-Dravidians, South Americans	Bantus
Tropical grasslands (savannahs)	Australoids	Hadza (East Africa)	Nilotes		North American Indians	Hamites
Drylands and deserts	Bushmen and Australians			Bedouins, Tuaregs	Oasis dwellers	Oases (riverine)
Temperate forests	Australians, Mesolithic Europeans	Tasmanians, Predmost	Iron Age Europeans		Chinese	Peasant Chinese
Mediterranean scrub	Strand lopers	Californian Indians	Balkans	Berbers	Neolithic Iron Age, Maori	Medieval Europe
Temperate Grasslands	Paleolithic Europeans		Mongols	*boerjaten,* mongols	Siouan Indians	Pawnee indians
Boreal	Fuegians	Samoyeds		Lapps		
TUNDRA		Eskimos		Lapps		

Fig. 828 *Habitats, economies and cultures*[a]

From this it appears that there is no simple relation between habitat and household management, as believed by physical determinists at the end of the last century.(Claval, 1976).

POPULATION	km^2 per head	heads per km²	for 100 people	
			km radius	nominally
Food gatherers				
Upper Palaeolithic (Eng.)	500	0,002	126	100
Australian aborigines	60	0,017	44	30
Tierra del Fuego islanders	20	0,05	25	30
Andamen Islanders	1	1	6	10
Developed hunters/fishermen				
Eskimos and Indians	500	0,002	126	100
Eskimos (Alaska)	80	0,0125	50	30
Mesolithic man (Eng.)	25	0,04	28	30
Pampas Indians	5	0,2	13	10
British Columbians	0,1	10	2	3
Arable farmers and nomads				
Neolithic man (Eng.)	1	1	5,6	10
Pastoralists and nomads	0,25	4	2,8	3
	0,03	33	1,0	1
Iron Age man (Eng.)	0,25	4	2,8	3
Middle Ages (Eng.)	0,05	20	1,3	1
Middle Age man	0,02	50	0,8	1
Swidden farmers	0,001	1000	0,2	0,1

Harrison, Weiner et al. (1964); Harrison, Weiner et al. (1970)

Fig. 829 *Economies and population density*

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[a] Harrison, Weiner et al. (1964, 1977 p 398) Harrison, Weiner et al. (1970)

Density and economy

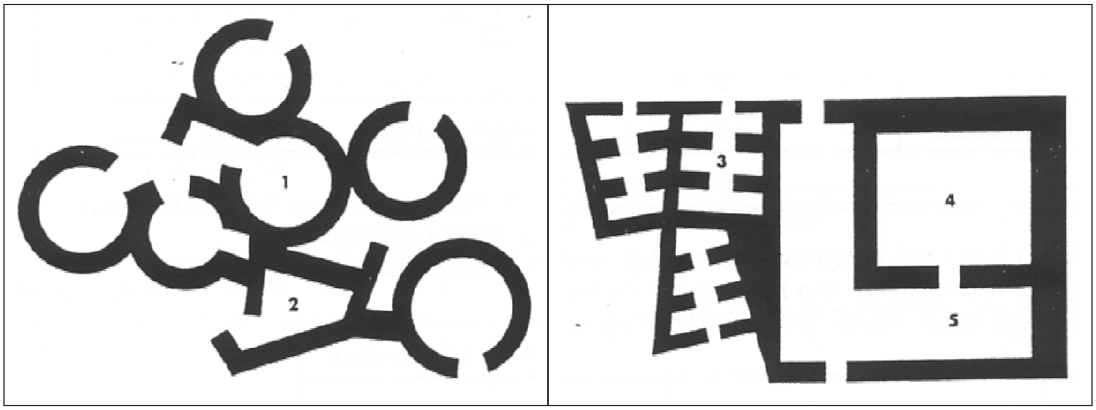
However, there is some relation between household management and population density (Fig. 829)[280]. In the last two columns, the areas are translated into the radius of a circle with the same or almost the same area for a group of 100 people[281]

The same approximated sizes will play an important role in comparing different urbanising models.

From hunting into agriculture

The transition from hunting to agriculture has had enormous societal consequences.

In the village Beidha, in Jordan, the floor plan of dwellings changed from round to square during the 500 years from 7000 BC. This reflects a probable social development towards sedentary living with more task division and functional differentiation of the built environment (Fig. 830).[282]



1 Living room
2 Storage places in the neighbourhood

3 shops
4 community building
5 inner courtyard
living in storeyed buildings

Fig. 830 *Historical floor plans of dwellings that reflect the transition from hunting to agriculture*[a]

6.1.3 Population growth

Agriculture

If an animal or plant species gains dominance in a new habitat, then, initially, the population of these species can increase unhindered, but sooner or later it comes up against boundaries in the carrying capacity of the environment (in terms of Opschoor and Weterings (1994) and Koten-Hertogs, Beckers-de Bruyn et al. (1995) environmental utilisation space (milieugebruiksruimte), or (in the case of human beings) boundaries, which they themselves fix, within the existing biocoenosis (ecological community). If we couple the beginning of mankind with the use of tools, then the species is approximately 1 million years old. Agriculture (the Neolithic revolution)[283] was invented 10,000 years ago (1% of 1 million!). By means of agriculture, the species was able to enlarge, single-handedly, the carrying capacity of the environment and thereby to increase its population according to from approximately 4 million to 200 million by the height of the Roman Empire in Europe and the Han Dynasty in China.

Overcropping and agricultural innovations

Round about the beginning of the Christian era this growth appeared to have slackened off, but, in the last 1000 years, growth has occurred again, which, as yet, appears to be exponential (see Fig. 831). The slowing down of growth around the beginning of the era can be explained by the fact that all available land at that time suitable for agriculture was in use[284]. Erosion occurred due to overcropping, forcing some human communities to leave their homelands, and tribal migrations began to take place. Because of the limitations of agricultural land, people learned to be more careful with the soil by

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[a] Leonard (1974)

implementing two- or three-year rotations, by applying fertilizers (nitrate cycle), by improving the plough and the storage (of the produce), etc[285]. After the Neolithic Revolution, the next big revolution came with the mastery of inanimate energy (Industrial Revolution beautifully described by Cipolla, 1970). Each technological revolution created the conditions for far-reaching economic, demographic, cultural and political revolutions and these, in turn, had enormous ecological consequences. Technical, agrarian and hygiene innovations can counteract the original environmental limitations and allow unlimited population growth for a time. Jong and Priemus (2002) discuss these and other approaches.

Medieval fluctuations

Fig. 831 shows that in Europe, during the Middle Ages, significant population fluctuations occurred partly because of erosion and starvation, and partly because of (pest) epidemics.
The new exponential growth has mainly taken place after the Middle Ages, after technological developments had made their influence felt in the fields of agriculture, trade and hygiene.
War and illness, such as the enormous pest epidemic around 1300 A.D. interferes with population dynamics in a similar way to the activities of predators in a population of their prey[286].

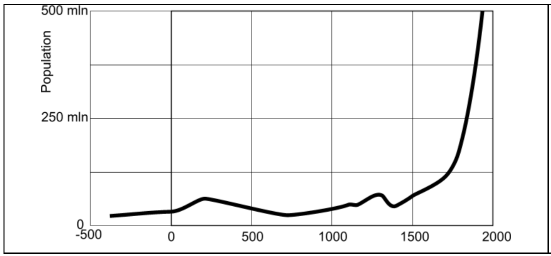

Fig. 831 *The supposed developments in population numbers in Europe*[a]

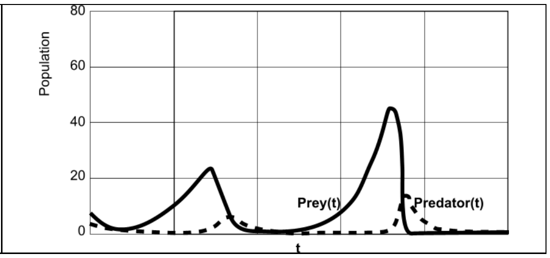

Fig. 832 *Predator and prey according to Lotke-Volterra*[b]

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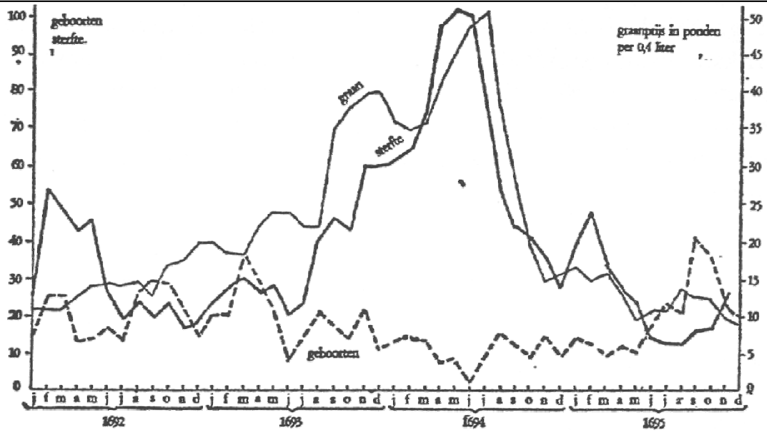

Fig. 833 *Demographic crisis in Meulan, near Paris 1693-1694*[c]

Hunger

Historically, hunger is recognisable by the number of deaths, and is often related to the staple food. Increases in the price of grain are generally followed by more cases of death. Then, once the crisis periods have ended, the numbers of births increase again. This relationship is not only evident in history, but is still actual today, and will become more evident as the current world population develops[287].

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[a] Schlicher van Bath (1960)
[b] Jong and Priemus (2002)
[c] Lachiver (1964)

Unlimited and limited growth

If there was no immigration or emigration, and the death rate remained constant, then population growth would be completely dependent on the number of children born. If the number of children k born to each individual was 1, then the population would remain constant, if $k<1$ then the population would decrease, if $k>1$, then it would increase. The total population y of parents y_0 and children ky_0 is then y_0+ky_0 (Fig. 834).

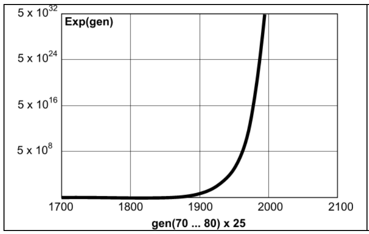

Fig. 834 *Unlimited growth*

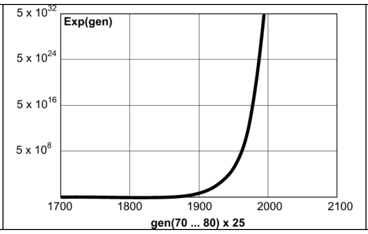

Fig. 835 *Adapted by parameter*

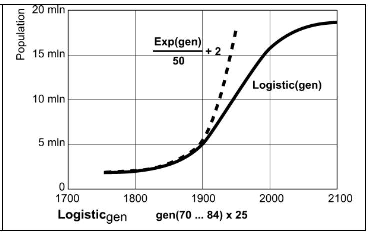

Fig. 836 *Limited growth because of carrying capacity*

Demography

Where death rates vary per generation, there is also a variation in birth rates. To contain these variations within one model, it is no longer sufficient to use a time-segment approach. Instead, one has to examine the population per cohort (Fig. 837)[288]. The branch of science that concerns itself with these activities is called demography.

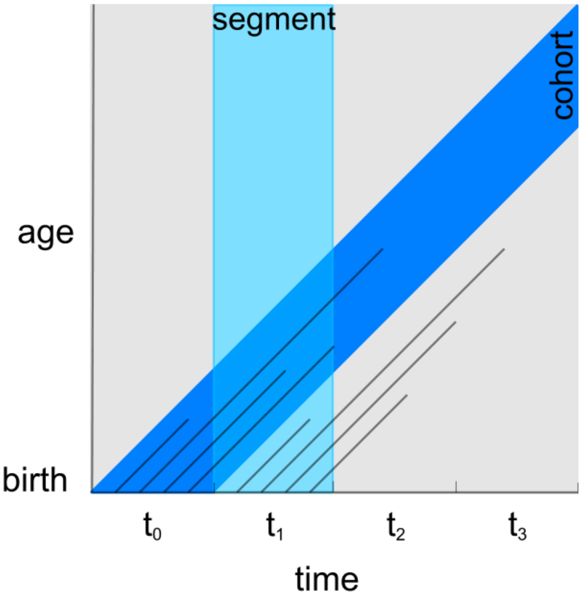

Fig. 837 *Population in a certain period and per generation (cohort)*[a]

Growth that is limited by the usable area of environment, or the carrying capacity of the ecosystem, is represented by a logistic curve (Fig. 836). Should we, for the time being, interpret the future of our population as one of unlimited or of limited growth?[289] Many people like Meadows, Meadows et al. (1992) think or hope, in view of limited raw materials, that growth will be limited. The logistic curve works beautifully for fruit flies, but when applied to the population of the United States, based on the demographic statistics from 1790 to 1910, reality proved this mathematical approach to be incorrect after 1950: growth is still exponential.

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[a] Pianka (1994) citing Begon and Mortimer citing Skellam

Technology

From technical history, we have learnt how a succession of technological innovations, in its totality (the ‘envelope curve’) can be reinterpreted as exponential growth (Fig. 838).[290]

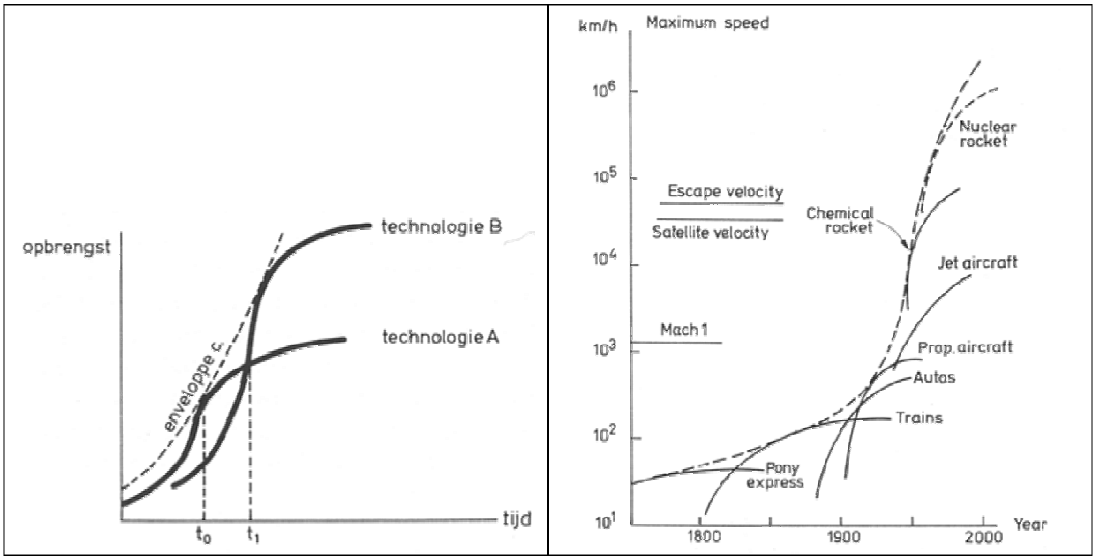

Fig. 838 *The envelope curve and an example for transport technology*[a]

Chaotic growth

Fig. 839, and the following figures, illustrate a reflexive chaos function $chaos_{i+1} := a \cdot chaos_i - a \cdot chaos_i^2$ for example with $chaos_0 := 0.0016$ and $i := 0 \ldots 15$ that looks similar to a logistic curve on a=2, but which shows chaotic shifts on higher values of the parameter a [291].

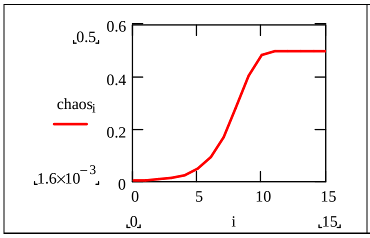

Fig. 839 Chaos using parameter *a* = 2

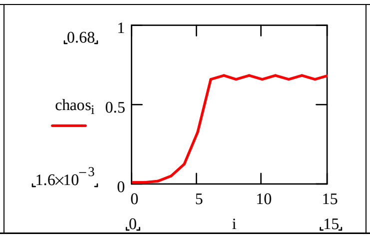

Fig. 840 Chaos using parameter *a* = 3

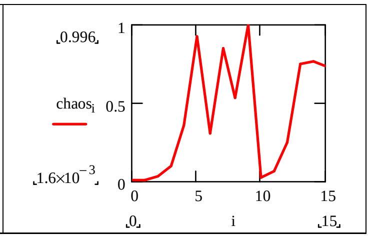

Fig. 841 Chaos using parameter *a* = 4[b]

Limits to growth

Death has been largely and lastingly restricted by improved food, hygiene and medical science to older age groups, although not everywhere to the same extent. The most important variable factor that determines world population growth is the fertility or reproduction factor. Worldwide, of course, immigration and emigration play no role at all. The big question is: When will the current exponential-like growth in population level off again? The Earth is still able to feed a multiple of the current world population, but the distribution is so uneven that an unacceptably large proportion of this population is starving and dying. In time, not only will distribution be a problem, but the total amount of food will become insufficient.

At the same time, during the last 25 years, erosion has made 10% of the agricultural land unusable. Rising world temperatures will intensify this process by causing more deserts to form.

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[a] Ayres R.U. (1965) en Jantsch E. (1967), cited by Doorn and Vught (1978)

[b] See also Jong and Priemus (2002)

Changing predictions

According to CBS calculations (see Fig. 842), the Netherlands can expect population numbers to flatten off after 2030.[292].[a] In 2002 a maximum of 18 million was expected, in 2006 a maximum of 17 million, declining after 2040.

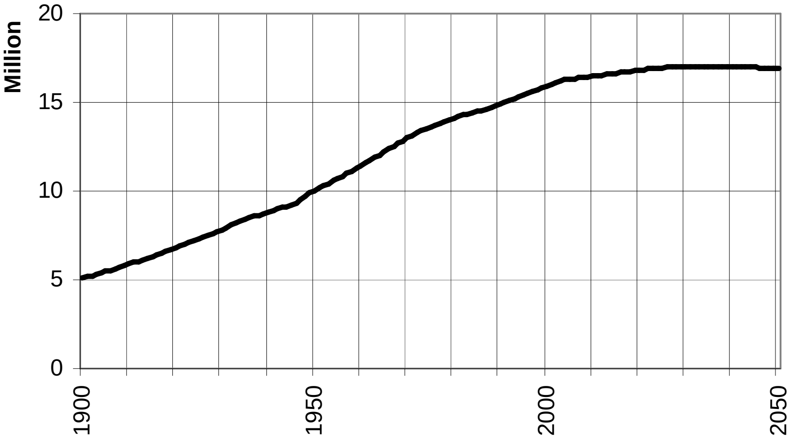

Fig. 842 *The CBS population prognosis for the Netherlands, 2006*

This development is expected in most Western countries, due to the decreasing number of births. Elsewhere in the world, so long as children are seen as the only form of health and pension insurance, this flattening off of numbers is not expected. The ecological crisis can then largely be seen to be linked with development problematics.

	infanticide	abortion	restricting coitus
Food gatherers and hunters			
Australian tribes (the Aborigine)	+	+	-
Tasmania	+	+	-
the Bushmen	+	-	-
Indians	+	+	+
Eskimos	+	+	-
Arable farmers			
Indians	+	+	+
Africa	+	+	+
Oceania	+	+	+
+ = number of confirmed cases - = no reported cases			

Fig. 843 *Methods of restricting the population used by ‘primitive’ peoples*[b]

Contraception

One of the most harrowing Western influences is that, so long as the mother breast-feeds her child and carries it with her, natural contraception is broken off. If the mother stops feeding her child for just one day, then she immediately becomes fertile again. A mother can feed her child for more than three years, but the Western example of laying a child in a cot and feeding it with a bottle has gained a higher status. The result is that a woman can become pregnant every nine months.

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[a] http://www.cbs.nl

[b] Harrison, Weiner et al. (1964); Harrison, Weiner et al. (1970)

Western influence has not only brought about higher fertility in the Third World, but also a harrowing neglect of children still in their first phase of life. Every time a new child is born to its parents: the youngest child always receives the most attention. Contraceptive devices are used by almost all 'primitive' peoples[293].

Medieval population reduction

In the Middle Ages, hard measures were taken to reduce the population. If an area of land became over-used, at the very least or mildest, people were forced to move to marginal land. The history of marginal small-holders, tinkers, bandits, in short 'the destitute' ("ellendigen", "uitlandigen" exactly meaning: 'those who have been turned off the land') has never been written. The army, the cloister and the celibate can be seen as forms of contraception in the Middle Ages.

In this way, one can also explain how social norms in a farming community can be tightened (traditional costume!). People who were unable to live by such high norms were 'excommunicated'. The exaggerated norms were used as 'a stick to beat the dog'. Up to as late as the 20th century, in Staphorst, the black sheep was actually forced into a cart and driven out of the village.

6.1.4 The urban environment

Industrial revolution

The biggest mass migration ever was (and is) the movement from the country-side to the towns that resulted from the Industrial Revolution[294]. The spatial and social consequences of that process are summarised under the term 'urbanisation'.

A progressive division between production, exchange and consumption (working, transport, living and recreation) has taken place, both in space and time, so that monofunctional spaces and interfunctional activities (activities that are only useful within a series of activities) have come into existence. This division of functions does not only take place between households, but also on the level of the individual households themselves. For everyone, there is a separate time for living, working and enjoying leisure. The household is losing its traditional functions such as providing training, religion, assurance and by that it is losing size and coherence.[295].

The use of time

How people spend their time gives a good indication of their daily lives and their use of space. Less and less time is needed to sustain life. Apes and people who currently live at subsistence level, and many households in the past, need(ed) to spend 40% of their time on that. Nowadays, by dividing tasks, we only spend approximately 8% of our time earning our daily bread, if one includes children, pensioners and others exempt from paid employment.

Misfit

The fact, that communities whose main activities are unrelated to the environment to which they have become attuned in the course of their history, can lead to long-term, unbalanced, over- (or under) stress in the organism. Insufficient adaptation to this stress causes lop-sized development. For example, one can wonder why hardly anyone has perfect teeth or cannot see clearly, without artificial aids, by his fiftieth birthday.

Crowding and disease

Living in closer proximity to others increases the risks of spreading infectious deseases, anonimity, loss of social control and new forms of criminality, even though according to Freedman (1975) the psychic effects appear not to be too adverse. A new biological tendency has come into existence that causes isolation, strongly polarising life into public and private spaces as Bahrdt (1957) described[296]. Accommodating to abnormal climates also sets physical demands on this isolation. The resulting 'inner environments' not only become a new habitat for humans, but also for birds, rats, mice, fleas, mites, fungi, bacteria, pets and house plants. Asthma, as the third largest cause of death after cancer, heart and vascular disease, is a problem mainly in temperate climates.

Stress

In addition to physical illnesses, there are also psychiatric disorders that can be linked with the new living environment, such as more frequent instances of schizophrenia in inner cities, although the cause can also be said to lie in the attraction of inner city areas for sufferers of schizophrenia[a]. Although many tests have been carried out on sensoric deprivation (the lack of sensory stimuli)[b], one should perhaps talk instead of ‘motoric deprivation’ in the modern urban environment, in other words, the lack of accompanying motoric sensations from the muscles, and, more generally, the awareness of one’s own body and thereby of non-fictitious ‘reality’. The time spent in the car, in front of a television screen, at a sports competition arouses all sorts of sensoric emotions which have no logical motoric counterpart. Stresses cannot be resolved motorically by physical exertion. This is one of the causes of obesity, heart and vascular disease. Where people live in close proximity to each other and where internal spaces are fragile, the ‘motoric sequel’ becomes systematically suppressed, from childhood onwards. This could provide an explanation for the popularity of sport and violence. Specialisation and the division of tasks splinter the unity of life, not only spatially (this happens here, and that there), but also in time (first this, and then that). The number of interfunctional activities is growing and is laying a heavy claim on tolerance to frustration, both for individuals and groups of people.[297].

Division of space and time

People, animals, plants and apparatus need space and time to remain functional and to realise their aims or possibilities. At a certain level of intensity of use, they start to restrict each others’ space and time so that displacement and waiting times occur, respectively. Systematic planning (spatial) and organisation (temporal) in the functioning of human beings and society become necessary as soon as either people or apparatus start to carry out, for example, more than 0.01 hr/m^2 of activities per year at a particular site (the present levels for agriculture in the Netherlands). If an activity takes place somewhere (a series of undertakings to meet a certain aim), then no other activity can take place on that same site and time. Therefore, if the intensity of use is greater than 0.01 hr/m^2, one has to separate any two activities in space (planning) or in time (organisation). If a separation is made on a certain scale level, it is also necessary to connect it to another scale level when, from time to time, activities such as natural or economic cycles need to be linked. This combination of separations in general, and connections here and there, and now and then, is a form of selection. Each wall with a door, town wall with a gate, every prohibition with exceptions is a selector[298].

Separation

Separations in space and time can come into being because of physical regulations or by territorial and prodecural consensus (‘you here, me there; now you, then me’). At higher scale levels, arrangements prevail; at lower levels, physical measures prevail. Consensus can be in the form of an order (‘forbidden access’), which, in a democracy, is founded on delegating authority to give orders within certain areas of responsibility. Consensus can also be promoted by conducting an information or advertising campaign (‘stop certain activities in this nature reserve’ or ‘come to the meeting’).
As soon as activities can be divided by barriers, walls, arrangements or more informal consensus (culture) and then by (spatial or temporal) selective links brought into association with each other again (logistics!), then much higher intensities of use than 0.01 hr/m^2·year are possible.[299].

The intensity of use

Intensity of use is an important factor. It is one of the factors that determines to what extent an environment can be supplied with facilities (density of investment), by guaranteeing a certain level of utilisation. The intensity of use also determines the speed of aging, and is related to the contribution made to the national product, energy density, ecological pressure, and the risk factor in dangerous situations, etc. [300] Nevertheless, this measure is not used very much in Environmental Planning because it is difficult to estimate the use of time and to bring this to the same denominator as the use of space.[301]

In 1983, the intensities of use of various spatial functions were, approximately like Fig. 844[302].

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[a] Het verhoogd voorkomen van bepaalde ziekten zoals schizofrenie in bepaalde delen van de stad is in de jaren '70 geregistreerd door de GGD van Rotterdam. Daarbij kwam ook een andere causaliteit aan de orde. De omgeving leidde niet zozeer tot een ziekte, maar selecteerde de immigratie van probleemgevallen op andere kenmerken, zoals inkomen.

[b] Sensore deprivatie, het verstoken blijven van zintuiglijke prikkels, is dikwijls experimenteel onderzocht. Zie voor een kort overzicht van het onderzoek tot 1978: Jong, T. M. d. (1978) Milieudifferentiatie; Een Fundamenteel Onderzoek *Faculty of Architecture* (Delft) Delft University of TechnologyJong, T. M. d. (1988) *Milieudifferentiatie* (Delft) DUT Faculteit Bouwkunde.

	hr/resident·year	m^2/resident	hr/m^2·year
ACTIVITY			
In and around the house	6552	137	48
Learning away from home	374	6	62
Moving	387	91	4
Social/cultural	539	8	70
Recreation	162	47	3
Sport	36	17	2
Shopping	238	2	135
Agriculture	11	1667	0.01
Exploitation of minerals	1	5	0.3
Industry	185	30	6
Public utility companies	8	10	0.8
Building firms	71	20	4
Trade	51	3	17
Transport & communication	33	2	22
Other services	77	4	19
Government, etc.	61	1	102
Use of time: both paid and unpaid			

Fig. 844 *Use of time/use of space = intensity of use*[a]

Urban uses of time

Residents optimise their use of time to achieve a balance between maximising their income and the availability of free time and space. They have thereby long been prepared to accept travelling times of three quarters of an hour twice a day between their homes and their work[303]. Because of this, a tentative effect analysis can be made of the various urbanisation alternatives in this optimalising process. By doing this, however, an impulse is given to far-reaching analyses of the economic, cultural and managerial effects.

Choices on different time scales

The use of time can be judged on different time scales: the daily rhythm, the weekly rhythm, the yearly rhythm and lifetime. On the first three time scales, the above-mentioned optimalising process leads to recognisable questions of priority in everyone's life in the daily, weekly or yearly rhythm (see Fig. 845).

Am I going home early or late today?	Do I give priority to (a) the family or (b) to work?
This weekend:	will I be (a) at home or (b) am I going out?
This year:	will I be (living and enjoying recreation) (a) with someone else or (b) alone?

Fig. 845 *Setting priorities in the use of time*

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	<tradition-directed						opportunity-directed>	
rhythm	A		S1				S2	B
daily	a	a	a	a	b	b	b	b
weekly	a	a	b	b	a	a	b	b
yearly	a	b	a	b	a	b	a	b

Fig. 846 *Alternative uses of time*

Tradition- or opportunity directed preferences

The (a) variants of Fig. 845 give more free time and strengthen the argument for national distribution and for Bundled Deconcentration; the (b) variants are conducive to more income and individual free

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[a] *NNAO, Ontspannen scenario, MESO Den Haag 1986*

space, thereby strengthening the argument for concentration in the Randstad and for a Compact City strategy. Eight alternative uses of time can now be distinguished (Fig. 846).

These possibilities of using time lead to different opinions about how space should be organised. Political schools of thought can also be positioned in this scheme. Traditionally (<) oriented parties (such as the CDA) will choose (a) variants in all time scales (A); opportunity (>) oriented parties (such as the liberals) will choose (b) variants (B); and the socialists will differentiate the variants into 'blood groups' (S1 and S2) that are, respectively, more <tradition- or opportunity> oriented.

Dispersion of time in space

These time-use alternatives also lead to another use of space between living, working and facilities and to another mutual proximity, other transport needs and to another economic accent.
Within the Randstad, however, there are boundaries to the maximalisation of collective free space within the opportunity-oriented> perspective of urbanisation.
The process of specialisation and division of tasks in urbanisation, splinters the unity of daily and weekly life, both spatially (this is happening here, that there) and in time (first this, then that).
In contrast to this, large and new freedoms have come into existence. We become about twice as old as we did at the beginning of the last century, and, in addition, have about twice as much free time. According to CBS (1994) since World War II, the number of people per dwelling has halved, from 5 to 2.5 people, so that, within a radius of 10 metres (R = 10m), we have at least twice as much space. Within a radius R = 100m, we have small areas of green, and within a radius of R = 1000m, large areas of green. We are suburbanised *en mass* in order to have a magnificent view close at hand. And there the story comes to a halt, because on each higher scale level, the emptiness disappears.

Political parties choose different 'accords' of dispersion

Historically, the preferences for traditional- or opportunity-oriented uses of time can best be read against the aims of political parties with respect to space, expressed in their programmes over a period of 40 years as th University of Amsterdam once found out. They can be styled in 'accords' of the concentration (C) and deconcentration (D) of urban areas on national, regional and local levels (see *Fig. 847* and Fig. 702)

In a radius of	100km	30km	10km
	(sub)national	regional	subregional
Liberal	C	D	D
Socialistic	D	C	C
Christian-democratic	D	C	D
'Purple'	C	D	C

Fig. 847 Political 'accords' of dispersion

Traditionally, the liberals have wanted a national concentration of urban areas, because that would benefit the competitive position of the Randstad. On regional and local levels, however, they have always preferred deconcentration to allow free choice of place of residence or establishment. In contrast, up to the 1980s, the socialists favoured deconcentration on the national level to encourage a fair distribution of residence and employment opportunities throughout the country, but concentration on the regional and local level for the benefit of public transport and the political cohesion of minority groups. To preserve the historical identity of the provinces, the Christian Democrats have favoured national deconcentration. On a regional level, they have favoured concentration in order to have provincial capitals with recognisable regional religious and civil administrations. On local levels, they again favoured deconcentration (suburbanisation) because, in their view, only small communities can offer a caring society in which the family, the corner-stone of society, can flourish. In this way, freedom, equality and brotherhood become recognisable and controllable in different design principles and on various levels of scale.

Changing preferences in national plans

But policies change by different coalitions as you can see in the successing National Plans in the Netherlands (see *Fig. 848*)

In a radius of	300km	100km	30km	10km	3km
2nd National plan 1966	Bundled Deconcentration				
	theory		C	D	C
	practice		D	C	D
3rd National plan 1983	Structuurschets Verstedelijking 1978: 'new towns' ('PTT naar Groningen')				
Socialist period		D	C		
	Structuurschets Stedelijke Gebieden 1983: 'growth towns'				
Liberal period		C	D	C	
4th National plan 1988	Compact city: nodal points				
	C	C	D	C	

Fig. 848 Changing preferences in national plans

The result of these changing policies is urban sprawl (see Fig. 703).

Freedom of choice supposes diversity

The largest number of possibilities for future generations will be achieved by realising maximum diversity in environments. Determining which scale levels require which forms of diversity (legends), is the most important task that urban architectural research has to face. The composition of the population and the life cycle of every individual provides changeable patterns of time-use, and, for this, specialised spaces are needed. One 'best' overall solution is the worst solution. The intermediary forms between On-going Deconcentration (D_{100km} ... D_{10m}) and Complete Concentration (C_{100km} ... C_{10m}) probably offer more possibilities than these extremes in themselves, but they also eliminate future possibilities for the Randstad, such as the availability of free space of the size of the Green Heart that can only be achieved where there is complete concentration. However, that, in turn, interferes with the identity of towns and cities, would require abandoning buffer zone politics.

6.1.5 Mobility between urban populations

Forces of attraction between masses

According to Newton (1687, beautifully described by Feynman, Leighton et al.,1977,1963), the attracting force F between masses M_1 and M_2 is inversely proportional to the square of their distance d:

$$F(d) := G \cdot \frac{M_1 \cdot M_2}{d^2} \text{ (Newton, 1687),} \qquad \text{while } G := 6.6725910^{-11} \cdot \frac{m^3}{kg \cdot sec^2} \text{ (Cavendish, 1798)}$$

The factor G was measured by Cavendish with a precision of 1% and until now again and again with greater precision. The formula inspired traffic engineers to formulate the travel benefit between urban populations in a comparable way.

Traffic flows by attraction

Human behaviour is more difficult to model than lifeless matter, but, because of their large numbers, in the long term, people's improbable individual choices cancel out one another statistically into a main probability. So, traffic between urban units can be modelled reasonably well in proportion to their population, taking into account their mutual distance.
If we represent moving people between sites of departure and destination according to their masses, then the Newton formula can be adapted to actual reality. For example it can be adapted by taking a power in the denominator of Newton's formula (see page 471) other than the square '2'.

Calculation traffic according to Newton's formula

Completely according to Newton, the power of attraction between two urban units would be proportional to their populations p_1 and p_2 and inversely proportional to the square ($b = 2$) of their mutual distance *d*. But if you make G=a=1, you take the mass of both poles as 100 and change the power b into 3 or into 7, then the function starts to look like the use of different slow (b=7, like bikes) or fast (b=3, like cars or trains) means of transport (see Fig. 849).

$$f(d,b) := \frac{a}{d^{b}}\cdot p_1\cdot p_2$$

a:=1
b:= {3,7}
p_1:=p_2:=100

another notation is:

$$f(d,b) := \frac{a}{e^{\ln(d)\cdot b}}\cdot p_1\cdot p_2$$

because d can be represented as a power of e = 2,718 : $e^{\ln(d)}$

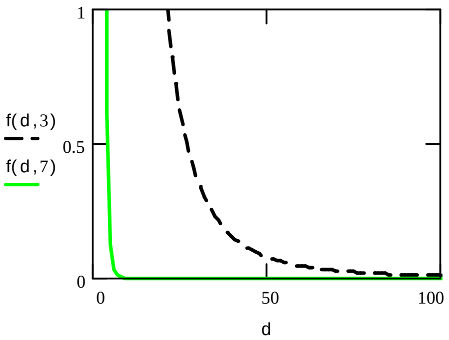
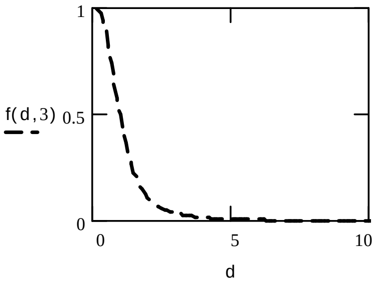


Fig. 849 *Traffic according to a modified Newton formula*

However, according to this graph, direct neighbours must exert a strong, almost infinite, force of attraction, like lifeless matter does. In the case of humans, this would mean that every desire to travel further would disappear, because the benefit of staying home is infinite. Consequently, for travel calculations the coefficient *a* / $e^{\ln(d)\cdot b}$ of the populations p_1 and p_2 has to be adapted.

Adapting the coefficient of the populations

To make that coefficient maximally equal to scale factor ‘a’ taken as 100% (a = 1), we have to make the denominator minimally 1 by adding 1: *a* / 1+$e^{\ln(d)\cdot b}$. Then, if scale factor a = 1 and the distance $e^{\ln(d)\cdot b}$ is zero, the force of attraction is 1 or 100% (see Fig. 850).



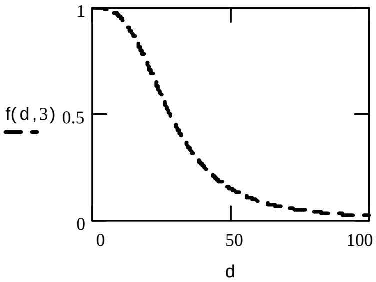


Fig. 850 $f(d,b) := \frac{a}{1+e^{\ln(d)\cdot b}}$

Fig. 851 $f(d,b) := \frac{a}{1+e^{\ln(d)\cdot b-\beta}}$

The graph now starts beautifully at 1 at a zero distance, but by a growing distance the attraction by fast traffic decreases to zero already below d = 5 in Fig. 850. To stretch the graph you can subtract a constant β from the power: $e^{\ln(d)\cdot b-\beta}$ (see Fig. 851, where β=10). In the mean time, this application shows the advantage of using the power of e instead of a power of d.

Attraction reduced by costs and distance < 30km

In addition, the model also has to take into consideration that not only the distance, but also factors such as congestion or useless delay, can reduce the effect of masses attracting each other. All such ‘costs’, including travelling time, partly increasing due to distance d, are summarised in current traffic models by the term ‘*travel resistance*’ *c* (costs, see Bovy, P.H.L. and N.J. van der Zijpp 2000). Between two populations, this travel resistance is operationalised in the travel benefit function *f(c)* as an effect of *c* (including distance d). This function reduces the attraction of the masses: the higher the costs, the smaller the travel benefit.

Travel benefit related to costs, calculated by traffic engineers

If the parameters are chosen well, *Fig. 852* is supposed to fit in with the current empirical reality. In the graph, the travel cost *c* can be largely identified with the distance travelled in kilometres.

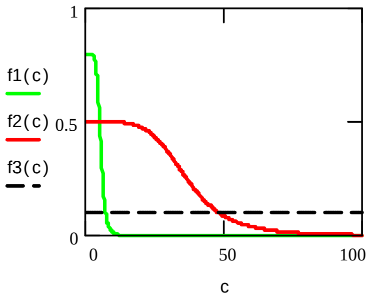
		Determining parameters		
		starting point 0 < a < 1	stretching 3 < b < 7	deflection 12 < β < 20
Bicycle $f1(c) := \frac{a1}{1 + e^{\ln(c) \cdot b1 - \beta1}}$ Car $f2(c) := \frac{a2}{1 + e^{\ln(c) \cdot b2 - \beta2}}$ Train $f3(c) := \frac{a3}{1 + e^{\ln(c) \cdot b3 - \beta3}}$		at 0.8, the function starts at 80% of the height. a1 := 0.8 a2 := 0.5 a3 := 0.1	at 7, the function deflects for the first time. b1 := 7 b2 := 5 b3 := 3	at 20, the function reaches its zero value for the last time. β1 := 12 β2 := 18 β3 := 20

Fig. 852 The type of log-logistic travel benefit function that is used in the WOLOCAS model, with which new VINEX districts were calculated[a]

Thus, one can read from this that the travel benefit of a car is, on average, greater after about 5 km than that of a bicycle. After about 50 km, the travel benefit of a train is greater than that of a car.

Modal split

However, at zero distance there is of course no traffic, and looking at empirical statistics of different traffic modes (see *Fig. 853*), the curves do not look like the log-logistic utility curves of *Fig. 852*.

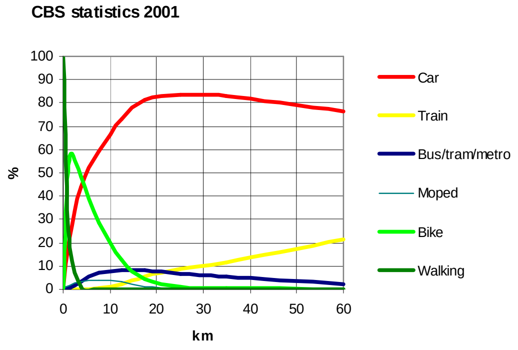


Fig. 853 Modal split

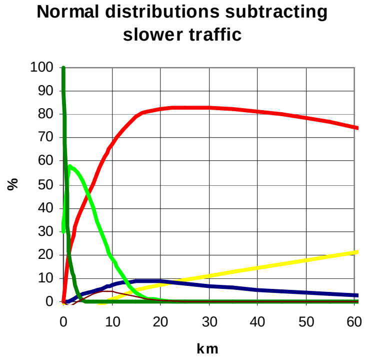


Fig. 854 Simulation of Fig. 853

They look more like normal distributions drawn crooked to the zero distance border. If you simulate them like that, the walking pedestrians and bikes look like a halve of such a normal distribution. The curve of the car can be simulated as a normal distribution, partly diminished by subtracting the curves of walking pedestrians, bikes and mopeds like *Fig. 855* shows.

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[a] Bovy, P.H.L. and N.J. van der Zijpp 2000

		walking	**bike**	**moped**	**car**	**bus&**	**train**
vertical scale factor		100	1000	100	15800	10000	11500
average at		0	0	7	25	-30	100km
standard deviation		1,5	6,4	5,5	76,0	100,0	100,0
subtract	**walking**		20%	0%	75%	40%	30%
	cycling			10%	75%	41%	40%
	moped				0%	15%	30%
	car					32%	27%
	bus, tramway, metro						40%

Fig. 855 Figures, used for the simulation of Fig. 854

6.1.6 The urban field is not homogeneous

In between two highway exits or (public transport)stops

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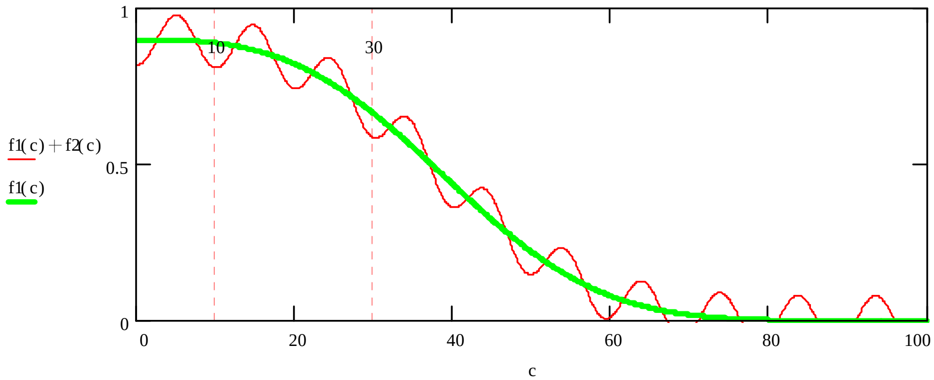


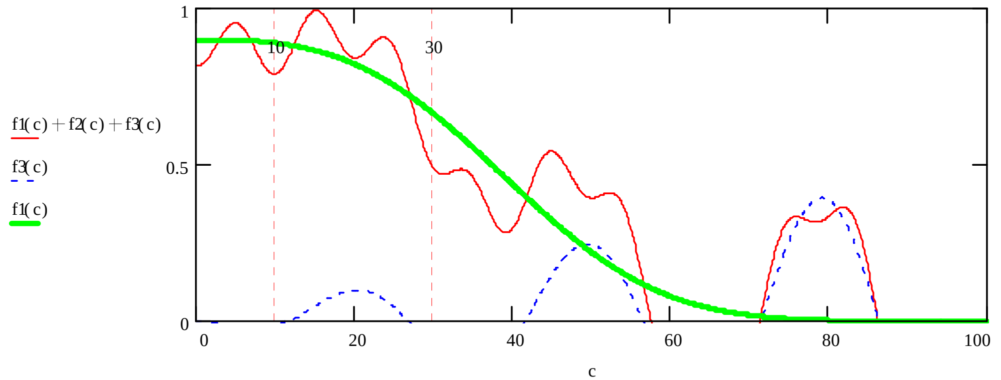
Here, *f*1(*c*) is the log-logistic travel utility, and *f*2 is a sine with a period of 10 km superimposed on it.

Fig. 856 *Fluctuations of travel utility with a periodic infrastructure of 10 km*

In practice, the travel benefit formula does not always decrease with an increasing distance or 'travel resistance' by costs *c*. The formula is true in a homogeneous field, but not in a heterogenous field of a network with exits or (public transport)stops. Everyone knows that taking a exit further on can sometimes result in more travel benefit. Suppose that the mesh width and exit distance of local highways is 10 km on average. Suppose from my departure point, it is a 5 km drive to the next local highway. Then, after 10 km, I am on the motorway, between two exits. In that case, the travel utility of 10 km is smaller than that of 15 km. The graph could therefore fluctuate when a radial motorway has an exit every 10 km (see Fig. 856).

Useful destinations increased by distance

For a train, these fluctuations are caused by the station stops: I cannot end my train journey between stations in the event of my seeing no utility any more in continuing the journey. With regional tracks occurring regularly, every 30 km, even more fluctuations with a 30 km period are superimposed on them.



*f*3(*c*) is a sine with a period of 30km and increasing amplitude

Fig. 857 *Fluctuations of the travel utility with a periodic infrastructure of 3 and 10 km and with increasing travel utility*

Passing rarified zones without direct utility

It is clear that, in this case, travelling 50 km has more utility than 40 km. In addition, the higher design speed on these speed-specialised lines, less plagued by stops and exits, lowers travel resistance, so that the kilometres used to calculate *c* shrink in travel time. I will leave these sorts of mathematical complication to more experienced calculators.

The conclusion could be that well-thought-out construction or improvement of fast infrastructure results in rarified zones designated as green areas, which are positioned radially around human masses in the direction of other masses, and have a greater travel utility for intersections situated further away than for the pure log-logistic decreasing travel utility functions without fluctuations. This is a beginning of the traffic concept for an interregional network city.

Broadening the travel horizon increases the number of attractive destinations

Without a division of tasks, broadening the travel horizon in a homogenous urban field increases the accessible area, and thus the destination possibilities by the square of its radius. The proportion of these possibilities that is actually utilised within an available budget in the form of money, means of transport and time, is the scale factor *a.* That factor becomes smaller the further (and faster) I travel to obain these possibilities. One can take this increasing travel utility into consideration as an effect on the costs of primarily decreasing travel utility function *f*(*c*), with an increasing amplitude of stops or exits situated further and further away. In Fig. 857, it is thus assumed that, at the first and second exit or stop on these lines, the utility, and thus the amplitude, will increase due to increased destination possibilities. This effect is strengthened by interregional task division".

Attraction between regions charged with task division benefit

In the current model philosophy, a positive travel utility is expressed more purely as a factor of the power of attraction of the masses, than just by the mass-effect-reducing travel utility function *f*(*c*). For each urban concentration, a traffic model can apply separate empirically determined corrections to the mass effect. However, in the case of interregional task division that is not logical. The power of attraction between regions, due to increasing interregional task division, appears to be more like electromagnetic attraction caused by a difference in positive and negative charges, which supplement one another. However, where there are more than two tasks, there are more sorts of charges than + and -, and the range is greater. It is essential that the attraction is not a characteristic of a mass, itself, but of its specialisation compared with other masses that are charged differently. Alternatively, equal charges cause repulsion. For this, a separate, not necessarily reducing, but accrediting, specialisation function will perhaps have to be devised.

Making lost time useful

Then, in working out the travel resistance *c* itself, the travel time as a cost post will be taken as being almost synonymous with distance and other inconveniences. However, travel time can be used as contact, work or rest time *en route*. In particular, it will be possible to facilitate work time in the future by means of communication technology. The remaining travel time does not always increase with distance, but is mostly due to slowness and delays when changing from one form of transport to another, and this can be included in *c.* This is why the design of multimodal intersections and means of transport, and their multifunctional, urban integrated and communicative equipment, is the primary project for a Delta metropole. At the same time, the most important item on the agendas of managers, designers and key actors is the mutual determination of the identity of regions, agglomerates and towns with respect to growth in task division. The new public transport between them must not eliminate chance, but organise it. One cannot confine oneself, then, to adapting *c* in existing models on the basis of empirical starting points, when some costs can be changed into benefits by shrewd design.

6.1.7 The force of specialization

Attractions >30km

About 90% of all traffic movements are kept within a radius of 30 km (region) around the departure address. It is natural that traffic modelling focuses on that section. Commuter traffic generates the problems that traffic specialists are hired to solve, so they gear their models to these.
As far as I am aware, there is still no model for the individual and collective benefits interregional traffic (> 30km radius), caused by regional specialisation. The attraction of mutually specialised masses should be greater than that of mutually unspecialised masses. Why would people travel at all, if there is no difference between departure and destination? And if a difference far away promises great profits, how important is distance then? If functions are specialised on a larger scale traffic benefit can increase with distance.

Exchange, traffic implies specialisation

Trade rests on that principle, and so does the ecological division of tasks between land and water, and between male and female flowers that exchange their life experiences with the help of insects, the travellors. On every scale level, life itself shows the evolutionary effects of specialisation: combination by exchange. The attraction of Disneyland has another travel benefit function than commuter traffic, certainly when Parisians are becoming bored with it.

External specialisation by internal integration

In the Dutch Golden Age, Zaandam[a] produced ships, Amsterdam used them. Amsterdammers with initiative felt more at home in Indonesia than in Zaandam near by. Regular destinations far away create an unknown zone close by, also recognised for commuters by Groenman (1960) as ‘ijle zone’. But that zone has its functional integration by other specialised populations. During the period concerned, Amsterdam, already a metropole with 100,000 inhabitants, became a world city with a national web of punctual towing boats (Vries, Jan de 1981). About 1600 AD the organising of the VOC by Van Oldenbarneveldt (Romein, J.M. 1938,1971) gave each of the United States of The Netherlands its own commercial part of the world changing mutual competing and conflict into cooperation. It was external specialisation by internal integration. Disneyland in Paris is a similar improbable example of organisation and offshore entrepreneurial spirit. Organisation is a matter of specialisation and combination.

External effort outgrowing internal integration

However, our colonial past gives reason for us to be ashamed of expansion, certainly if it costs too much energy. Ever since Stadtholder Willem III, setting sail from Hellevoetsluis, exported our commercial democracy to England by conquering it, in a final effort, with an armada three times larger than that of the Spanish, (Israel, Jonathan I. 1995), we would rather stay closer to home. Ever since Thomas Jefferson visited our country in order to study our republican constitution (Eskens, E. 2000), the roles have been definitively exchanged with Anglo Saxon players. From Scherpenzeel (birth place of Peter Stuyvesant), no one will establish a New Amsterdam again, if there is still enough space in neigbour village Munnekeburen. Now investments from New York are welcome. Whether foreign investments will come or not, again depends on the percentage of key actors who, sometimes by chance, discover that it would be better to grow (for example) coffee outside one’s own region, than at home. If people are alert, this will not lead to exploitation this time, but to cooperation.

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[a] In Zaandam the Russian Tsar, Peter the Great, learnt to build ships.

Travel benefit fluctuating by distance

Between the region and the world, however, there are still a number of scale levels on which the travel benefit can be increased for some destinations by including rarified zones, for example green areas close to home. If we show a collective will for fast lines of interregional public transport, communication and decisionmaking, then the travel benefit function in the travel models can be adjusted. However, the question is: On what level do we want to spread our towns and green spaces? Bundled deconcentration within the region (NRO2, RPD 1966, see Fig. 702 and explaining text) has been disposed of since 1983 (NRO3, RPD 1983, see *Fig. 848*): it broke up the green spaces in urban landscapes. Its variant, a regional network town, breaks green spaces into even smaller pieces.

Declining specialization by local congestion

The compact city (RPD 1988, see *Fig. 848*) increases travel resistance locally due to congestion, whereby the strength of cooperation between the big cities decreases in full accordance with prevailing traffic models. That is a self-fulfilling prophesy. Wings that do not divide their tasks, but without sufficient coordination go their own way, are probably unable to make an international flight. Moreover, in the unintentionally expanding compact city, green areas are only accessible by car. In addition, on public holidays, part of the free weekend is claimed by traffic jams. That can only be compensated by holidays in further-away places that make a joke of the travel utility function. The result is a vicious circle of local travel resistance and less cooperation based on reliable specialisation.

External competition by internal cooperation

The Delta metropole is not a regional, but an interregional network city. It is a world city not because of its masses, but because of spatial specialisation. Urban masses become more attractive, if better and faster decisions can be made than elsewhere in the world. That saves the energy of interregional competition for attracting international acclaim. International power is achieved through interregional cooperation, based on a division of tasks. In doing that, one aspires to create an international site and expansion base for business establishments with extensive green and blue spaces within cycling distance from home.

Regional division of tasks

The classical *trias urbanica* of management, culture and market is recognisable in the centre of every medieval town, where townhall and church made space for the market. This is where the surrounding consumption and production converge, managed in the town hall, reflected in church. This territorial division of spaces by task has, since then, been subject to scale enlargement. Until after World War II, Bonn, Cologne and the Ruhr area, The Hague, Amsterdam and Rotterdam had divided these tasks interregionally to give managerial, cultural and economic accents, respectively. Due to the movement towards a service economy after the war, cultural identity came to have more of an economic meaning.

The right diversity on the right scale

A culturally equipped town or city furthers the chance of a productive meeting. Thereby, Amsterdam, gained better chances of being chosen as a place of settlement by the key actors responsible. Rotterdam and the Hague regained a cultural identity by means of international film and jazz festivals, unmatched architecture, and decision-making culture. Making faster and better decisions requires the lubricant of cultural eye-opening. In the much smaller, but more central, inland Utrecht, the ‘captains of service’ confer at the crossroads of polders, rivers and forests, with dunes and harbours on the horizon. Here too, the converging peat, clay and sand diversify ecosystems while from here they determine more uniformly the ecology as far as the Urals (Constandse, 1967). Also in the opinion of the youngest generation, growth should not be concentrated there.

Direct, distribute, disperse and concentrate on the right level

There, key actors from the heart of Europe are shown a route via the Rhine axis in their Delta over the Mondriaan-like network called Holland (see Fig. 858).

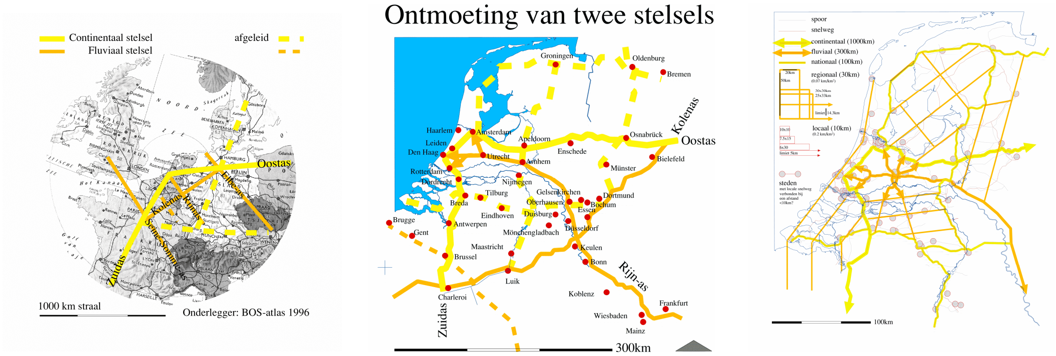

Fig. 858 *Potential continental, fluvial and national network systems*[a]

In addition, in the Delta, rail and road transport via the south and east can be brought together on an even greater scale along the European coasts to choose our water and air space as main ports (and the reverse). This will be achieved, if the foreign actors are received in a well-considered, cooperative network of towns, each suited for its own task, attractiveness as a place to settle and with it own identity. There are large projects with small consequences and small projects with large consequences. The Delta metropole is not directed towards projects in which the one section expects to dominate the other, but, in the end, steals an advantage.

Limitation shows the master

Does one section choose projects that deprive the other of success, or can people delegate among eachother so that, together, international functions can be given the best position in the whole network? The latter requires subnational decision-making skills, regional loyalty and again local decisiveness. If one chooses non-traditional regional solutions, using traditional national means, the Delta's inherited urban constellation can be turned into an international novelty. One can grow interregionally by trimming regionally, integrating by mutual specialisation, by accepting one-sidedness in order to excel, and by developing the rest elsewhere.

Specialisation as a paradox of scale

Managerial initiative, innovation, growth, integration and versatility are a question of scale. In contrast, on another scale, they require loyalty, tradition, trimming, specialisation and one-sidedness.
The implicit presuppositions of the Stedenland perspective (VROM 1998) that preceded NRO5, illustrate this kind of scale paradox. They are made explicit in Fig. 860. That perspective supposes national initiative and subnational laissez-faire, national tradition and regional innovation, national division of tasks, subnational integration, national concentration, local dispersion.

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[a] *Jong and Paasman (1998)*

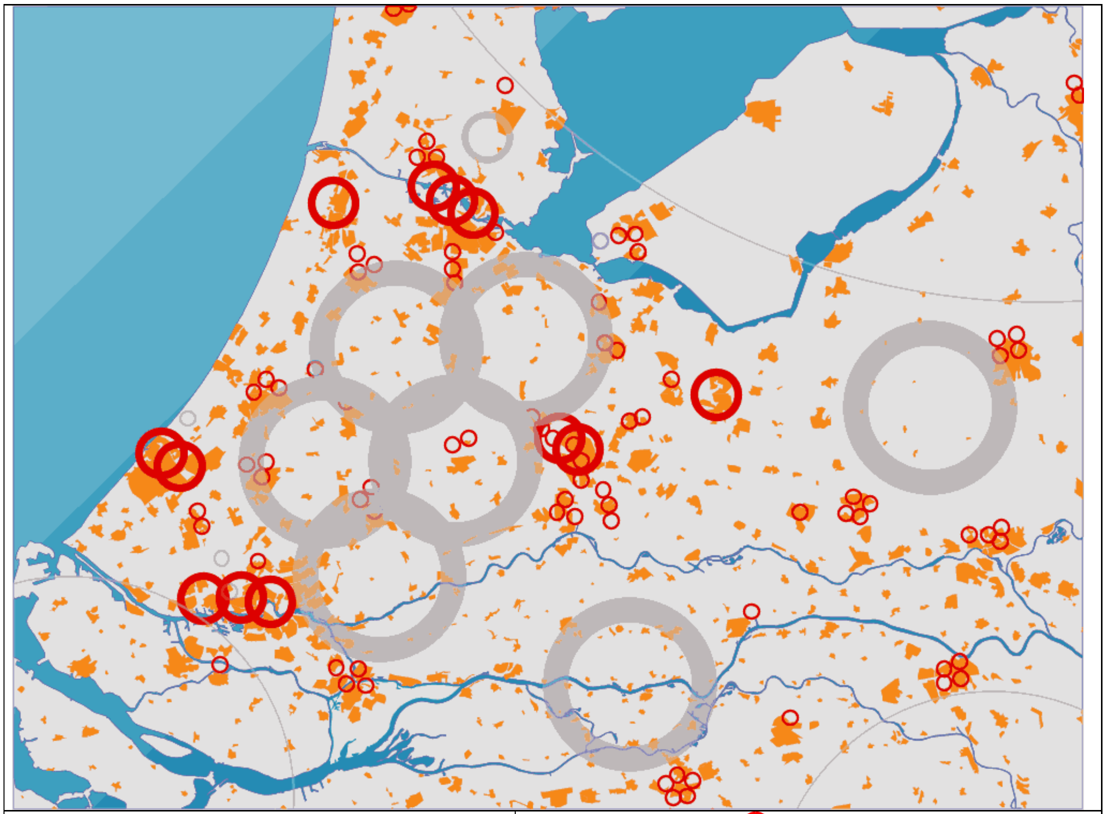
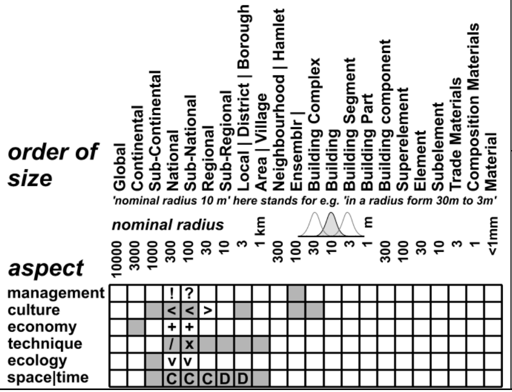


Fig. 859 The Stedenland perspective[a]



order of size

'nominal radius 10 m' here stands for e.g. 'in a radius form 30m to 3m'

aspect \ order of size, nominal radius	Global 10000	Continental 3000	Sub-Continental 1000	National 300	Sub-National 100	Regional 30	Sub-Regional 10	Local | District | Borough 3	Area | Village 1 km	Neighbourhood | Hamlet 300	Ensemblr | 100	Building Complex 30	Building 10	Building Segment 3	Building Part 1 m	Building component 300	Superelement 100	Element 30	Subelement 10	Trade Materials 3	Composition Materials 1	Material <1mm
management				!	?						▨											
culture			▨	<	<	>		▨			▨	▨										
economy		▨		+	+																	
technique				/	x	▨	▨	▨	▨													
ecology			▨	v	v																	
space|time			▨	C	C	C	D	D	▨													

CONTEXT and impacts within a PERSPECTIVE

Variable per level of scale and period of change.

For example tentative nationally:

managerial:	initiative (!)	< >	(?) laissez-faire	7 years
cultural:	traditional (<)	< >	(>) experimental	15 years
economics:	growth (+)	< >	(-) shrinkage	30 years
technical:	specialisation (/)	< >	(x) integration	60 years
ecological:	heterogeneous (v)	< >	(o) homogeneous	120 years
mass-space-time:	concentration (C)	< >	(D) deconcentration	240 years

Fig. 860 *Context organ (example: the Stedenland perspective (VROM 1998) and effects (grey))*

According to the combinatorial system, it is possible to play 10^{65} other chords/accords on this organ. The Delta metropole accord is much the same. The difference is that subnational deconcentration and a great effort to achieve technical integration that facilitates the division of national tasks has been requested (VROM 2001, 2002).

Specialisation supposes exchange

The division of tasks consists not only of where projects are established, but also the network. A didactive rule of thumb that, for each higher unit of road system, an approximately three times larger mesh width should be maintained, turned out to be more realistic than was first thought. It has been calculated in three different ways that, by doing this, an optimum of accessibility and construction

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[a] VROM 1998

costs is achieved (Nes, R. van and N.J. van der Zijpp 2000). However, this would mean that, in the Netherlands, there would have to be nine orders, each with its own design speed and exit frequency (Jong, T.M. de and M. Paasman 1998): continental, fluvial, national, regional, local motorways, urban motorways, district, neighbourhood and residential streets drawn with a mesh width of 1000, 300, 100, 30, 10, 3, 1, 0.3, 0.1 kms, respectively, if one draws the same mesh length and breadth. The first three are drawn in Fig. 858, and if one styles the remainder, then one gets a typology of dry connections with square meshes, as shown in *Fig. 494*. These can be stretched using the same mesh density as shown in *Fig. 497*.

Calculating missing links or simply drawing them?

In the absence of exact knowledge about departure sites and destinations, designers can sketch in the missing links with transparent, squared elastic paper. The design will alternatively consider first the network as the directing force and then the settlement site (Angremond, Kees d', Pieter Huisman et al. 1998; Jong, T.M. de 1998). However, very many exits would have to disappear to improve travel times and safety (Reuzer, Bart and Marijn Schenk 1999). Though, especially within towns, the national strategy is to reduce the number of orders at the expense of travel time, but in favour of an assumed safety (Duurzaam Veilig; Sustainable Safety Project). Therefore, the current travel benefit function remains calculable and negative. Is that what we want?

Networks between specialised cities

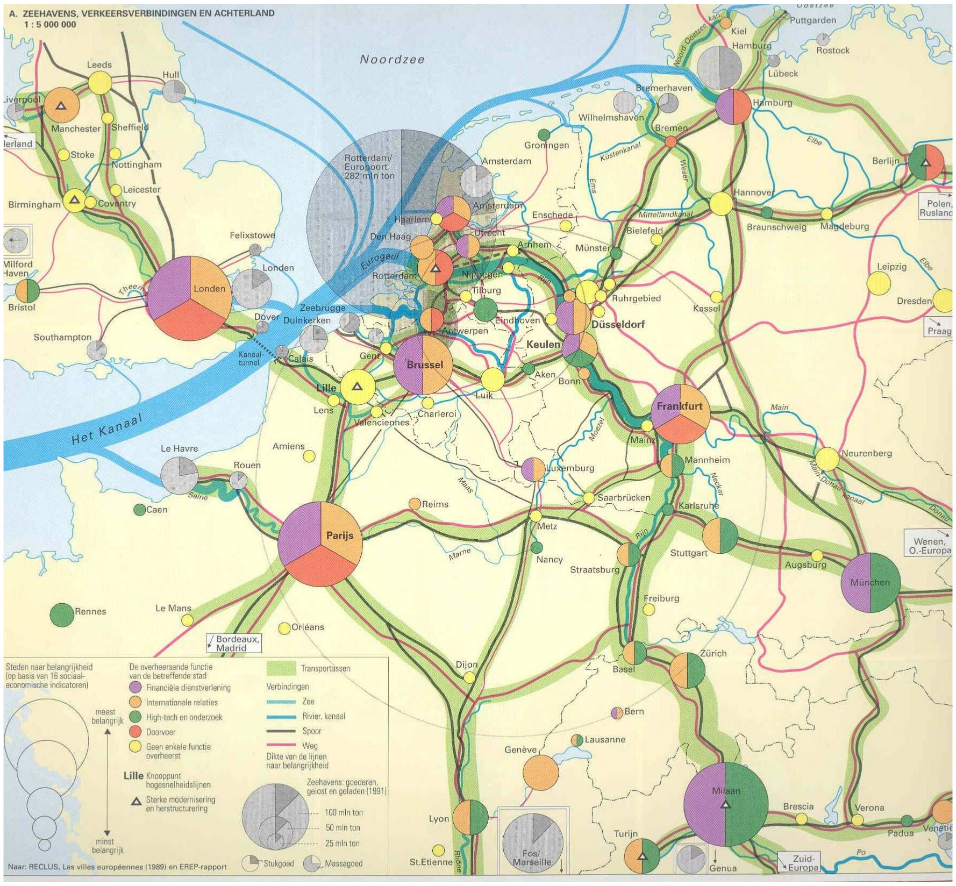

Fig. 861 *Population, socio-economic weight and connections in a radius of 1000 km*[a]

Fig. 861 gives a global impression of the population of central Europe in 1996, with the highest densities shown along the Rhine. This figure also shows those centres that score highly in a large

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[a] RECLUS, Les villes européennes (1989) and EREP-rapport, cited in Wolters-Noordhof (1996)

number of socio-economic factors. The highest scores are for London, Paris and Milan. Centres of secondary importance are Brussels, Frankfurt and Munich. Amsterdam and Rotterdam are aligned with a large number of centres of tertiary importance. The beginnings of a 21st century network, with a mesh width of approximately 100 km are also visible in this figure. Southern Europe and the large population of eastern Europe are attempting to join this economic network. Railways parallel to the northern and western coasts form a forerunner and starting point for, what is still, a hypothetical 300 km grid (see Fig. 858. The Netherlands is situated in the corner of this grid, as a terminal with main ports for transfer to air and water.

6.2 Habitat

6.2.1 Dutch heritage

The physical identity in Europe

At the end of the 20th century agriculture, due to a reduction of its market coupled with higher productivity, lost its primary position in national self-sufficiency. Globalisation leads to a division of tasks internationally as Steekelenburg (2001) elaborates. The main task for the Netherlands is trade and the conservation of rare natural areas.

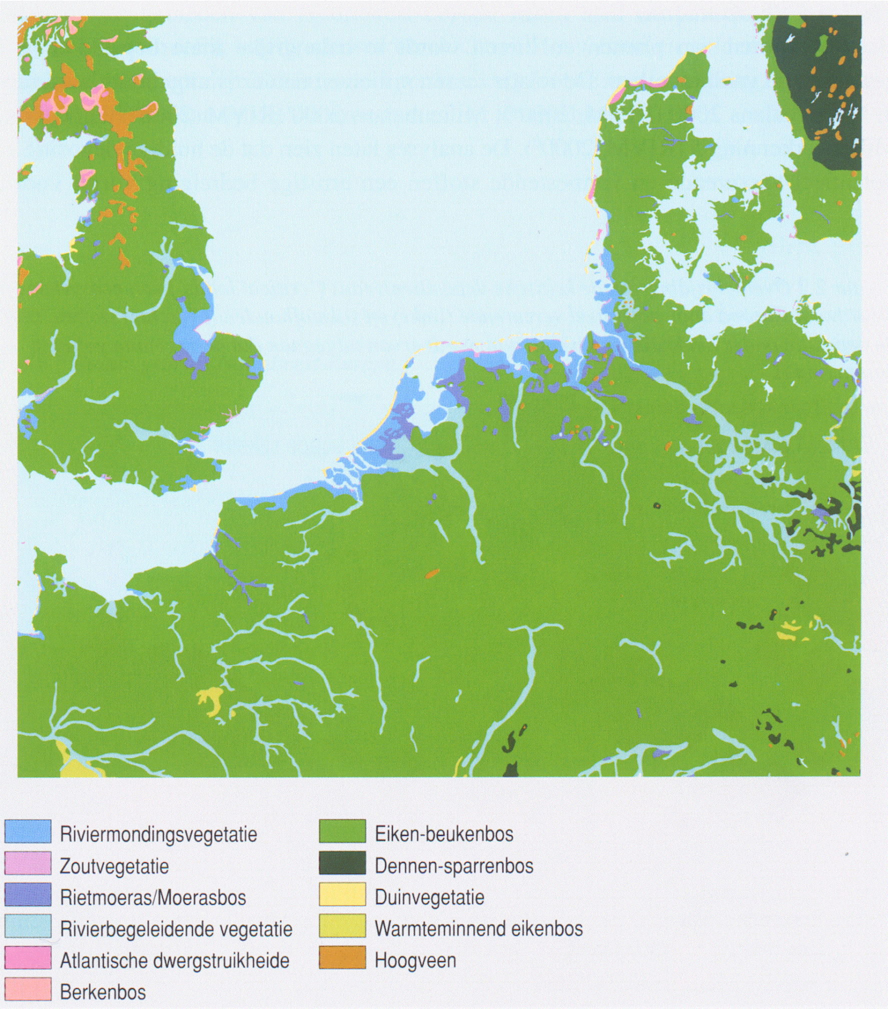

Fig. 862 *Potential natural vegetation*[a]

The lowlands of Zeeland, Holland and Friesland as a whole, with a boundary consisting of young dunes and older ones, up to 5000 years old, together with their potential vegetations, are viewed as rare on a European scale, within a radius of at least 1000 km. Dyke construction has enlarged the area and diversity of the land in the course of a 1000 years, with Old Marine Clay polders and

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[a] RIVM (2001)

reclaimed land, albeit to the detriment of rare saline plant communities. By doing this, the largest area of potential estuarine vegetation in north-western Europe has come into being.
Further inland there is a just-as-rare and irreplaceable zone of potential reed swamp / swamp forest. 'From Amersfoort to the Urals, one does not encounter another landscape that is so full of big surprises' (Constandse, A.K. 1967). Further up-stream lies the largest, though less rare, area within this radius, of river-dependent vegetation.

Rare in The Netherlands, common in Europe

The sandy soils, situated on higher ground, form the beginnings of a potential European oak-beech forest. Although not a rare form of vegetation, these forests are highly valued nationally as recreation areas. Ecologically, pine forests in our country are viewed as recent, artificial anomalies.

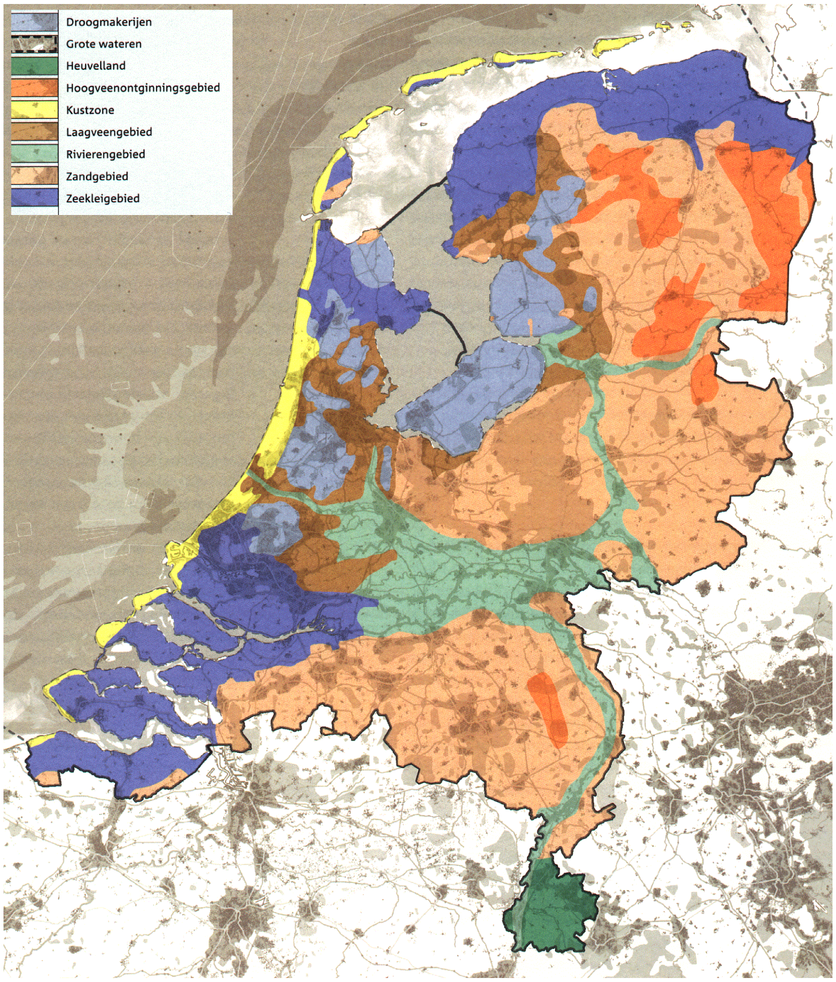

Fig. 863 *Nine types of landscape*[a]

Rare in Europe, common in The Netherlands

If one looks in more detail at these important international possibilities (in a section of 60 x 60 km), then the landscapes of very great significance that one recognises are the Old Marine Clay polders, the reclaimed land and the peat exploitations in our country in the neighbourhood of Leiden. In addition, the mud flats (Wadden), the dunes, the Young Marine Clay polders, fluvial basins and ridges

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[a] LNV (2002)

are also of great international importance. The landscape types identified by LNV show the Old Rhine to be an extension of the fluvial area, surrounded by areas of peat lying below the present water table (*laagveen*), bordering on areas of Marine Clay.On both sides of the Old Rhine there is an interesting series of potential transitions.

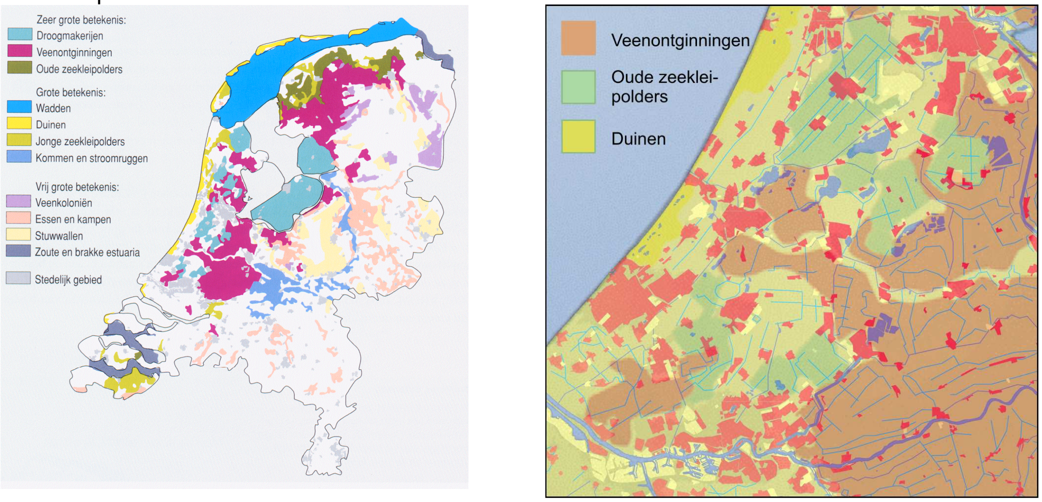

Fig. *864 Internationally important landscapes*[a]

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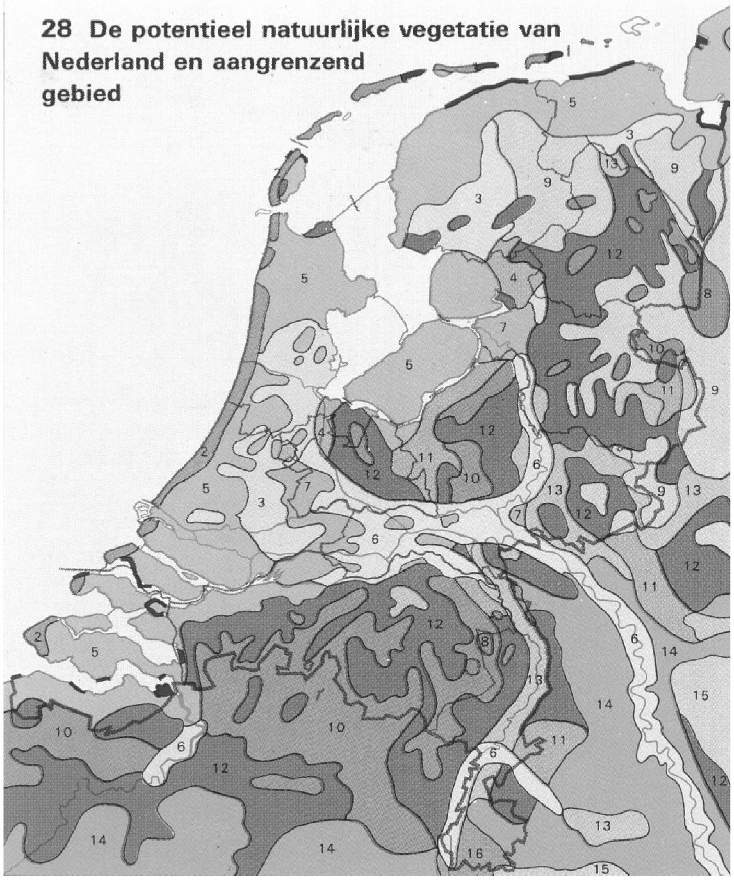
[a] RIVM (2001) page 16 ; LNV (2002)

6.2.2 Human impact

The Netherlands undisturbed

If, apart from providing a stable system of water management, the Netherlands would be left undisturbed by human beings from now onwards, then the following forests would come into existence:



Legends

1	salt-marsh vegetation with, among other plants, sea lavender and salt-marsh grass: transitions from a salt to fresh-water environment.
2	dune heath, -grassland and -thicket, dune birch forest and dune oak forest, birch– common oak forest
3, 4	marsh fern–alder swamp, and similar
5, 6, 7	ash–elm forest, and similar
8	blanket bog, and similar
9	moist alder, birch, common oak forest
10	dry birch–common oak forest
11	moist durmast oak forest, and similar
12	dry durmast oak, and similar
13	oak–hornbeam, and similar
14	millet grass–beech, and similar
15	woodrush–beech forest with oak
16	beech forest, alder- and ash natural forest, and similar

Fig. 865 *Potential natural vegetation*[a]

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[a] Sticht.Wetensch.Atlas_v.Nederland, Piket et al. (1987) page 13

Only where water floods the land regularly or for a lengthy time, where wind moves sand, and where grazing animals keep meadows in forests open[a] would vegetations other than forest be able to maintain themselves.

Human impact

Against the background of this ‘nil variant’, in the following paragraphs the effect of human intervention is demonstrated in images that have been developed by the University of Utrecht (see Fig. 74)[304]. The influence of humans expresses itself in draining, raising, hardening, digging up, treading upon, burning, systematic grazing, mowing, ploughing, harvesting, fertilising and polluting. Because of these activities, earlier stages of plant successions are kept in existence artificially.[305]

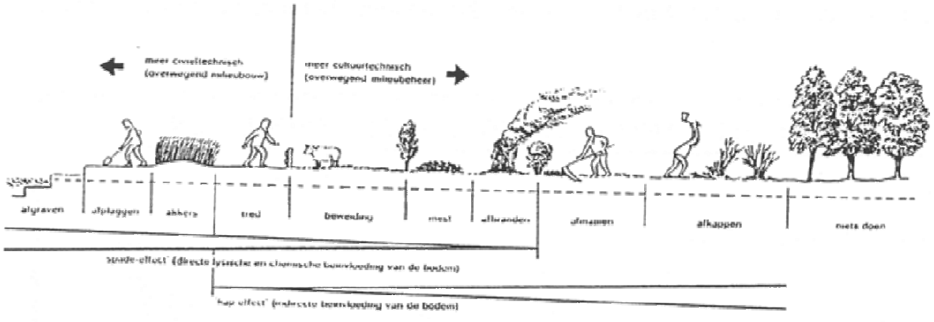

Fig. 866 *Human interventions in relation to dynamics*[b]

Decreasing ‘culturalness’ around settlements

For centuries, this ‘anthropogenically added dynamic’ decreased with the distance from residential buildings

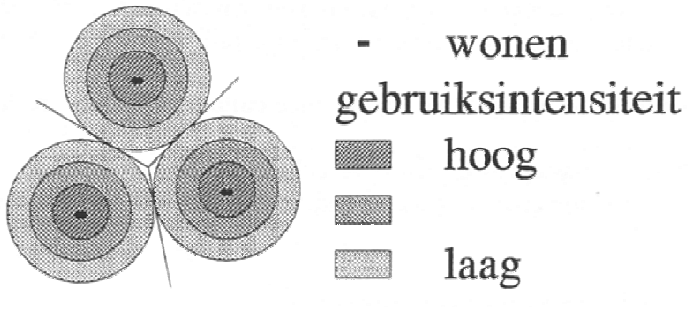

Fig. 867 *Intensity-of-use gradients around farm and town*[c]

The intensity-of-use gradient around farms and towns was strengthened by a mineral gradient. For centuries, traditional agricultural systems have enriched local soils with minerals to the detriment of poorer soils further away, that thereby leave behind specialised, and thus rarer, types of vegetation, such as hay fields, heathlands, shrublands and forests. Where people stored minerals for use in agriculture, only a few rapidly maturing species grew there. However, where people removed them, an increasing diversity of slow-growing, but uncommon, specialist species, cooperating of necessity in ecosystems, grew undisturbed and in scarcity. Over the centuries, this has led to an increase in the number of plant species.[306]

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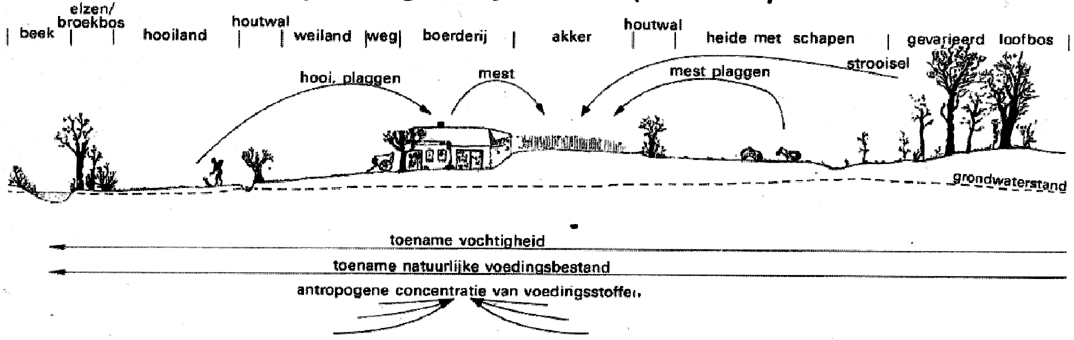
[a] Vera, F. (1997). *Metaforen voor de wildernis*. ('s-Gravenhage) Ministerie van Landbouw, Natuurbeheer en Visserij.
[b] Leeuwen (1971)
[c] Thünen (1921), Leeuwen (1973)

Living between dry and wet

Farms and settlements on the high, infertile sandy soils were mostly situated along rivers and streams. On slopes between the lowest wet soils (known as 'green soils' in animal husbandry) and higher, drier soils ('common lands' used as arable land) the nitrogen cycle used in mixed husbandry gave the best chances of survival. Fights took place to secure these scarce sites, so that, once established there, the tendency was to concentrate, organise and defend the common land. The result was a village (*esdorp*, in Dutch) built around a village green or *brink*. This concentric village shape contrasts sharply with the 'linear village' (*lijndorp*, in Dutch) from which, along both sides, and at 90º angles to the village street, strips of fertile but wetter peat soils were colonised and drained. In the *dijkdorp,* farmsteads, also positioned at 90º angles to the street were built on the higher, drier ground at the side of the street, which followed the highest line of the dyke.

a traditionele landschapsecologische processen (19e eeuw)



b huidige landschapsecologische processen

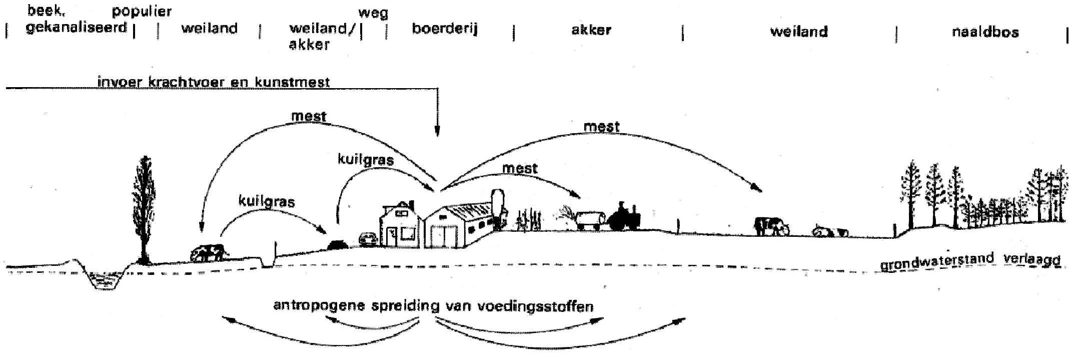


Fig. *868 Traditional and present-day ecological processes with respect to landscapes*[a]

Homogeneity by artificial manure

Modern agricultural methods, especially the discovery of artificial manures round about 1900 have changed these developments drastically from rare, infertile and thus species-rich biotopes into biotopes that are equally fertile overall and thus to biotopes that are predictable, but with few species.[b]
307

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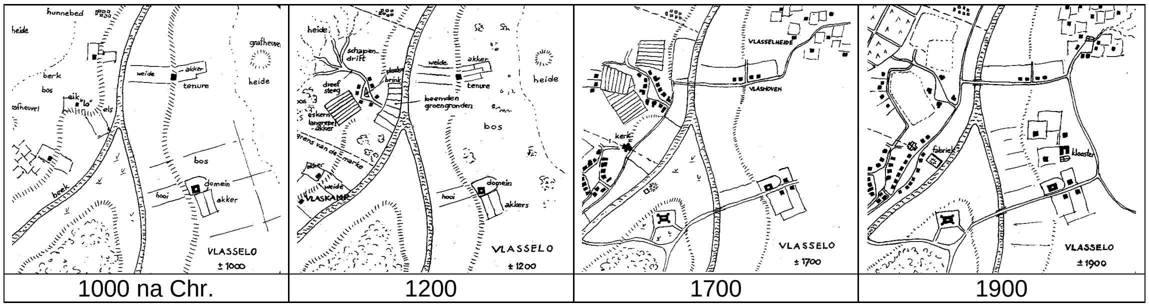
[a] *Atlas van Nederland Part 16:18*

[b] Nederland heeft overigens van nature een aantal zeer voedselrijke gronden zoals rivierafzettingen, zeeklei en loss.

Settlements on sandy grounds

In Fig. 869 Steegh (1985) designed a concept for the development of settlements on sandy ground

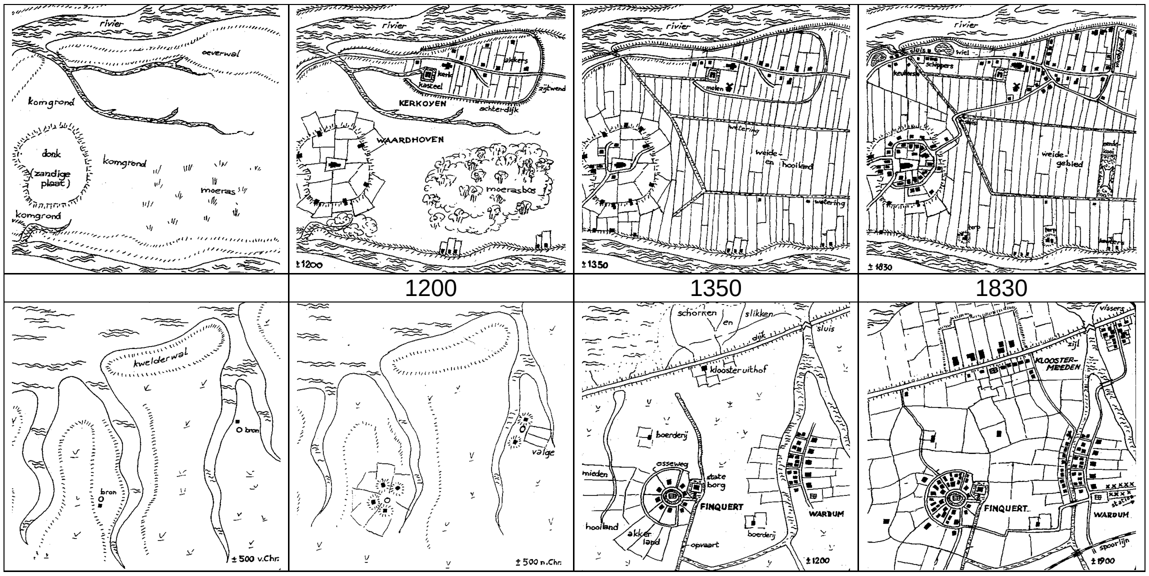


1000 na Chr. | 1200 | 1700 | 1900

Fig. 869 *An ideal-typical development of a settlement on sandy ground*[a]

Terp villages on Marine Clay areas

However, the oldest settlements that are still recognisable date from Roman times. Since those times, churches, farms, and sometimes settlements, in coastal areas, especially in Groningen and Friesland, have been built on raised mounds of earth (a *terp*).(Fig. 870).



1200 | 1350 | 1830

500 v. Chr | 500 n. Chr | 1200 | 1900

Fig. 870 *The ideal-typical development of terp villages on Marine Clay areas*[b]

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[a] Steegh (1985)

[b] Steegh (1985)

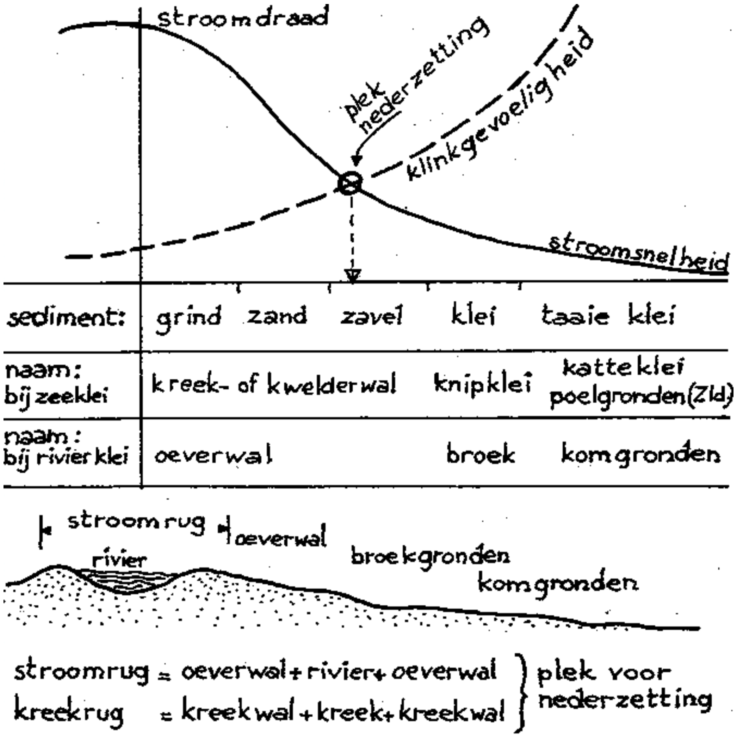

Fig. 871 Historical conditions for situating settlements along the water's edge[a]

Roman settlements on the loess soils of South Limburg

The best preserved land surveying outlines from the Roman times are of the loess region of South Limburg: an underlying NW-SE and NE-SW grid of 707 x 707 metres or fractions of this. By creating lots of land by cutting it into blocks ('quadrangulation') in this rational way, Roman army veterans were rewarded with a villa as a retirement present. Steegh (1985) shows how these developed further in his ideal types 'Willerich', 'Willerrode' and 'Wilderbaan' (Fig. 872).

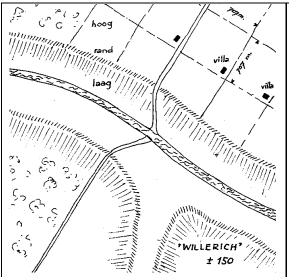	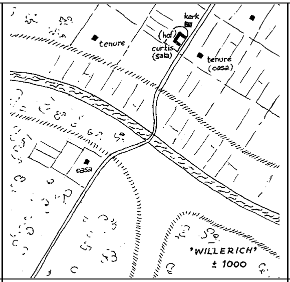	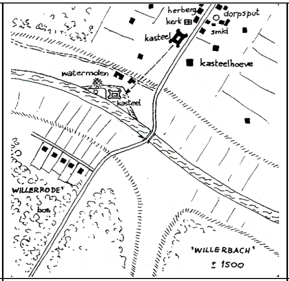	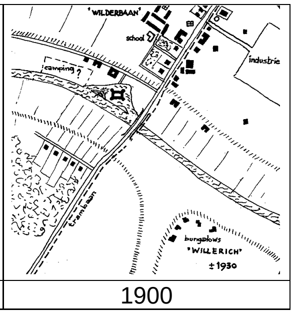
150 na Chr.	1000	1500	1900

Fig. 872 *The ideal typical development of settlements on the loess soils of South Limburg*[b]

Development of these settlements in feudal times around 1000 AD

Following the decay of the Roman Empire, the feudal court system began to use material from the most strategically situated villas (not too high, not too low, along a road crossing a nearby stream or river) to build a *curtis* or *sala* with an encircling wall in the form of a shield from which the farms

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[a] Steegh (1985)
[b] Steegh (1985)

(*tenures* or *casae*) around were managed. The agrarian surplus was sent to the Lord of the Manor via the old Roman road. Since the time of Charlemagne, one tenth of the produce had to be given to the church, so the local manager built a church to collect these tythes himself and so that he only needed to maintain a priest. A smithy, brewery and safety-seeking small-holders formed a compact village centre and the *curtis* became the castle.

Development of street villages around 1500 AD

Wetter areas allowed a larger number of village wells to be dug, so these villages had a more dispersed shape. A tenant farmer, whose land bordered on water, who later gained independence, would divide his land among his children into a larger number of units. In this way, a street village was formed, comprising easily defendable 'closed courtyards'. This is still a well-known type of farm building, even today, in the landscape of South Limburg. Millers' dwellings were added to the water mills and the lord of the castle built a new castle with gardens bordering the water, thereby displacing a number of farms that had occupied that land.

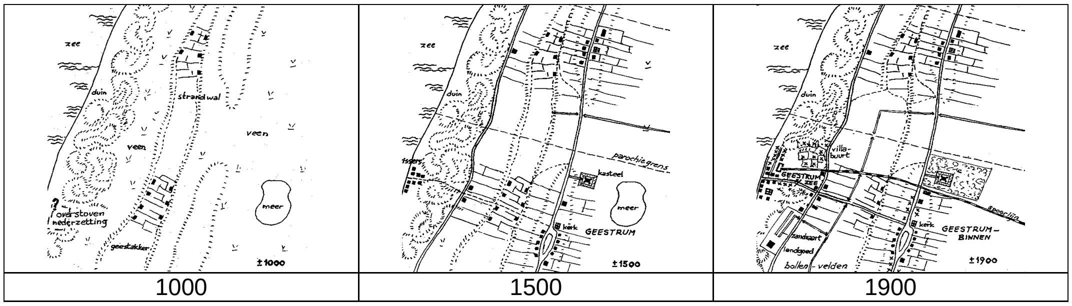
Later developments

Sometimes, the Lord of the Manor systematically developed waste ground into a street village such as 'Willerrode'. The church remained on the site of the old castle in the centre of the village, where now the lord levied tolls, and an inn to accommodate the post stagecoach was built. After centuries of stagnation, the construction of a tramline to the coal mines in the vicinity brought about far-reaching changes. The inn became a centre for the mineworkers. The higher personnel built houses along the tramline and a mineworkers' colony, 'Wilderbaan', grew up with its own shops, a new church and a patrons'cloister, financed by the mine owners, with boys and girls schools. Supply industries established themselves there with workers' districts and bungalows built on sites which had the nicest views. On pages 161-162, Steegh (1985) names many villages where elements of ideal typical 'Willerich' are recognisable.

6.2.3 The last millennium

The Netherlands about 1000 AD

Round about 1000 AD, the human population lived on *terps* (in Friesland), along the rivers, behind the dunes, and, in a more dispersed form, on the sandy soils.



1000 | 1500 | 1900

Fig. 873 *The ideal typical development of settlements on sandy soils behind the dunes*[a]

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[a] Steegh (1985)

After 1000 AD

From 1000 AD onwards it is people who have determined the appearance of the Netherlands. No longer they adapted their life to the country, they started to accommodate the country to their life (see Fig. 74, *Fig. 874* and *Fig. 875* are enlargements).

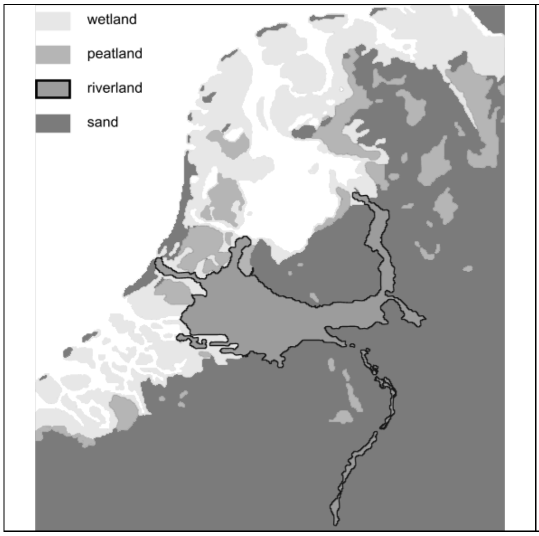


Fig. 874 Natural regions before 1000 AD

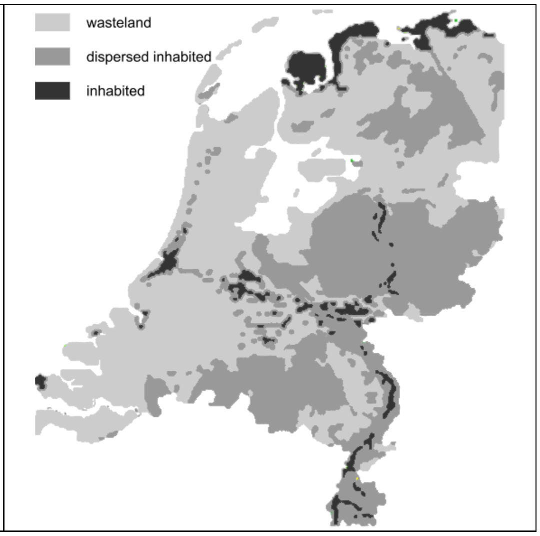


Fig. 875 Settlements in the Netherlands about 1000 AD[a]

Rising sea level

After about 1000 AD, the sea advanced in the south of the country. The Delta waterways came into existence, but the free play of water and land was prevented by dams built by the rapidly growing population.

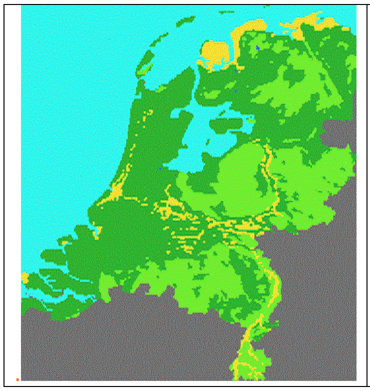


Fig. 876 *(*Fig. 875*) 1000 AD.*

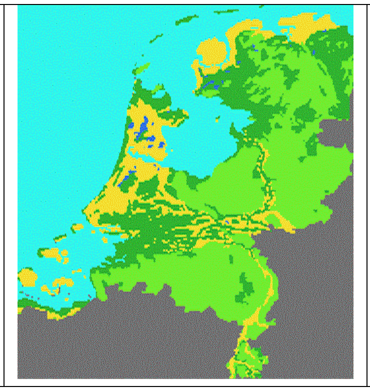
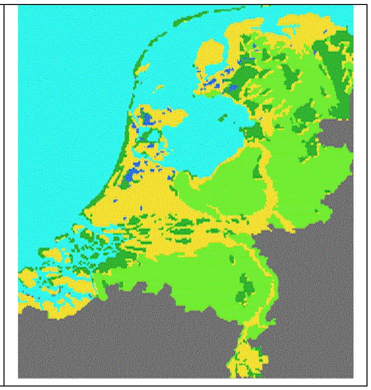


Fig. 877 *1100 AD*



(see also Fig. 74)

Fig. 878 *1300*[b]

Land, no longer on loan from the Emperor: the end of feudalism

The ecological history of the low-lying lands is closely linked to reproduction, family links, illnesses and occupations, in short, to the ecology of the human species.

Count Dirk II married a descendant of Charlemagne and, in 987, was granted full ownership of his fiefdom in North Holland by Emperor Otto III. Dirk III extended the fiefdom to include wet lands in the

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[a] University of Utrecht

[b] University of Utrecht

south. The only people who lived there at that time, were those living along the Old Rhine and at its mouth, at Leiden (Lede, water course Vries (1962)). In 1063, Dirk V was the first to adopt the title Count of Holland, but it was not until approximately 1100 that the name Holland came to be used for the whole county. What happened during that century?

Making your own land

There is evidence of an enormous expansion in agriculture and settlement in the centuries immediately subsequent to 1000 AD. In particular, people learnt how to reclaim and cultivate peat bog (fen).

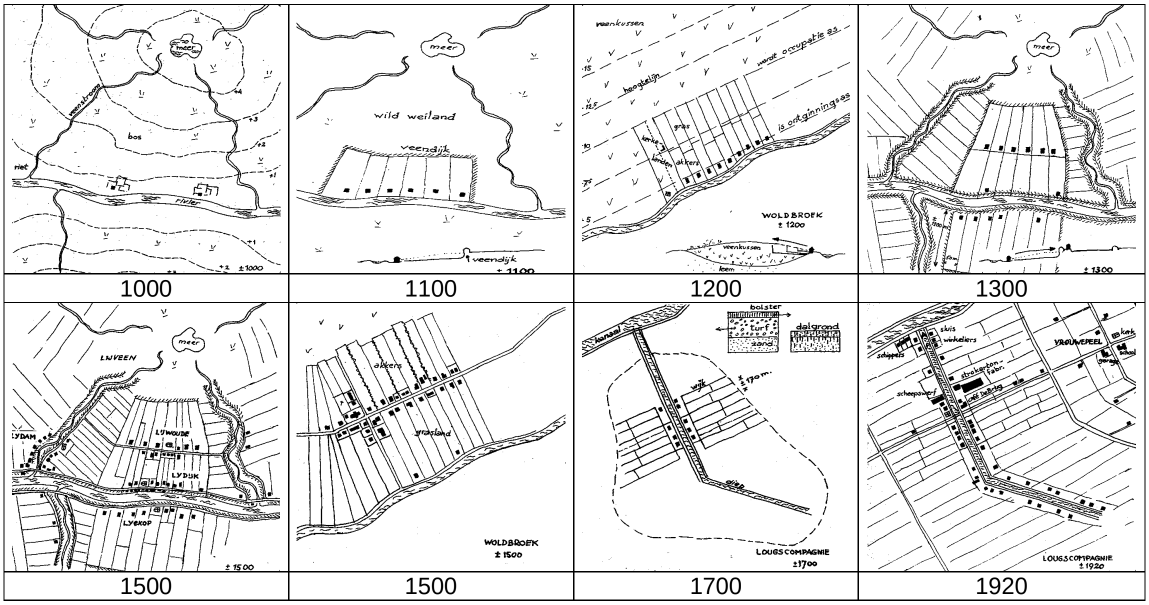

Fig. 879 *The ideal typical development of old and new peat settlements*[a]

Colonisation

In the course of a century, the Netherlands was far-reachingly colonised. There were a number of small towns at this time. Around 1300, these towns began to grow. There was also growth on the sandy grounds, and forests started to disappear. The sea retreated in some places and advanced in others. By about 1300, there was hardly any ‘nature’ left any more.

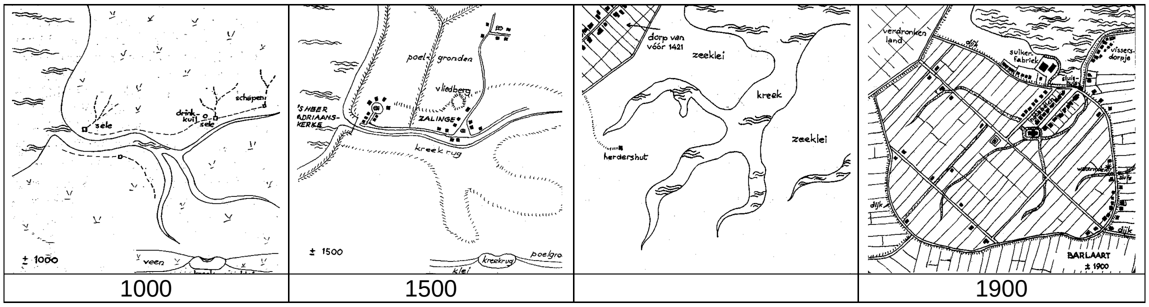

Fig. 880 *The ideal typical development of new settlements on the clay soils*[b]

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[a] Steegh (1985)

[b] Steegh (1985)

The reconstruction made by the University of Utrecht for NNAO (see Fig. 74) shows an unmatched colonisation of these low-lying lands. The first dateable information about the participation of Dutch farmers in the colonisation of peat areas in eastern Germany (Hollerbroek) appeared in 1113. These farmers were especially welcome because of their skills in draining low-lying areas.

Democratic water boards

Dirk VII's brother, Count Willem I, had a grandson, Floris V, 'The blokes' God', who was married with Beatrix. By founding democratic water boards, he prioritised agrarian development that was based on the growth of population resulting from draining the land. He met with resistance from feudal aristocracy, such as Gijsbrecht van Amstel, who were becoming empoverished, which, in 1296, cost him his life.

Growing wealth replacing taxes by toll

Towns, and particularly Dordrecht, were centres for the toll system of Holland and needed to extend the trading basis on which they were founded. Most of them were granted their town charter in the 13th century. This was the century during which the influence of Holland grew to such an extent that Count Willem II became the Holy Roman King of Germany with his polder model. The Pope was making preparations to crown him as emperor when he was beaten to death on the slippery Friesian ice. However, his grand nephew, Willem III, was able to marry the daughter of the French king and arrange marriages for his own daughters to the English king, Edward III and the Bavarian emperor, Ludwig.

Feudal interference

However, that last-mentioned strategy led to renewed feudal interference. The emperor went fishing for the fattened cod that Otto III had allowed to slip off his hook (the Hook and Cod Disputes (*de Hoekse en Kabeljauwse Twisten*[a])). Struggling to free themselves from the aristocratic–feudal 'Hooks' were the 'Cod'-supporting farmers and citizens, such as those of Delft.

Ecological influences on trade economy

The County of Holland remained relatively free from the pest epidemics that had brought about a demographic reversal in Flanders and the towns of the Hanseatic League. Bruges partly lost its cloth trade to Holland (Leiden). The movement of herring shoals from the Baltic Sea to the North Sea, and herring gutting skills that had been discovered in the mean time, gave fishermen there an ecological advantage. They sailed to wool-rich England and gradually took over the freight trade. After 1500, partly due to the St. Elizabeth flood in 1421, Dordrecht was forced to relinquish its position as main port to Delft, Rotterdam and Amsterdam. After the Treaty of Utrecht in 1475, the towns of Holland took over the Baltic trade from the Hanse as Jansen (1995) describes. Counts became Stadtholders. For one more century Holland accepted a foreign head-of-state before starting to fight for definitive freedom.

Crucial waterways

The making of dykes, widespread partition of land and draining in Holland encouraged population growth. This caused the peat areas to settle and allowed little by way of occupation other than animal husbandry, fishing and shipping. For this reason, the Hollanders were dependent on grain from the regions around the Baltic Sea. Fortunately, the Hanse preferred to transport their Baltic goods via the, in the mean time deepened, waterways of Holland, to their entrepot in Bruges, than over the dangerous North Sea. In exchange for the much reduced damage to their ships by using this route, the Hanseatic League paid tolls to the Counts of Holland.

Tax relief, Republic and Public Works

This income for the Counts brought tax relief to the farmers. As they had made their own land, they no longer saw themselves as being bound by the requirements of the feudal system (Jansen (1965)). Uneven economic growth reduced any natural areas that still existed to a few areas of blanket bog. The low-lying peat bogs were used as fuel, and winds exposed the underlying Marine Clay. The Mast Forest in Breda was planted to provide shipping with masts. However, the impulse of Golden Age slowed down when people began to live off their private means instead of investing. This resulted in

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[a] Jong, Taeke M. de (2004) *Schaalgeleding bij Hoeken en Kabeljauwen* (Zoetermeer) MESO *http://team.bk.tudelft.nl/* > Publications 2004

the wet land of Woud (1987)[a] being left behind and caused the French to establish a department of Public Works in 1798.

The first Republic since Rome: The United States of The Netherlands

Then, in 1585, Antwerp capitulated to the Spaniards, led by the Duke of Parma. Antwerp, with its multicultural way of life and its urban hinterland, had become the trading centre of the 16th century world. It was the northern entrepot for products from countries around the Indian Ocean as Bouman (1979) describes. This is where modern banking and economic individualism bundled into companies began. During the following four years, almost half (approx. 38,000 people) of its largely Protestant inhabitants fled to the north as Israel (1995) describes, thereby laying the *laissez faire* foundations of the partly immigrant-inhabited metropole of Holland and its trade emperium.The French did not help the young Republic gain acceptance and sovereignity, as the Orange's continued to hope, but they did help by diverting the attention of Philip II, and thus the Duke of Parma, southwards. That gave Maurits opportunities and Van Oldenbarneveld succeeded in bringing competing parties together to form the VOC. That Maurits continued to believe in predestination, and thus in aristocracy, cost Van Oldenbarneveld his life.

The early urbanisation of Holland

Around 1550: more than half of the population of Holland lived in towns that had grown up for the purpose of conducting trade.

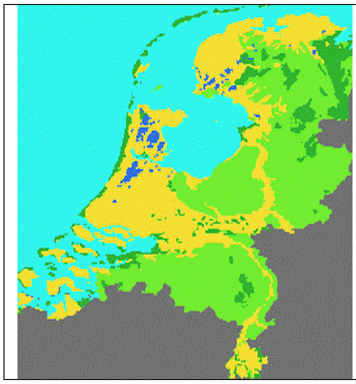

Fig. 881 *1550*

Fig. 882 *1675*

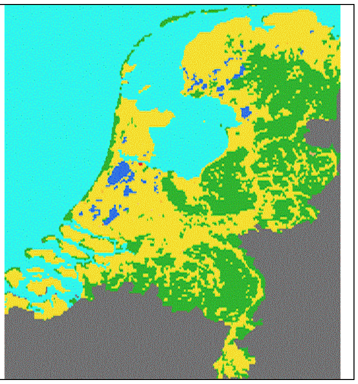

Fig. 883 *1800*[b]

The Golden Age and the economic decline that followed.

Around 1675: the towns in the west had grown fast. A network of tow-barge canals had come into existence.[15] Development on the sandy soils had come to a halt.

Around 1800: following the impoldering of North Holland, large areas of blanket bog were reclaimed. More dykes were built. From a hydraulic point of view, the land was in a deplorable state.[16]

Recovering land and nature

This is how the relatively recent nature of the Netherlands, has come into existence. It is so different from anywhere else in Europe that a separate legend unit is needed to register it on the European nature map of Bohn[c] (see Fig. 862). The task of impoldering the land was completed with the use of the steam engine. To work on the remaining 'waste grounds', the Heide- and Grondmij were established at the end of the 19th century. These relatively new natural areas were later reduced again to provide employment during the 1930s, when unemployment levels were so high.

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[a] Woud, A. v. d. (1987). *Het lege land. De Ruimtelijke Orde van Nederland 1798-1848 (Proefschrift)*. (Amsterdam) Meulenhoff informatief.

[b] University of Utrecht

[c] Bohn, U., G. Gollub, et al., Eds. (2000) *Map of the Natural Vegetation of Europe scale 1: 2.5 million* BN Bundesambt für Naturschutz (Bonn) Federal Agency for Nature Conservation.

Artificial fertilisers

Artificial fertilisers were discovered round about 1900. Since then, fertilising areas of soils with low-mineral content has favoured rapidly maturing crops, to the detriment of slowly maturing specialist species. Animal husbandry, drainage and atmospheric deposition have all contributed to this process. Just as it is easier to dissolve sugar in coffee than to take it out again, so will much time be needed before these levels of fertilisation are cut down. For this reason, it is not just rarity expressed in kilometres that counts, but also (ir)replaceability in years. One can use the product of these two values to gauge the value of natural areas against the rarity and replaceability of human artifacts.

Recent centuries

Around 1850: the growth of industry in Twente and in North Brabant. Impoldering of lakes caused by peat exploitation in the western fenlands. The digging out the peat of the blanket bogs of the higher eastern areas.

Around 1900: western areas were still the most urbanised. The population of Amsterdam exceeded 500,000. The railway network was completed.

Around 1930: industrialisation on the sandy soils reached a peak. Conurbations began to form everywhere.

Around 1960: land reclamation and the Delta works, in addition to large urban and industrial expansion.


Fig. 884 *1850*


Fig. 885 *1900*


Fig. 886 *1930*

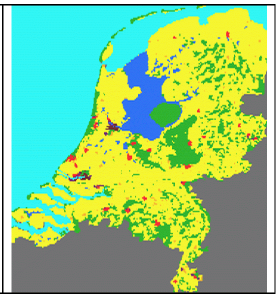
Fig. 887 *1960*[a]

In the second half of the 19th century, two cultivation associations, the Heidemij and the Grontmij were established to bring new nature areas under cultivation again, that had originated since the Golden Age.

Land consolidation and nature management

These associations played an important role in land consolidation (ruilverkaveling).

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[a] University of Utrecht

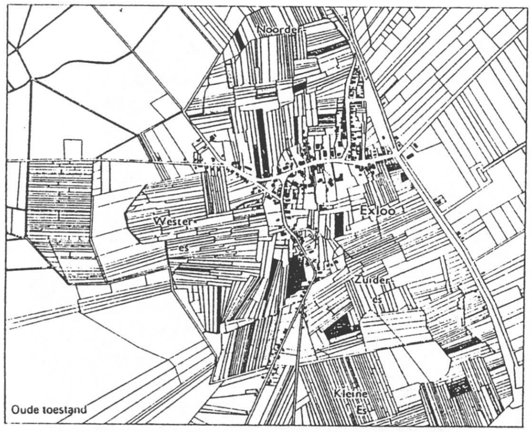

Fig. 888 *Before land consolidation*

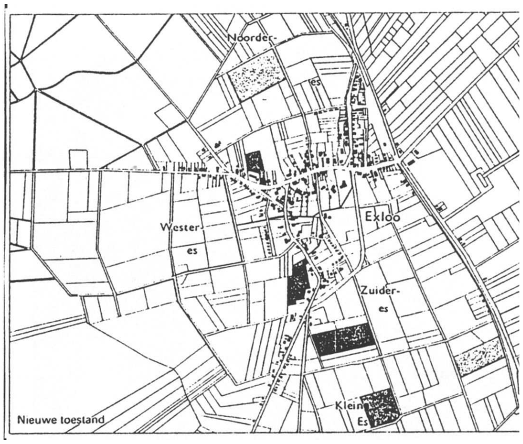

Fig. 889 *After land consolidation*[a]

An interest in nature conservation and management arose at the beginning of the 1900s. Since 1970, there has been an increasing interest in managing nature and in introducing policies to conserve nature by consolidating land. At present, land consolidation is also an instrument to nature conservancy policy-makers (in riverine and peat bog areas).

Road and air transport play a large new role, but a threatened environment requires a place of its own, too.

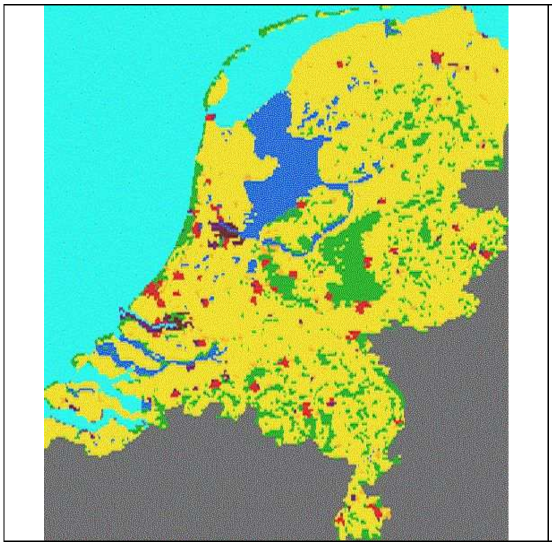

Fig. 890 The Netherlands in 1989

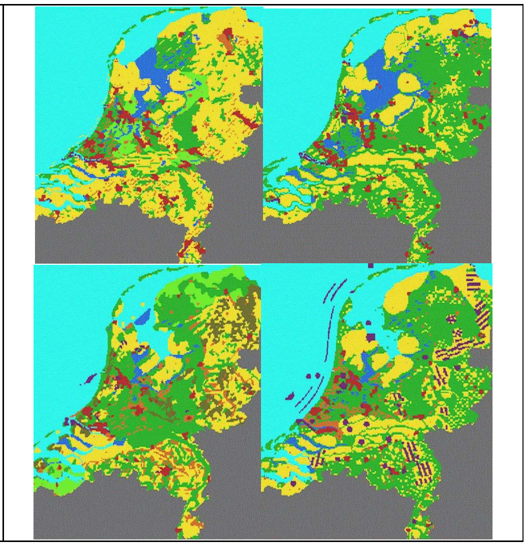

Fig. 891 *Ideas for 2050*[b]

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[a] Wolters-Noordhof (1981)

[b] NNAO (1987)

6.2.4 Reading topographical maps (Visser)

Map images of higher grounds in The Netherlands

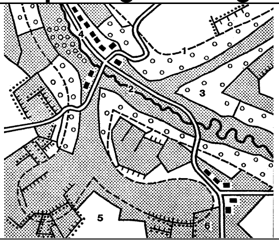
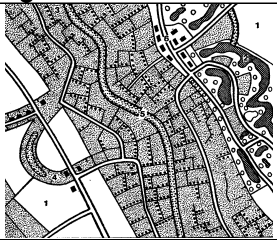
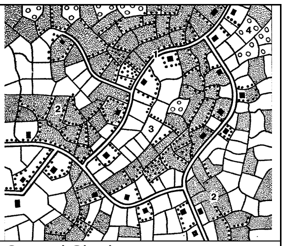
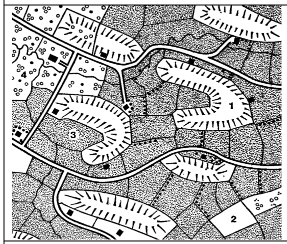
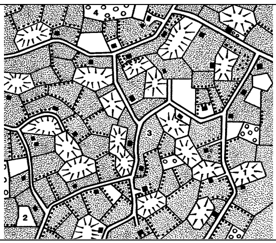
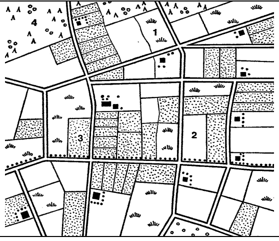
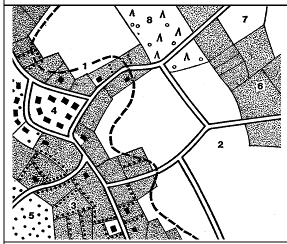
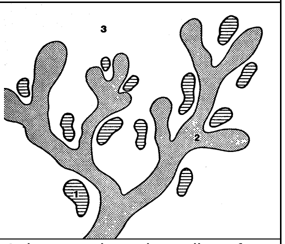
			
South Limburg 1. edge of valley 2. stream 3. wooded side of valley 4. settlement 5. arable land 6. grassland with wooded banks	North-Limburg 1. arable land on a fluvial terrace 2. old fluvial dunes 3. hedged landscape 4. old fluvial beds 5. river 6. settlement	North -Brabant 1. dune ridge (duinrug) 2. small peat bog/fen mere 3. stream 4. woodland along a stream 5. settlement on old arable land 6. fluvial- or water meadows 7. cultivated land outside the valley of a stream 8. planted forest	Central Slenk 1. road 2. grassland 3. arable land 4. remains of a woodland
			
Wind-borne sand dunes 1. parabolic-shaped sand dune 2. small arable field on flatter terrain 3. grassland between hill ridges 4. woods on a country estate	Achterhoek 1. hill with old arable land 2. little field on plain surface 3. grassland of lower grounds 4. little wood	heathland reclamation 1. heath 2. field 3. grassland 4. wood	
			
Lateral moraines of East-Twente 1. contour of lateral moraines (stuwwal) 2. old farmland on flank of lateral moraine 3. grassland surrounded by wood on moisty grounds 4. settlement 5. wet woods (broekbos)	6. grassland of younger relamations 7. farmland of younger relamations 8. planted coniferous wood	Lateral moraines of West Twente 1. contour of lateral moraine (stuwwal) 2. meltwater ridge 3. settlement 4. old farmland on Eastern flank of lateral moraine 5. grassland on moisty plans 6. heath 7. planted coniferous wood	Ash trees along the valley of a stream 1. field (es) 2. stream valley (beekdal) 3. tableland

Fig. 892 Landscape elements on maps of higher grounds in The Netherlands[a]

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[a] Visscher (1972)

Map images of lower grounds in The Netherlands

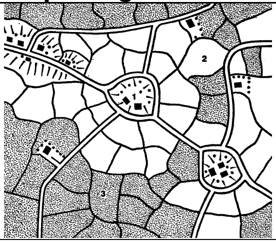
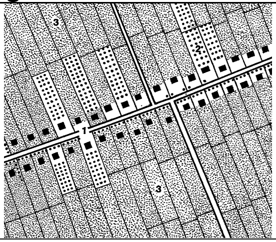
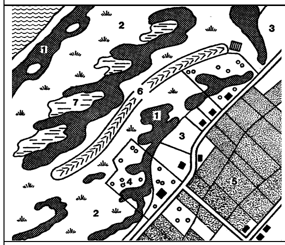
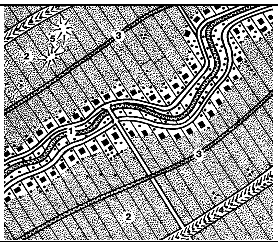
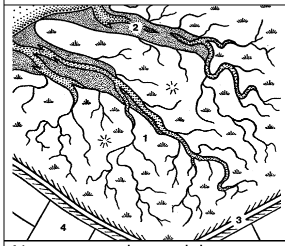
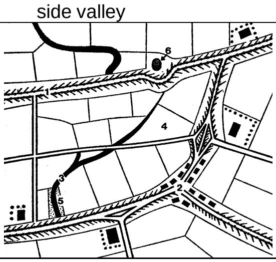
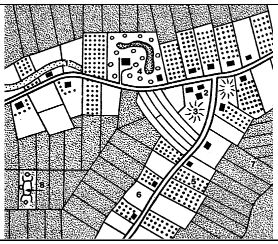
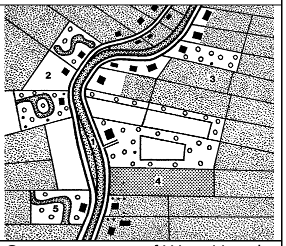
			
terp landscape 1. terp with buildings 2. field 3. grassland	Parcelled landscape of West Friesland elongated lots 1. regional village (streekdorp) 2. orchard 3. grassland	Parcelled landscape of the northern Netherlands (slagenlandschap) 1. stream 2. road village (wegdorp) 3. lot border 4. grassland 5. farmland (bouwland)	
			
Water collection on dune landscapes 1. dune ridge 2. lower part of dune area 3. digged perpendicular watercourse (dwarswetering) 4. small wood dyke (houtkade) bordering village area 5. surface dune relic (donk)	Beach banks between Leidenand Haarlem (strandwal) 1. road village 2. country estate on ridge 3. wet wood on sea side valley 4. canal for shipping digged sand 5. bulb field on digged part of sea side ridge 6. grassland in moisty sea side valley	peat bog area with peat stream 1. stream with regional village 2. grassland 3. digged perpendicular watercourse 4. small wood dyke bordering village area 5. surface dune relics	
			
Nature areas beyond the dyke(s) in South West Netherlands 1. salt marsh (schor) 2. mud flat (slik) 3. sea dyke 4. farmland	The dyke system of SW Netherlands 1. dyke planted with trees 2. dyke village 3. creek relic 4. farmland 5. grassland on creek bed 6. pool as relic of bursting of the dike (wiel)	Fluvial landscape 1. abandoned river bed 2. settlement 3. raised old arable land 4. country estate 5. orchard 6. field 7. grassland	Country estates of West Utrecht 1. river 2. field 3. grassland 4. orchard 5. country estate

Fig. 893 *Landscape elements on maps of lower grounds in The Netherlands*[a]

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[a] Visscher (1972)

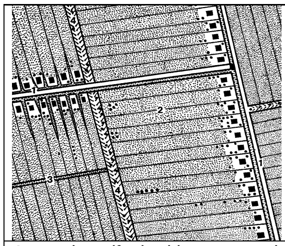
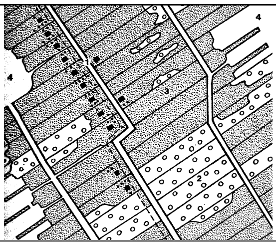
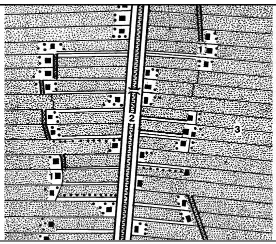
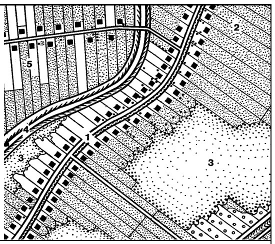
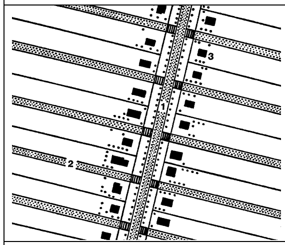
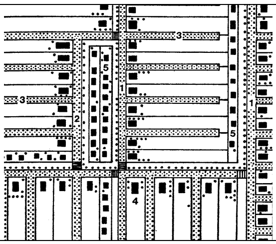
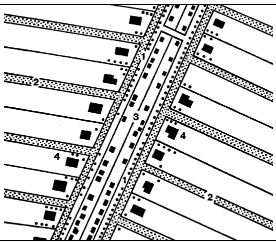
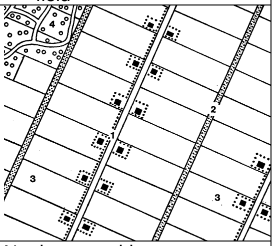
			
A peat bog (fen) with excavated waterways 1. regional village 2. grassland 3. digged perpendicular watercourse 4. small wood dyke	The peat bogs (fens) of NW Overijssel 1. water region village alongside watercourse 2. marsh wood (moerasbos) 3. grassland 4. pool from peat extraction	The peat bog (fen) at Kamerik 1. buildings on clay ridge 2. canal with rest of building alongside 3. grassland parceled out in strips	A peat bog (fen) with lakes and drainage systems 1. regional village 2. grassland 3. lake (plas) 4. ring-dyke 5. polder with grassland and field
			
A fenland community along a canal 1. canal 2. perpendicular canal (wijk) 3. farm	Fenland communities along canals 1. canal 2. back canal (achterdiep) 3. perpendicular canal (wijk) 4. peat extraction with farm 5. strip with dwellings	Fen community along a canal that gives dual access ' 1. road alongside canal 2. perpendicular canal (wijk) 3. strip with dwellings 4. farm	North-east polder (*Noordoostpolder*) 1. road with farms surrounded by wood belts 2. canal 3. fields 4. wood with unimproved roads

Fig. 894 More recent landscape elements on maps of lower grounds in The Netherlands[a]

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[a] Visscher (1972)

6.3 Density

6.3.1 Global densities$_{10\ 000km}$

The Earth's surface counts 511 185 932 km^2 and 6 501 085 722 humans (estimation march 3rd 2006)[a]. So, the gross population-density is nearly 13 inhabitants per km^2 (nearly 8 ha per person).

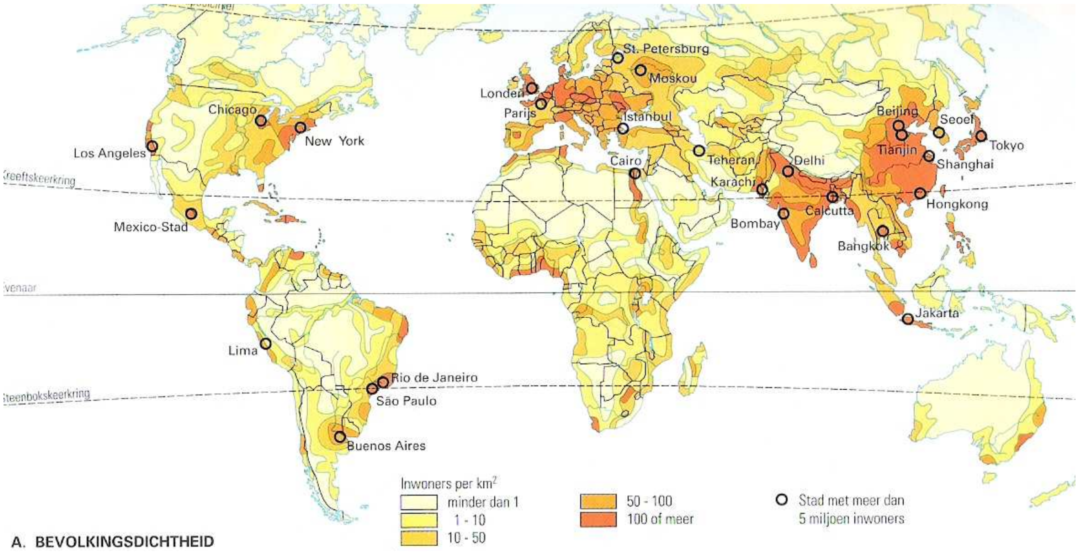

Fig. 895 Global density from <1 until >100 inhabitants per km^2 [b]

However, people usually do not live in the sea. The net population-density *on land* is about 44 inhabitants per km^2 (about 2 ha land per person), because about 29% of the Earth's surface is land. So, the measure of density is most dependent on the kind of surface you take into account.

6.3.2 Gross and net density

Having excluded the oceans as tare surface to measure globally net human density on the Earth's surface, the question arises if, on continental level, you should take all land into account, including the arctic areas, mountains, deserts, forests (continentally gross), or only the habitable land (continentally net). After all, for application in urban design, the aim is to compare inhabited areas. If so, what is habitable land? Looking at Fig. 895, many areas count less than 1 inhabitant per km^2, mostly useless for agriculture and sustainable settlement. We can call that 'tare surface' on a continental level (see *Fig. 896*). The remaining 'net surface' with a higher ('net') density, usable for any form of settlement, we can call 'habitable land'.

Higher level	**gross**		
	net		**tare**
Lower level	gross		
	net	tare	

Fig. 896 Net, tare and gross on different levels of scale

However, most of these habitable surfaces are actually used for agriculture, some for urban concentrations. These urban areas sometimes count more than 5000 inhabitants per km^2

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[a] *http://www.census.gov/ipc/www/world.html*
[b] Bosatlas(1996)

(50 inhabitants per ha). Urban areas are most interesting to us if we would like to compare metropolises, conurbations, towns, districts, neighbourhoods and so on. Going on systematically with the interval boundaries 1-10-50-100 into 500-1000-5000 in the legend of Fig. 895, the legend units of highest density would become invisible on the scale of the map. Moreover, the intervals are not equal. That means the shown pattern is accidental. The pattern is changing by the choice of intervals. They are chosen to produce the most striking pattern, but if population grows, the chosen intervals may become insufficient to see any pattern. Moreover, on an urban scale we are most interested in subdivisions between 1000 and 10000. So, changing scale to visualise details we have to skip the lowest densities calling them 'tare'.

6.3.3 A binary legend: net and tare surface

On any level of scale from the gross surface you can subtract relatively unused areas as 'tare surface', resulting in gross and net density. On a lower level of scale the net surface becomes gross surface from which you can subtract other kinds of tare. So, to compare densities properly, you have to distinguish levels of scale, each with its own legend (see *Fig. 897*) to determine gross and net density.

	m nominal radius		**binary legend**	
Name frame	**frame**	**grain**	**net**	**tare**
Global	10 000 000	1 000 000	continents	oceans
Continental	3 000 000	300 000	habitable lands	lakes and waste lands
Subcontinental	1 000 000	100 000	urbanised areas	rural areas
National	300 000	30 000	urban networks	landscapes
Subnationaal	100 000	10 000	urban regions	landscape parks
Regional	30 000	3 000	conurbations	town landscapes
Subregional	10 000	1 000	towns, quarters	town parks
Urban, local	3 000	300	districts, villages	district parks
District	1 000	100	neighbourhoods, hamlets	neigbourhood parks
Neighbourhood	300	30	ensembles	dispersed greenery
Ensemble	100	10	lots	opening up (access) area
Lot	30	3	houses	gardens, patios
Dwelling	10	1	living rooms, studies, bedrooms	inaccessible space, wet rooms, circulation and storage spaces
Room	3	0,3	sitting areas, dinettes, beds	walking area, cupboards, closets, windowsills
Place	1	0,1	action-surrounding space	commodities

Fig. 897 Fifteen levels of scale to distinguish 15 different kinds of density

6.3.4 (Sub)continental densities$_{3\,000 \text{ and } 1\,000\text{km}}$

On a European level of scale, adding an extra interval boundary of 200 inhabitants per km^2, you can observe a central urbanised axis of more than 200, surrounded by ‘rural’ areas of less than 200 inhabitants per km^2. However, at a regular distance within these ‘rural’ areas, there are some conurbations (London, Paris, Lyon, Milan, Munich, Prague, Berlin, Hamburg; see *Fig. 899*). Some of these do have the highest European density measured within a local radius of 30km.

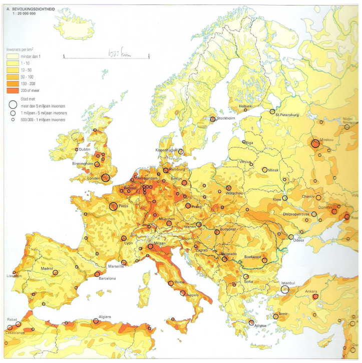

Fig. 898 Continental densities

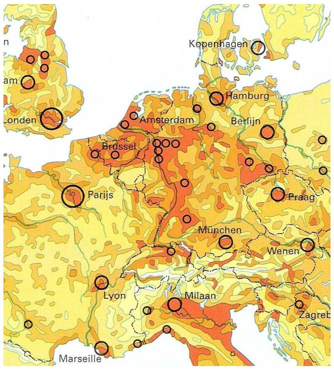

Fig. 899 Subcontinental densities

Fig. 900 Legend[a]

So, there are not only different *densities*, but also different *distributions*, producing patterns interesting from a viewpoint of design.

6.3.5 National densities and distributions$_{300\text{km}}$

Land use, the reciproque of population density

The Netherlands as a whole counts more than 42000km^2 (sea excluded) and 16300000 inhabitants, that is about 390 inhabitants per km^2 (about 4 inhabitants per ha) with extremes ranging from 0 to 20 000 inhabitants per km^2 if you take smaller areas into account.

The reciproque of population density is land use. The advantage of a land-use unit is that different destinations of use can be discerned. In the Netherlands, the land use is about 2700 m^2 per inhabitant, roughly divided as 1500 m^2 of agrarian land per inhabitant, 500m^2 of water, 300 m^2 of nature areas and forest, 300 m^2 of urban areas and infrastructure, 100m^2 industry and recreation. [308]

Residential area, part of urban area

Of this 300m^2 urban area, only about 160m^2 are ‘residential areas’[309]. According to CBS’s definition of ground statistics[b], these are homes with green areas, hardened surfaces and primary facilities, such

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[a] Bosatlas(1996)

[b] **Dwelling area** Spaces that are primarily meant for dwelling, we count as dwelling areas including primary services like shops, schools for pre-school kindergarten and primary schools, offices of banks but also green spaces, streets, parking places, urban canals less than 6 meter wide, premises, gardens, grass plots and playgrounds. In case dwelling areas are located in forests, the whole area is marked as dwelling area only in case a street structure can be perceived.

Ribbon development of mainly non-agrarian dwellings is counted as dwelling area if the distance between the houses is less than 50 meters with a minimum of five dwellings.

In case of building blocks, the relative distance between the blocks may be a maximum of 100 meters. Included in the dwelling area are also caravan camps (excluding wrecked cars storage, houseboat harbours, warden-assisted flats, student housing, housing and flats for hospital staff and student housing, homes for the elderly. Only realised dwellings are counted as dwelling area.

Socio-cultural facilities Here is included all educational facilities (excluding schools for pre-school kindergarten and primary schools that belong to dwelling areas), boarding schools, conference centres, hospitals, sanatoriums, nursing homes, psychiatric hospitals,

institutions for the mentally handicapped, homes for the elderly, churches, monastries, museums (also for castles open to the public), but excluding open-air museums, theatres, cinema's, concert halls, conference centres, cultural centres, community centres, club buildings, youth associations and sheltered workshops. Also counted to these facilities are the accompanying facilities like parking lots and gardens. Forests belonging to these facilities are only counted as such in case they are 1 ha or larger.

as local shops, schools for pre-school and primary education, as well as other residential facilities such as caravan camps, house-boat harbours, service flats, etc.[310]

in dots of 100 m^2 per inhabitant.

Fig. 901 *Residential area per COROP area*

Fig. 901 shows the distribution of this residential part of the urban area, divided over 40 statistical (COROP) areas, expressed in the absolute sense and per inhabitant according to CBS (1994) .

The residential area per inhabitant varies in space. In the west of the Netherlands, an average of about 100 square metres of residential area is available per inhabitant; in East Groningen, about 300 m^2 ; and in a number of other places between those two extremes, about approx. 200 m^2 per inhabitant[311].

So, ‘norms’ for the number of m^2 of residential area per inhabitant differ regionally. That also applies for other facilities, such as (daily) recreational areas or drinking water basins. Apart from variation in space, land-use norms also show a variation in time: they change.

So, the use of Planological Index Numbers for the amount of space needed for facilities is relativised by these spatial and temporal variations.[312]

Population density divided by the number of occupants per household

If one divides the density of inhabitants by the local average number of occupants per household, then one arrives at the local density of homes[313]. However, since WW2, the number of people per household, especially in the towns, has dropped from about 5 to 2.5[314]; and this number continues to fall. This, by the way, was the main reason for scarcity of housing in the later post-war period, and for the urban explosion after 1960. There are not only great variations in time in the number of people per household, but also large regional differences. The number of people per household is the lowest in the Randstad and here the numbers have decreased the most rapidly in the last 50 years. In Fig. 703, the urban areas in the Randstad in 1965 are compared with those in 1995.
During this period, the Randstad hardly grew in numbers of inhabitants (from 5.3 million to 6.1 million). The extension of urban area was caused, among other things, by fewer people living in one household (family dilution).

Floor space is more reliable than the number of houses

The objects to be counted should be equal. That is why the floor surface, to be measured in m^2 is much better a measure to get a ratio of climatised volume per earth area than the number of houses of different size (as often done). For example the Dutch housing policy Secretary of State 1973-1977 Van Dam approximately doubled the number of houses produced per year in the Netherlands by halving their floor surface. Coincidentally the demand of one person households for smaller houses was increasing. It was a great political succes, but few politicians realised that Van Dam did not increase the newly built floor surface (and building effort) substantially.

Drawing the real measure dot distribution

The regional spatial effect becomes obvious when you redraw the map in real measure units of 100,000 and 10,000 inhabitants, counting 300m^2 per inhabitant (the approximate overall urban spatial use mentioned on page 502). In Fig. 703 these are shown as circles with a radius of 3 and 1 km, respectively. Read: ‘3 km radius’ or ‘3 km in the round’ and say: ‘town’. Read: ‘1 km radius’ and say ‘district’ if part of a town or ‘village’ if separate. If circles overlap, then one has to conclude that the urban density is higher than the average national density. If there are about ten 3km circles (1 million people) within a radius of 10 km, then you can talk of ‘conurbations’ and draw them as one circle of 10km.

Growing conurbations by growing land use

According to this representation, the old situation of 1965 (Fig. 703) was characterised by three large and three small conurbations and only a few small (separate) towns. In 1990, the first thing that strikes one is the dilution of households: the conurbations had grown, sometimes even losing inhabitants into suburban settlements. One can call this form of expansion ‘deglomeration’. This influences not only the built-up areas drastically, but also the open areas in between. As soon as urban areas are no longer surrounded by rural areas of the same order of size as the urban area, a reversal in the image of the urban area occurs: the town is no longer situated in the countryside, but the countryside is now enters the town, a reversal pointed out by Tummers and Tummers (1997,see Fig. 789)

Fragmentation of urban and rural areas

The fragmentation of urban and rural areas on different scale levels can be visualised in the legend in Fig. 771.[315] The figures shown in this table are not absolute. They can be interpreted with a tolerance of up to the previous or the next figure shown in that column. The legend units shown in red are represented as circles with a size that reflects the present average urban spatial use in the Netherlands of approx. 300 m^2 per person: 160 m^2 urban residential area, 60m^2 working area[a] and 80 m^2 of infrastructure (a part of it lies outside the built-up area and therefore does not need to be regarded as an urban area).

Dry and wet infrastructure

For linear-shaped legend elements, a similar sort of semi-logarithmic series is possible. *Fig. 494* shows nine levels of access.[316] Something similar is possible for drainage (*Fig. 493*). ‘Without information to the contrary’, in the (former) low peat areas, the legend units are considered to be completely filled with the named networks. In clay aeas the lowest orders with higher network densities disappear. In dunes, nature conservancy areas, and higher sandy grounds, even more lower orders disappear. In urban areas, ditches and drainage channels disappear. Their function is taken over by a relatively fine-meshed underground drainage network.[317]

Distinguish existing and future population

Fig. 771 shows a legend for representing the dispersion patterns in a stylised manner on a regional scale. On the basis of this, regions can be compared. The estimated economic, cultural and/or managerial efforts needed to realise the areas drawn into the design can be indicated using different thicknesses of lines. The thinnest lines represent existing areas. This more or less reflects the importance of the element in the design. At the same time, this provides an elegant way of distinguishing existing areas from the new ones proposed (the ‘planning layer’). Apart from this, the legends are literally ‘open’ in the sense that the circular legend units can still be coloured with functional accents or identities. For the time being, the circles can be seen as ‘little magnifying glasses’ which conceal unfilled-in details of towns, villages, hamlets, landscaped parks, urban

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[a] **Extraction of minerals** Here are included all grounds that are used for the extraction of minerals both opencast mining and mining industry, as soon as the exploratory drilling and exploitation has started. Included are also all buildings, depository spaces for minerals and the residues and leftovers like the mountains of residues from mines, except if these are planted with forest and 1 ha or larger. Quarries and open-pit mining often lead to large holes, are also counted to this category as long it still is the main function. As soon as on part of the grounds the main function changes, it is counted to that category like water after sand and gravel extraction that is used for recreation as main type of land use, daytrip facilities and grounds and water for agricultural use.
Grounds that already have a concession but where the actual extraction has not yet started are not counted to this category. As minerals we include natural gas, petroleum, rocks and stones, gravel, clay, loam, marl, peat, sand (not the extraction in existing lakes and rivers) and salt.
Company grounds To this category are counted businesses and premises (including the storage yards, areas for transshipment and transfer of goods, parking lots, warehouses and company houses, working grounds and office buildings, infiltration grounds and the like) like factories, port areas, auction halls, exhibition grounds, cattle markets (both covered and outdoors), wholesale premises, storage yards for trade (also groundmoving businesses)) and garages (including parking garages). Grounds for extension of businesses that have already been bought, rented or in ground lease are also counted to this category, as far as they border on existing grounds and as far as they are already changed from the original land use.
Not to this category belong fallow and wasteland, not yet finished sites for building, grounds that have been taken an option on but not yet been given out, harbour basins, clay excavation grounds for brick factories and company grounds no longer in use.
Provision of services To this category belong business areas in the service industry like shopping centres (also in case there is residential use on the upper floors), banks, insurance companies, ministries, town halls, offices for public works etc., border facilities (customs etc.), provincial government buildings, police stations, fire stations, courts of justice, prisons, goods markets (if they are used at least two days a week for this purpose), businesses in hotel and catering industry, garages of bus companies, laboratories.
Not to this category belong laboratories that belong the group of socio-cultural facilities (education, hospitals, judicial laboratories, other public facilities (waterworks, water treatment companies) and industrial facilities.
Other public facilities In this category are included public businesses (gas, water, electricity, district heating and central aerial systems including the grounds that belong to them, water treatment plants and incineration plants, including sludge fields, infiltration grounds (except those belonging to industry) and storage yards for the national, provincial and municipal governments (including municipal yards) excluding storage yards for road maintenance, storage grounds for slurry (dredge and port slurry), military objects like ammunitiion depot, barracks, mobilization centres, radar stations and rifle ranges (excluding barrack squares, that are counted as natural areas.

landscapes or urban parks. The drawings function as ‘colouring pictures’ that have not yet been filled in.[318]

6.3.6 Regional distribution$_{100\text{ and }30\text{km}}$

Drawing the existing situation

To draw the existing situation in different plan layers, one layer, the number of inhabitants per municipality, can be shown according to actual CBS statistics in real measure circles of 100,000,10,000 and 1000 inhabitants (see Fig. 902).

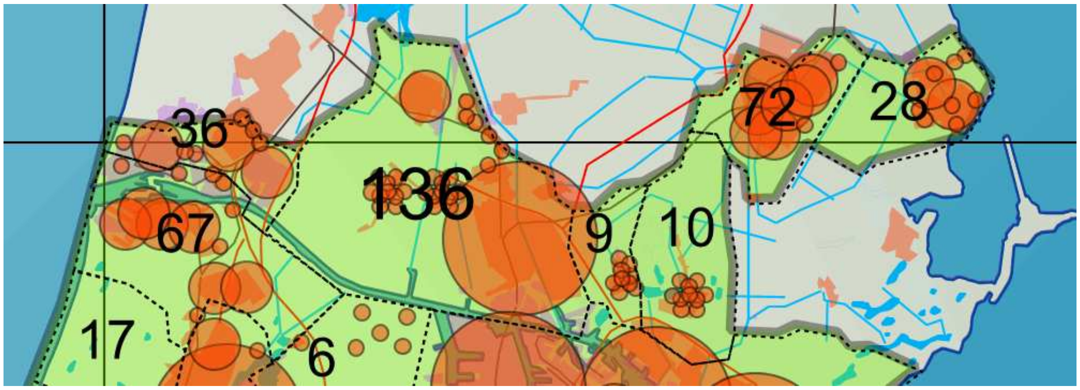
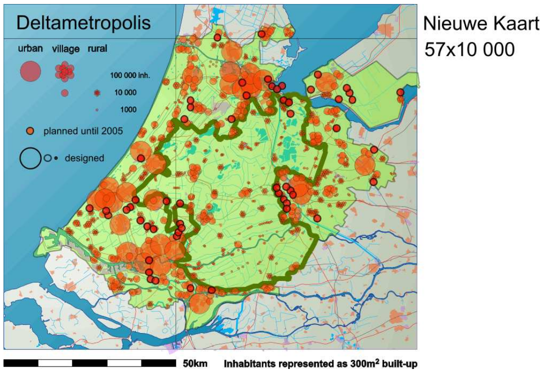


Fig. 902 *Population statistics per municipality, drawn as circles of 3, 1 and 0.3 km radius of 100 000, 10 000, and 1000 inhabitants (300m^2/inhabitant). These circles represent the built-up area such a population needs at average in The Netherlands. Their location is roughly determined by the urban topography read from the map.*

In such a pointillistic representation, a higher density than the current average in the Netherlands can be read off directly from overlapping circles. Dispersion within a municipality is quite accurately determined by the position of the built-up area on the map (see Fig. 902).

Adding existing local plans

To that has been added the capacity of existing municipal residential building plans, which, according to the New Map of the Netherlands 2000, is roughly estimated as being 570 000 inhabitants (see Fig. 903). This capacity has been aggregated with that of the existing built-up area to create a basic map for the year 2005, thereby making it possible to compare the designs. In this way, ten 1km units of 10 000 inhabitants (for example Amstelveen and Nieuwegein) could be aggregated into one 3km unit of 100 000 inhabitants. In a simple way, this represents locally increasing urbanisation, as distinct from expansion in general.



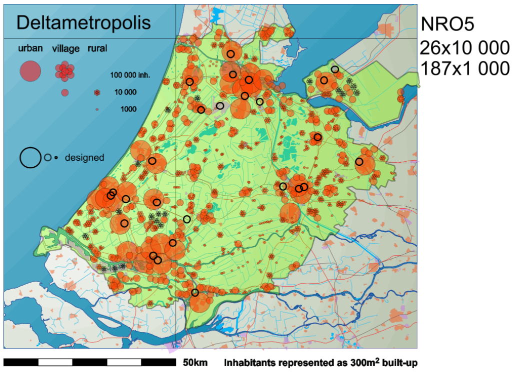


Fig. 903 *The year 2005: including existing plans*

Fig. 904 *The year 2030: NRO5*

Adding existing national plan NRO5

In Fig. 904 the remaining capacity of 5th National Plan of Spatial Policy NRO5 (intermediary scenario for 2030) has been drawn onto this background as a reference. That figure shows the mapped images of the existing situation, the plans that, according to the New Map of the Netherlands, are being carried out, and the part that remains after being subtracted from that for NRO5, according to the EC intermediary scenario (ABF).

Interpreting plans

Fig. 905 shows the interpretation of NRO5 used in Fig. 904. In the same way other plans can be added.

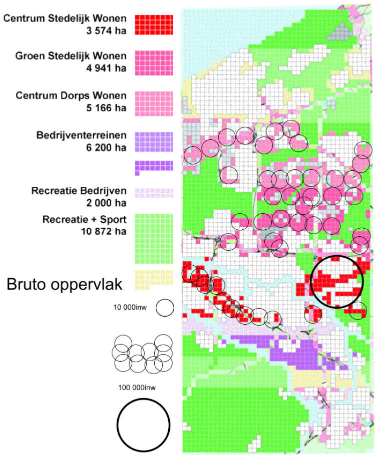


Fig. 905 *Interpretation NRO5*

Fig. 906 *Interpretation OMA*

In OMA, 7, 12 and 13 squares of 25 ha are converted into circles of 10,000 inhabitants (Fig. 906). Ten circles in the centre of Rotterdam, within a radius of about 3 km are aggregated to a circle with a radius of 3 km (100,000 inhabitants).

Adding complementary plans

OMA's and TKA's designs (see Fig. 906 and Fig. 907 respectively) are calculated back to the numbers of inhabitants from the design sketches, and, after subtracting the existing local plans, are distributed according to the topography of the drawings.

Fig. 907 *Interpretation TKA*

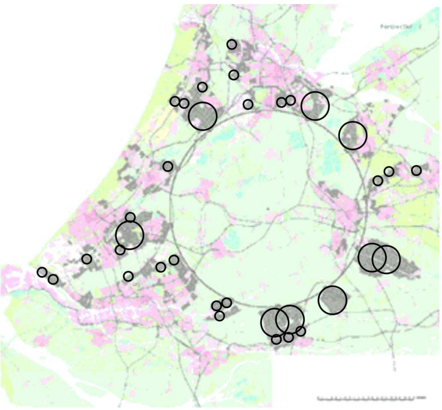


Fig. 908 *Interpretation Snozzi*

Summarising and comparing with an alternative

Snozzi's design is interpreted exclusively and globally from the drawing (Fig. 910). In H+N+S's design, ABF estimated the capacity of the Green Heart to be 51 000 homes. This means about 100 000 inhabitants, represented as one dotted circle of 100 000 inhabitants in the middel of the summarising drawing of Fig. 909, because although a dispersion of 100 inhabitants (shown by small dots) might be possible, it is no longer visible or discernible. OMA, TKA and H+N+S's designs could now be represented in one drawing (see Fig. 909).

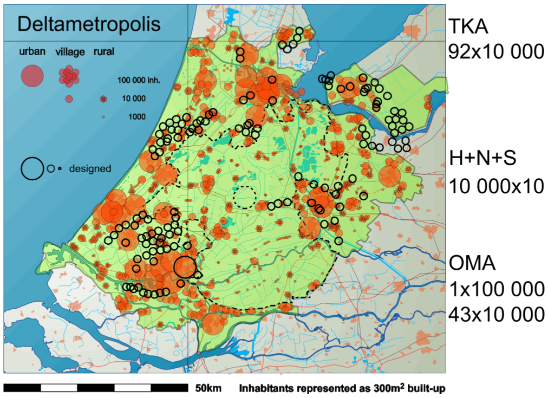


Fig. 909 *Three complementary designs 2050*

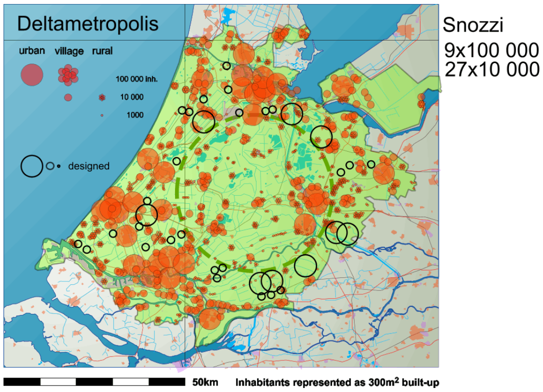


Fig. 910 *Alternative Snozzi*

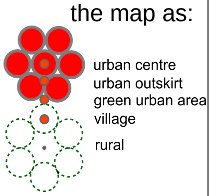
Snozzi's design includes the entire Delta metropolis and is therefore drawn separately (see Fig. 910) The legends are restricted to units of 100,000 (3 km radius) and 10,000 inhabitants (1 km). In the background, units of 10,000 inhabitants have been divided into units of 1000 inhabitants (300 m), where the topography requires it. This has not been done in the design layer, which improves overall comparability.

A comparison of quantities and rough morphology

Fig. 911 compares NRO5 with five alternatives: developing the South flank only, the Green Heart only, the North flank only, developing these three together, or following Snozzi's design.

Context

recognisable on
the map as:



Name:	Population x 1000			OMA, South flank				H+N+S Green Heart				TKA, North flank				Total				Snozzi			
	Now present	Existing plans	NRO5-EC trend	100 000	10 000	1000	Inhabitants + existing plans	100 000	10 000	1000	Inhabitants, including existing plans	100 000	10 000	1000	Inhabitants + existing plans	100 000	10 000	1000	Inhabitants + existing plans	100 000	10 000	1000	Inhabitants + existing plans
	2000	2005	2030																				
Urban centre	710	700	988	1			800				700		8		780	1	8		880				700
Urban areas outside the centre	2818	2810	2448		11		2920				2810		25		3060		36		3170	9			3710
Urban green areas	415	410	655		16		570				410		35		760		51		920		3		440
Village centre	1337	1890	2090		16		2050				1890				1890		16		2050		24		2130
Rural living	251	400	505				400		10		500		24		640		34		740				400
Working area	512	380	454				380				380				380				380				380
Total	**6043**	**6590**	**7140**	**1**	**43**		**7120**		**10**		**6690**		**92**		**7510**	**9**	**27**		**8140**	**9**	**27**		**7760**

Fig. 911 *Five alternatives for NRO5 and their population specified to their urban or rural context*

It can be concluded from Fig. 911, that OMA already realises the NRO5 programme in the South wing, while TKA exceeds it already in the North wing. The three plans together exceed the NRO5 programme by 1 million inhabitants. Snozzi arrives at an extra capacity of over 600,000 inhabitants. These extra capacities are mainly achieved in urban areas outside the centre. Centres score lower than in the NRO5 design. To answer economic questions by this kind of representation further differentiation of the comparison into contexts of living and costs can be elaborated by calculation[a].

6.3.7 Density or real measure dots distribution

Misleading density comparisons if the compared surfaces differ

Density measures are abstract ratios of objects per area. To compare different areas, in principle, their surface has to be exacly the same, otherwise very different values could appear (see *Fig. 912*).

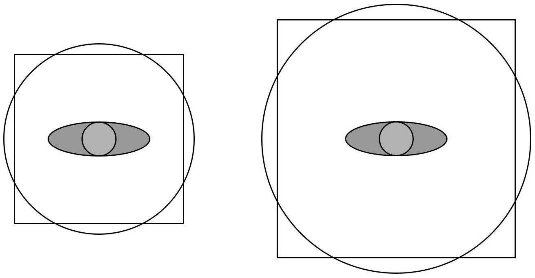


Fig. 912 The same person at 1 or 2 m^2 results in very different density values of 10000 or 5000 inhabitants per ha

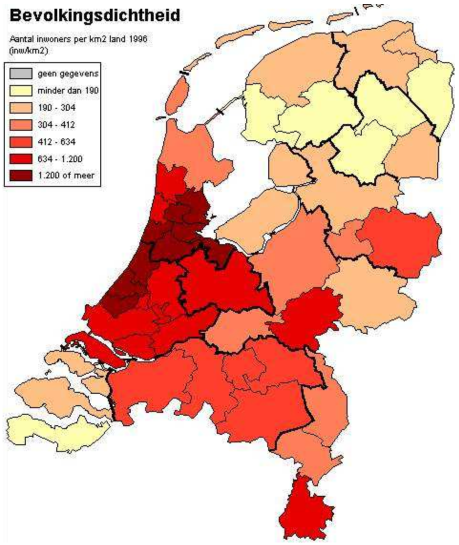


Fig. 913 Misleading image of densities applied on the different surfaces of COROP areas

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[a] Jong ()

For example, the statistical COROP areas, based on temporary socio-economic and administrative boundaries, differ too much in surface to allow any comparison of variables like density with surface as a factor (see *Fig. 913*, where Rotterdam has a lower density than some smaller suburban areas).

A misleading regular GIS-grids

Even a regular, exacly equal square km grid applied in GIS-applications can produce misleading images. An occasional boundary could divide a concentration or not, leading into very different images and conclusions, loosing essential information and design qualities (see *Fig. 914*).
Data to compare contexts of living and their costs are lost in an average representation, while the easier to draw dot representation gives a more realistic image. Moreover, they can be counted per km^2 and by doing so, immediately translated in more abstract densities, while the reverse is impossible.

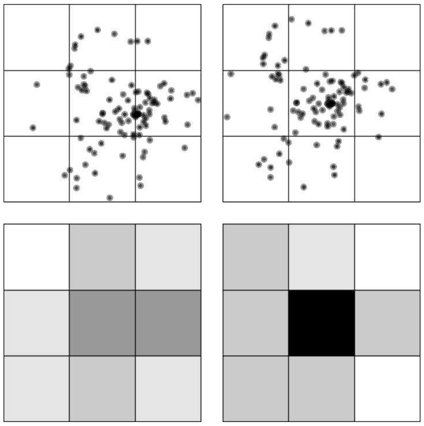


Fig. 914 Two average density interpretations of the same dispersion

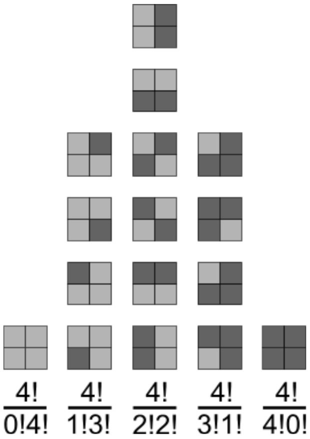


Fig. 915 Combinatorial possibilities of arrangement between emptyness and full coverage

From a viewpoint of design the grey values inbetween emptiness and full coverage give mathematically proven the most possibilities of arrangement (see *Fig. 914*, column in the middle) and probably the highest chance for high quality solutions. On page 518 we try to find other relations between density and quality, depending on the definition of quality.

Mistakes using densities as a standard

While more advantages can be found in a representation of real measure dots distribution, density has the advantage to express an attribute of a site in one single number. That is why density is still very popular by administrators, developers and managers to formulate standards for design.

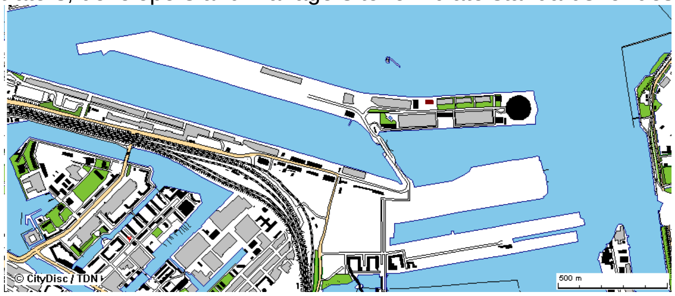
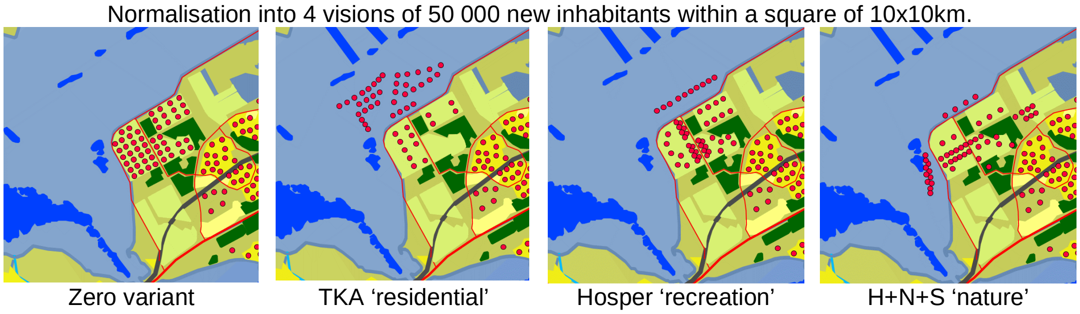


Fig. 916 The Amsterdam harbour islands, developed as residential area

However, densities are boundary-sensitive. So, if somewhere high densities are reached and used elsewhere, the comparison could be very disappointing. The residential plans for Amsterdam harbour islands (see *Fig. 914*) reached very high densities, often used as reference that such densities can be reached without loss of quality. However, when taking the surrounding water into account by measuring the reached densities, their value would become much lower considering the effect of *Fig. 912*.

Comparing designs by real measure dots distribution

Such mistakes can not be made representing plans by real measure dots distribution.


Normalisation into 4 visions of 50 000 new inhabitants within a square of 10x10km.

Zero variant TKA 'residential' Hosper 'recreation' H+N+S 'nature'

Fig. 917 Comparing plans for Almere Pampus

Three plans for Almere Pampus, normalised into the same capacity were represented that way. This representation gives a rough, but direct idea of the visions. For many kinds of specialists like travel engineers, housing specialists, civil engineers this representation gives necessary starting points for evaluation. For every desired square kilometre you also can find the population density or floor-space index (FSI), because every dot represents 1000 inhabitants, now drawn by a circle of 30 000 m^2 floor space (100m radius net dots). If you like to count more or less than $30m^2$ floor space per person, then the circles have to be drawn only a little larger or smaller.

Extreme gross and net dots

In Fig. 902 the dots of 1000 inhabitants had a radius of 300m (about 30 ha or $300m^2$ per inhabitant). These dots represent the average urban area an inhabitant needs for all urban facilities in The Netherlands according to the figures mentioned on page 502. However, in Fig. 917 they had a radius of 100m (about 3 ha or $30m^2$ per inhabitant, the average floor space you appoximately need for living only).

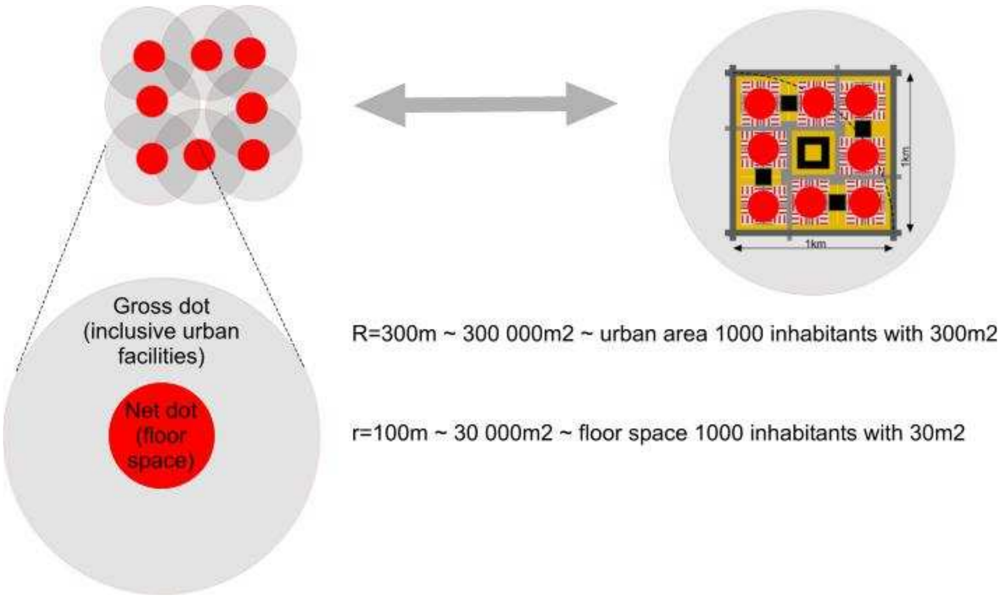


Fig. 918 Extreme gross and net dots

Within a district the gross dots of Fig. 902 would often overlap (see *Fig. 918*). Net dots already give some idea about the mutual arrangement of dwelling areas. In *Fig. 917* the urban facilities other than homes have to be imagined in between the ‘net dots’. In *Fig. 918* the allotment of a district quarter is drawn showing the surface other than dwellings like surrounding facilities like green areas, pavement, schools and shops. However, the gross dots overlap, showing there is more than that, apparently outside the local district. So, measuring the density of a district with district facilities only (district tare) will be higher than the density of a town including town facilties (town tare). The same applies for any level of scale you take into account.

Comparable surfaces in urban areas

By counting the digits of the number of m^2, we could *name* these categories with a useful tolerance by their *nominal* radius (see Fig. 919). For example, you can name an area with a surface between 10000 and 99999 m^2 (5 digits): ‘R=100m’ (ensemble).

Digits	Min. area	Max. area	Min. radius	Max. radius	Nominal radius	Gross	Tare
	Smin	Smax	R_{min}	R_{max}	R_{nom}	**name of area**	**including for example**
	m^2	m^2	m	m	m		subtracted on lower level
10	1000000000	9999999999	17841	56419	**30000**	metropolis	landscape parks, metropolitan infrastructure and facilities
9	100000000	999999999	5642	17841	**10000**	conurbation	town landscapes, conurbarion infrastructure and facilities
8	10000000	99999999	1784	5642	**3000**	town, town quarter	town parks, town water, town infrastructure and facilities
7	1000000	9999999	564	1784	**1000**	district, district quarter, village	district parks, district water, district infrastructure and facilities
6	100000	999999	178	564	**300**	neigbourhood, hamlet	neighbourhood parks, small water, neighbourhood infrastructure and facilities
5	10000	99999	56	178	**100**	ensemble	small public green area residential public space
4	1000	9999	18	56	**30**	urban island, property, building complex	pavement directly opening up building complexes, open space in private parcels (lots, plots)
3	100	999	6	18	**10**	parcel, plot, lot or building	gardens, unbuilt places, patios
2	10	99	2	6	**3**	building segment,	rooms, unbuilt spots
1	1	9	1	2	**1**	building part	inaccessible spaces

Fig. 919 Ten different tare categories, ten different density measures

Though the range of surface difference is still a factor of nearly 10, this restriction is strict enough to get roughly comparable densities. However, even by that tolerance there are still ten different urban density measures to be confused. So, a gross density D_{100m} is something else than a gross density D_{300m}, but a net density D_{300m} in this scale range is the same as a gross density D_{100m}.

6.3.8 Metropolis density$_{30km}$

Tokyo-Yokohama is the largest metropole, counting nearly double the number of inhabitants of the next five between 15 and 20 mln (see *Fig. 920*). New York covers the largest area. However, the way the areas are counted may differ making the comparability doubtful.

Nation	Urban Area	Population	Km2	Density
Japan	**Tokyo-Yokohama**	33200000	6993	4750
United States	**New York**	17800000	8683	2050
Brazil	**Sao Paulo**	17700000	1968	9000
South Korea	**Seoul-Incheon**	17500000	1049	16700
Mexico	**Mexico City**	17400000	2072	8400
Japan	**Osaka-Kobe-Kyoto**	16425000	2564	6400
Phillipines	**Manila**	14750000	1399	10550
India	**Mumbai**	14350000	484	29650
India	**Delhi**	14300000	1295	11050
Indonesia	**Jakarta**	14250000	1360	10500
Nigeria	**Lagos**	13400000	738	18150
India	**Kolkota**	12700000	531	23900
Egypt	**Cairo**	12200000	1295	9400
United States	**Los Angeles**	11789000	4320	2750
Netherlands	**Amsterdam**	1100000	324	3400
Netherlands	**Rotterdam**	1325000	531	2500

Fig. 920 The largest of 1200 cities listed by demographia.com

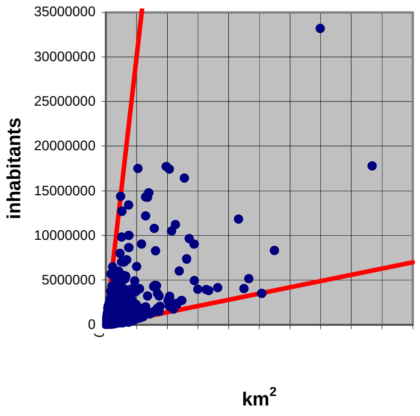
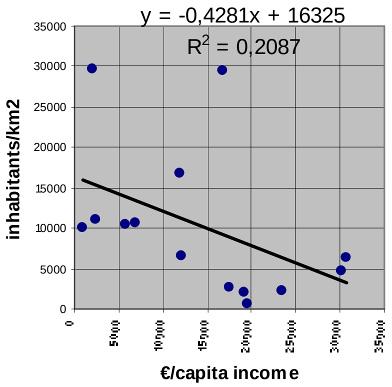


Fig. 921 1200 cities between the density lines 30 000 and 700 inhabitants per km^{2}[a]

On the density lines of 30 000 and 700 inhabitants per km^{2} (see *Fig. 921*) you find Mumbai and Atlanta as the largest cities, with incomes of €2 000 and €19 000 rper capita espectively. The €/capita income (see *Fig. 922*) and $/capita gross domestic product (GDP, see *Fig. 923*) are very roughly related to metrolopitan density.



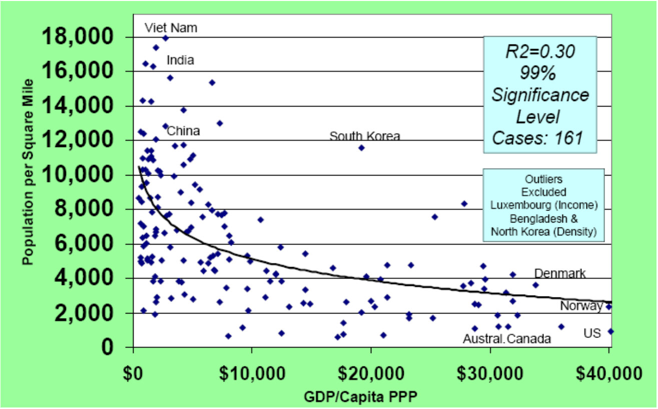


Fig. 922 Density related to €/capita income in 14 cases

Fig. 923 Density related to $/capita gross domestic product in 161 cases[b]

However the sources differ and the figures change rapidly. Van Susteren (2006) compared 101 metropoles on many aspects using different sources.

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[a] http://www.demographia.com/db-worldua.pdf
[b] http://www.demographia.com/db-worldua.pdf

6.3.9 Conurbation density$_{10km}$

The municiality of Amsterdam has an average density of 4400, the municipality of The Hague 6500 inhabitants per km^2. Are these figures comparable? No. The administrative municiality of Amsterdam comprises more vast empty areas than The Hague. Such empty areas have to be subtracted as tare surface. In *Fig. 924* and *Fig. 925* the built-up municipal area is dotted, but if you count the adjacent municipalities with more than 50% commuters into the central city, comprising at least 15% of their working population (see conurbation definition page 528), then the densities of these ‘conurbations’ are lower (2700 and 3300 inhabitants per km^2 respectively).

Fig. 924 Population and floor space of Amsterdam

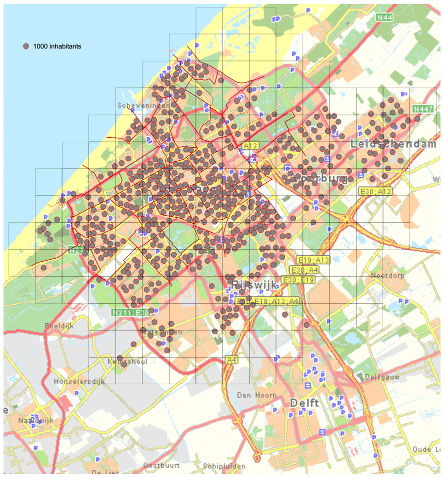


Fig. 925 Population and floor space of The Hague

Using population statistics per district and drawing dots representing 1000 inhabitants with a radius of 100m (30m^2 floor space per inhabitant), you can get an idea of the diversity of densities within these average conurbation densities (see *Fig. 924* and *Fig. 925*).

Deriving density from a distribution of dots

In *Fig. 925* a km grid is drawn. You can count the dots per grid cell to determine the local density per km^2. However that depends on the location of the grid (see *Fig. 914*). It is better to make a mask of 1km^2 and shovel that mask over the drawing to find the highest density. Multiplying that figure by 100 gives the density of inhabitants per ha. Dividing it by the average household size gives an estimate of the number of houses per ha.
You can also estimate the floor-space ratio (FSI: floor-space index) multipying the inhabitants by the used average (here 30m^2 at home, but you have to add other floor space, say 30+20=50m^2) per inhabitant. A hundred times FSI gives %floor surface on a conurbation level. High densities may suggest high rise buildings (at a smaller-scale map, the dots could be drawn piled-up to suggest high-rise). However that conclusion is put into perspective on page 520. Inbetween home-dots you have to imagine the tare space for urban facilties. The largest of these are industrial areas, parks and natural areas like dunes.

6.3.10 Town density$_{3km}$

Town densities are incomparable if you do not precisely define the boundaries of the towns compared. To determine the main national subsidies for municipalities the distance between buildings has to be less than 100m to determine the ‘built-up area’ as a factor in subsidy calculation. That mainly means excluding ‘open area’ like agricultural areas, natural areas and parks larger than 100m in any direction as tare surface of higher order. The question if you have to include national or regional highways and waterways crossing the town and other facilities to calculate density has to be solved.

6.3.11 District density$_{1km}$

Many adminstratively bounded districts include such tare surfaces of higher order, not to be included to calculate district density. So, statistical figures about their total area are not reliable.

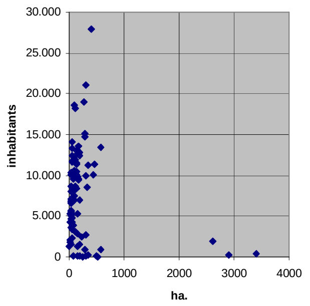


Fig. 926 Inhabitants and surface of administrative districts in the municipality of Amsterdam

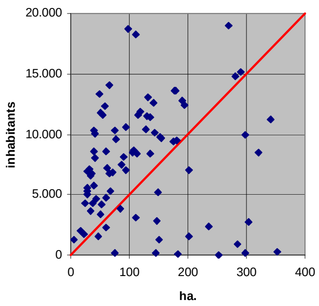


Fig. 927 The figures of Fig. 926 excluding districts of more than 1000 ha and 20 000 inhabitants

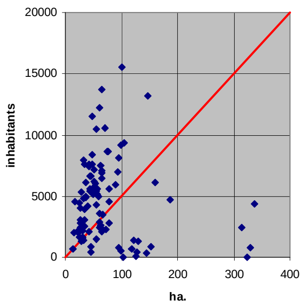


Fig. 928 The same figure as Fig. 927 concerning the municipality of The Hague

Fig. 926 shows the great difference in size of administrative districts in Amsterdam making these incomparable in principle. In *Fig. 927* districts of more than 20 000 inhabitats are excluded. They should be subivided to be comparable with the smaller ones.
In the rough approach of Fig. 919 you should exclude also districts with a surface counted in m^2 of more or less digits than 6, that is 2 counted in ha, but we can take an even rougher boundary. Excluding three districts of more than 3 digits (>999 ha) in *Fig. 927* already gives an interesting view, but the question remains if you have to include urban highways and waterways crossing the district, town parks and other facilities derived from page **Error! Bookmark not defined.** (see also Fig. 995) to calculate density.

Rough boundaries of district density

In *Fig. 927* and *Fig. 928* the drawn line y=50·x (‘inhabitants= 50·ha’) represents the density of 50 inhabitants per ha. So, the slope indicates the density. In both municipalities there is a concentration of districts with a higher density above this line. If you draw a line from 0(0) into 20 000(50), then you get the line of density representing 20 000/50=400 inhabitants per ha. Below that line none of the districts appear. However, on lower levels of scale with closer fitting boundaries you may find higher densities. You can also estimate the floor-space ratio (FSI: floor-space index) multipying the inhabitants by the used average (for example 50m^2) per inhabitant. A hundred times FSI gives %floor surface on a district level.

6.3.12 Neighbourhood density$_{300m}$

Boundaries

Subdividing a municipality in partial municipalities, districts and neigbourhoods (see *Fig. 929*) raises questions of financial responsibility for (re)arrangement and maintenance of public space. So, determining the boundaries of that units becomes increasingly important on lower levels of scale. The smaller the area, the more the boundary surfaces count in relation to the enclosed surface. That is why such boundaries are often drawn on the middle of a shared road or waterway. If they are drawn on one side, the other side has to pay for it.

Subtracting tare of a higher order

In the beginning, private plots are sold, also paying for the surrounding public space as designed. However, if their neigbourhood comprises surfaces used by adjacent neigbourhoods as well, the costs have to be shared (tare of a higher order). That applies on every level of scale, from national scale until common roofs and walls in buildings and common hedges in gardens. So, in the initial exploitation scheme of a district or neigbourhood, these surfaces have to be distinguished as tare of a higher order. A neigbourhood density calculation can use this financial distinction by subtracting such tare surfaces from the piece of map you take into account (the map cutting).

The result is a net neighourhood surface, which is, according to Fig. 919, the same as the gross surface of all ensembles involved (see *Fig. 931*). Politicians are still interested in the reached number of houses per ha, but they do not often distinguish these surfaces. By using the 'net house neigbourhood density' (in fact the average 'ensemble house density') you can name a higher figure than using the 'gross house neigbourhood density'. However, as argued on page 503, floor space is more reliable than the number of houses to determine densities.

Fig. 929 Partial municipality Osdorp of Amsterdam, divided in 5 districts

Fig. 930 The 500x500m neigbourhood indicated in the middle of Fig. 929

a **m^2 Map cutting**
b m^2 Non district surface of higher order
c m^2 Common district surface
d **m^2 Gross neighbourhood (a - b - c)**
e Number of houses
f Gross house density per ha (10 000 · e / d)
g m^2 Common neighbourhood infrastructure and facilities
h **m^2 Net neigbourhood (d - g)**
=m^2 gross ensemble surface
i m^2 Total floor surface

Fig. 931 Primary figures to know on neigbourhood level

Non residential surface

There could be many (political, social, financial, technical, ecological, spatial) reasons to distinguish residential and non residential surface. Non residential initiators may have to pay more for their plots per m^2, they may need more parking space or other public facilities, they do not contribute to the number of inhabitants supporting shops and so on. That distinction may be not primarily important to determine the total %floor surface your design offers, but the distinction is often asked, especially if the non residential area is a substantial part of the total area. If you would like to take up that distinction in your density calculation, you need to specify more (see *Fig. 932*).

h **m^2 Net neigbourhood (d - g)**
i m^2 Total floor surface
j m^2 Non-residential surface
k m^2 Non-residential private surface (ca. 60% j)
l m^2 Total private surface (k + u)
m m^2 Ensemble public surface (h-l)
n m^2 Total built-up surface
o %built-up, 100xGSR or GSI (100·n/h)
p Average dwelling occupation (inh./dwelling.)
q Inhabitants per hectare ((e x p)/(h/10000))
r **Net residential surface (h - j)**
s m^2 Housing floor surface (gf.+storeys.)
t Net house density (10000 e/r)
u m^2 Private residential surface
v m^2 Public paved residential surface
w m^2 Public green residential surface (r - u - v)

Fig. 932 Secondary figures to know on neigbourhood level

Subtracting the non residential surface (j in *Fig. 932*), including the surrounding public space) from the net neighbourhood surface (h in *Fig. 932*, mentioned earlier in *Fig. 931*)produces a third surface you can take as a basis to name an even higher house density: the net residential neighbourhood surface (r in *Fig. 932*).

Private and public space

Both total residential and non residential surfaces have to be distinguished in private and public space. If you do not want to measure the proportion of public space in a not yet designed non residential area (j in *Fig. 932*), you can take 60% as an approximation (k in *Fig. 932*), but you have to measure the private residential surface (u in *Fig. 932*) and the paved residential surface (v in *Fig. 932*) to check the third category, the green residential surface and water (w in *Fig. 932*).

Inhabitants per hectare

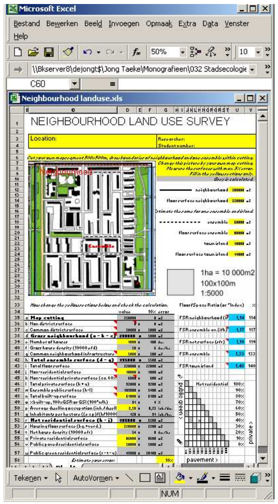
If you know the average dwelling occupation (p in *Fig. 932*) and the number of houses (e in *Fig. 932*) you can calculate the number of inhabitants on the gross neighbourhood surface (h in *Fig. 932*). If you know the housing floor surface (s in *Fig. 932*) and the average floor surface per inhabitant (for example 30m^2) you can divide them to get the number of inhabitants supporting the facilities of the neigbourhood.

Built-up surface and building height roughly determine the floor space

The %built-up surface (100xGSI, Ground Surface Index) is an important part of private surface to determine the kind of environment your design produces (think about shadows). It is much work to measure that surface in a neighourhood, but a free downloadble brain scanning computer application called ImageJ may help, if you have a topographical map in TIFF. format.[a] If you know the number of storeys you can roughly calculate the floor space by multiplying it by the built-up surface. However, some buildings cover open space loosing floor space to be subtracted.

Measuring and calculating

The Excel sheet below[b] gives these measures of neighbourhood density in their mutual relationship to make calculation easy. But you still have to measure many surfaces from the map or drawing.



NEIGHBOURHOOD LAND USE SURVEY

Location:
Researcher:
Student number:

Cut your own map segment 500x500m, draw boundaries of neighbourhood and one ensemble within cutting.
Change this picture by your own map cutting.
Measure the surfaces with max. 5% error.
Fill in the yellow sections only.
Grey is calculated.

neighbourhood
floorsurface neighbourhood
Estimate the same for one ensemble and island.
ensemble
floorsurface ensemble
town island
floorsurface town island

1ha = 10 000m2
100x100m
1:5000

Now change the yellow sections below and check the calculation.

value
10% error

a Map cutting
b Non districtsurface
c Common districtsurface
d Gross neighbourhood (a - b - c)
e Number of houses
f Gross house density (10000 e/d)
g Common neighbourhood infrastructure
h Total ensemble surface (d - g)
i Total floorsurface
j Non-residential surface
k Non-residential private surface (ca. 60%
l Total private surface (k + u)
m Ensemble public surface (h-l)
n Total built-up surface
o %built-up, 100xGSR or GSI (100*n/h)
p Average dwelling occupation (inh./dwell
q Inhabitants per hectare ((e x p)/(h/1000
r Net residential surface (h - j)
s Housing floorsurface (bg.+verd.)
t Net house density (10000 e/r)
u Private residential surface
v Public paved residential surface
w Public green residential surface (r - t - u)
Estimate your error: 10%

FloorSpace Ratio (or *Index) %
FSR neighbourhood (i/ 1,14 114
FSR ensemble av. (i/h) 1,17 117
FSR net surface (s/r) 1,19 119
FSR ensemble 1,33 133
FSR town island 1,40 140

Net residential 100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
public green >
private >
pavement >

Fig. 933 An Excel sheet calculating of different kinds of density[c]

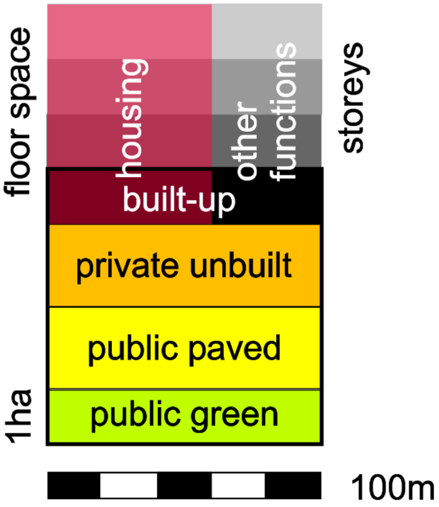


Fig. 934 Amsterdam Kinkerbuurt visualisation of surfaces per ha[d]

The urban development office of Amsterdam study group Kinkerbuurt from the sixties of previous century found an elegant way to visualise key factors of neighbourhood land use (*Fig. 934*).

Five kinds of density

	for example	expressed as FSI
% floor space on gross neighbourhood (i/d)	114%	1.14
% floor space on net neighbourhood (i/h)	117%	1.17
% floor space on net residential surface (s/r)	119%	1.19
% floor space on a particular ensemble	133%	1.33
% floor space on a particular town island	140%	1.40

Fig. 935 The output of calculation: five kinds of density

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[a] *http://team.bk.tudelft.nl/Databases/2004/GebruiksaanwijzingImageJ.doc*
[b] Downloadable from *http://team.bk.tudelft.nl* Publications 2003.
[c] *http://team.bk.tudelft.nl/* Publications 2003
[d] Hartman, W., H. Hellinga, et al., Eds. (1985)

Fig. 935 shows the output of the Excel sheet: there are five kinds of increasing density you can distinguish, dependend on what kind of surface you take into account.
If you do not only take the floor space, but also the housing density, then there are another five.

Private to be sold / public paved / green

The private surface P raises the profits to be maximised, the public space A-P the costs to be minimised. However, a high amount of green, parking space and easy acces by paved circulation space may increase the ground price per m^2 of private lots. So, the proportion privat / public paved / green has to be optimised according to local context.
Politicians, project developers, housing corporations, professional colleagues or buyers often want to know the proportion of private plots to be sold, public paved and public green surface in the net residential area, determining qualitative and financial characteristics.

If three factors total 100%, you can visualise the proportion in a triangular graph earlier done in Error! Reference source not found. for three soil components. The Excel-sheet creates such a graph in a necessarily orthogonal way giving a cross in the appropriate cell (see *Fig. 936*) to be interpreted as a very rough rounded off indication.

In the Osdorp neigbourhood example of Fig. 930 the 46% net residential private ground to be sold and 27% pavement resulted in 26% public green are calculated in the Excel sheet of *Fig. 933*.

However, the graph with three 100% corners rounds these figures off into 40/30/30. The surface public green and pavement are rounded off at the cost of residential private ground to be sold. The graph is pessimistic about the profits.

So, this graph only can be used for a very rough comparison with other neigbourhoods, or has te be redrawn in a more precise triangular way like Error! Reference source not found. according to the real figures given as well.

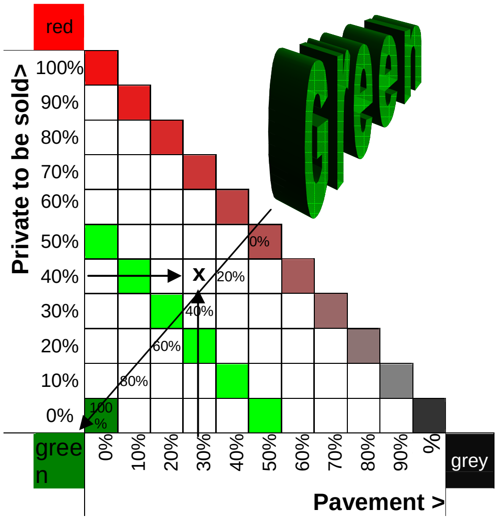

Fig. 936 40% Residential private ground to be sold, 30% pavement and 30% public green

6.3.13 Ensemble density$_{100m}$

Simplified dimensions

The division of a neigbourhood in ensembles mostly results in homogeneous residential or non residential areas. So, on this level that functional distinction will no longer play an important role.
We can concentrate on basic formal surfaces as total area A, built-up surface B, floor surface F, private surface P, non-specified public surface A - P and average building height or average number of storeys S. The gross ensemble surface A is equal to the net neighbourhood surface (see h in *Fig. 932*). So, neigbourhood infrastructure and ~facilities are excluded, and there is only one basis for density: F/A (FSI). The coverage of the total surface A by buildings B/A (GSI) is a primary variable.
B multiplied by the average number of storeys S (if façades are vertical) produces the floor surface F.

Spacemate

If F = S · B, then F/A = S · B/A. To compare ensembles with different A, Permeta draws a diagram[a] called Spacemate, plotting F/A against B/A. In *Fig. 937* both are given as percentage of B and F from the total area A. Moreover, the diagram is extended from 0 into 100%. So, B on the horizontal axis includes also unusual, mostly theoretical high densities.
In that diagram the %floor surface as a function of %built-up area appears as a straight line starting in the origin with a slope according to the average number of storeys. Any ensemble appears as a spot according to %F and %B (*Fig. 937*).

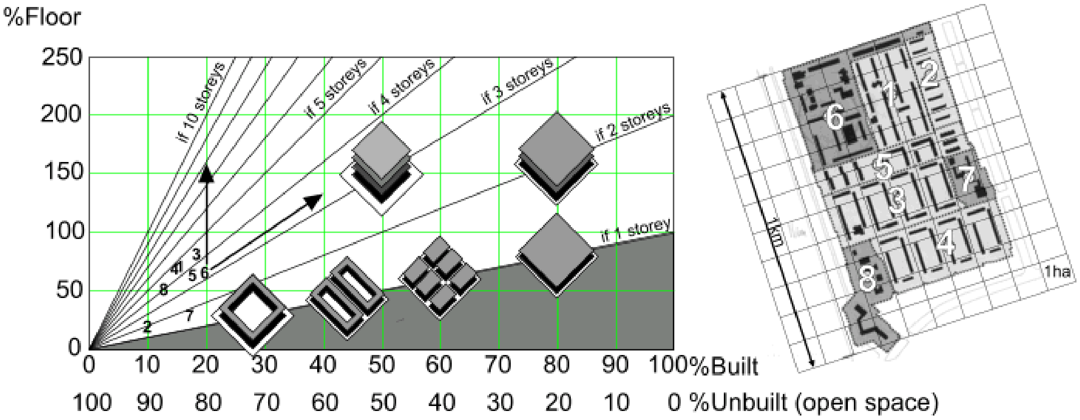

Fig. 937 Spacemate: floor surface as a function of built-up surface according to Permeta

In *Fig. 937*, 6 theoretical parcellations are drawn on 1 hectare (approximately 1 quarter of a nominal ensemble R=100m). The 8 actual ensembles in Osdorp, Amsterdam West as measured by Permeta are given as numbers. They have all less than 20% built area, and the theoretical parcellations have more. For example, ensemble 6 has the highest %built surface, but not the highest %floor surface.

Intensifying floor surface

Making plans to increase density in existing areas, political targets are often expressed in increasing FSI (%floor surface/100). The Spacemate is primarily made to visualise the qualitative effect of such operations. Permeta calculated many examples, real or made by students, on different spots in the diagram to show the effect. A computer programme shows different photographs of ensembles categorising them in clickable surfaces of the Spacemate.

To intensify the floor density you have to increase the building height or the average number of storeys (arrow crossing lines of floor density with the same number of storeys in *Fig. 937*) or without increasing the number of storeys you have to increase the %built surface (arrow parallel to lines of floor density with the same number of storeys in *Fig. 937*). By increasing the %built-up surface (decreasing open surface A - B) more, one can cross the lines of floor density with average 3 storeys in horizontal direction even decreasing the number of storeys to 2 (draw it yourself).

Urban quality

Most design alternatives will appear on 50% built-up area (see *Fig. 915*). Then the potential of urban-architectural quality and the length of façades, where building and open space are connected is highest (structural quality). However, lower levels increase the potential of open space, afforded views and green space (form quality), higher levels increase the support for schools, shops and other population-dependend facilties (functional quality). So, there are at least three components of urban quality direcly related to the %built-up surface.

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[a] PERMETA architecten (2002) Spacemate. FSI-GSI-OSR als instrument voor verdichting en verdunning (Amsterdam) Bureau Parkstad / TU-Delft, Faculteit Bouwkunde**:** 79, preceded by the graduation work of Meertens, R. (2000) Density? (Delft) DUT Faculty of Architecture.
Haupt Per and Meta Berghauser Pont (2005) *Spacemate©the spacial logic of urban density* (Delft) Imprint: DUP Science ISBN 90-407-2530-6

More than 50% built-up area

Parcellations with more than 50% built area have seldom courts or streets larger than 10m width.

Fig. 938 Ensemble in Venice 1: 5000; 200x200m[a]

Fig. 939 Auction Aalsmeer 1:25000, ha grid of 1kmx1km, one building nearly covering a district

Such urban areas have no cars like Venice (*Fig. 938*) or they have internal traffic in buildings like the flower auction in Aalsmeer (*Fig. 939*).

The use of open space

The elegantly simple and useful diagram by Permeta is complicated without necessity by introducing %unbuilt/%floor (OSR), or in formula: (A-B)/F. It is supposed that factor determines the use of open space: little unbuilt area compared to a large available floor space would give a pressure of floor-space users on the unbuilt area and for example a shortage of space for cars.

However, the intensity of use of public space (part of the open space) is not very dependend on use by local inhabitants. The traffic intensity of residential streets usually is 1% of its capacity (see *Fig. 543*) The expectation of urban liveliness (intensity) by design is overestimated in districts other than for example the city of New York. In student plans, that overestimate is frequently represented by drawing too much people in suburban public space. A global calculation[b] proves that you must be economical with the crowd pullers to get *some* lively places in the city. And to feed that, you need still a lot of quiet suburbs in the conurbation.

Empty streets

That calculation goes approximately this way. According to the ground usage statistics of CBS[c], in The Netherlands we have approximately 1 billion m^2 circulation area, whereas our population of about 16 millions (including home-bound children and elderly) is on the street at the most half an hour per person per day. This means that, on 100m^2 public area through the daytime, at average you will see someone driving or walking approximately one minute within a quarter of an hour. Assume that you call a public space as ‘urban’ in contrast with ‘suburban’ if you come across someone on 100m^2 for one minute long each minute (‘urban intensity’). How much public space can be then ‘urban’?

Stealing liveliness from the suburbs

You must make almost 2000m^2 street elsewhere quieter for 100m^2 urban intensity, but not too quiet, otherwise people cannot come to the urban space you want to make ‘urban’. That ends up then on 5% of the paved area. If you divide 3% of it concerning the districts, you keep still 2% for the concentration of urban crowd pullers. You should not subdivide urban crowd pullers too much; because you lure more people out of their house with bigger free choice-serving centres. You can at most try to make the public space so attractive, that people exchange the street to their television for a little bit longer than a half hour per day. Can a master plan contribute to that, or should you trust the architectural development?

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[a] Novelli (1989)

[b] Jong, Taeke M. de (2004) Grenzen van Stedelijkheid (Zoetermeer) http://team.bk.tudelft.Netherlands/ > Publications 2004

[c] CBS is the Dutch national bureau of statistics.

Building height, number of storeys

Multipying the Built-up surface by the number of Storeys produces the Floor surface B x S = F (if all façades are vertical). So, the number of storeys S = F/B. If we make F = 100% of the Area A (FSR=1), then the Area is fully covered with one storey, half covered with two storeys, but doubling the number of storeys again reduces the profit of open space (see *Fig. 940*). So, piling up storeys is subject of diminishing returns in terms of open space, while the visual impact of the high rise on open space increases.

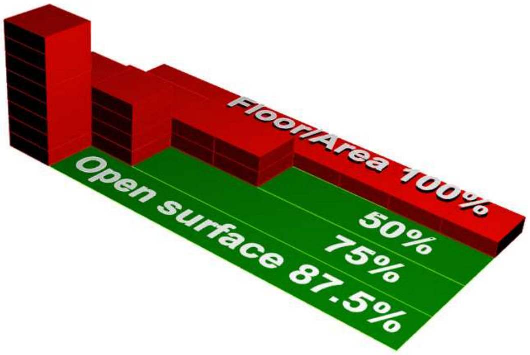

Fig. 940 Diminshing returns of open surface by increasing high rise building

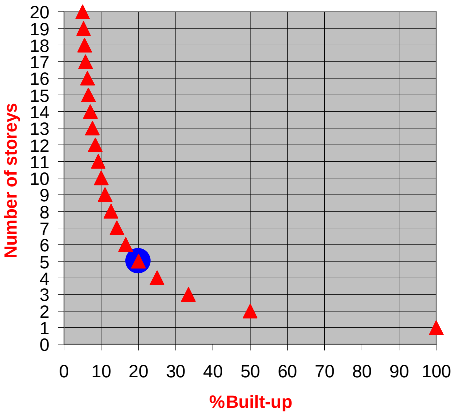

Fig. 941 Progressively increasing Built-up surface by decreasing number of storeys on 100% F/A[a]

The Built-up surface B is the complement of open surface. The %Built-up (of A) is dependend on the number of Storeys S if we keep FSR or %Floor surface (of A) constant. You can try different %Floor values yourself to change *Fig. 941*.[b] The profit of open space does not increase much above 5 storeys (blue spot in *Fig. 941*).

Non-vertical façades

The Built-up area B is recognisable on the topographical map as the vertical projection of the building on the ground-level. However, for example a pyramid will have less floor space than a cube. So, F < S x B. The same applies for buildings with different heights, extended parts, internal voids and non-vertical façades.

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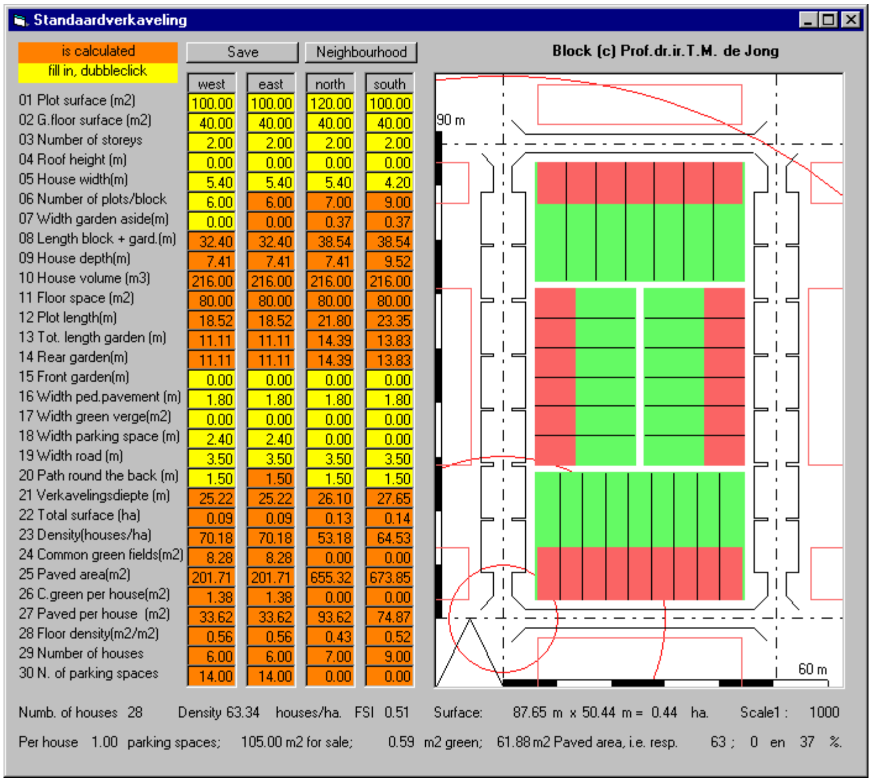
[a] *http://team.bk.tudelft.nl/* > Publications 2006 > %Built-up.xls
[b] *http://team.bk.tudelft.nl/* > Publications 2006 > %Built-up.xls

6.3.14 Urban island density$_{30m}$

The urban island is the best level to avoid coincidental differences that could disturb a reliable density comparison. An urban island is bordered by the axis of public infrastructure that opens up or encloses private properties in closest surrounding not intersected by other infrastructure. So it encloses no other public infrastructure than dead-end streets, opening up backyards and garages, water and green area only functional to the smallest publicly opened-up urban area.



🟧 is calculated
🟨 fill in, dubbleclick

	west	east	north	south
01 Plot surface (m2)	100.00	100.00	120.00	100.00
02 G.floor surface (m2)	40.00	40.00	40.00	40.00
03 Number of storeys	2.00	2.00	2.00	2.00
04 Roof height (m)	0.00	0.00	0.00	0.00
05 House width(m)	5.40	5.40	5.40	4.20
06 Number of plots/block	6.00	6.00	7.00	9.00
07 Width garden aside(m)	0.00	0.00	0.37	0.37
08 Length block + gard.(m)	32.40	32.40	38.54	38.54
09 House depth(m)	7.41	7.41	7.41	9.52
10 House volume (m3)	216.00	216.00	216.00	216.00
11 Floor space (m2)	80.00	80.00	80.00	80.00
12 Plot length(m)	18.52	18.52	21.80	23.35
13 Tot. length garden (m)	11.11	11.11	14.39	13.83
14 Rear garden(m)	11.11	11.11	14.39	13.83
15 Front garden(m)	0.00	0.00	0.00	0.00
16 Width ped.pavement (m)	1.80	1.80	1.80	1.80
17 Width green verge(m2)	0.00	0.00	0.00	0.00
18 Width parking space (m)	2.40	2.40	0.00	0.00
19 Width road (m)	3.50	3.50	3.50	3.50
20 Path round the back (m)	1.50	1.50	1.50	1.50
21 Verkavelingsdiepte (m)	25.22	25.22	26.10	27.65
22 Total surface (ha)	0.09	0.09	0.13	0.14
23 Density(houses/ha)	70.18	70.18	53.18	64.53
24 Common green fields(m2)	8.28	8.28	0.00	0.00
25 Paved area(m2)	201.71	201.71	655.32	673.85
26 C.green per house(m2)	1.38	1.38	0.00	0.00
27 Paved per house (m2)	33.62	33.62	93.62	74.87
28 Floor density(m2/m2)	0.56	0.56	0.43	0.52
29 Number of houses	6.00	6.00	7.00	9.00
30 N. of parking spaces	14.00	14.00	0.00	0.00

Numb. of houses 28 Density 63.34 houses/ha. FSI 0.51 Surface: 87.65 m x 50.44 m = 0.44 ha. Scale1 : 1000

Per house 1.00 parking spaces; 105.00 m2 for sale; 0.59 m2 green; 61.88 m2 Paved area, i.e. resp. 63 ; 0 en 37 %.

Fig. 942 The urban island[a]

An ensemble encloses several urban islands + ensemble infrastructure, a neighbourhood encloses several ensembles + neighbourhood infrastructure and so on. The %floor surface per area of an urban island is equal or higher than any other useful density measure by lack of urban tare, except the %floor surface of a particular plot (FAR). Jong (2001) made an interactive computerprogramme showing the behaviour of an orthogonal island changing any of the determining design measures (*Fig. 942*).

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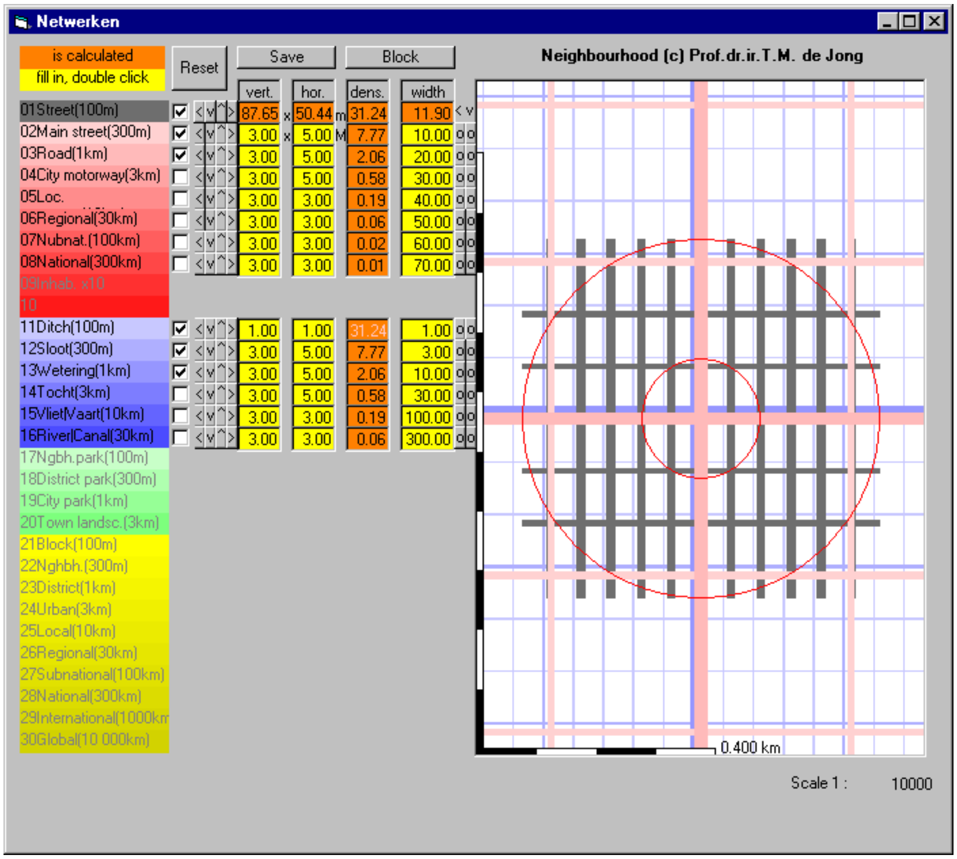
[a] *http://team.bk.tudelft.nl/* publications 2003

Multiplying urban islands into a neighbourhood

Any higher level of scale adds its own tare decreasing the density. The programme shows in a next window the considerable surface occupied by dry and wet infrastructure on every higher level (*Fig. 942*).



is calculated

fill in, double click

		vert.		hor.		dens.	width
01Street(100m)	☑	87.65	x	50.44	m	31.24	11.90
02Main street(300m)	☑	3.00	x	5.00	M	7.77	10.00
03Road(1km)	☑	3.00		5.00		2.06	20.00
04City motorway(3km)	☐	3.00		5.00		0.58	30.00
05Loc.	☐	3.00		3.00		0.19	40.00
06Regional(30km)	☐	3.00		3.00		0.06	50.00
07Nubnat.(100km)	☐	3.00		3.00		0.02	60.00
08National(300km)	☐	3.00		3.00		0.01	70.00
09Inhab. x10							
10							
11Ditch(100m)	☑	1.00		1.00		31.24	1.00
12Sloot(300m)	☑	3.00		5.00		7.77	3.00
13Wetering(1km)	☑	3.00		5.00		2.06	10.00
14Tocht(3km)	☐	3.00		5.00		0.58	30.00
15Vliet|Vaart(10km)	☐	3.00		3.00		0.19	100.00
16River|Canal(30km)	☐	3.00		3.00		0.06	300.00
17Ngbh.park(100m)							
18District park(300m)							
19City park(1km)							
20Town landsc.(3km)							
21Block(100m)							
22Nghbh.(300m)							
23District(1km)							
24Urban(3km)							
25Local(10km)							
26Regional(30km)							
27Subnational(100km)							
28National(300km)							
29International(1000km							
30Global(10 000km)							

Neighbourhood (c) Prof.dr.ir.T.M. de Jong

Scale 1 : 10000

Fig. 943 Adding dry and wet infrastructure[a]

Green surfaces and surfaces for amenities are not yet shown in this window. It should be clear that such infrastructure of higher order should not be counted in the density of the lower order when they lack in other locations to compare. On this level of scale these surfaces are *location factors* by which the external *context* of the urban island differs, but not its *density*. They become comparable by density measures on a higher level of scale.

6.3.15 Urban details$_{10m}$ influencing density

Many questions[b] about the influence of urban details of a closed buiding block on density like built width and length, the building depth, the width and length of court, the width of streets, the width and length of island, the built-up surface, the %built-up, the average height of storeys, the number of storeys, the date and hour of sunlight[c], solar angle limits, the outer wall ratio limit and the surface of outer wall are answered quickly by experimenting with all these measures in a downloadable spreadsheet (see *Fig. 944*)[d]. These parameters can be changed easily to find their influence on density. By experimenting with this spreadsheet you are warned for dark buildings, courts or streets changing them.

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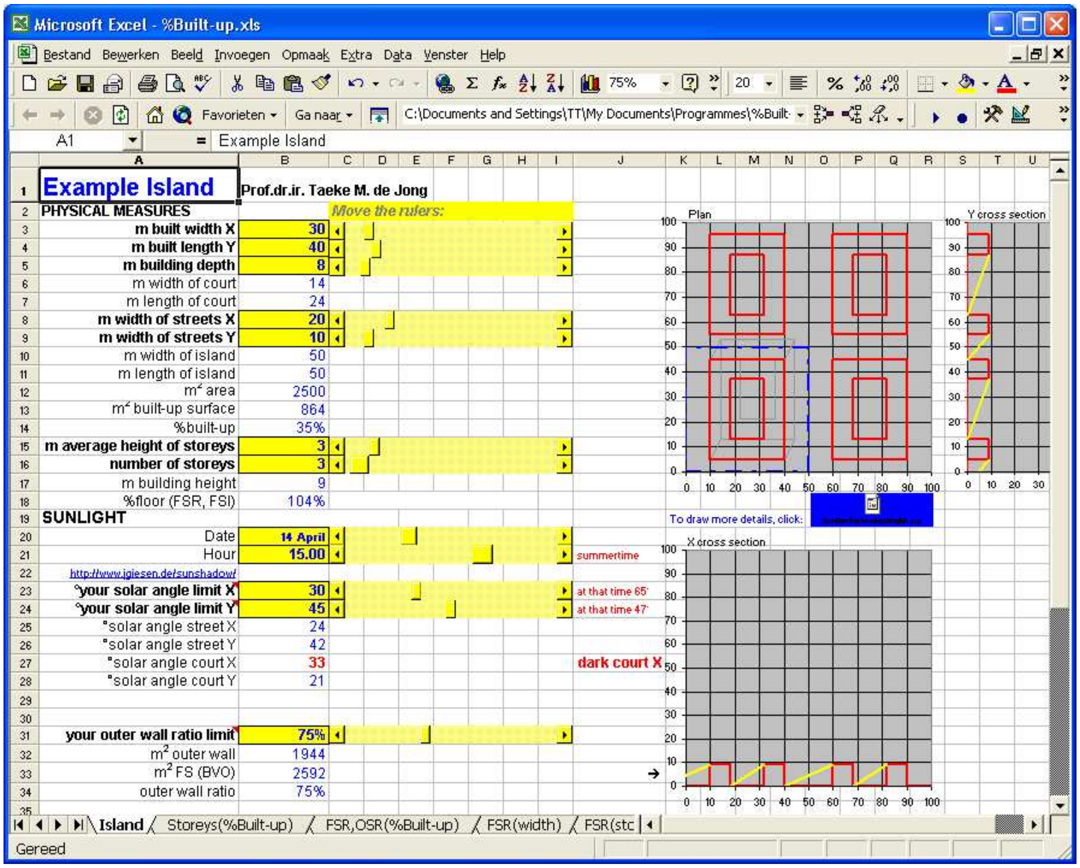
[a] *http://team.bk.tudelft.nl/* publications 2003
[b] Uytenhaak (2005)
[c] see *http://www.jgiesen.de/sunshadow/*
[d] *http://team.bk.tudelft.nl/* > Publications 2006



= Example Island

	A	B	J
1	**Example Island**	**Prof.dr.ir. Taeke M. de Jong**	
2	**PHYSICAL MEASURES**		*Move the rulers:*
3	**m built width X**	**30**	
4	**m built length Y**	**40**	
5	**m building depth**	**8**	
6	m width of court	14	
7	m length of court	24	
8	**m width of streets X**	**20**	
9	**m width of streets Y**	**10**	
10	m width of island	50	
11	m length of island	50	
12	m² area	2500	
13	m² built-up surface	864	
14	%built-up	35%	
15	**m average height of storeys**	**3**	
16	**number of storeys**	**3**	
17	m building height	9	
18	%floor (FSR, FSI)	104%	
19	**SUNLIGHT**		
20	Date	**14 April**	
21	Hour	**15.00**	summertime
22	http://www.jgiesen.de/sunshadow/		
23	**°your solar angle limit X**	**30**	at that time 65°
24	**°your solar angle limit Y**	**45**	at that time 47°
25	°solar angle street X	24	
26	°solar angle street Y	42	
27	°solar angle court X	33	**dark court X**
28	°solar angle court Y	21	
29			
30			
31	**your outer wall ratio limit**	**75%**	
32	m² outer wall	1944	
33	m² FS (BVO)	2592	
34	outer wall ratio	75%	

To draw more details, click:

Fig. 944 The %built-up spreadsheet[a]

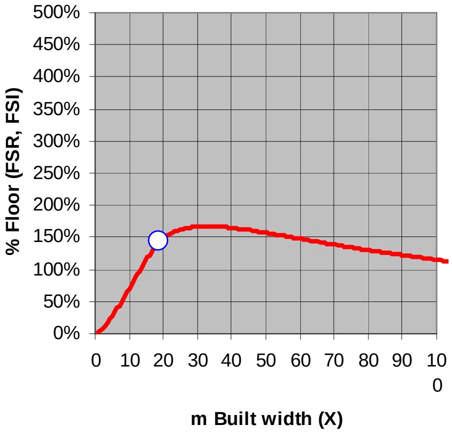


Fig. 945 FSR(Built with)

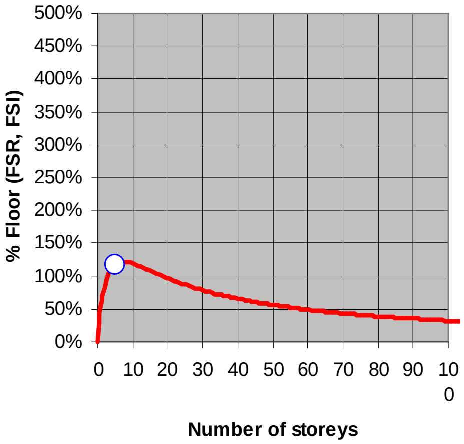


Fig. 946 FSR(Number of storeys)

Many graphs like *Fig. 945* and *Fig. 946* can be constucted according to their hidden supositions about these parameters.

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[a] living.*xls*, downloadable from *http://team.bk.tudelft.nl/* > Publications 2008

6.4 Economy

6.4.1 Dutch statistics

Every year, as far as I can remember, the the national bureau of statistics CBS has produced the Statistisch Jaarboek (earlier a more extensive Statistisch Zakboekje). Since 2006 it is also available in English (Statistical Year Book). This inexpensive publication gives an overview and a popular extract of CBS statistics (referring to much more data, to be found on http://www.cbs.nl/).

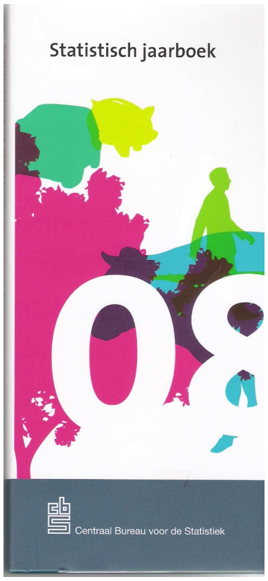

Fig. 947 The Dutch statistical year book 2008

An example for direct use in urban design

There, for example, you can find characteristics of 240 urban facilities[a]. Dividing their number by total population of The Netherlands you can calculate how many people you need to support each facility at average. How many schools, restaurants, petrol stations has a Dutch district of 10 000 inhabitants at average? The deviation from this average determines the functional profile or identity of a region, conurbation, town, district or neighbourhood.

Intellectual substance

Those who are familiar with this pocket book are mostly of the opinion that one is not an intellectual unless one has a subscription to it. I support this view. At some point early in the year, as soon as my new copy falls through the letter-box, I settle down in a comfortable chair to look through it. Then, I am unavailable for a few hours, as, with the help of this impressive statistical material, I see numerous popular myths collapse before my eyes.

Manipulating figures in Excel

It appears in the bookshops at the same time as the inexpensive CD-ROM. Like the website http://www.cbs.nl/ this is a great blessing, because now all the tables can be transported to Excel and then the feast of selecting and working with this material can begin.

1 Population
1.1 Population
1.2 Health and well-being
1.3 Education
1.4 Culture, recreation and other uses of time
1.5 Legal protection and safety
1.6 Residence

2 Employment, incomes and social security
2.1 Employment and wages
2.2 Incomes, property and expenditures
2.3 Social security

3 Businesses
3.1 Demography of businesses
3.2 Business book-year accounts
3.3 Automation and research and development (R&D)
3.4 Agriculture and fisheries
3.5 Energy and minerals
3.6 Industry
3.7 Building industry
3.8 National trade and service industry
3.9 International trade
3.10 Traffic, transport and communication

4 Government, politics and management
4.1 Government finances
4.2 Politics and management

5 Macro-economy and the money and capital market
5.1 National accounts
5.2 Money and capital market
5.3 Producer and consumer prices

6 Geography and environment
6.1 Geography
6.2 Environment

Fig. 948 The content of the Statistisch Jaarboek 2001

A number of establishments are listed for every organization and branch. To give an impression of the kind of data you can find and manipulate, I have taken my CD-ROM *Statistisch Jaarboek 2001* with figures from 2000 and put the relevant urban architectural tables from the chapters indicated in *Fig. 948* in Excel[b].

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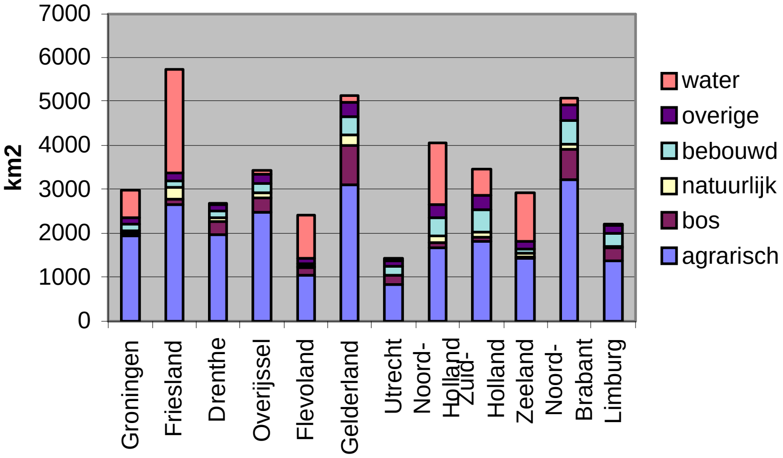
[a] Summarised in living.xls, downloadable from http://team.bk.tudelft.nl/ > Publications 2008
[b] http://team.bk.tudelft.nl/ > databases

It is up to you to make the same graphs with more recent figures and to compare them with those of 2000.

6.4.2 Public space

National territory

In 1996, the Netherlands occupied a territory of 41,526 km^2 , divided over various provinces and land-use categories, as shown in *Fig. 949*. Of these categories, forest, nature and water can be seen as public facilities, to a greater or lesser extent. Built-up areas occupy a relatively small area.

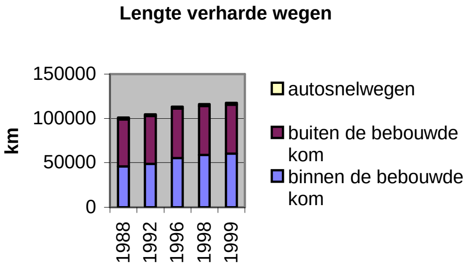


Legend: water, built-up, nature, forest, agriculture

Fig. 949 *Land use in different provinces (from below: agriculture, forest, nature, built-up, otherwise, water) in the Netherlands*

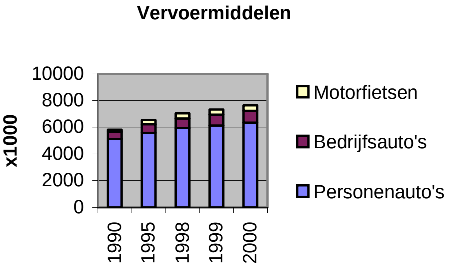
The lengths of roads

In 1999, the Netherlands had 117,430 km of surfaced roads (if one was to include unsurfaced roads, this would be approximately 95% of the total road network). The growth of this road network is shown in *Fig. 950*. Although not all means of transport are public facilities, they form, together with the surfaced roads, a transport system (*Fig. 951*).



Legend: highways, roads outside and inside the urban area

Fig. 950 *Extent of paved roads*



Legend: motorcycles, business and private cars

Fig. 951 *Means of transport*

The density of roads

Outside the built-up areas, the prevailing road network has an average mesh width of approx. 1 x 1 km (density 2 km per km^2). Within built-up areas, the mesh width is almost 100 x 100 m (20 km per km^2). Motorways have an average mesh width of approx. 30 x 30 km (0.07 km per km^2).

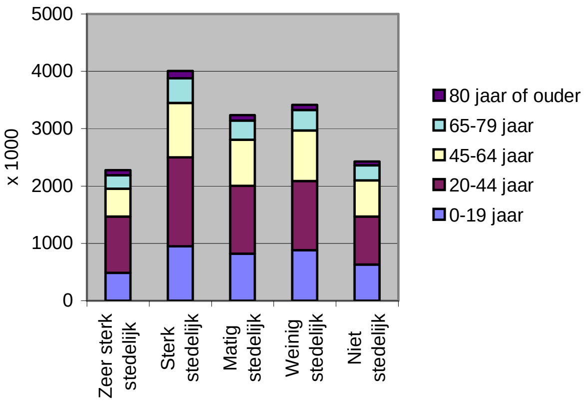
	length	**surface area**	**density**	**average mesh width in km**
motorways	2256	29261	0.077	30
outside the built-up areas	54820	26060	2.104	1
inside the built-up areas	60354	3201	18.85	0.1
total extent of surfaced roads	117430	29261	4.013	
railways	2808	33873	0.083	30

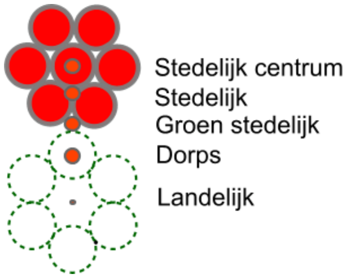
Fig. 952 *The density of the road network*

The density of the railway network can be compared with that of the motorways. Approximately 135 people are needed as a support base for a kilometre of road.

6.4.3 Urbanity

For the classification of urbanity the numerical values for the neighbourhood address densities of the different municipalities are categorised into five groups or classes.





Legend: urban centre, urban, suburban, village, countryside

Fig. 953 *Inhabitants by urban CBS environment category*

Fig. 954 *On the map*

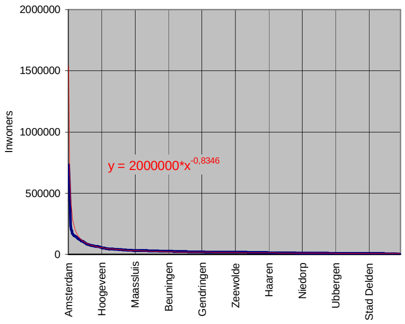
The boundaries of the classes have been chosen in such a way that all the classes contain about the same number of residents. In this way, the following categories can be distinguished:

- very strongly urban municipalities with a neighbourhood address density of 2,500 addresses or more per km^2 ;
- strongly urban municipalities with a neighbourhood address density of 1,500 to 2,500 addresses per km^2 ;
- moderately urban municipalities with a neighbourhood address density of 1,000 to 1,500 addresses per km^2 ;
- hardly urban municipalities with a neighbourhood address density of 500 to 1,000 addresses per km^2;
- non-urban municipalities with a neighbourhood address density of less than 500 addresses per km^2.

The number of residents who live in these environments is therefore divided rather similarly, with small variations in age.
In NRO5, the RPD used a similarly grouped classification to that of a stipple chart, for reading off a location.

Order of municipality by size

On 1st January 2000, this population was resident in 537 municipalities. When one lists these municipalities according to size, one gets the ‘ordering’ of municipalities (rank size). In *Fig. 955*, using the ordering in this list, 1 in 40 of the municipalities is named. This does not produce a straight line, because the size of municipalities from the largest, downwards, diminishes rapidly, at first, before slowing down. When the *y* axis is made logarithmic, the graph becomes clearer (Fig. 956).



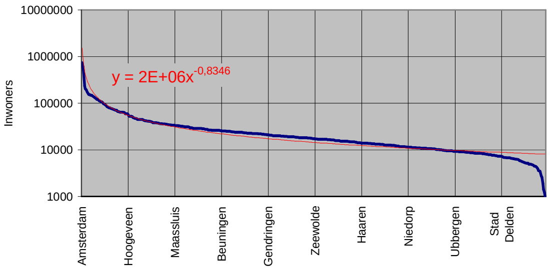


Fig. 955 *Ordering municipalities using a power trendline in Excel*

Fig. 956 *Ordering municipalities, expressed logarithmically, using a trendline in Excel*

Then it also becomes clear that, for the smallest municipalities, the trendline is no longer accurate: reality decreases faster for populations from below 10,000 to the smallest municipality (Schiermonnikoog), probably due to the geographical restrictions of the island boundary.

Order of conurbations

The historical boundaries of municipalities cut through the reality of amalgamated built-up areas (urban conurbations), so that these graphs give an incorrect picture of the Ordering of urban areas. However, the *Yearbook* also gives a table of urban conurbations of over 100,000 inhabitants. The somewhat out-of-date definition of this type of conurbation is given in the *Yearbook* as follows:

A central town with surrounding municipalities that (on 31st May 1960) fulfilled the following conditions:

- more than 50% of the commuters resident there must be employed in the central town;
- in addition, the above-mentioned commuters must comprise at least 15% of the working population of the central town.

This table is shown next to the upper section of the municipality table (*Fig. 957*) in *Fig. 958*.
In general, municipal density is much higher than conurbation density.

	inhabitants	km² land	no. inhabitants /ha.
Amsterdam	731288	165,13	44
Rotterdam	592673	208,61	28
DenHaag	441094	67,92	65
Utrecht	233667	61,42	38
Eindhoven	201728	87,31	23
Tilburg	193116	117,42	16
Groningen	173139	80,15	22
Breda	160615	127,00	13
Apeldoorn	153261	340,30	5
Nijmegen	152200	53,70	28
Enschede	149505	140,04	11
Haarlem	148484	29,45	50
Almere	142765	131,62	11
Arnhem	138154	98,57	14
Zaanstad	135762	74,50	18
DenBosch	129034	85,00	15
Amersfoort	126143	62,88	20
Maastricht	122070	57,01	21
Dordrecht	119821	80,58	15
Leiden	117191	22,16	53
Haarlemmermeer	111155	180,01	6
Zoetermeer	109941	35,59	31
Emmen	105972	340,56	3
Zwolle	105801	95,35	11
Ede	101700	318,29	3

Fig. 957 *Municipalities > 100,000 inhabitants*

	inhabitants	km² land	no. inhabitants /ha.
Amsterdam	1E+06	365,12	27
Rotterdam	989956	355,50	28
DenHaag	610245	187,50	33
Utrecht	366186	140,93	26
Eindhoven	302274	181,27	17
Leiden	250302	87,26	29
Dordrecht	241218	153,42	16
Heerlen	218078	109,22	20
Tilburg	215419	159,47	14
Groningen	191722	126,09	15
Haarlem	191079	76,67	25
Breda	160615	127,00	13
Amersfoort	154890	121,50	13
DenBosch	154368	118,55	13
Apeldoorn	153261	340,30	5
Nijmegen	152200	53,70	28
Enschede	149505	140,04	11
Arnhem	139576	126,50	11
GeleenSittard	127322	98,13	13
Maastricht	122070	57,01	21
Zwolle	105801	95,35	11

Fig. 958 *Conurbations > 100,000 inhabitants*

From these tables, it appears that some conurbations (Heerlen and Geleen–Sittard) are composed of municipalities smaller than 100,000 inhabitants, while a number of municipalities (Almere, Zaanstad, Haarlemmermeer, Zoetermeer, Emmen and Ede) with more than 100,000 inhabitants are missing, partly because, due to commuting, they have been included in the conurbation of a larger municipality nearby. *Fig. 959* shows the Ordering of the agglomerates in *Fig. 958*.

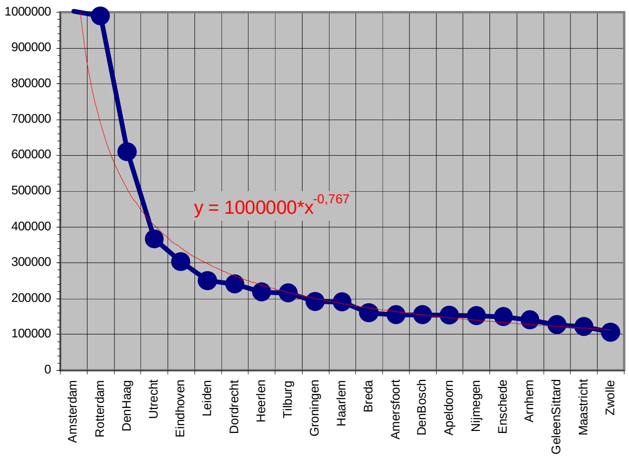


Fig. 959 *Ordering of conurbations*

Going beyond The national order

In the Netherlands, two large conurbations dominate the ordering. If Amsterdam had 2 million inhabitants, the ordering would fit better into the formula. When we map the deviations from the formula (*Fig. 960*), then Amsterdam or Rotterdam, and, to a lesser extent, The Hague, are incongruous. This can indicate an international position, which has its own order. Following this line of thought, then, Utrecht falls within the national ordering.

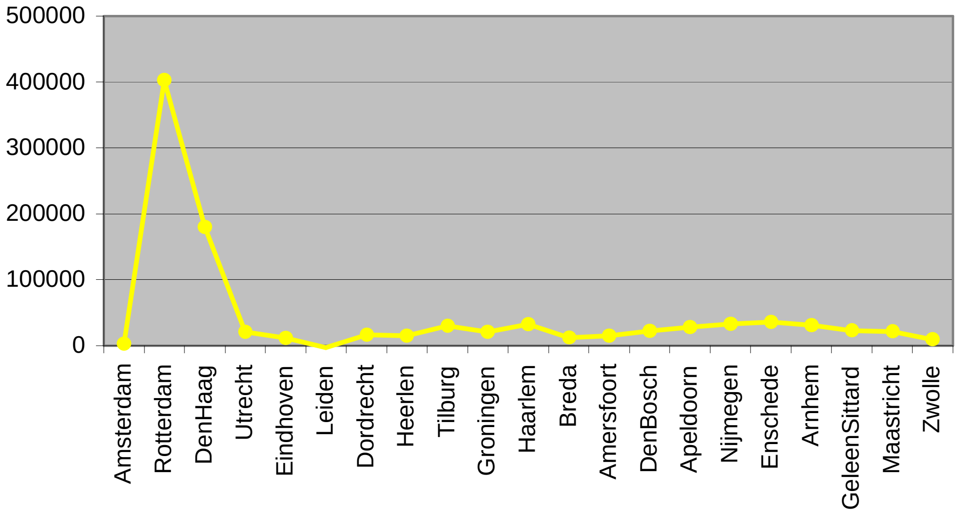
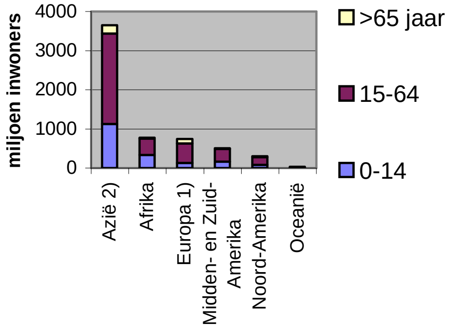


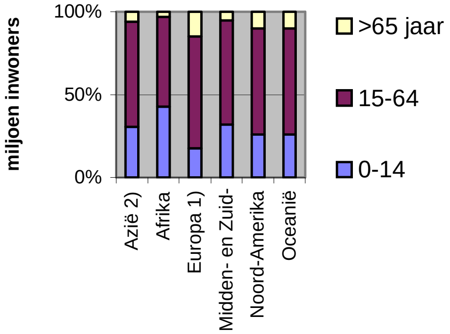
Fig. 960 *Deviations from the ordering y = 1000000·x-0.767 in the higher regions*

6.4.4 Population

Compared to other continents

Compared with Asia, Europe is not only small, but, in contrast to all other continents, its population is much older (*Fig. 961* en *Fig. 962*).



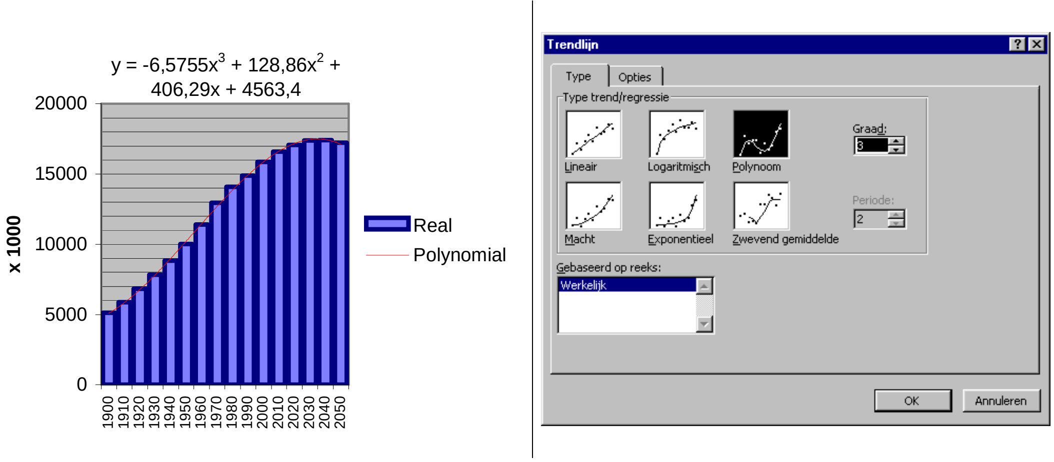


(1) Including Russia, excluding Turkey. (2) Including Turkey.

Fig. 961 Number of residents per continent

Fig. 962 Age range per continent[a]

Population development in the Netherlands



Graad: 3

Periode: 2

Gebaseerd op reeks: Werkelijk

Fig. 963 How the Dutch population has developed (see also Fig. 842), using a polynomal trendline from Excel

When you make a chart in Excel to show how the Dutch population has developed (omitting the years between the 10s), you discover that, for a century, every 10 years, the population has increased roughly by a million. Select a chart and click on the toolbar ‘chart/add trendline’ and you will find the above menu (see also *Fig. 427*). If you choose a third-degree polynomial and, from ‘options’, click on ‘show equation in chart’, then you get the above result. A polynomial appears to fit in well here, and allows interpolation between the available years, but it has no rational linkage at all with reality. To find that kind of formulas is the task of demography (see page 464). So, it should not be used for extrapolation.

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[a] U.S. Bureau of the Census International Database

Population characteristics

After World War 2, the number of people per household (which almost equates with ‘occupance per dwelling’) decreased from 5 to 2.3 and the expectation is that it will decrease even further. From an urban point of view, this is an important figure because this halving of occupancy meant that, for the same population, twice as many dwellings had to be built (*Fig. 964*). Family dilution has mainly come about due to the increasing number of single-family households (*Fig. 965*).

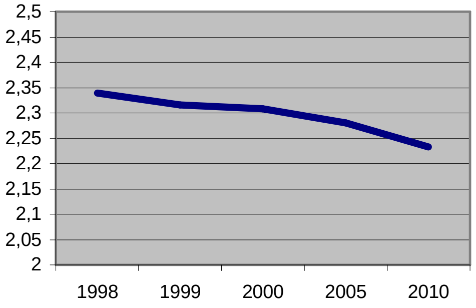


Fig. 964 Average number of people per household

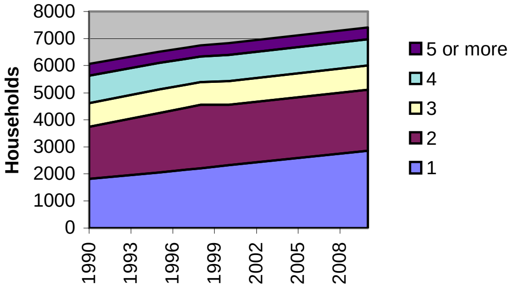


Fig. 965 Number of people per household

Ageing

The population continues to age, but the question is whether, under the new politics, the number of immigrants will continue to grow as was forecast in 2001.

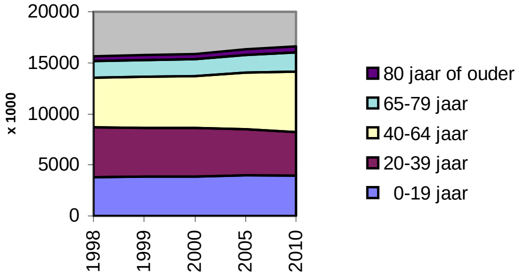


Fig. 966 Changes in age range

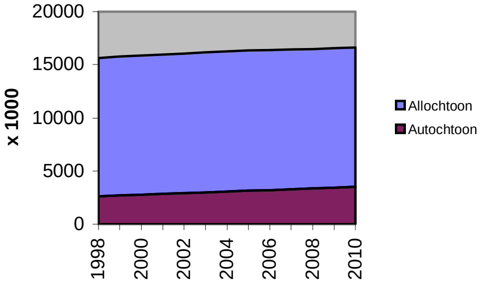
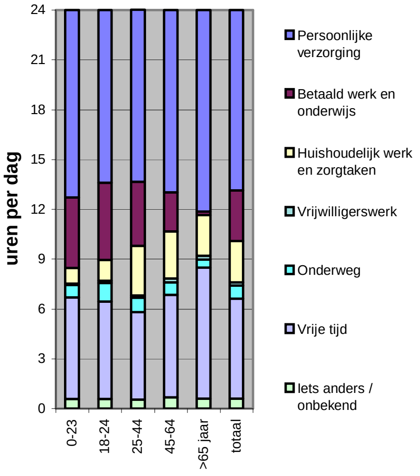


Fig. 967 Proportion of first and second generation immigrants

6.4.5 Time and movement

Time utilisation



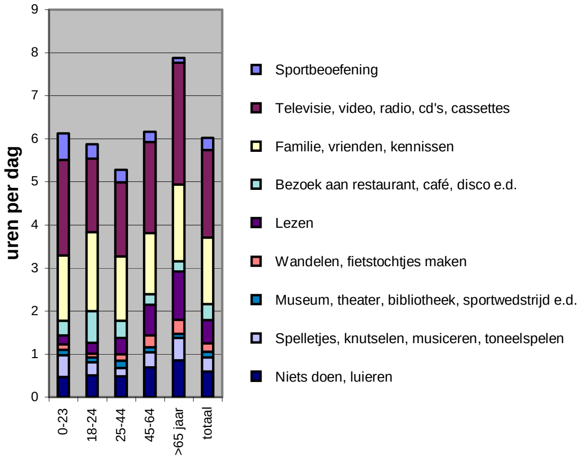
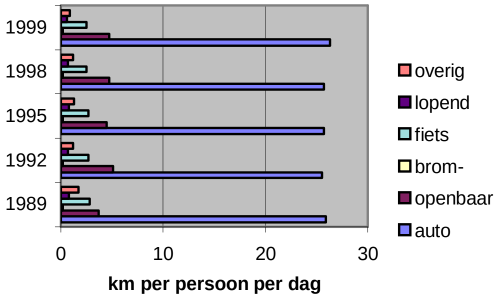


Fig. 968 Time utilisation in 1997

Fig. 969 Use of free time in 1997

Daily population movements

The average total distances travelled, mainly by car, per person per day is fairly constant at 35 km (*Fig. 970*). Commuting accounts for almost 10 km of this distance (*Fig. 971*).



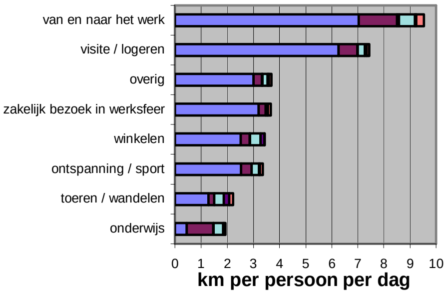


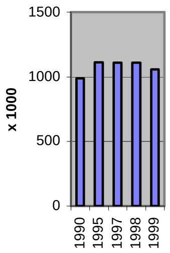
Fig. 970 Total distance travelled per means of transport

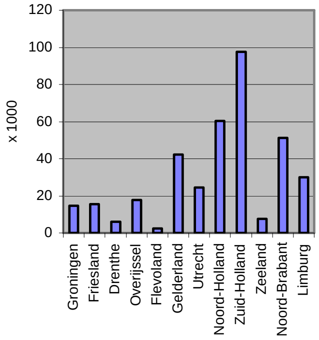
Fig. 971 Distance travelled per motive and means of transport

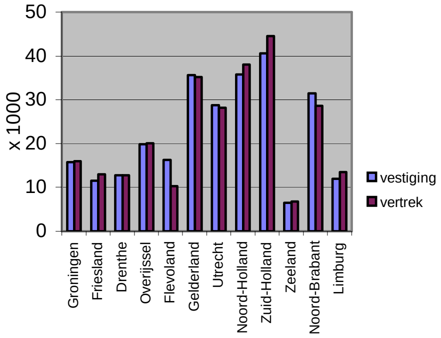
Removals

In 1999, 1,696,000 Dutch people moved to another place of residence in the Netherlands. More than a million of these changes of address were within the same municipality (3 km radius), more than a quarter of a million within the same province (30 km radius) and almost 0.4 million from one province to another (300 km radius).

Removals in 1999 within	3km	30km	300km	total
	1058000	267000	371000	1696000
	See *Fig. 972*	See *Fig. 973*	See *Fig. 974*	







Number of removals

Fig. 972 Municipal *Fig. 973 Provincial* *Fig. 974 National*

The largest number of removals took place within and between the provinces South and North Holland.

6.4.6 Dwellings

How many of each kind

On 1st January 2000, in the Netherlands, there were approximately 6,588,000 homes, the value of which totalled € 575,945,000,000, divided into categories, as shown in *Fig. 975*

	year	**population x 1000**	**number of dwellings**	**support base in persons**
Home	1999	15760	6390100	2.47
Own home	1999	15760	3303700	4.77
Rented home	1999	15760	3086400	5.11
Home with central heating	1999	15760	89700	176
Flat/appartment, etc.	1999	15760	1965000	8.02
End of terrace-/terraced house	1999	15760	2689900	5.86
Home with a garden or grounds	1999	15760	75600	208
Home with a garage and/or a carport	1999	15760	33600	469
A detached house	1999	15760	979400	16
A semi-detached house	1999	15760	755800	21
A 1 or 2-roomed home	1999	15760	580500	27
A 3-roomed home	1999	15760	1273800	12
A 4-roomed home	1999	15760	2164100	7.28
A 5-roomed home	1999	15760	1556300	10
A home with 6 or more rooms	1999	15760	815400	19

Fig. 975 *Housing categories and their number in relation to the total population of the Netherlands*

So, on every 19 inhabitants there was a dwelling with 6 or more rooms.

Price and age

From *Fig. 976* and *Fig. 977* you can determine the average age and price of dwellings.

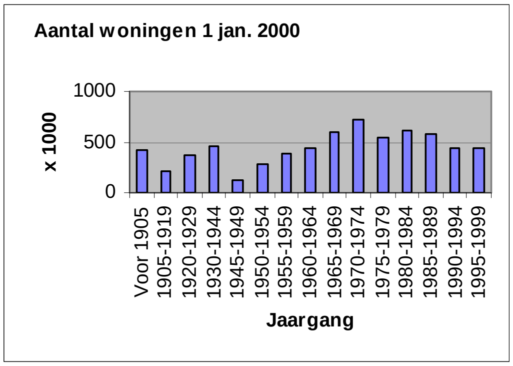


Fig. 976 *Number of homes per year of construction*

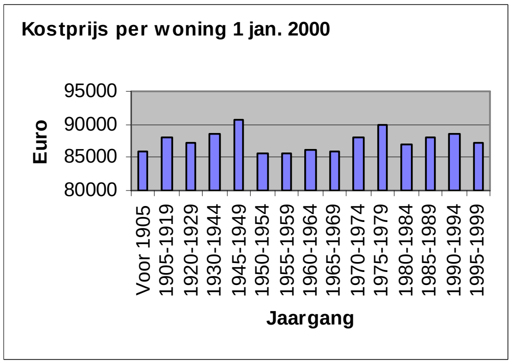


Fig. 977 *Value of home per year of construction*

Singles rent, families buy mainly new houses

The majority of people in the Netherlands live in accommodation that was built after World War II, between 1960 and 1990 (*Fig. 978*). Single-person households are mainly accommodated in rented homes. Couples usually buy their own living accommodation (*Fig. 979*).

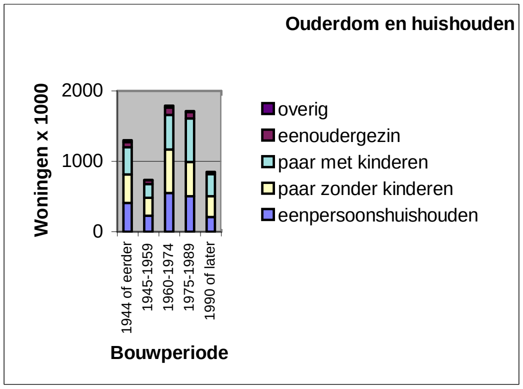


Fig. 978 *Occupancy per year of construction*

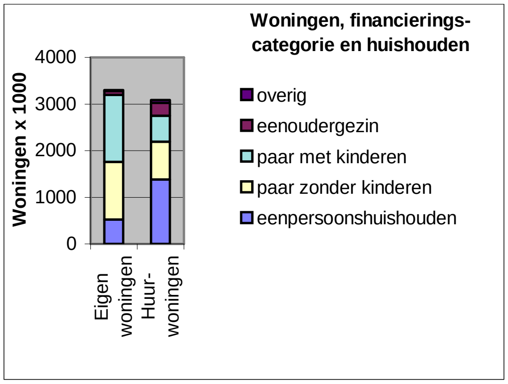


Fig. 979 *Occupancy in own or rented houses*

6.4.7 Public utilities

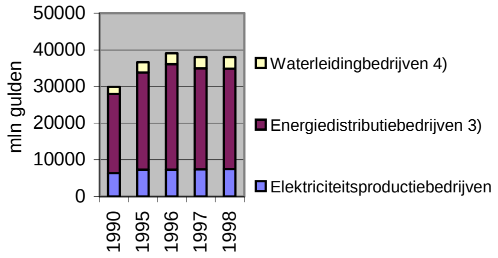
Less energy companies and water boards

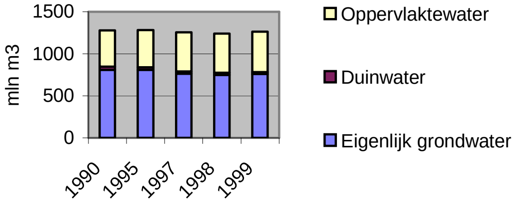
The number of water boards has decreased from 32 in 1990 to 20 in 1998. However, the number of employees or cubic metres of water produced remained the same (*Fig. 982*). As with agrarian firms, this indicates concentration.

Establishments for:	year	population	number	growth per year	support base
Electricity producing company	1998	15654	5	0%	3130838
Energy distribution company	1998	15654	70	-1%	223631
Water Board	1998	15654	20	-9%	782710

Fig. 980 *Number of utility facilities compared with the size of the Dutch population*

Decreasing energy and water production





Note 3: Including power installations(>50 GWh per year), in the context of joint ventures, exploited by energy distribution companies and industrial companies.
Note 4: Excluding multi-utility companies.

Fig. 981 *Production value of utility companies*

Fig. 982 *Water production*

Selective increase of facilities for health and welfare

Establishments for:	year	population	number	growth per year	support base
after-school care centres	1998	15654	992	18%	15780
hostels caring for vagrants and homeless people	1999	15760	228	5%	69124
host-family care centres	1998	15654	189	1%	82826
half-day crèches/nurseries	1998	15654	169	9%	92628
full-day crèches/nurseries	1998	15654	1749	16%	8950
family doctors'/ general practitioners' (gps') practises	2000	15864	4809	0%	3299
established general practitioners (gp)	2000	15864	7217	1%	2198
childrens' independently homes	1998	15654	789	4%	19841
homes for the mentally handicapped	1999	15760	151	2%	104372
homes for the those with sensory handicaps	1999	15760	12	-1%	1313352
community care centres	1999	15760	75	3%	210136
childrens' hospitals and hospices	1999	15760	13	1%	1212325
medical day centres for infants	1999	15760	56	8%	281433
psychiatric hospitals	1999	15760	76	-1%	207371
dentists	1998	15654	7030	-1%	2227
nursing homes	1999	15760	334	0%	47186
care homes for the elderly	1998	15654	1380	-1%	11344
crisis centres for women	1999	15760	80	25%	197003
independent dispensing chemists	1998	15654	1547		10119
hospitals	1999	15760	136	-2%	115884

Fig. 983 Number of health facilities compared with the size of the Dutch population

Fig. 983 is a table showing 20 different types of public health facilities. By dividing the population by the number of facilities, a potential support base emerges that indicates the number of inhabitants that would be needed to support this type of facility. Due to an irregular, historically determined distribution of the facilities and the factors determining their establishment at a specific location, their distribution is, of course, unevenly concentrated, which, in turn, means that the actual support base, locally, can also vary.

The growth figures for the latest available year, compared with the year prior to that, give an indication of the figures for the years to come, but, in the longer term, they must be calculated more closely in the light of rational expectations of their expected use.

More outdoor facilities for young children and less (larger) for the elderly

Fig. 984 and *Fig. 985* show the growth of facilities for children and elderly not reflecting the number of *users* (dependent on growing Dutch population), but rather the number of establishments.

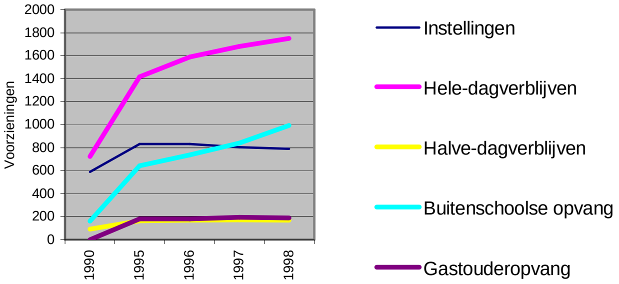


Fig. 984 *Development of facilities for children*

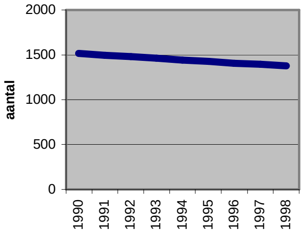
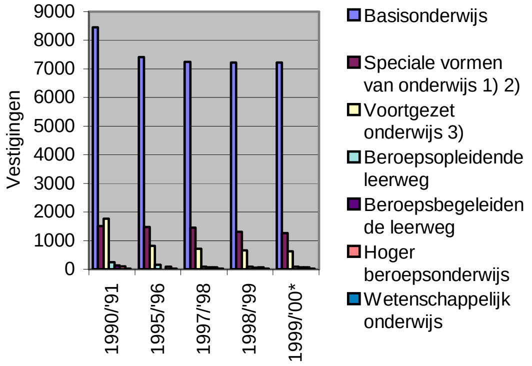


Fig. 985 *Facilities for the elderly (care homes for the elderly)*

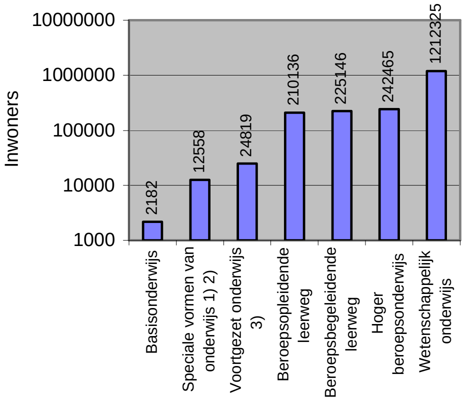
Decreasing number of schools



Note 1: Number of departments.
Note 2: Including practical education.

Legend top down: primary, special, secondary, technical and vocational training, technical and vocational guidance, higher technical and vocational, scientific.

Fig. 986 *Development in the number of schools*



Note 3: University Preparatory Education (vwo), Senior General Secondary Education (havo), Junior General Secondary Education (mavo), Preparatory Vocational Education (vbo) and Learning Path Supporting Education (*lwoo*)

Fig. 987 *The average support base of* Fig. 990[a]

From **Error! Reference source not found.** you can learn you need a conurbation of more than 1 000 000 inhabitants for a university, a town of >100 000 inhabitants for technical and vocational schools, a district of >10 000 inhabitants for secondary and special schools and a neigbourhood of more than 1 000 inhabitants for a primary school.

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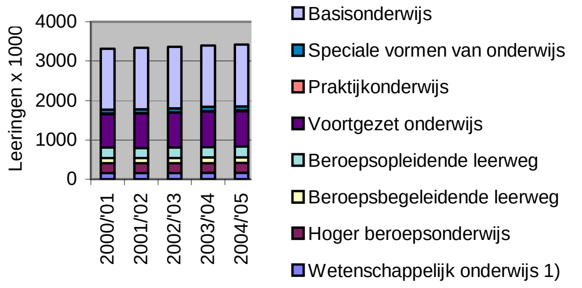
[a] CBS-publication: Education Year Book

Equal number of pupils



Note 1: Including part-time education.

Fig. 988 *Expected number of pupils*

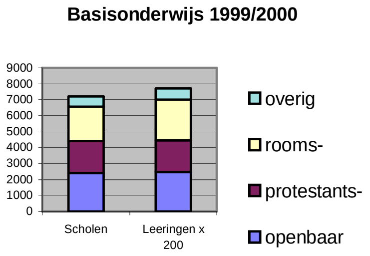


Fig. 989 *Establishments and users of primary schools*

An equal number of pupils combined with the decreasing number of schools shown in **Error! Reference source not found.**, means a development into larger schools.

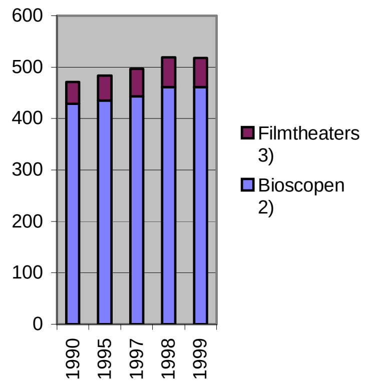
Less (and larger) schools (at a larger distance)

Establishments for:	**year**	**population**	**number**	**growth per year**	**support base**
primary education	1999	15760	7224	-1%	2182
day-release learning path	1999	15760	70	-4%	225146
vocational learning path	1999	15760	75	-7%	210136
higher vocational education	1999	15760	65	-3%	242465
special forms of education	1999	15760	1255	-2%	12558
secondary education	1999	15760	635	-6%	24819
scientific education	1999	15760	13	1%	1212325

Fig. 990 *Number of educational facilities compared with the size of the Dutch population*

6.4.8 Facilities

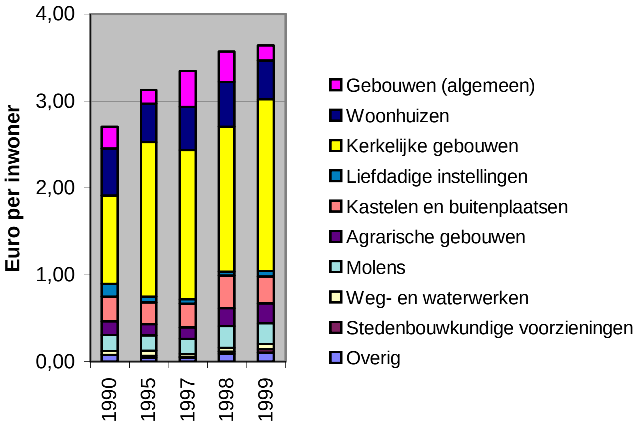
More cinemas and film theatres, more money for monuments and historic buildings



Note 2: Including two drive-in cinemas
Note 3: Excluding non-specifically equipped performance rooms

Source: (Cinemas) Dutch Federation for Cinematography; (film theatres) Dutch Film Theatre Association

Fig. 991 *Cinemas and film theatres*



Legend top-down: general buildings, dwellings, churches, charity buildings, castles and estates, agricultural buildings, mills, civil engineering works, urban facilities, remaining.

Fig. 992 *Expenditures on historic building projects*

Cinemas are just one category of facilities for culture and recreation summarised in Fig. 993. There you can conclude their number did not increase in 2000.

Facilities for culture and recreation

Establishments for:	**year**	**population**	**number**	**growth per year**	**support base**
amusement hall l	1998	15654	420		37272
amenity park	1998	15654	35		447263
ballet theatre	1997	15567	2	-6%	7532471
cinema	1999	15760	461	0%	34187
cabaret theatre	1997	15567	20	2%	761849
casino or lottery	1998	15654	40		391355
creativity centre	1997	15567	63		247097
dance theatre	1997	15567	8	6%	2048304
dance theatre	1997	15567	13	-2%	1173400
zoo	1999	15760	27		583712
film theatre	1999	15760	57	-2%	276495
music and creative arts centre	1997	15567	52		299367
hotel with 1000 over-night stays per year	1999	15760	29053	4%	542
academy of fine arts	1997	15567	244		63800
yacht harbour	1997	15567	400	3%	38918
camping grounds, holiday chalet complexes, youth and group accommodations	1999	15760	3595	-3%	4384
museum	1997	15567	942	1%	16526
mixed museum	1997	15567	19		819321
industrial and technical museum	1997	15567	260		59873
fine arts museum	1997	15567	102		152619
historical museum	1997	15567	491		31705
natural history museum	1997	15567	50		311342
museum of ethnology and folk history	1997	15567	20		778355
musicians’ performance stage	1997	15567	50	1%	310514
music school	1997	15567	129		120675
muziektheater	1997	15567	44	4%	355413
theatre for operettas, musicals and revues	1997	15567	8	1%	1954030
horticultural gardens, show gardens and arboretums	1999	15760	104		151541
different types of performing platforms	1997	15567	4	-2%	3736106
place of performance for ensembles	1997	15567	9	0%	1729679
place of performance for improvised music	1997	15567	13	5%	1219356
place of performance for large orchestras	1997	15567	6	1%	2731071
place of performance catering for 300 concerts per year	1997	15567	189	1%	82409
puppet theatre	1997	15567	13	2%	1203642
open-air sports facility	1997	15567	4090		3806
indoor sports facility	1997	15567	2115		7360
theatre	1997	15567	78	0%	200780
playhouse	1997	15567	48	-2%	321413
watersportclub	1997	15567	950	0%	16386
zeil- en surfschool	1997	15567	90		172968
swimming bath	1997	15567	710	0%	21926
swimming bath complex	1997	15567	140	3%	111194
open-air swimming bath	1997	15567	245	-2%	63539
indoor swimming bath	1997	15567	325	1%	47899

Fig. 993 *Number of cultural facilities compared with the size of the Dutch population*

Facilities ordered by number, divided by population: support base

Throughout the Yearbook 2001, numerous tables are included that mention the number of established faclities for many organizations and branches. The numbers of 244 types of establishment are summarised in a downloadable Excel sheet[a] allowing to adapt the figures into more recent years or to determine their trend. Divided by the real or expected national population of the relevant year the average support base needed for each type of facility is produced. In *Fig. 994* some of these facilities and their average population support base are mentioned. So, on a next tab of the sheet you can make an average programme for any urban area. However, some areas do have more swimming pools than the average, others more theatres. The deviation from the average offers a profile determining the identity of the place. Many facilities are still missing, such as prisons, police stations, ministeries, embassies, surrogate family homes, boarding schools, monasteries and convents, but these can be added.

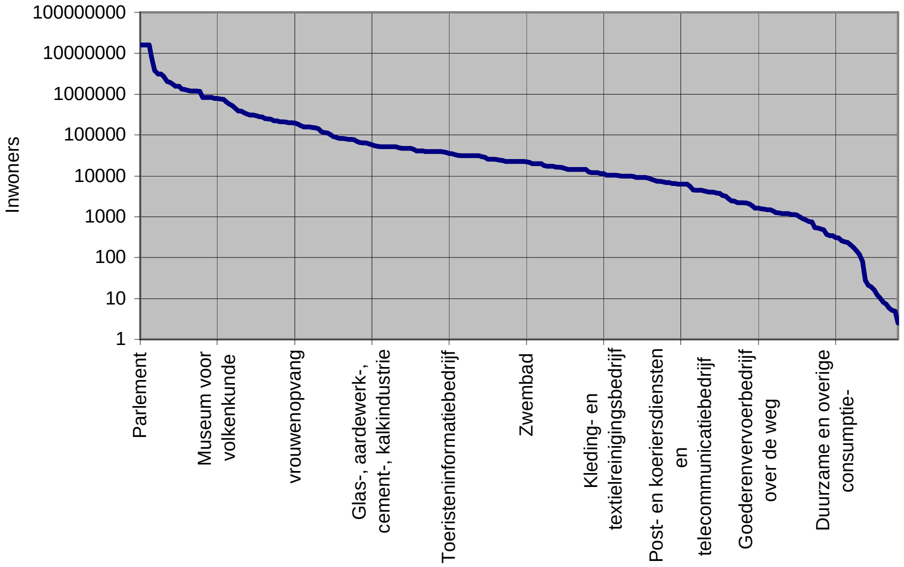


Fig. 994 *244 types of establishment ordered by number and their support base shown logarithmically*

From this, one can see that, for a population of 100,000 inhabitants, a ‘town’, most facilities can find a sufficient support base. For those who would like to know more about these urban facilities on the level of a town, *Fig. 995* gives an enlarged picture.

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[a] living.*xls*, downloadable from *http://team.bk.tudelft.nl/* > Publications 2008

Facilities sustainable on town level

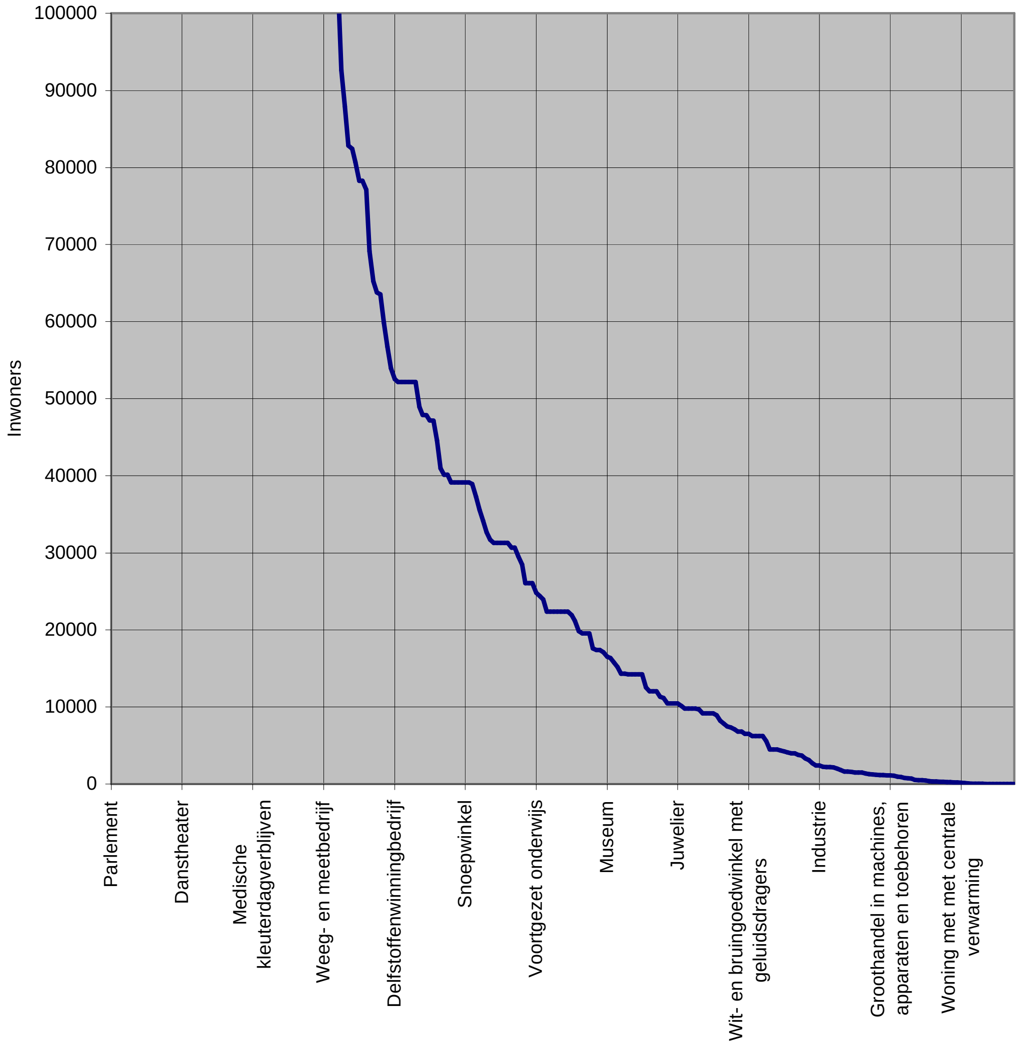


Fig. 995 *Ordering of facilities for 100,000 inhabitants*

This graph has a certain multi-staged characteristic. In the steep vertical parts, urban growth apparently allows little growth in the level of facilities that it can offer. For populations between 55,000 and 100,000 inhabitants, the number of types of facility hardly increases at all. In the horizontal parts, a little growth can deliver much more facilities. With 25,000 inhabitants (a village or large district) one already has a support base large enough to support half the number of known facilities. A 1000 inhabitants (neigbourhood) give support to 1/3 of the district facilities. To examine that lowest part from 10 000 inhabitants in more detail, *Fig. 996* gives an enlarged picture.

District or village facilities

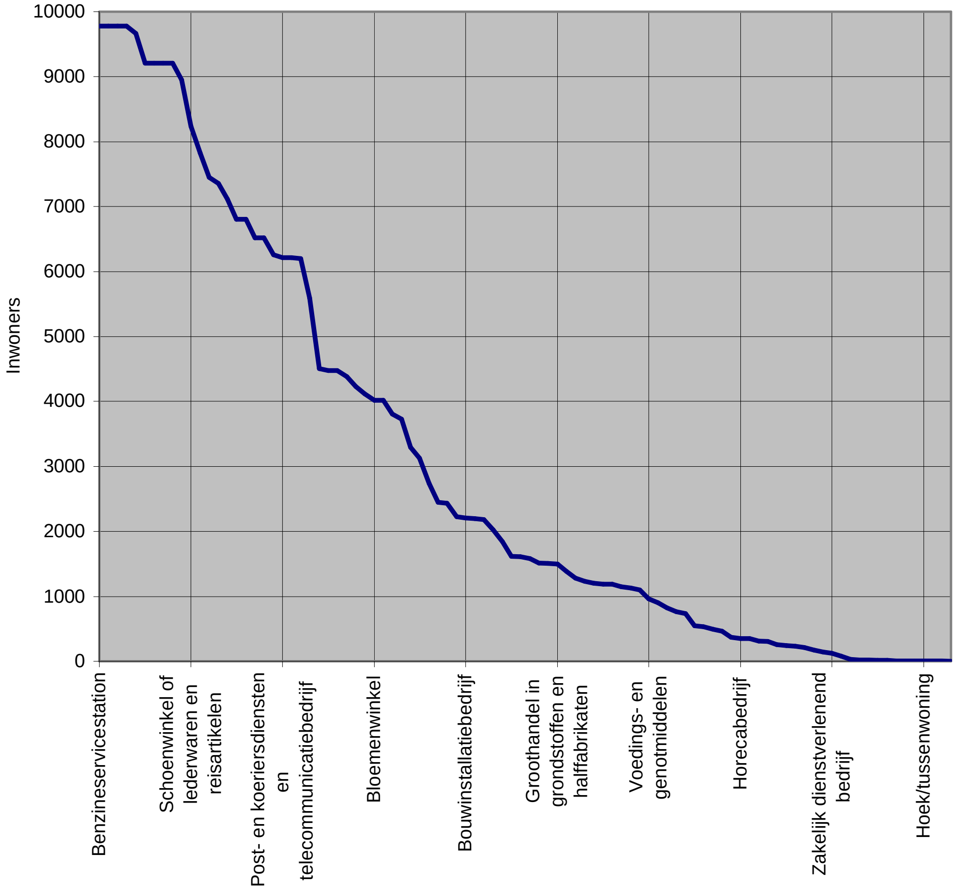


Fig. 996 *Ordering of facilities for 10,000 inhabitants.*

6.4.9 Businesses

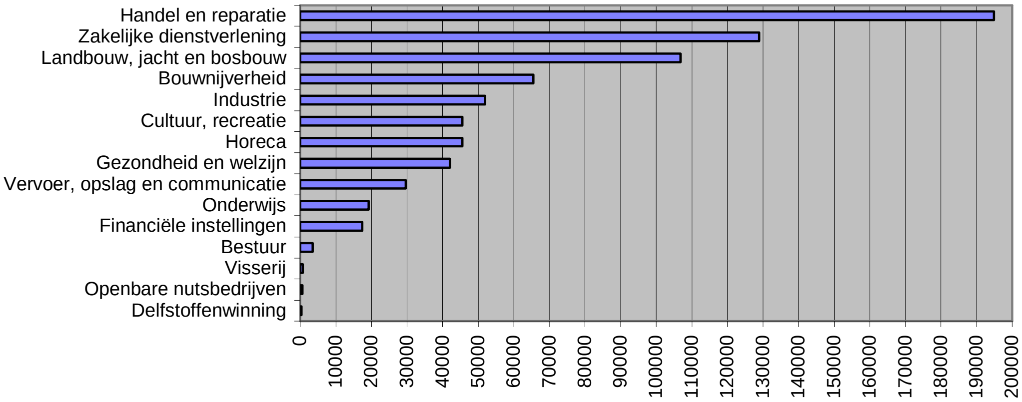


Fig. 997 *Business establishments in 1999*

On 1st January 1999, there were 752,825 active businesses in the Netherlands, divided into the main categories as shown in *Fig. 997*. A number of these are more finely subdivided in the paragraphs below.

Agriculture and Fisheries

In 1999 there were still more than 1 million active agrarian firms in the Netherlands (see *Fig. 998*).

Establishments for	**year**	**population**	**number**	**growth per year**	**support base**
agricultural, hunting and forestry firm	1999	15760	106815		148
fishery firm	1999	15760	745		21155

Fig. 998 *Number of agrarian firms compared with the size of the Dutch population*

Larger farms

The increase in the scale of these firms can be seen in *Fig. 999*.

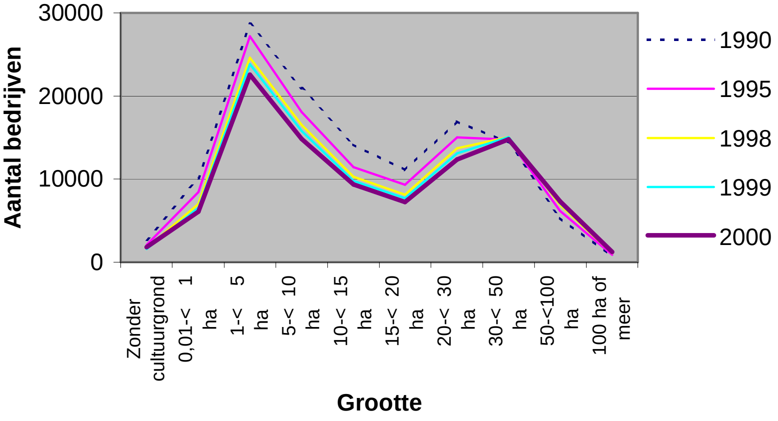
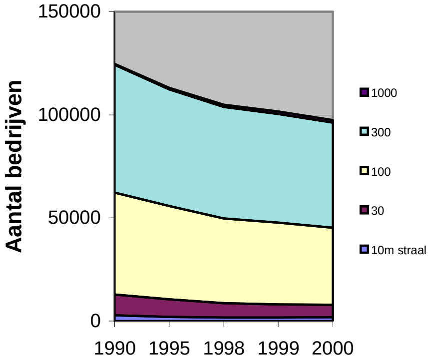


Fig. 999 *The increase in the scale of agrarian firms*

The scaling-up of individual farms while the surface remains equal implies decrease of the number of farms (*Fig. 1000*), but increase of the number of large farms (*Fig. 1001*).



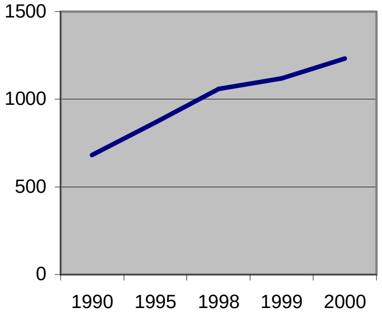


Fig. 1000 *The development in the order of size of agrarian firms*

Fig. 1001 *The growth of agrarian firms larger than 100 ha. (with a radius of 1 km)*

The surface farms need

The surface areas in hectares in these charts have been recalculated into radii used in urban architecture (*Fig. 1002*).

	from	**To**	**Radius**		**Number of firms**			
-	**m^2**	**m^2**	**in m**	**1990**	**1995**	**1998**	**1999**	**2000**
Without arable land			10	2714	2061	1691	1585	1769
0,01-< 1 ha	100	9999	30	10046	8453	7010	6515	6086
1-< 10 ha	10000	99999	100	49556	45253	41076	39613	37355
10-<100 ha	100000	999999	300	61906	56568	54038	52712	51042
100 ha of meer	1000000	9999999	1000	681	867	1058	1120	1231

Fig. 1002 *Areas in hectares recalculated into radii used in urban architecture*

Industry

Establishments for:	**year**	**population**	**number**	**growth per year**	**support base**
chemical industry	1998	15654	327	1%	47872
clothing and fur industry	1998	15654	77	8%	203301
electrical apparatus industry	1998	15654	390	0%	40139
food-processing and drinks industry, tobacco processing industry	1998	15654	891	1%	17569
furniture and related industries	1998	15654	382	-3%	40980
glass, earthenware, cement and chalk industry	1998	15654	276	3%	56718
industry	1998	15654	6433	1%	2433
leather, leather goods and footwear industry	1998	15654	41	-7%	381810
machine and apparatus industry	1998	15654	915	3%	17108
metal products industry	1998	15654	1093	4%	14322
office-equipment and computer industry	1998	15654	24	-8%	652258
paper (goods) and carton (goods) industry	1998	15654	203	15%	77114
publishers, printers, reproduction	1998	15654	654	-1%	23936
rubber and synthetic-material processing industry	1998	15654	351	1%	44599
textile industry	1998	15654	178	-5%	87945
transport vehicles industry	1998	15654	332	-3%	47151
wooden, cork, and cane goods industry (excluding furniture)	1998	15654	194	5%	80692

Fig. 1003 *Number of industrial branches compared with the size of the Dutch population*

Building Industry

Establishments for:	**year**	**population**	**number**	**growth per year**	**support base**
building company	1998	15654	31459	1%	498
building company specialised in finishing off buildings	1998	15654	8514	4%	1839
building company specialised in *b&u, gww*, excluding excavation	1998	15654	14268	0%	1097
building company specialised in preparing building sites	1998	15654	1095	3%	14296
building company specialised in hiring out building machinery and personnel	1998	15654	479	-1%	32681
building company specialised in installation	1998	15654	7103	-1%	2204

Fig. 1004 *Number of companies in the building industry compared with the size of the Dutch population*

Retail and inland Trading

Establishments for:	**year**	**population**	**number**	**growth per year**	**support base**
florists	1998	15654	3900		4014
bookshops	1998	15654	1100		14231
building material retailers	1998	15654	1300		12042
computer retailers	1998	15654	500		31308
pet shop	1998	15654	1500		10436
diy retailers	1998	15654	3900		4014
chemists	1998	15654	1700		9208
chemists selling medical goods, perfumes and cosmetics	1998	15654	2100		7454
durable consumer goods and other forms of consumption -	1998	15654	50500		310

Establishments for:	**year**	**population**	**number**	**growth per year**	**support base**
cycle shops	1998	15654	2300		6806
audio and amplification equipment retailers	1998	15654	700		22363
glass, porcelain and earthenware retailers	1998	15654	700		22363
greengrocers	1998	15654	2200		7116
wholesalers	1998	15654	61496		255
wholesale suppliers of business requisites and packaging	1998	15654	2524		6202
wholesale suppliers of raw materials and semi-fabricated goods	1998	15654	10420		1502
wholesale suppliers of wood, building materials, iron and metal goods	1998	15654	5727		2733
wholesale suppliers of machinery, apparatus, accessories and parts	1998	15654	13899		1126
wholesale suppliers of non-food consumer goods	1998	15654	21193		739
wholesale suppliers of food, spices and energisers	1998	15654	7733		2024
(textile) handicrafts shop	1998	15654	600		26090
household goods retailers	1998	15654	900		17394
household linnen retailers	1998	15654	100		156542
ironmongery (hardware) and tool shop	1998	15654	700		22363
jewellers	1998	15654	1500		10436
jewellers selling costume jewellery	1998	15654	300		52181
cheese shop	1998	15654	600		26090
stationers	1998	15654	2000		7827
kitchen equipment retailers	1998	15654	500		31308
dress fabric retailers	1998	15654	400		39135
lamp and lighting retailers	1998	15654	400		39135
retailers of leatherware and travel goods	1998	15654	300		52181
lingerie retailers	1998	15654	700		22363
furniture shop	1998	15654	1700		9208
furniture shop with home textiles, lighting goods and floor coverings	1998	15654	5000		3131
musical instrument retailer	1998	15654	400		39135
sewing and knitting machine shop	1998	15654	200		78271
opticians	1998	15654	1100		14231
perfumery	1998	15654	300		52181
poulterers	1998	15654	300		52181
health-food shop	1998	15654	300		52181
shoe shop	1998	15654	1600		9784
shoe shop with leatherware and travel goods	1998	15654	1900		8239
butchers	1998	15654	3700		4231
off-licence	1998	15654	1100		14231
sweet shop	1998	15654	400		39135
toy shop	1998	15654	700		22363
sports and camping-gear retailers	1998	15654	1600		9784
supermarket, grocers	1998	15654	3500		4473
tobacconists	1998	15654	1700		9208
textile supermarket	1998	15654	400		39135
textile retailers	1998	15654	9900		1581
garden centre	1998	15654	600		26090
paint and wallpaper shop	1998	15654	700		22363
fishmongers	1998	15654	700		22363
carpet shop	1998	15654	500		31308
foods, spices and energisers	1998	15654	16300		960
shop	1998	15654	66800		234
shop selling glass, porcelain and earthenware; household articles or toys	1998	15654	2300		6806
shop selling durable household goods	1998	15654	3800		4120
photographic shop	1998	15654	800		19568
retailers of medical and orthopedic goods	1998	15654	100		156542
retailers of kitchen apparatus, other electrical goods and audio equipment	1998	15654	2400		6523
interior decorators, general assortment	1998	15654	1300		12042
home furnishing retailers	1998	15654	1100		14231

Fig. 1005 *Number of trading companies compared with the size of the Dutch population*

Inland Services

Establishments for:	year	population	number	growth per year	support base
job centres/employment bureaus for assessing, attracting and selecting personnel	1998	15654	1300		12042
architectural and technical design and drawing consultancy	1998	15654	13200		1186
suppliers of spare-parts and accessories for cars	1998	15654	400		39135
car servicing company	1998	15654	3500		4473
tyre servicing company	1998	15654	200		78271
job pools (job-opportunity projects)	1998	15654	100		156542
garage for industrial vehicles, trailers	1998	15654	800		19568
petrol station	1998	15654	1600		9784
bookkeepers, accountants	1998	15654	13200		1186
cafe	1998	15654	12700		1233
cafeteria, snack bar	1998	15654	10400		1505
bodywork repair firms	1998	15654	1500		10436
catering (w.o. party-catering)	1998	15654	1600		9784
car tyre wholesalers and trade intermediaries (middle men)	1998	15654	300		52181
wholesalers and trade intermediaries in spare-parts and accessories for cars	1998	15654	1500		10436
hotel, b&b (bed & breakfast), conference centre	1998	15654	2500		6262
camping ground	1998	15654	1700		9208
camping ground or holiday chalet park, bungalow park	1998	15654	2800		5591
cantine (incl. contract catering)	1998	15654	800		19568
cantine and catering	1998	15654	2400		6523
hairdressers	1998	15654	11300		1385
testing or checking office	1998	15654	500		31308
dry cleaners	1998	15654	1400		11182
motor cycle retailers	1998	15654	500		31308
private car garages	1998	15654	13000		1204
advertising agency	1998	15654	12200		1283
restaurant	1998	15654	9700		1614
restaurant, cafeteria, snack bar	1998	15654	20400		767
beauty salon, pedicure or manicure	1998	15654	13600		1151
cleaners for buildings and transport vehicals	1998	15654	6400		2446
temporary employment agency	1998	15654	900		17393.55
holiday chalets or bungalow park	1998	15654	1100		14231

Fig. 1006 *Number of service-providing firms compared with the size of the Dutch population*

Traffic, Transport and Communication

Establishments for:	year	population	number	growth per year	support base
inland shipping company	1998	15654	4200	-1%	3727
forwarders, ship-brokers or chartering brokers	1998	15654	1620	-5%	9663
road freight haulage companies	1998	15654	9750	5%	1606
loading, unloading and trans-shipment companies	1998	15654	320	7%	48919
airports and other air transport services	1998	15654	30	0%	521806
air transport companies	1998	15654	10	0%	1565419
storage/warehousing companies	1998	15654	510	2%	30694
pipeline transporting companies	1998	15654	10	0%	1565419
post, courier services and telecommunications companies	1998	15654	2520	11%	6212
travel agencies	1998	15654	1030	-5%	15198
travel organisations (tour operators)	1998	15654	550	0%	28462
taxi firms	1998	15654	2520	-7%	6212
tourist information offices	1998	15654	440	19%	35578
tram and bus/coach companies	1998	15654	290	-6%	53980
land transport service companies	1998	15654	390	8%	40139
water transport service companies	1998	15654	240	9%	65226
weighing and measuring companies	1998	15654	110	-15%	142311
ocean-going shipping companies	1998	15654	510	-9%	30694

Fig. 1007 *Number of transport companies compared with the size of the Dutch population*

6.5 Environment

Definition

We define environment as *'the set of conditions for life'* (Hendriks 1993). In this definition, both 'conditions' and 'life' can be more closely specified. By means of substitution, more precise concepts of the environment emerge, such as 'the set of physical conditions required for plant life' or 'the set of managerial conditions required for animal life'.

conditions	**life**
managerial	human
cultural	
economic	animal
technical	
ecological	plant
mass/time/spatial	

Fig. 1008 *Substitution possibilities in defining environment*

One can presume a sequence of conditionality in both columns (one cannot imagine management without a culture to carry it; one cannot imagine animal life without plant life, etc.). That becomes an issue as soon as one attempts to weigh the importance of different environments against each other.

Different environments

However, also *without* the above presumption, these substitution possibilities allow 18 more precise environmental definitions to be made. We can summarise managerial, cultural and economic conditions as 'societal conditions' and the remaining ones as 'physical conditions'. In this way, the number of environmental definitions is reduced to 6. Plant and animal life-forms can be summarised as 'non-human life-forms' (12 environmental definitions), but they can also be more precisely distinguished in the five 'kingdoms'[a] currently recognised in biology, with *homo sapiens* as the sixth category, bringing the number of environmental definitions up to 42. This figure increases further, if we define a species-specific environment for every species.

Physical conditions for human life

The current environmental definition of 'physical surroundings of society' (more or less according to Udo de Haes in Boersema, Peereboom et al. (1991)) is just one of the environmental definitions identified above.

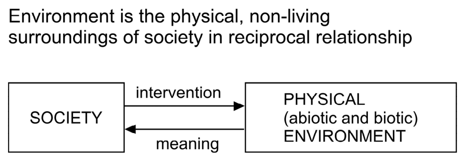


Fig. 1009 *Environment according to Udo de Haes*

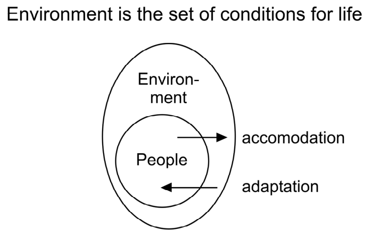


Fig. 1010 *Environment in technical sense*

Udo de Haes' formulation can be expressed as a technical definition, by reducing it to 'the set of physical conditions for human life'. However, by doing this, the 'mutual relationship' between physical surroundings and society becomes less 'causal' than those postulated as a *condition* for human life. In

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[a] Formerly only plant and animal worlds were distinguished. Nowadays, next to these two, are also disitnguished 'monera' (bacteries without nucleus), 'protoctistan' (single celled organisms with nucleus) and fungi (moulds); see: Margulis, L., K. Schwartz, et al. (1994) The illustrated Five Kingdoms; A guide to the diversity of life on earth (New York) Harper Collins College Publishers ISBN 0-06-500843-X.

other words, an asymmetry is assumed in the ‘relations’ between society and the physical environment.

After all, one cannot imagine people, let alone a society, without physical surroundings, but one can imagine physical surroundings without people. A physical environment is thus a technical *condition* for human and societal life. Because of this, a specific physical environment is not the *cause* of one or other form of human life[319], such as physical determinism at the end of the last century would have led one to believe[a]. Human beings adapt themselves to existing conditions (adaptation) or change physical conditions (accommodation) exploring its possibilities, but they can not surpass its boundary conditions[320].

6.5.1 Conditions

Conditions determine what is possible

Technical conditions are related to what is possible, while causal relations have a bearing on what is probable within that possibility. After all, what is probable is, by definition, also possible, but not everything that is possible is also probable. So, there are improbable possibilities. One cannot *predict* these, so one has to *design* them.[321]

In the same way as the set of probable futures is a subset of possible ones, the set of causes is a subset of conditions. Every cause is a condition for something to happen, but not every condition is also its cause (a last added condition for something to happen). So, there are more conditions than causes, often operating as (ceteris paribus) suppositions hidden in causal reasoning. Economy can be studied as long as the dykes do not burst, that is such a hidden supposition (a technical condition not discussed) of economic reasoning. In everyday life we are not aware of the many background conditions making life possible.

Conditions making other conditions possible.

The foundation of a house can be a condition for that house, but in the same time not its cause. The cause may be an economic one. On its turn a house can be a condition for a household (it can create the *possibility* of a household) but in the same time not causing it. According to the technical definition of environment the house belongs to the environment of the household making a household possible like the foundations belong to the environment of the house on their turn making the house possible. So, there can be a sequence of conditions making each other possible and a design is summing up these technical conditions in a drawing.

Design makes possible, not probable

The above argumentation gives an exact indication of what the responsibility of the designer is, in contrast to that of the researcher. If (s)he designs a home, (s)he must not do it in a way that presumes its occupancy by a specific type of household - that would be an encroachment on the freedom of choice of the future occupants – her or his design must keep possibilities open for its occupancy by different sorts of households.

The same sort of dilemma exists in ecology. It is not always possible to forecast where a certain ecosystem will come into existence. Many subtle factors and initial conditions determine its emergence. We cannot *cause* an ecosystem. We only can create the *conditions* under which a set of ecosystems can exist, while others can not.

Environmental problems

With this conditional environmental definition, *environmental problems* are simply ‘*missing conditions for life.’* These problems now can be specified further in a technical sense (see Fig. 1008), by specifying ‘conditions’ (physical or social) and ‘life’ (human or other).

For the other forms of life, human beings have become a plague, the cause of many environmental problems. But it is also dangerous for the species itself. In a life time the human population has doubled. The agricultural surface is in danger to be halved by desertification, erosion and

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[a] The rise and fall of determinism in the spatial sciences around the change of the 20th century, is clearly described in Claval (1976) De geschiedenis van de aardrijkskunde (Utrecht) Het Spectrum.

contamination. It will decrease even further if we use its products as fuel for our cars. So, you can count on a quarter of the grain area per person compared to the conditions a century ago. The productivity per ha. increased more than twice, but that progress stagnated (see Fig. 1011). Many environmental problems seem marginal compared to that doom scenario.

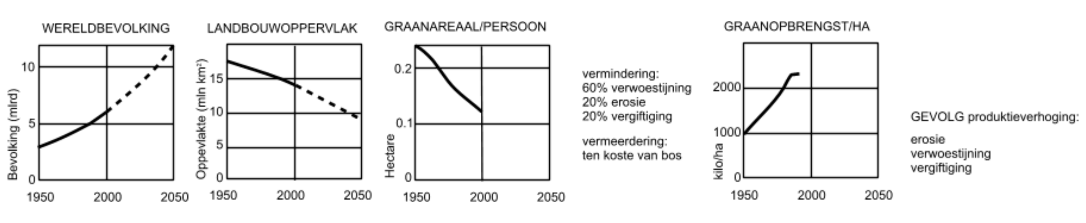

Fig. 1011 *Doom scenario: increasing human population, decreasing agricultural surface*

Using the technical definition chosen here, environmental problems are easily definable as missing conditions for life, and environmental regulations as actions designed to provide for them. These do not have to be the same as the eventually lost conditions, they also can be new conditions.

Creating new conditions instead of restoring old ones

For a technical definition environmental measures do not need to be directed only on restoring an earlier situation (that is often an illusion by the actual human population), they can also create new life-sustaining conditions (see 6.5.6, page 571). This perception of environmental problems distinguishes designers from researchers. The relations between organisms and their surroundings (including that of the human society and its physical environment) can still be only very partially understood. However, they do not need to be completely understood to restore lost conditions, and to create new ones.

Taking away the causes is not enough

In addition, many environmental problems cannot be solved any more by removing the cause.
We cannot return any more to the situation of 10,000 years ago. At that time, there were an estimated 3 million people on earth and at least 50,000 species more than there are now.
And, because we cannot go back, we have to do more than just maintain the old environmental conditions. We *have* to create new ones.

Diversity of conditions

What is meant by ‘conditions’ and ‘life’, can turn out to be different when put into practice. For example, the abiotic conditions for plant life are contained in an environmental concept that is different from those for animal life. In particular, the construction of ecological connections creates new abiotic conditions for certain forms of animal life. Viewed from their predominantly botanical understanding of the environment, the authoritative plant ecologists Westhoff and Van Leeuwen (see page 395), value separation more than connection by ‘ecological infrastructure’.

One can define abiotic, biotic, technical, economic, cultural and managerial conditions for different forms of plant, animal and human life (see Fig. 1008). General technical environmental definitions of these different substitutions form just as many environmental concepts, in which apparently conflicting opinions about environmental problems and regulations are brought to the fore.

Conditional conflicts

It is thus impossible to talk about ‘the environment’ in general, and to put a general stamp of ‘environmentally friendly’ on one or the other regulation. Every interference with the surface of the earth increases the possibilities of the one species, to the detriment of other ones.

In agriculture, for instance, we create optimal conditions over enormous areas of land (by fertilisation, hydraulics, etc) for a few plant species, with the result that, with such strong competition, every other species is eliminated. In urban architecture, we optimise in favour of the human species and, within that, for each location, according to certain societal categories. Thus, for each intervention, we must specify which environment we are talking about.

Urban design providing human conditions

In that perspective, we can now define urban design and architecture as supplying, research- and design-based conditions for *human* life by constructing buildings and organising space (whether or not on a larger scale than that of a single building). *Urban and architectural problems* consist of the (future) absence of those conditions. The aim of *urban and architectural research* is to draw attention to, anticipate or formulate in a programme these (missing) conditions. Therefore, it includes not only anticipatory, explanatory and problem-indicative research, but also design research and effect analysis *beforehand* (ex ante) and evaluating research *after* completing the construction (ex post). The aim of *urban and architectural design* is to present these conditions in a realisable spatial relationship.

Probable, possible and desirable conditions

Environment is the set of conditions for life in general. *Ecology* is the research into the *probability* of these conditions, and *technical ecology* is the (design related) research into their *possibility*. *Environmental planning* is the provision of conditions for life in general by means of research, design and policy (of course, as far as these can be appreciated by human beings), viewed from the higher scale levels to the lower ones (*an inward-directed approach*). In a similar way, *environmental technical design* is viewed from the lower scale levels to the higher ones (*an outward-directed approach*).

Anthropocentric and ecocentric viewpoints

With respect to the environment, two standpoints, one of them *anthropocentric* and the other *ecocentric*, can be discerned. The first standpoint should view every aspect from the point of view of human beings (nature as part of culture, see *Fig. 1012*), and the second one, from the point of view of 'nature' (culture being part of it). As 'nature' is a human concept, the debate between anthropocentrists and ecocentrists, that flares up once in ten years or so, invariably veers in favour of the anthropocentrists. Thus, an '*ecocentric standpoint*' includes only that part of the anthropocentric standpoint that attempts to distance itself from human biases (*έποχη*, epochè) in depicting and organising the environment (the conditions for life). Due to this, the concept 'anthropocentric' has, in fact, become useless, because as long as animals and plants are unable to speak an understandable and convincing language, every standpoint is, by definition, anthropocentric.

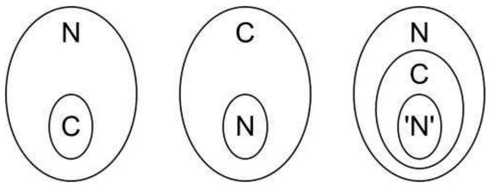

Fig. 1012 Culture (C) and nature (N)

Fig. 1013 Conditional or operational approach

Operational and conditional action

There are *direct* requirements for human life which, if missing, cause loss of comfort or even the death of people, and *indirect* requirements (such as the existence of plants and animals) that, should they be missing, would adversely affect these direct requirements. The existence of direct requirements for life is thus linked to indirect requirements and, in turn, these are linked to requirements that lie even further away (*conditional links*).[a] For example, for many organisms, the necessary existence of oxygen in the air is, itself, indirectly dependent on the existence of photosythesis by plants. It is these indirect requirements that are often either easier to influence by *conditional* design or (if they have been irretrievably lost) by providing a new form, than to 'tackle' the missing direct requirement *operationally* as being the 'cause' of the problem (see *Fig. 1013*).

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[a] The theory of conditionality is elaborated in Jong, T. M. d. (1992) *Kleine methodologie voor ontwerpend onderzoek* (Meppel) Boom, translated and extended in English in Jong, Taeke M. de (2006) *Suppositions of imagination, boundaries of design* (Zoetermeer) *http://team.bk.tudelft.nl/* Publications 2006.

A quiet study room can be a requirement for studying. Noise from neighbours leads to the problem that this direct requirement for studying is destroyed. Indirect conditions that can restore this direct requirement can, in this case, be: adopting a complementary living rhythm (so that the noise occurs at times when no one is studying), thick walls or quiet neighbours. Noise from neighbours can thus be solved in more ways than just by ‘removing the cause’.

Interference of conditions

By providing missing direct requirements (to solve environmental problems) one can, in addition, adversely affect other (mostly indirect) conditions. In building a house, one provides, in a direct way, requirements (an ‘environment’) for human life, but, by so doing, one adversely affects the environment for other life forms and thereby perhaps the indirect conditions for human life. Thus, not only living requirements, but also environmental measures (the provision of certain conditions), are conditionally linked with each other.

For example, to save energy, there is no sense in letting sun enter the house if that house does not stand in the sun, but, in reverse, there is. If the last-mentioned condition is not met, then it would be senseless to provide the first-mentioned requirement. Environmental measures can become each others’ conditions or restrictions, without, however, also being each others’ direct cause.

Conditional sequence

Environmental problems (missing conditions) have a conditional link with each other in this way. After all, one environmental problem can facilitate another one, without directly causing it. Eliminating the direct causes (operationally) without analysing the condiotions, followed by creating (conditionally) all related requirements for success has often be shown to be ecologically counterproductive.

For example, one cannot bring a manure-polluted drainage ditch back to its original state by stopping the manure pollution as Nienhuis (1993) and Hekstra, Strien et al. (1993) show. In the short term, manure pollution is irreversible. The same sort of problem occurs in medical science: a complaint appears to have a direct cause, but the true cause may lie in shortages elsewhere in the body, so that, unexpectedly, one of the conditions of the body that would otherwise ensure that this sort of complaint does not manifest itself, is not met.

Environmental strategies are combinations of environmental regulations, such that they enable and even strengthen each other, both in the time taken and in the sequence of requirements, without creating new problems. *Environmental tactics* is one of the locally or temporarily (politically, culturally, economic, technically) adapted effects of the strategy to the various situations.

6.5.2 Emissions

In this section, a number of technical aspects of environmental hygiene are brought to the fore that are important for making short reports on environmental effects and environmental policy plans. There is much literature about this subject primarily summarised in Boersema, Copius Peereboom et al. (1991) to be completed with recent figures from RIVM (2001).

Environmental hygiene, spatial planning and nature conservancy are policy sectors concerned with the unwanted side-effects of human activities. In spatial planning and nature conservancy, in the first place, this has to do with the mechanical effects such as management, disruption, and small and large interventions in nature and space. Environmental hygiene is mainly concerned with material and energetic effects, among others, on materials, people, other organisms, systems and entire geographical areas, including nature reserves.

A chain of impacts

In order to be able to estimate the unwanted side-effects of all sorts of activities in a given location, beforehand, it is best to divide these activities into living, traffic, nature and agriculture, businesses and incidental activities. These categories can be subdivided into a multiplicity of activities for which, for each activity, emission factors are known. By multiplying these factors by the number of inhabitants, jobs, or km^2 , one can gain an impression of the emissions. This emission is dispersed by air, water, the ground or other dispersion agents, and eventually has a negative effect on materials, people or other organisms. These can be summarised in the following diagram:[322]

economic activity---->	direct effect of emission ---->	indirect effect of transmission ---->	end-effect, exposure
SOURCES (page 553) 1. Homes 2. Traffic 3. Agriculture 4. Businesses 5. Incidents	EMISSIONS (page 555) 1. Inorganic 2. Energetic 3. Mechanical 4. Information 5. Potential emissions	DISPERSED BY (page 559) 1. Air 2. Water 3. The ground 4. Food chains 5. Transport	OBJECTS (page 563) 1. Materials 2. People 3. Other organisms 4. Systems 5. Locations

Fig. 1014 *The chain of environmental effects*

In this table, no account is taken of unwanted socio-economic side-effects. All that is given is a checklist to assess the environmental effects. The nature of sources, emissions, dispersing media and objects is dealt with in more detail, respectively, in pages 553 - 563.

By estimating the expected emission, transmission, immission and exposure, one can make a report of the environmental effect for an activity or for an entire area. However, in such a report, no policy will still have been formulated to restrict these effects.

A policy to restrict environmental effects

A policy of that kind must weigh-up the unwanted side-effects against the useful effect of the intended activity, or of the situation that has come into being, which can then be expressed in an environmental policy plan. A similar consideration occurs due to standardisation. Standards to reduce the damage that many objects suffer due to different human activities, originate in these objects. Initially, it can be established where the limits of damaging influences need to be set, in order to prevent that particular object from suffering an adverse effect.

Standards

This can lead to quality standards being set for the ground, water and air, that, in turn, lead to the setting of limits for emissions from a wide range of activities. Finally, one can bring about changes in the harmful activities themselves by linking the processing, the product, or the particular establishment as a whole, to standards and regulations. These are summarised in Fig. 1015[323].

STANDARDS, applied to:			
the source	the emission <----	the dispersing medium <----	the object <----
product standards processing standards	emission standards - emission ceilings	quality standards	exposure and immission standards
EXAMPLES OF NON-NUMERICAL STANDARDS (‘Policy starting-points’)			
‘Avoiding at the source’ (of the emission)	‘Combating at the source’ (of the emission) ‘Best technical means’ ‘Most practical means’	‘standstill’ principle	‘no effect’ ‘no adverse effect’
EXAMPLES OF NUMERICAL STANDARDS			
Lead content of petrol	max. 99.2 metric ton CO_2 per year in the Netherlands	average % of oxygen in the water	EPEL value

Fig. 1015 *Standardising to reduce adverse effects*

All standards contain a policy-based consideration of the useful effect of various activities compared with their unwanted side-effects. This is an economic consideration, which is examined further in Section 6.5.5, page 568.

Sanctions

This standardisation, intended as a feed-back system on human activities in order to prevent negative side-effects, must, of course, be achieved by sanction possibilities.

The Environmental Management Law offers the integral legal framework to accommodate these standards. The international, national, provincial and municipal environmental policy plan can play an important role in this. Whether the standards in the environmental policy plan must be adapted beforehand (by a licencing system), or afterwards (by environmental accountancy) is not yet of importance for the technical aspects of environmental hygiene. In both cases, these remain the same.

Sources of environmental stress

For the registration of emissions in an area, more facts about the sources are necessary.They can be gained according to Fig. 1016 (a further elaboration of Fig. 1014)

Sources	**Subdivision**
1. housing, temporary-stay recreation	1.1 households 1.2 encroachment onto public space 1.3 public green areas
2. traffic, infrastructure	2.1 cars and other petrol-powered vehicals 2.2 routes used for transporting dangerous substances 2.3 railways and other electrically powered routes 2.4 shipping 2.5 airways 2.6 cables and pipelines 2.7 beam transmissions (e.g. for radio and tv)
3. nature agriculture, forestry, nature recreation	3.1 natural areas 3.2 forestry 3.3 arable farming 3.4 glasshouse cultivation (incl. mushrooms) 3.5 open-air horticulture and fruit growing 3.6 animal husbandry, fisheries
4. business, day recreation	4.1 mineral exploitation 4.2 historical manual skills 4.3 industry 4.4 public utility companies 4.5 building industry 4.6 services
5. incidental activities	

Fig. 1016 *Overview of the sources*

In1977, the total emissions for all provinces in the Netherlands were estimated by means of collective registration, supplemented by individual registration. For example, for Gelderland, the emission registration for the four most important emissions gave the picture of Fig. 1017[324].

gram per day	Carbon monoxide CO	Sulphur dioxide SO_2	Nitrogen oxides NO_x	Hydrocarbons C_xH_y	per:
Housing	12	4	6	13	inhabitant
Traffic	200	8	54	48	inhabitant
Nature		869	32	690	km^2
Glastuinbouw	362	1346	317	43	job
Glasshouse cultivation	107	5	5	35	job
Firms	180	588	266	393	job

Fig. 1017 *Four important emissions per source category*[a]

The figures given above are clearly out-of-date, but the type of table made for different years provides comparative material for assessing policy. For the benefit of an initial global reference for emission factors for a particular area, one should use a more recent version of such figures (*http://arch.rivm.nl/environmentaldata/*).

Combustion emissions and other types of emission

Emissions occur due to the processing of fuels or raw materials. This causes combustion emissions and process emissions, respectively. Energy saving could lead to a significant reduction in combustion emissions. The following table gives some insight into the relation between both types of emission during the 1970s.[325]

		Combustion emissions	Process emissions	total
1Tg = 1000 000 000 kg = 1 mln ton		g/inhabitant/day	g/inhabitant/day	Tg/year*
carbon dioxide	CO_2	8920	90	46.04
carbon monoxide	CO	286	49	1.71
nitrogen oxide	NO_x	108	6	0.58
sulphur dioxide	SO_2	70	8	0.40
hydrocarbons	C_xH_y	33	25	0.30
aerosols, dust, soot		20	0.13	
hydrated calcium sulphate (gypsum)	$CaSO_4$		427	
salt	NaCL		67	0.34
sulphuric acid	H_2SO_4		22	0.11

Fig. 1018 *Relation between combustion emissions and process emissions*[b]

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[a] calculated from the Emission Registration for Gelderland (1977) and LEI statistics (1977)

[b] CBS statistics 1978; Emission registration 1974/1981; Hermans and Hoff 1982

Types of emission and environmental stress

To estimate the nature of the end effect and the manner of dispersal, the emissions need to be distinguished from each other, either by source or by groups of source, as in Fig. 1019 (an elaboration of Fig. 1014).

Types of emission	Subdivision	Examples
1. inorganic emissions	1.1 metallic 1.2 other inorganic	copper, lead, mercury CO, SO_2, NO_x
2. organic emissions	2.1 pure 2.2 halogenic 2.3 oxygenic 2.4 nitrogenic 2.5 sulphuric 2.6 metallic 2.7 other inorganic	methane, toluene, benzene vinyl chloride alcohols, esters amino acids thiols organic mercury organic phosphorus
3. mixtures	3.1 complex mixtures 3.2 aerosols 3.3 solid waste 3.4 microbic	BZV (biological oxygen consumption), CZV (chemical oxygen consumption), kjeldahl (method for measuring nitrogen) fly ash, industrial waste tetanus, botulism
4. energetic emissions	4.1 heat 4.2 sound 4.3 radiation, magnetic 4.4 radiation, radioactive 4.5 magnetic field	cooling-water traffic, industry light, infra-red, ultra-violet, radar, ether waves alpha-, beta-, gamma- high-voltage transmission lines
5. mechanical emissions	5.1 disturbance 5.2 small interruptions 5.3 substantial interruptions	treading on the ground, mowing, vibrations, up-rooting, digging ploughing, vandalism, clearing ground, building explosions
6. information emissions	6.1 visual 6.2 olfactory 6.3 others	horizon pollution bad smells misleading sounds
7. potential emissions	7.1 emission reduction 7.2 risk 7.3 variation in emissions	cloth filter, sedimentation plant, lpg (liquid propagaz) tank, (waste) storage day–night variations

Fig. 1019 *Types of emission*

Further information is given briefly below about a few of these types of emission.

Material emissions

Metallic inorganic compounds can produce accumulating pollution that is heavily poisoned. For water pollution, mercury and cadmium, in particular, and compounds of these substances, are on the black list. The black list is a European list of the most dangerous substances for the environment that may not be released in any quantity at all.

The other inorganic compounds include: *carbon monoxide, sulphur dioxide, nitrogen oxides, halogen compounds, phosphates and arsenic*. These include, therefore, the quantitatively most important emissions and the majority of the combustion emissions. Special attention is given to a few of these below.

Carbon monoxide (CO) is formed when combustion is incomplete. It is a poisonous, colourless and odourless gas. The total amount of CO throughout the world remains surprisingly constant, despite increasing (industrial) production. In addition, CO occurs naturally in the atmosphere, due to the oxidation of hydrocarbons. However, CO is effectively oxidised to CO_2, so CO only remains in the atmosphere for 0.1 of a year.

Sulphur dioxide (SO_2) is a colourless gas with a suffocating smell. It irritates the mucous membranes and the lungs, but, apart from this, it is not so damaging. It occurs naturally in the atmosphere, among other things as a result of volcanic eruptions. A high concentration of SO_2 is indicative of pollution by tiny particles (aerosols).
Sulphur dioxide is extracted from the atmosphere by oxidation to SO_3 , which reacts with water to form sulphuric acid (H_2SO_4). Together with other substances, this is the cause of acid rain.
This is the reason why more and more lakes in Canada, Scandinavia and the Netherlands have become sterile, why forests have lost their vitality or have been declared as dead, why heather has been taken over by grass, why wood and agricultural yields have declined and why our cultural heritage has been irreversibly harmed. A small part of the SO_2 is immediately washed out and absorbed by vegetation and water. The time that SO_2 stays in the lowest part of the atmosphere is in the order of a number of days, and, under certain conditions, a number of hours.

Hydrogen sulphide (H_2S) is a smelly, poisonous, inflamable gas, that irritates the eyes and the respiratory tissues. It is released into the air by natural bacterial decomposition processes, but also by many industrial processes. It disappears from the atmosphere via oxidation to SO_2 or due to the activities of certain bacteria. It remains in the lowest part of the atmosphere from a few hours to a number of days.

The nitrogen oxides (NO_x, i.e. NO, NO_2 and NO_3) originate from nitrogen and oxygen in the air at temperatures higher than 800℃. NO occurs in the first instance, but as it cools, it is partly transformed in the atmosphere to NO_2. NO is a colourless gas that, in itself, is not harmful.
The reddish-brown NO_2, on the other hand, is much more harmful due to its irritating effect on the muscous membranes. NO_x is finally oxidised to nitrate and stays for about five days in the atmosphere. NO_x, in combination with hydrocarbons, can form all manner of new compounds in the atmosphere that can contribute to 'photo-chemical smog'. This results, among other things in *'PAN'(peroxide-acyl-nitrate) and formaldehyde (HCHO).*

Of the inorganic halogen compounds, it is mainly the compounds with fluorine (F) and chlorine (Cl) that are important.
Hydrofluoride (HF) is a very corrosive, poisonous fluid, that, due to its low boiling point (19.4℃), is easily emitted as a gas (of importance as a potential emission from storage sites). It is a cumulative poison, i.e. it builds up inside organisms.
Chloride gases enter the atmosphere mainly as a result of industrial accidents and leakages, as an insecticide, or due to burning plastics.
The phosphates are mainly important in water pollution. They can cause such an enormous richness of food in the water that it becomes devoid of oxygen.

Organic emissions

Organic ammonia (NH_3) occurs especially in the bio-industry. It stays for about seven days in the atmosphere.

Of the *hydrocarbons* in the atmosphere, only about 15% originate from human activities. However, this amount has another composition, and is concentrated in a relatively small area. The natural hydrocarbons come from the decomposition of organic material and emissions from plants, especially certain trees. Above pine forests and citrus cultivations a haze can often be seen due to photo-chemical smog formation. The majority of hydrocarbons disappear from the atmosphere due to photo-chemical smog formation. They remain for quite a long time in the atmosphere; methane (CH_4), for example, remains there for about four years.

However, the length of time that these substances remain in the atmosphere is dependent on reactivity. A total of 150 different hydrocarbons have been identified in car exhaust gasses. They are released mainly due to incomplete combustion and by evaporation. From the many different hydrocarbon compounds, a number of examples are given below.

The group of *halogenic hydrocarbons* contains a large number of black-listed substances, such as alpha-, beta-, gamma- *hexachloro-cyclohexane*, the PCBs (polychloro-biphenyles) and *PCTs* (polychloro-therphenyles), hexachloro-benzene, hexachloro-butadiene, pentachloro-phenol and trichloro-phenol.

The chlorofluoro-hydrocarbons (CFKs, such as freon) belong to the halogenic hydrocarbons. They are used in cooling systems, as a propellant in spray cans, and are not poisonous in themselves. However, they can harm the ozone layer of our atmosphere, so that there would be no resistance any more to ultra-violet rays. [326]

The **other material emissions** include complex mixtures, aerosols, dust or particulate matter in the air, solid waste and free-coming bacteria, viruses (sick buildings!) or genetic material.

Mixtures

The complex mixtures include a large number of emissions from mostly organic material that can be largely biologically decomposed, and therefore their exact chemical composition does not need to be known. For these complex mixtures, standards are used such as BZV (biological oxygen consumption), CZV (chemical oxygen consumption) or the Kjehldahl method for measuring nitrogen.[327]

Areosols

The aerosols are tiny solid and/or fluid air-borne particles that have such a slow rate of fall that they can be considered to float or drift. They originate naturally, enter the atmosphere through combustion processes, or are formed in the atmosphere by chemical reactions (e.g. by photo-chemical smog). Rain or snow is formed by condensation and sublimation, respectively, on the aerosols. Compared with the air over oceans, the average pollution of the air over rural areas by aerosols is ten times higher. Above small towns, air pollution by aerosols is 35 times higher, and above large cities 50 times higher than over the oceans. In unfavourable situations, this figure can increase to 4000 times or more.

Fine dust or particulate matter (PM)

Fine dust or particulate matter in the air (particles <10μm notated by PM_{10}) of different substances could be dangerous for human health. That is why the European standard from 1st of January 2005 is maximally 40 $\mu g/m^3$ average *per year*, with maximally 35 times per year a *24-hour average* exceeding 50 $\mu g/m^3$. Enduring exposition seems to be more dangerous than short exposition, but in 2005/2006 many Dutch building projects were rejected by jurisdiction based on measurements and prognoses of exceeding the short 24-hour average exposition standard. However, a distinction should be made in more dangerous fine (0.1 - 2.5 μm, deeply penetrating the lungs) and less dangerous coarse mode (2.5 - 10 μm) particulate matter and their composition concerning health-effects varying over Europe.

[a]*'Inorganic ions nitrate, sulphate and ammonium sum to 34% of PM mass and the measured organics from combustion processes up to 2%. Rough estimates of the traffic contributions of these two fractions vary from 30% to 60%. In the framework of the project 'Health effects of particles from motor engine exhaust and ambient pollution - HEPMEAP', a unique European collaboration between toxicologists and epidemiologists, ambient particulate matter (PM) was collected at various sites across Europe during the periods November 2001 and March 2003. The HEPMEAP project studies the relation between the composition of particulate matter, and the toxicity and health effects. Besides strong similarities, PM samples from these various locations/sources show substantial differences in chemical composition. For example, samples from the rural location in Northern Sweden were highly dominated by organic matter, most likely originating from wood combustion.'*

In The Netherlands natural salt spray particles from the sea vary around 7 $\mu g/m^3$ along the West Coast until 3 $\mu g/m^3$ in the Eastern part of the country. So, since August 2005, dependent on the location from West to East a municipality may subtract 7 to 3 $\mu g/m^3$ from the measurements to reach the maximally 35 days exceeding the 50 $\mu g/m^3$ 24-hour average.[b]
If you subtract this harmless part of particulate matter, the European picture becomes less threatening (see *Fig. 1020*).[c]

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[a] *http://www.rivm.nl/bibliotheek/rapporten/863001002.html*

[b] http://www.vrom.nl/get.asp?file=Docs/milieu/200508_meetvoorschriftluchtkwaliteit2005.pdf.

[c] *http://www.tno.nl/tno/actueel/magazine/bouw_en_ondergrond/2006/juni_2006/beno_2_2006_16.pdf?__lang=nl*
http://www.tno.nl/tno/actueel/magazine/2006/june_2006/em_2_2006_18.pdf?__lang=nl

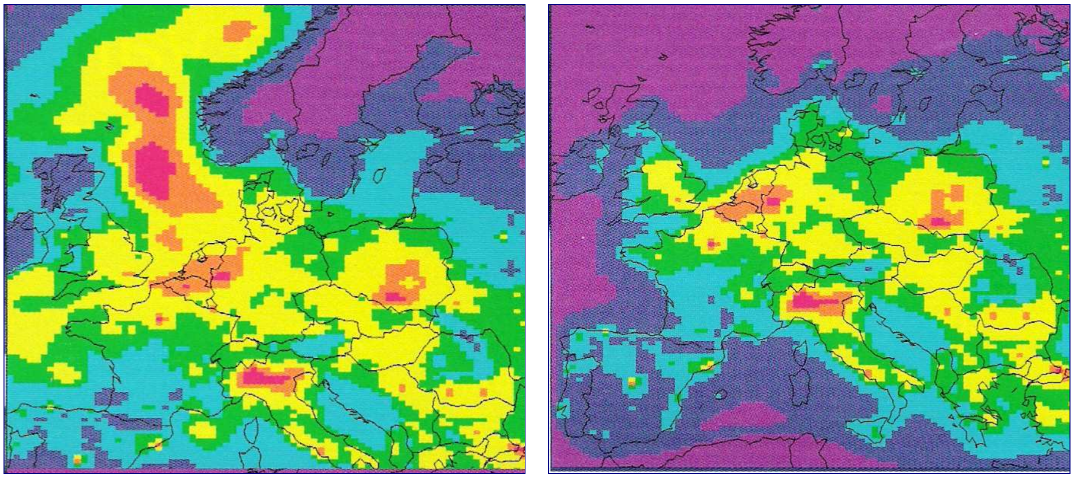

Fig. 1020 Calculated PM10 concentrations with and without salt spray particles in Europe[a]

In 2006 more recent measurements changed the expectation of PM10 values in 2010 dramatically (see *Fig. 1021*).

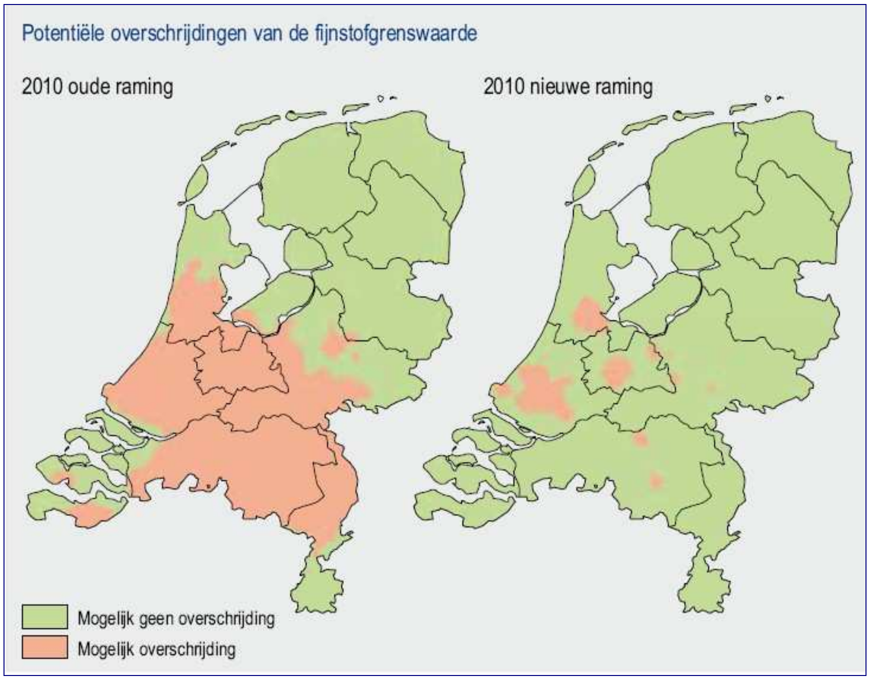

Fig. 1021 2005 (left) and 2006 (right) prognoses of exceeding European standards for particulate matter in 2010[b]

A more precise evaluation of health effects of different PM components may change the imminent social and economic effects of these standards up to now even more.
Kuypers (2006)[c] claims plantation can clean the urban air. A tree could take the equivalent NO_2 and PM_{10} of a car driving 10 000 km.[a]

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[a] LOTOS-EUROS computer model, TNO magazine, june 2006

b http://www.rivm.nl/bibliotheek/rapporten/500093003.pdf

[c] Woestenburg (2006) Naar een zelfreinigende groene stad in: Het kwartaaltijdschrift van Wageningen Universiteit en Researchcentrum Nummer 2, Juni 2006

Energetic emissions

Energetic emissions include warmth, sound, electromagnetic and radioactive radiation, and changes in the magnetic field. With the exception of radioactive radiation, in so far as it originates from radioactive substances that are dispersing, this is a form of emission, the spread of which is very predictable. If these emissions occur, it is known that almost all objects in the vicinity will be subjected to immediate exposure. Because of that, in measuring emissions (as in the case of sound), certain aspects of the exposure can already be included. The unwanted side-effects of energy-in-motion emissions can, on the basis of a named characteristic, best be controlled within the framework of spatial planning.[328]

Mechanical emissions

Mechanical emissions, such as disturbances, small and substantial interruptions, are, within the framework of environmental hygiene, not generally considered to be ‘emissions’. They are a part of the working field of spatial planning, ‘urban management’ and nature conservancy. However, logically and systematically, they fit in with an overview of types of emission and environmental stress, such as that shown in Fig. 1019. These emissions can also be largely controlled using spatial planning regulations.

Information emissions

Information emissions include all influences that disturb the functioning of our ability to form images by sight, smell, taste, touch, balance, and voluntary movements. They are subjective, difficult to measure, and traditionally belong partly to the working field of spatial planning. However, a lot of research still needs to be carried out in this area. For example, if symptoms of psychiatric illness could be linked to urban living conditions (e.g. in the form of sensoric or motoric overloading or deprivation), then interesting new requirements could be placed on urban surroundings.

Potential emissions

Potential emissions include emission-reducing regulations, risks[b] and variations in emissions. Emission-reducing regulations and risk management are part of the continuing responsibility of all engineers.[c] The variation in emissions makes it somewhat more complicated to set standards than to fix an average. Local and temporary periods of peak stress are, after all, the most dangerous. Variations in stress can be cyclical, subject to trends, and/or can increase abruptly, in leaps.

6.5.3 Transmission

Transmission is especially important for material emissions. It contains the propagation of energetic, mechanical, informational (noise) and potential influences (risk) and of material by air, water, the ground or via food-chains, mainly the territory of specialists and extensive computer programs. Transmission includes the transport, dilution, dispersion, conversion and removal of material in and out of the air, water, ground, food-chains and other relocating systems.[329]

Air pollution

We will go into the spreading of air pollution the most thoroughly below. In addition, ground and water pollution is partly a result of pollution in the air, so that, also from this view point, priority must be given to gaining a better understanding of air pollution. In this respect, it is important that a distinction is made between vertical and horizontal air movements.

Where there are no vertical air movements in a stable atmosphere, pollution stays at low levels and can become highly concentrated locally. Horizontal air movements are important in predicting where air pollution will occur. For water pollution, especially important are the horizontal displacements, and only in the case of deep lakes or seas do vertical displacements also play a role. The displacement of ground pollution is largely dependent on ground water currents, and possibly on human transport.

Vertical air movements

The sun acts as the motor for all air movements. Sunlight is partly intercepted by the atmosphere and, especially in the higher layers, warms it up. The lowest layers of air receive their heat mainly from the

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[a] Woestenburg (2006) Naar een zelfreinigende groene stad in: Het kwartaaltijdschrift van Wageningen Universiteit en Researchcentrum Nummer 2, Juni 2006

[b] The chance of effects is called risk (popular formulated chance times effect). The risk approach is starting point for standardization and is extensively dealt with in the parallel lecture on security policies (Hale)

[c] Memorandum 'handling risks', published simultaneously with the 'Nationaal Milieubeleidsplan'

surface of the earth, which is warmed up during the day, releasing its heat again by radiation at night. Because of this, the lowest layer of air (to about a height of 10 km), the troposphere, has, in principle, an upwards-decreasing temperature. However, the stratosphere, that lies above it, becomes warmer in its higher levels. If rising air comes into contact with warmer layers of air, it stops rising. There is thus little exchange between the troposphere and the stratosphere, also with respect to air pollution. The troposphere is approximately 10 km high and contains about 80% of the total mass of the atmosphere. This is where almost all weather phenomena occur; this is where the largest warming up and cooling down takes place, and where the air pollution increases and decreases due, respectively, to emissions being released and washed away.[330]

Polluted air remaining low

Warm air rises until the surroundings become warmer, but, in retaining its own heat content, rising air also cools off due to expansion. This cooling off process amounts to about 1℃ for every 100 m that the air rises.[331] An air bubble warmed up by the surface of the earth that is 2 degrees warmer than its surroundings will thus rise 200m if the surroundings of the air bubble stay the same, and it will rise more than 200m if the surroundings become colder.

It is clear that if the lowest part of the troposphere has become relatively warm because of a number of hot days, there will be very little rising air, so that the air pollution will stay below. One can talk then of a stable atmosphere. Especially after the night time cooling off of the lowest layers of air due to radiation from the earth's surface, temperatures, that rise with height, can occur the next morning.[332]

Inversion

If a chimney doesn't rise above the point where the temperature starts to go down again, as is normal in the troposphere, then the smoke stays held in the lowest layer of air, because the surroundings are too warm to allow the air to rise. Such a situation is called *inversion* (an inverse temperature gradient).

In the course of the day, a rise in temperature in the lowest layer of air can cause the inversion to disappear. However, that does not happen if there are clouds in the sky, or if the rise in temperature is insufficient to make the lowest layer of air much warmer than the layers above it. Because of this, an inversion can last for several days.[333]

Moisture

The amount of moisture in the air is just as important for the development of vertical air movements. Moist warm air, rising from the surface of the earth, cools down by expansion and, above a certain height, loses its moisture by condensation. This condensation produces heat that causes the air to rise further and then to cool down further, thereby producing more condensation. The height at which condensation begins forms the flat underside of the cloud layer.[334] Thus, because of the heat development that then occurs, a loss of moisture can cause the air to rise even more.

Horizontal air movements

At ground level, the air is warmed up the most in the tropics and the least at the poles. Because the air in the tropics is continually rising, warm air moves northwards in the higher layers, partly due to it cooling down over the subtropics, and then it sinks to the lower layers of air in our latitude (see Fig. 220). The continually sinking air at the poles produces a cold northerly wind, that meets the warm humid air masses from the south in our latitude. This results in a lot of condensation and precipitation in our latitude, in cold polar air wedging its way under rising warm air until this too is heated up by the earth's surface. Because of this, the polar front in our latitude produces a much more turbulent weather pattern than elsewhere.[335] On the one hand, this is good for the mixing and dispersion of air pollution, but it also makes air pollution less predictable than in tropical or polar climates.

Southwestern winds

The sun rises in the east because the earth rotates eastwards. The atmosphere rotates with the earth. Therefore, in contrast to polar air masses, tropical air masses have a strong eastward impulse. As they move towards the north, this eastward tendency persists, so that tropical air in our latitude comes mainly from the southwest. As relatively stationary polar air masses move southwards, they become increasingly confronted with the earth's rotation and thus have a tendency to move westwards in relation to the earth's surface. Because of this, in our latitude, cold polar air masses come mainly from the northeast.[336]

Polar front

The eastward tendency of the tropical air and the westward tendency of the polar air, when they meet in our latitude (the ‘polar front’), cause air movements that circulate in an anticlockwise direction.[337] In low pressure areas (depressions), into which the winds always blow, this is usual. That means, for example, that the winds are southerly if a depression lies to the west of the Netherlands, and northerly if the depression lies to the east. Based on this, a number of frequently occurring circulation patterns can be identified for Europe, and their frequency over the years can be established statistically.
From this, statistical indicators have been formulated of expected weather types, and these can be applied to dispersion models for air pollution.

Coastal circulations

A very frequently occurring type of circulation, on a smaller scale, occurs systematically in coastal regions. Because of the alternation between day and night, there is also an alternation here between sea and land winds. A sea wind occurs along the coast when the sun shines strongly and, due to this, the land warms up faster than the water, causing a difference in air pressure. At night, the land cools off faster than the sea, causing a wind to blow from the land, seawards.[338]

Turbulence

Based on climatological factors, regularity in wind direction, as mentioned above, applies to flat, open spaces, but not to built-up urban areas. Very many smaller circulations occur there that are summarised by the concept ‘turbulence’. Where there are eddies behind buildings, the only way of predicting turbulent air movements in these urban areas to any extent, is to place maquettes in wind tunnels, on a revolvable platform. To carry out very exact tests on them, such maquettes must be built by specialists, because it is very important to simulate the roughness of the material and it is impossible to position gauge points on a normal maquette.[339]

Mathematical models of wind circulation

For sources in relatively open areas, mathematical models can be applied. One can distinguish pollution-point sources, such as chimneys, line sources, such as main roads, and surface sources, such as an industrial sites. The most frequently used dispersion model is the Gaussic Plume model, of which there are a number of variations. In addition, there are ‘grid models’ and ‘trajectory models’ as described in KNMI KNMI De Bilt (1979). In the Gaussic Plume model, it is assumed that air pollution is dispersed perpendicular to the direction of the air movement, according to a statistical distribution.
Grid models divide the space into box-shaped units, by means of a co-ordinate system whereby the input and output is calculated per box.
Trajectory models are based on forward-moving box-shaped units of air, each unit of which has input and output values.[340]

Concentration of air pollution

The concentration of air pollution substances can be shown in three different ways:[341]

- volume/volume (unit ppm)
- weight/weight (unit ppmm)
- weight/volume (µg/m^3)[a]

RIVMs national gauging network for air pollution was drastically modernised in 1985 and now comprises 68 gauge points. In addition, TNO manages ten more points, and the provinces and municipalities 80 and 20, respectively.

Deposition

Apart from the dispersion of air pollution, the fall-out (deposition) of particles and the washing out of air polluting substances in rainwater, chemical changes in the air pollution itself also play a role in the total transmission of air. However, not much is yet known about these processes. Most of what is known concerns photo-chemical smog, in which mainly the chemical composition of combustion emissions changes under the influence of light.

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[a] The term µg/m3 stands for one million gram (microgram) per m^3

Smog

Photo-chemical smog mostly occurs as a result of 'ground inversions' caused when the lowest layers of air cool down faster than the layers of air above. Because of this, condensation occurs in the lowest layers of air (fog), and, as there is an inversion, the pollution also stays trapped in these layers. Aerosols serve as nuclei for condensation and the drifting drops of water catch the remaining pollution, whereby all manner of reactions occur. The formation of ozone (O_3) under the influence of sunlight can play an important role in these reactions. However, compared to water pollution, chemical and biological reactions in air pollution do not play such a large role.

Water pollution

Pollutants enter water by deposition from the air, by draining out of polluted ground and by direct discharge. Thus, in the pattern of currents in a river, one can find pollution-surface sources on the surface of the water, line sources along the banks and point sources at the location of the discharge. Apart from these sources of pollution, the following means of 'removal' also play a role:

- extractions, removal to groundwater, to tributaries;
- reactions of a physical, chemical or biological nature.

Based on this input and output, a balance can be drawn up for each stretch of river. As one can talk here of a one-dimensional current movement, the concentrations can be calculated using rather simple models. However, after 1965, models were developed that could also handle two-dimensional situations (as in shallow lakes, bays and harbours).

Mathematical models of water pollution

Insight into bio-chemical processes also became more advanced. Before 1965, already, the models took into consideration the deterioration of dissolved oxygen and the decomposition of organic material from waste water. Between 1965 and 1970, the oxidation of reduced nitrogen compounds was also included in the models. Between 1970 and 1975, three-dimensional situations, such as deep lakes and seas, were included in the models. The water masses were thereby divided up into layers (stratification). In addition, the growth and death of algae, and the physiological reaction of organisms to temperature, sunlight and the availability of food materials were described. After 1975, the behaviour of toxic substances in biological processes (among others, their accumulation in the food chain) was researched, as well as their transport on floating particles and sediment.[342]
Because of the increasing complexity of the models, it has to be recognised that their reliability is decreasing. For this reason, one-dimensional models are still being used.[343]

Ground pollution

In chapter 6.6 Soil pollution, page 577 and further you can find a more comprehensive treatment. Here we restrict to some fundamentals. Ground pollutants can be transported in the ground water. They can held and removed by absorption into soil particles, precipitated by chemical processes and dissolved again, and (partly) decomposed by micro-biological processes, especially in the thin zone that is not completely saturated with water.
The speed, direction and depth of a groundwater current depends very much on the type of soil and the variation in subsoils. In principle, three-dimensional current models are available for this, but these need to be fed with an extremely large amount of detailed information about the subsoils. This information is largely unavailable, so one has to make do with simpler current models. For regional studies, in particular, taking the relatively limited depth of the water transporting systems into account in relation to the extent of the region, a calculation in two dimensions is usually sufficient.[344]

Absorbtion

The speed and direction of groundwater currents are, of course, initially dependent on the type of ground. For removing pollution by absorbing it onto the surface of soil particles, the specific surface area of a solid soil particle is important. For clay, for example, this is larger than for sand. The more acid the environment, the more difficult it is for pollutants to attach themselves to the soil particles. Acidity, therefore, leads to some pollution of the groundwater. In addition, of course, as time goes on, the whole surface area can become saturated, so that larger amounts of pollution come to be transported in the groundwater currents. In that case, certain substances can still be precipitated out of the water or dissolved into it again. The solubility of chemical substances is also dependent on the acidity (pH) and on the 'redox potential' (Eh).

Conversion

Micro-biological decomposition and conversion processes are generally the most effective in the thin zone that is not completely saturated with water. Especially in the transition zone, where the presence of oxygen may or may not still play a role, can anaerobic decomposition processes (without oxygen) be of great significance. Among the well-known micro-biological conversion processes are nitrification, denitrification and sulphate reduction.

Data

For a quick orientation regarding the possible risks of extending pollution that has appeared on or in the (water) bed, reference can be made to archive information (van Duijvenbooden 1982). Among other sources of information, reference can be made to:

- geological maps
- ground maps
- topographical maps
- hydrographic charts
- geo-hydrological mapping (surface contour charts, seepage/infiltration charts, quality charts)
- geo-electrical mapping
- individual reports and data.

By studying the information listed above, a preliminary insight can be gained of the local direction and speed of the groundwater currents. If information on substances is available, then it is also possible to estimate their transport.

Points of interest

Attention should be given, among other aspects, to: [345]

- the structure and composition of the soils (clay/peat with low *k** and high CEC; sand with large *k* and low CEC, pH, redox; and the mud and organic-material content);[a] [346]
- the geological structure (presence of pockets of sand in contrast to layers of clay, heterogeneities, holes, stratification);
- the hydrological situation (seepage/infiltration, current direction and speed, location of the watershed, drainage or infiltration channels);
- topography (on the basis of height characteristics, gives a first impression of the probable current direction).
- If necessary, extra information can be collected in the field (van Duijvenbooden 1982).

6.5.4 Immission and exposition

Exposed objects

Determining the end effect (see Fig. 1014) is the final and most difficult part of every environmental-impact statement. The first thing that has to be established is which objects situated in the neighbourhood of the environment-damaging activity are the ones on which the effects have to be determined. In this section, the types of object distinguished are materials, people, plants and animals, (eco)systems, or entire areas. When there is no clear prior agreement regarding on which objects the effect has to be reported, there will always be criticism afterwards on the effect report that is delivered. If one already has a list of objects on which one has to report, then the question still remains of which effects have to be reported.

Damage

If the object is people, then one can still distinguish absolute effects (such as the mortality rate) from gradual effects (such as the illness rate). To be able to view the effects against each other and against the useful effect of an environment-damaging activity, it is desirable, though usually impossible, to quantify it to a common denominator. Of course, especially in the United States, frequent attempts have already been made to express the damage caused by environment-damaging activities in terms of money. The table below pictures this for the Netherlands (1978).

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[a] k and CEC are measures for the adsorption capacity of the soil type. For k is true: low value means high adsorption. For CEC is true: high value means low adsorption

Damage to	mln.guilders	no. guilders per inhabitant
materials	110	8
health	1000	71
commercial crops and livestock	85	6
lost residential value	1400	100
total estimative damage	2600	185

Fig. 1022 Damage due to air pollution in the Netherlands estimated in 1978[a]

Costs of damage

The most reliable datum in this table is ‘damage to materials’. The way in which ‘damage to health’ is calculated is already indicative of the dubious assumptions that have to be made when expressing this damage in terms of money. The costs of early death were estimated as the (discounted) income that the deceased would have earned had there been no air pollution. The amounts used to arrive at the costs of illness were ‘loss of production’ and ‘the costs of curative care’.

There are, though, three methods of approach for damage due to death:

1. The ‘human capital’ approach;
2. The ‘costs of risks’ approach;
3. The comparison with costs made to prevent unnecessary death.

The method used in *Fig. 1022* is the ‘human capital’ approach. For the second approach, wage differences – that can be interpreted as ‘risk surcharge’ – are used as the point of departure. To determine the value of a life, the extra wage paid for a 1% higher death risk is, for instance, multiplied by 100. The third approach ought to be based on the amount that the Dutch society is prepared to spend on ‘the most expensive patient in the Netherlands’.
For example, a vaccine should not cost more than € 18 000,- per life year gained (NRC Handelsblad 2003-07-06).

Distinguishing the environmental part of damage

It must be clear that, even if the nature of the effect can be described clearly and unambiguously, it is usually difficult to quantify[347]. In addition, it is difficult to separate the effects of environment-damaging activities from other influences. In this way, the ‘lost residential value’ in *Fig. 1022* is estimated on the basis of differences in house prices observed in transactions in Rijnmond. However, the house-price differences are also dependent on house characteristics (type of home, house size, year of construction, with garden, etc.) and the characteristics of the district in which the house is located (green facilities, nearby shops, noise levels, accessibility, etc.)

To be able to determine the effect of a home located in a foul-smell zone from these fixed variables, complicated regression analyses and daring assumptions are necessary. Instead of 1.4 billion guilders, a few changes in the assumptions would have given 1.7, 2.4 or 3.3 billion guilders as the lost residential value in the Netherlands. [348]

Dose-response of living objects

The effect of environmental pollution on living organisms can be shown in the form of a dose-response diagram (Fig. 1023).

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[a] Jansen en Olsthoorn (1982), Jansen et al (1974)

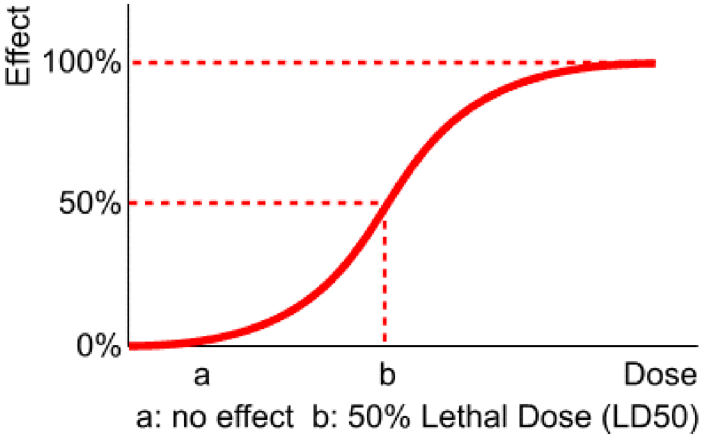

Fig. 1023 Dose-response relation

A similar diagram can be drawn for poisoning a large number of individuals with different doses. The dose that causes death in 50% of the cases, within a given time, is called ‘the lethal dose at 50%’ (LD50).[349]
It is clear that dose-effect relations are only known for a small number of substances on a small number of organisms. It is, of course, difficult to establish the dose-effect relations for human beings empirically, so there are still many knowledge gaps in this area.

Material damage

Research has established that the worst damage to materials is brought about by the action of SO_2 on painted steel, galvanized steel and on zinc foil. Research (*Fig. 1024*) was set up by Jansen and Olsthoorn (1982) consisting of:

- Measuring the concentration of SO_2;
- Determining the exposed quantity of materials;
- Establishing the dose-effect relations;
- Making an economic evaluation of the effects.

In this research, only maintenance costs, the costs resulting from reduced economic lifespan and substitution costs were taken into account. Indirect costs (for example, those resulting from the failure of affected parts) were not taken into account.
The costs listed above were estimated using a number of formulas by which, if the concentration of SO_2 in the air is known, the reduction of the galvanized layer, the length of protection of the paint layer, or the lifespan of the construction part were derived. These sorts of formula, in fact, represent dose-effect relations. Recalculated as costs and added up, it is possible to give a dose-effect relation for the whole of the Netherlands.

Doses in mln.kg SO2	Effect of damage in mln. guilders.	Dose per inhabitant kg SO_2	Effect per inhabitant Damage in guilders.
1300	225	93	16
1200	177	79	13
1000	151	71	11
900	123	64	9
800	92	57	7
700	74	50	5
600	56	43	4
500	40	36	3
400	25	29	2
300	18	21	1

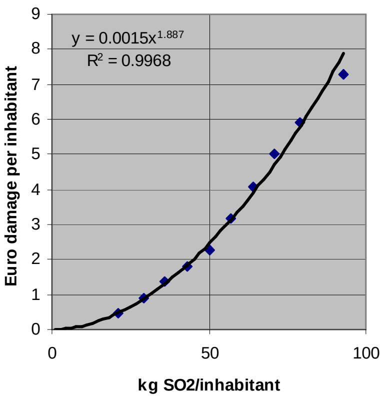

Fig. 1024 Dose-effect relation of SO_2 on a range of metal constructions in the Netherlands (1978)[a]

This dose-effect relation is thus composed of different dose-effect relations that are only related to a certain material part of the damage not including health effects.[350]

Toxicology of people

For people, the lethal doses of a lot of poisons are known, as well as many of their clinical characteristics and side-effects (the absolute and gradual effects). The branch of medical science that concerns itself with poisonings is 'toxicology' see: Sangster (1987).[351] The process by which humans take up, re-absorb, transform, apportion, store and excrete poisons can be summarised in the following diagram.[352]

Contrary to materials, human beings, animals and plants can develop resistance to repeated exposure to poisons. However, a slow build-up of toxins is equally likely to have sudden, serious consequences. In addition, the effects of different types of pollution can be increased by their interaction. One example of this is evidenced by smokers' increased susceptibility to the adverse effects of air pollution. As a rule of thumb, one can say that if air pollution increases by 10%, the mortality will increase by approximately 1%.[353]

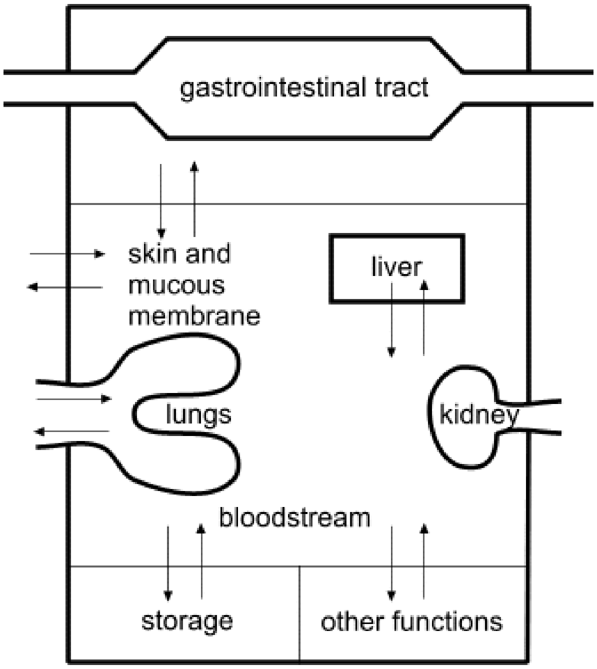

Fig. 1025 Toxicological access routes into the human body[b]

Historical disasters

As the literature on toxicology is fairly easy to access, we will restrict ourselves here to human exposure to a few historical cases of severe air pollution (*Source*: KNMI 1979)

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[a] Figures per year, calculated according to Jansen and Olsthoorn (1982)

[b] *Verberk and Zielhuis (1980)*

In December 1930, the narrow and heavily industrialised Meuse valley, in the neighbourhood of Leige, experienced weather conditions, which – for almost a week – hindered the spread of the pollution produced there. The result was that a large number of people became ill due to respiratory problems, and, before the end of that week, 60 people had died. It is not clear whether very high concentrations of sulphur or florides were the cause of the disaster, because no pollution measurements were taken at that time.

A disaster that has been extensively researched is the one that hit the small town of Donorain in the valley of the River Monongahela in the State of Pennsylvania in the United States in 1948. Also here, unfavourable meteorological conditions, together with the hills that encircle this industrial town, hindered the dispersal of air pollution. The result was that thousands of people became ill, mainly with respiratory complaints and problems with the eyes, nose and throat. During this 7-day period, 20 people died.

Even worse was what happened in London from 5-9 December 1952. The majority of Great Britain was covered in fog at that time. Elderly people in particular became ill, suffering from heart problems or respiratory difficulties, and had to be taken to hospital. Even after the worst period of pollution had subsided, more deaths occurred than was usual for December. The total number of deaths rose to between 3,500 and 4,000 above the usual number of deaths in December. The extremely high concentrations of soot and sulphur dioxide were probably the cause of this disaster

In the Netherlands, air pollution has not led to a *demonstrable* number of deaths (that is something else tnan calculated decrease of lifetime-expectenace or brain performance), but there were obvious increases in the numbers of both illnesses reported and hospital admissions, such as in the period 26-30 January 1959 and 4-6 December 1962. In Rotterdam, in 1959, the amount of smoke in the open air, and, in 1962, the sulphur dioxide concentrations, reached extremely high levels. In both these cases, too, it was long periods with no wind and bad vertical exchange that caused increasing concentrations of toxins in the air.

Plants and animals

Hardly anything is known about the extent to which material pollution has caused the disappearance of plant and animal species. For a number of species, such as lichens, a clear link can be made with air pollution. The extinction of plants and animals is largely due to the loss of their biotope. This is mostly caused by light and heavy mechanical interferences, such as agriculture, urbanisation and road building. For instance, lowering the water level of ditches can cause a significant reduction in the diversity of vegetation.

However, a correlation does not always have to be a causal relation. The distance to a farm and the related reduction in agrarian activities can also offer a better explanation for local diversity, even if there is already a correlation with the water levels in drainage ditches. Water levels in themselves can correlate with the distance to the farm, if that farm is situated on higher ground so that the water level in the nearby drainage ditches is deeper than in those further away.[354]

Systems and areas

The effect of various forms of environmental stress on eco-systems and related geographical areas or utility zones is largely unknown. The effect of the ‘mechanical emissions’ named in Fig. 1019, such as treading on the ground, mowing, up-rooting, digging, ploughing, clearing the ground, and building, is the easiest to determine.

The vulnerability of different geographical units to light or heavy interferences is recorded on environmental charts. Vulnerability charts are compiled to show the vulnerability for each environmental theme. More will be said about this in the following section. The old objections to environmental charts are, that these divert attention away from the interferences, their alternatives and effects, so that only alternative locations are discussed. These are less of an issue now that the instrument of environmental impact assessment (MER) is available. Although by far not everything is known about the environmental effects on plants, animals and ecosystems, an interesting part of the MER series has been published, entitled: Effect prognoses. Part V: ‘Plants, animals and ecosystems’.VROM/LNV (1987)

6.5.5 Creating standards

Effect-directed norms

In the previous sections, the unwanted side-effects of the activities summarised in Fig. 1016 are described. Effect reports can be compiled along these lines. However, in this section, the focus is no longer on ascertaining the effects, but on the policy-wise reduction of those effects

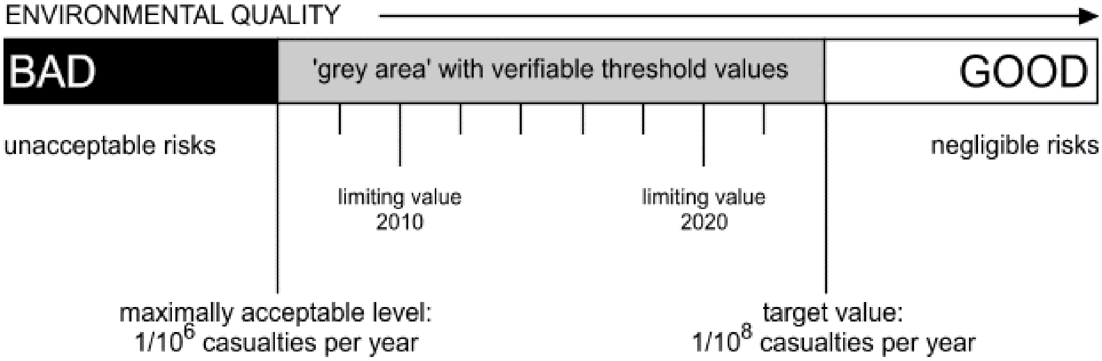

Fig. 1026 *Threshold, limiting and target values*

Accepted risks

The starting point is the end effect on people, ecosystems and economic functions, as shown in the previous diagram. In the totality of risks, to human beings an individual chance of dying of 10^{-5} per annum is accepted by government; the *maximal acceptable level of risks*. For each single activity or substance, the maximal acceptable level is 10^{-6} per annum.[355] For illness (effects with a threshold value) comparable levels are given, as well as for disturbance resulting from noise or foul smells. For ecosystems, a similar sort of approach is developed. The maximal acceptable level is achieved when the concentration of a substance is the same as the calculated concentration, whereby protection is offered to 95% of the species in an ecosystem. However, in many cases these norms appeared to be unattainable (RIVM 2003).

Negligible effects

It is assumed that below 1% of this maximal acceptable level the effects are negligible. This marks the target value of all emissions and environmental effects: the value that should be eventually achieved[356]. Between both levels there is a so-called ‘grey area’ within which targets for a certain period can be formulated using verifiable threshold values[357].
As soon as these threshold values have gained the legal status that they may not be exceeded, they are referred to as ‘limiting values’[358]. If such values may only be exceeded when reasons are given, then they are referred to as ‘guide values’[359]. Before these values are fixed, one can refer to them as environmental quality targets[360], and after that, as environmental quality requirements[361].

Target values

As a target value can only be reached in the longer term, for the shorter term, one can fix lower limiting values for what must be achieved during a certain year as an interim step towards the year in which the target value has to be achieved. An example of environmental quality targets is the table of target and limiting values of priority substances from the first National Environmental Policy Plan (see Fig. 1027).

substance	target value	limiting value	average	concentration around the sources	% reduction for the benefit of the target value	% reduction for the benefit of the limiting value	reference
trichloro-ethene	50	50	0.65	80	35-40	35-40	IMP
surface water	0,1		2,0		95		1987
tetrachloro-ethene	25	2000	1,0	30	20		IMP
surface water	0,1		3,5		98		1987
benzene	1	10	2	40 (185)	97,5	75	base doc
phenol	1	100	0,008	2	50		MP
etc							

Fig. 1027 *Target and limiting values of priority substances and the percentages of necessary reductions in emissions that result from this. Amounts in ?g/m^{3} for air (or ?g/l for water)*[a]

Time to reach target values

Regarding the priority substances, after thoroughly studying the effects of each substance, target values will be prepared in a ‘basic document’ for the general environmental quality of water, ground and air. In the grey area, for phasing the policy, limiting values must be fixed that indicate how far the protection will extend during the period agreed. This takes place on the basis of an economic consideration.

Weighting costs and environmental quality

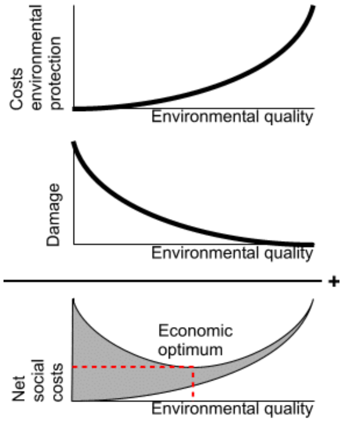

Fig. 1028 *Net societal costs after deducting environmental damage*

The costs of this protection increase progressively with the quality of the environment that we want to achieve in this way. It is not always possible to achieve an immediate recovery of environmental quality to the target value. One only has to think of the amounts of money involved in soil decontamination to understand that complete recovery of environmental quality not only financially, but also technically, takes time to achieve.

Limiting values include a consideration whereby the damage to exposed objects is weighed against the economic interests associated with the activities involved.

In so far as this damage can be expressed in terms of money, this consideration is rather simple. After all, the costs of the damage can be added to the costs of protecting the environmental quality for every protection level imaginable. From this, for a certain threshold value, an economic optimum is obtained.[362]

Threshold values

However, in section 6.5.4, it became clear how open to interpretation the concept ‘damage’ is, and how dependent this is on the value we place on the protected objects. In addition, the graph does not run as continuously as in Fig. 1028. Locally, a small additional protection effort can suddenly save a species of fish. These sorts of quality aspect are therefore expressed as verifiable threshold values. For example, a threshold value can be established for the oxygen content of water, above which a species of fish will certainly survive.
A legally established limiting value will go further than the economic optimum, as other values are also taken into consideration than those that can be expressed in terms of money.

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[a] VROM (National Environmental Policy Plan) (1989) page 141

The limiting value can be established regionally; it can also be differentiated according to different functions (special environmental quality). Special environmental quality is the opposite of 'general environmental quality'. Based on separate general protection levels for drinking water, inland fisheries and shellfish, norms were established in, for instance, the Indicative Long-term Water Programme (IMP Water). Each of these protection levels is based on different criteria.

Different supposed uses of damaged objects

The criterium for fishing water can thus be a dose-effect relation for a certain species of fish and a certain form of pollution. Also the consumability of the fish that will be caught can be used as a criterium for the quality of the water in which the fish will have to be caught. It is clear that the criterium for drinking water will be different again from that needed for fish.

Levels of standards

Setting norms takes place on different managerial levels, beginning with the European level. The higher the managerial level and the larger the area over which the norm must apply, the more flexible the norm has to be to encompass all eventualities and to maintain a certain feasibility.[363]

The length and frequency of exposure

The length and frequency of exposure are essential considerations when setting norms. Certain norms may be exceeded for a short while, but not too often. In addition, it can be established that excesses, if they take place at all, may not follow each other within a certain interval of time. Human beings or organisms need time to recover from a certain excess. From this it appears that, in many cases, setting norms demands a statistical approach. This approach, whereby norms can be given an average value, must not lead, though, to ignoring periods of peak stress. Exact values remain necessary, therefore, not only as a means of evaluation, but also especially because of their role as an indicator and as a maximum value for incidents ('98 percentile, and similar).

An example of these sorts of peak sensitive exposure norms are the so-called EPEL and MAC values [a]. The MAC values are hygienic values for companies, fixed by the national MAC commission under the terms of the Working Conditions Law (ARBO). The MAC values are the Dutch version of the American Threshold Limit Values (TLV).[364]

Spatial zoning

The association of Dutch municipalities (Vereniging van Nederlandse Gemeenten VNG) made a list of approximately 700 businesses and 80 installations categories. For each category that list recommends to keep a distance in metres (zone) from quiet and mixed residential areas.
A downloadable Excel sheet offers that extended list in selectable parts[b].

code	Distance to quiet residential areas	Distance to mixed areas (one category lower)
0,0	0	0
1,0	10	0
2,0	30	10
3,1	50	30
3,2	100	50
4,1	200	100
4,2	300	200
5,1	500	300
5,2	700	500
5,3	1000	700
6,0	1500	1000

Fig. 1029 Category codes of businesses and recommended distance to keep from residential areas[c]

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[a] MAC means 'Maximaal Aanvaardbare Concentratie'

[b] environment.xls, downloadable from http://team.bk.tudelft.nl/ > Publications 2008

[c] VNG, Vereniging van Nederlandse Gemeenten (2007) Bedrijven en milieuzonering. (Den Haag) SDU Uitgevers bv.

For different kinds of nuisance (**odor, dust, noise**, **danger**, **quiet areas**, **traffic**, **visual, soil, air**) different distances are given. The largest distance determines the category of nuisance (see *Fig. 1029*). Distance to mixed areas are one category lower than to quiet residential areas.

From effect- into source-directed standards

The development of environmental quality requirements originates from the exposed objects (risk criteria, dose-effect relations). From this end effect, limits can be set on the indirect and direct effects of activities and on the activities themselves (see Fig. 1014 and Fig. 1015).

Non-accepted exposure effects result in limiting values for the media air, water and the ground, from which environmental quality norms can be derived.
Emission limiting values and emission ceilings follow from this, as well as requirements and norms for products and processes towards which the activities lead.

The advantages and disadvantages of norms on the source and emission side compared with norms on the exposure and environmental quality side lie, on the one hand, in the area of the practical applicability of issuing licences and, on the other hand, in the possibility of objective under-pinning and the mutual consideration of different environmental stresses.

Process and product standards

Applying quality and imission norms can, after all, in principle, prevent the sum of all sorts of different activities (e.g. industry, traffic and home heating, as sources of air pollution), even though reasonably clean in themselves, from causing, nevertheless, an unwanted or unacceptable situation. On the other hand, they do not help to grasp the specific possibilities that can exist in an individual pollution-reducing source. Process and product norms have the advantage that they tackle pollution at source. However, they make an approach based on regional conditions impossible. Emission norms and ceilings have a sort of intermediary position between both.

6.5.6 Environmental policy

International principles: sustainable development and biodiversity

The ‘Brundtland Committee’ (World commission on environment and development, 1987) declared the principle of ‘sustainable development’ (to leave at least as many possibilities for future generations as your generation encountered). Since Agenda 21 (UN 1992), ‘biodiversity’ became an issue of these ‘possibilities’.

Core aim of the first National Environmental Policy Plan (NMP1)

The core aim of the first National Environmental Policy Plan (Ministry of Traffic, Spatial Planning and Environment (NMP) VROM (1989) was the *preservation* of environmental-usage space (milieugebruiksruimte) for the benefit of ‘sustainable development’[365].
So, the *production* of new environmental-usage space by building, the many possibilities of gain by urban and architectural design are thereby overlooked.

Building, health and biodiversity

After all, the proper task of building is to increase the utility of the space for human beings and their future generations. Building is good for human health, because, without buildings there would be distinctly fewer survivors. In addition, buildings can increase the biodiversity of an area[366]. This means not only gains for human health, but also demonstrable gains in terms of biodiversity in the built-up environment.[a] [367]
From the 500 wild plants that are found in Zoetermeer, Fig. 770 shows, above the line, the species that already occur more frequently in urban areas than on average in the Netherlands. Thus one can conclude that building not only takes over existing environmental utility space, but also produces — and to a much greater extent — environmental utility space for human beings, plants and, in some

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[a] Jong, Taeke M. de (2003) *Milieuwinst en milieuverlies door bouwen.* In: Boersema, J.J.; Pulles, T.; Straaten, J. van der; Bertels, J. (2003) *De oogst van het milieu* (Amsterdam) Uitgeverij Boom *html*

cases, even for animals. If one doesn't include that environmental effect in the calculation, then the bookkeeping of the environmental utility space is incomplete.

Urban and architectural contributions to environmental problems

However, in environmental policy the building industry is not appreciated for her environmental profits, but merely its negative impacts are taken into account (see Fig. 1030). In a supplement of the NMP (Ministry of VROM 1990) for the building industry, it has been established what 'contribution' this 'target group' (other target groups are: agriculture, traffic and transport, industry and consumers) makes to each field of problems (theme) within the estimated total for the Netherlands:[368]:

THEME	SPECIFICATION	CONTRIBUTION
Climatic change	air conditioning, isolation foam energy from fossil fuels for commuter traffic, the production of building materials, and heating	23% of the total CFC use > 33% of the total CO_2 production
Acidification	commuter traffic, building materials, heating	>16% of the total NO_x and SO_x production
over-manuring	household waste water, emissions into the ground and into groundwater	24% of the total nitrogen and phosphorus production
Dispersing environmentally damaging substances	solvents, preservation, upkeep, asbestos, heavy metal emissions when insufficiently re-cycled	9% of the volatile organic substances, 40,000 tons of heavy metals, 7,000 tons of pigments
Removal of waste materials	building and demolition waste	20% of the total waste
Disturbance	noise and foul smells due to traffic, building, production and quarrying building materials	2.85 million homes suffering from (serious) disruption due to traffic, 25% of the population in small towns irritated by foul smells
Wastage	careless use, not much re-cycling	120 milliom tons of raw materials per year, 90% of which are primary raw materials
Internal environment	health effects due to building materials, moisture, quality of the internal air, sound, vibrations	number of homes above the reference value: 90% NO_x, 80% radon, 80% airborne sound insulation, 60 % respirable substances, 15% moisture problems, 6% carbon monoxide, 40% of the offices are 'sick' buildings
Damage to ecologically functioning area	building surface with isolated ground ecology, quarrying for building materials	3,100 km^2 of hardened surface, 1,000 ha/year open-cast mining, of which 500 ha of definitive changes in destination

Fig. 1030 *The contribution of the building industry to environmental problems in the '90s*

The building industry was able to bring about reductions of spare parts of more than 20%, for example, by not applying foam containing CFKs to insulation material or by not basing air conditioning on these compounds, or by rendering them totally redundant. This applies to more of the contributions named in this table.

In 'Environmentally considered building' started by the Ministry of Traffic, Spatial Planning and Environment (VROM), discussions took place with the industrial branch as to which reductions in the different types of environmental pressures could be achieved in the long term (target values) and various shorter term limiting values that had to be met before a certain year.

Environmental problems and targets

The NMP1 distinguished environmental problems according to the level of scale they can be solved (not according to their effect, which is always local):

- Global problems: ozone layer and climate change[369];
- Continental problems: border crossing air pollution, ozone on living level, acidification, smog, heavy metals[370];
- Fluvial problems: rivers, regional waters, salty waters, water bottoms[371];
- Regional problems: accumulation of pollution, over-manuring, pesticides, heavy metals, removing waste, soil pollution, drying up[372];
- Local problems: noise pollution, smell pollution, urban air pollution, inside environment[373].

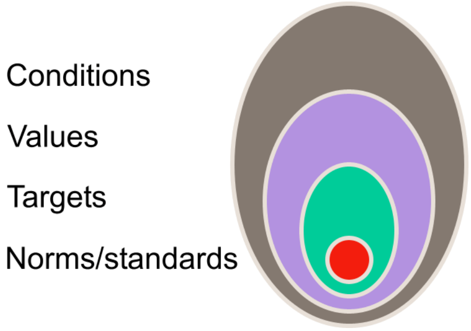

Fig. 1031 Conditional suppositions of norms/standards

According to these levels, targets were elaborated into standards according to limit values (see *Fig. 1031*) in cooperation with international, national, provincial and local authorities.

From an effect-oriented into a source-directed policy

The NMP1 marked a change into source-directed policy by making separate appointments with target groups like:

- agriculture;
- industry;
- refineries;
- energy supply companies;
- building companies;
- trade, services and governmental institutions;
- traffic;
- consumers;
- waste processing companies;
- participants in the water chain;

However, effect oriented measures remained actual for:

- problems herited from the past;
- source-directed measurements not coming in time;
- preventing calamities;
- failing source-directed measures.

The source-directed measures were distinguished into:

- emission directed;
- volume directed;
- structural measurements like integral chain management, energy saving and quality improvement.

These measures were discussed with the target groups (see Fig. 1032).

An agenda to discuss with target groups

The NMP used the following policy outlines as an agenda to the discussions with target groups:

effect oriented (main emphasis of the ‘70s: ground, water, air)		
source oriented (the ‘80s)	*emission oriented* (removal at source)	
	volume oriented (less consumption and production)	
	structural	*energy saving* (energy)
		integral chain management (material)
		quality improvement (information)

Fig. 1032 *Outlines of environmental policy*

In these ‘policy outlines’, environmental care is recognisable within effect, emission and volume oriented policy. It is only when it comes to ‘structural’ policy that innovational environmental techniques are dealt with.[374]

Strategic agenda

The government itself handled a strategic agenda of:

- reducing uncertainties;
- making choices from scenarios;
- formulating themes, instruments and cooperation.

These themes, instruments and cooperation are elaborated below.

Environmental themes supposing each other

Since the first National Environmental Policy Plan environmental themes have been: wasting, removing, disturbing, drying up, spreading, acidifying, over-manuring (the 'VER-thema's' in Dutch)[375].

However, a conditional analysis of these (VER-) themes " (zie Fig. 1033)[376] shows they overlap. For example wastage has been tacitly presupposed as an environmental problem in all of them. If wastage is the main problem, then sunlight, rain, and leaf-fall in the autumn should also be avoided. The theme words are interpreted here according to their meaning in everyday language[377].

In a professional sense, a clarification of that is presupposed, but is sometimes forgotten. What is meant by 'dispersion' is the dispersion of environmentally toxic substances, excluding CO_2 (climate).

The tacit presupposition is thus: 'in so far as it is not connected with the dispersion of acidifying or manuring substances, or CO_2 .

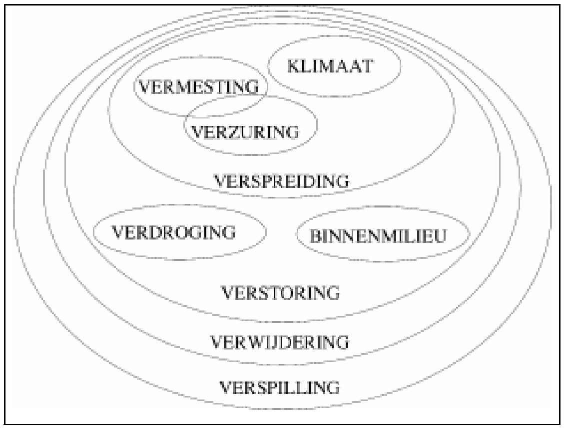

Fig. 1033 *Environmental themes from the NMP, shown according to their conditionality*

However, in everyday language, one cannot imagine climate problems, acidification and over-manuring without the dispersion of substances responsible for this. Ecologically, this dispersion is irrelevant, in so far (again, according to everyday language) as it causes no disturbances. However, 'disturbance', in professional language refers mainly to disturbance of the living environment due to noise, foul smells, insecurity, and is thus, in contrast to climatic problems, very local. The tacit presupposition is then: disturbance in so far as it is not connected with drying up, interior environmental problems and dispersion.

Double counting

The government prefered to convert environmental effects into these themes. That means that, in effect analysis, there is a danger of double counting, due to environmental values that presuppose each other. In methods such as LilfeCycleAssessment, an attempt is made to add up the effects by theme, but if a certain environmental pressure has more than one effect, it is unjustifiable to include that pressure several times in the calculation.

Calculations by RIVM

That is why for each theme, the environmental planning bureau RIVM yearly checking governmental policy results, repeatedly asked itself the same question: 'and why is that bad?'. The conclusion remained unchanged, that it is hardly possible in the Netherlands to determine the effects on health, but that, for each theme, 'a possible loss of biotopes' should be regretted.

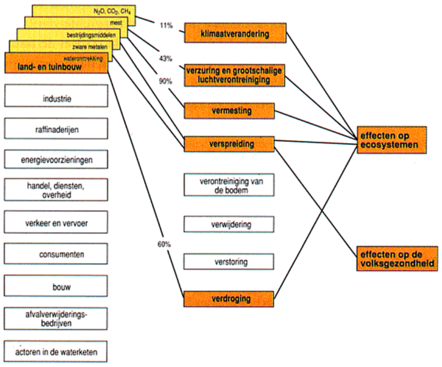

Fig. 1034 Calculating impacts of target group ‘agriculture’ on every theme, reduced to impacts on biodiversity and health

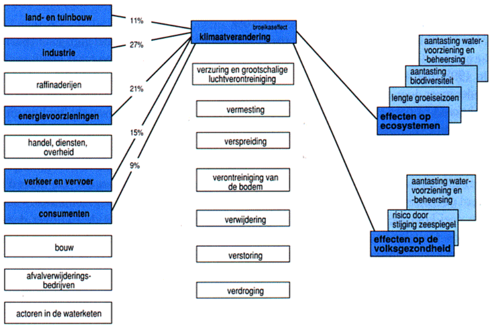

Fig. 1035 Calculating themes from contribution of every target group, reduced to impacts on biodiversity and health

Instruments and cooperation

NMP1 distinguished the following instruments:

- regulations by law;
- liability;
- financial regulations;
- environmental care in companies;
- product norms;
- information and public relations;
- technology;
- energy saving.

in cooperation with: international, national, provincial and municipal institutions.

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National policy documents after NMP1

Fig. 1036 *Four national plans concerning the environment*

There are four more recent national policy documents with environmental criteria for plans on different levels of scale from the Ministries VROM[a], LNV[b] and V&W[c]:

- The 5th National Plan of Spatial Policy NRO5, VROM (2000),
- The National Plan of Nature Policy LNV (2000),
- The 4th National Plan of Environmental Policy NMP5, VROM (2001),
- The 4th National Plan of Watermanagement PolicyV&W (1998) (stressing environment), and
- its successor 'Anders omgaan met water' V&W (2000) (stressing security).

Some of these policies are elaborated in a regional policy. The RIVM[d] is supposed to test plans on the subjects of health, environment and nature.
Some of the produced criteria are summarised below.

European policy

P.M.

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[a] *http://www.minvrom.nl/minvrom/pagina.html*
[b] *http://www.minlnv.nl/*
[c] *http://www.minvenw.nl/cend/dco/home/data/index.htm*
[d] See *http://www.rivm.nl/*

6.6 Soil pollution

Choice of location

The choice of location for a building, complex or new neighbourhood depends on position, orientation, land shortage and potential soil pollution, and as such comes with a price tag attached. Readers are not expected to “know” the contents of this chapter. Those factors that play a part in the choice of location are marked with a question.
As well as determining the choice of location, this topic is also of interest to urban planners and architects. After all, most contracts depend on the commencement date of building activities, allowing sufficient time to obtain the relevant permits and to plan activities. A lack of knowledge concerning soil pollution – including the relevant permits – will delay activities.

Soil protection act

This chapter offers guidelines for carrying out research in the context of the decontamination clauses of the Wet Bodembescherming (Soil Protection Act), with the emphasis placed on "terrestrial soils". Detailed information will be given on a range of pedologic properties and concepts. Examples of potential areas affected by soil pollution are also included, as is a brief summary of remediation techniques.

Surveys to obtain a clean soil statement

This monograph, coupled with a concluding report, will enable building contractors to carry out exploratory and preliminary surveys into soil pollution to initially obtain a “clean soil statement”.

Clean soil statement depending on purpose

Until comparatively recently, planning permission applications needed to include a so-called "clean soil statement". This has been replaced by a suitability certificate, indicating intended purpose. As a result, the soil no longer needs to be completely "clean", provided it is deemed suitable for its designated use. Building work cannot commence until this declaration has been issued. This certificate is not only concerned with the topic of soil pollution, but also with “cleaning”, soil remediation, if pollution has been detected.

Protocols and methods

To encourage greater understanding of the underlying problems, this thesis shall focus on the protocols involved in the investigation procedure into (likely) contamination (and resulting reports), and highlight a number of pedologic concepts.
This chapter is concerned with outlining the different types of contamination, coupled to industry activities, their prevention and location in the townscape and landscape. Current and developed remediation methods have been included for the sake of completeness. The underlying idea is that decontaminating and preparing a terrain for development follow naturally from one another, or could even be carried out in unison, thereby influencing the overall design.

6.6.1 Soil pollution

Suitability for future purposes

The term ‘soil pollution’ denotes a negative impact on soil quality, which affects the soil to such an extent, that it is rendered unsuitable or less suitable for its intended purpose.
The soil must be protected in such a way, that future generations can make use of it. This means that the soil must not be damaged, or become irrevocably damaged, in accordance with the concept of sustainability.

Different types of damage

When analysing our exposure to substances in the soil, we can identify different types of damage/exposure. In the case of soil pollution, this exposure includes inhaling VOCs (volatile organic compounds), consuming soil particles when drinking water, etc.
The situation is exacerbated by the consumption of dangerous substances that put our health at risk. The level of exposure is expressed in ADI (acceptable daily intake). Please note that ADI differs from person to person. As such, an average figure applies.

Functions of soil

With regard to soil pollution, it is advisable to consider the different functions of the soil, and the relevant quality assessments to be adopted.

- supportive function for buildings, roads and other constructions
- productive function: growth medium for natural vegetation and agricultural crops to feed people and animals.
- filter function for water
- ecosystem function; life in the soil makes a major contribution to the cycle of C, N and S.

To acquire a better understanding of these functions[a], it is essential that we have a general understanding of the concept of soil.

6.6.2 General soil knowledge

Soil and ground

What is the difference between soil and ground?

- The term ‘ground’ refers to all the loose natural materials found at the earth’s surface. In terms of composition, it is an undefined material. The material consists of mineral matter and organic components that can be retraced to plant remains and conversion.
- The term ‘soil’ refers to the arrangement of the individual soil particles, their size and how they occur in nature. Chemical, physical and biogenic processes play an important part in soil formation.

A closer definition

The Dutch language fails to differentiate the terms ‘soil’ and ‘ground’. This problem can be solved by including a definition.
Soil and ground are made up of solid, liquid and gassy constituents. Solid constituents are divided into mineral and organic constituents.
The naming of ground types is based on particle-size distribution of the mineral particles. Please note that most grounds do not have a homogenous particle size. In other words: the designation ’sandy ground’ implies that the majority of particles fall under the particle size fraction of sand.

Particle size

We can distinguish the following particle size fractions:

- to 2µ: clay fraction or clay
- 2µ to 50µ: silt or loam
- 50µ to 2000µ: sand (2000µ= 2 mm)
- 2 mm to 64 mm: gravel

Organic matter

The organic matter in ground is made up of decomposed plant remains. If these remains form a thin layer on the soil surface, we refer to them as humus, which is brown-black in colour. Thicker layers of organic material (up to several metres thick) are known as peat. Due to excess water, the plant material has not been converted into humus. Peat is primarily converted into humus following drainage of moist peatland, in particular under influence of oxygen.

Groundwater

Water contained in the ground can take on different forms. A distinction is made between

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[a] Dauvellier and v.d. Maarel, Globaal ecologische model, Rijksplanologische Dienst 1978

- groundwater: this water fills all pores between the particles, both big and small, and flows freely.
- The upper limit of the groundwater is known as the ground-water table or phreatic level.
- The depth (or height) of the ground water is always measured in relation to the ground level
- capillary water: this water saturates the fine pores and fissures of the ground, and is unable to move freely.
- swell water and adhesion water: water in and around the solid soil particles.
- Capillary water, swell water and adhesion water are also known as soil water.

The colour of drilled water

The groundwater level of a terrain can easily be established through soil drilling. In the Netherlands, the ground beneath the ground-water table – fully saturated by water – is grey in colour due to iron having the bivalent oxide FeO. Above the phreatic level, iron only occurs as Fe_2O_3, which is rusty in colour. This method is not 100% foolproof however, as numerous grounds in the Netherlands contain little or no iron.

Groundwater tables

Groundwater tables are divided into water-table classes, where the highest mean groundwater level (HMGL) and lowest mean groundwater level (LMGL) groundwater level is processed. The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative.[378] The annual natural fluctuation of the groundwater in the Netherlands amounts to several centimetres (10 or more). This movement is characterised by rust stains in the grey-blue groundmass.

Gt	I	II	III	IV	V	VI	VII
GHG	-	-	<40	>40	<40	40-80	>80
GLG	<50	50-80	80-120	80-120	>120	>120	>120
N.B. groundwater level in cm's below ground level.							

Fig. 1037 Main subdivision of the water-table classes

Groundwater flows

Downward groundwater flows are the result of differences in groundwater levels in an area. Although the general direction of the groundwater flow is known, it will need to be determined for local situations.

In addition to horizontal groundwater flow, we can also identify a vertical movement of water in the ground. This is known as effluent seepage (kwel), where the water ‘surfaces' from the ground-water, and infiltration, characterised by ‘downward movement’ of water.
Soil pollution can spread through the soil through groundwater flow. An insight into the degree, velocity and direction of spread is therefore essential.

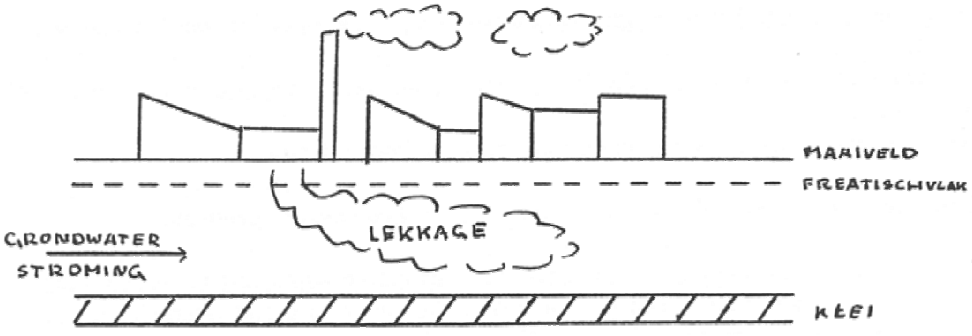


Fig. 1038 Horizontal groundwater flow

Soil vapour

Soil vapour occurs in all areas where the pores of the soil are not saturated by water. This air plays a part in all biogenic activities in the ground, but can also be relevant for the different chemical processes in the soil.
The composition of this soil vapour can vary strongly. The air is usually more or less identical to the atmosphere. However, because of the chemical pedological processes and soil pollution, the composition can differ significantly from the atmosphere, and even be toxic.

Ground types

On the basis of the solid constituents of the ground, it can be classified into sand, clay and peat.

- sandy ground; this ground primarily consists of mineral soil particles with a particle size of 50 to 2000 mu, while the clay content (particles) is less than 8% of the overall weight per unit of ground; ground permeability is good
- clay; this ground contains at least 25% clay fraction; ground with a clay content of 8-25% is known as sandy clay; ground permeability is poor or non-existent.
- peat ground; this ground is primarily made up of decomposed plant remains other than humus. The organic dust content must be at least 22.5% of the weight. The other constituents are mineral and can contain particle sizes of clay and sand.

6.6.3 Soil pollution and building activities

Application (previous) "clean soil statement"

Until comparatively recently, planning permission applications needed to include a so-called "clean soil statement". This has been replaced by a suitability certificate, indicating intended purpose. A soil survey report needs to be submitted during the application stage. The investigation must be carried out in accordance with the "Soil Protection Guidelines". If the exploratory survey (historic survey) reveals signs of soil pollution, a follow-up investigation will be required.

Historic survey

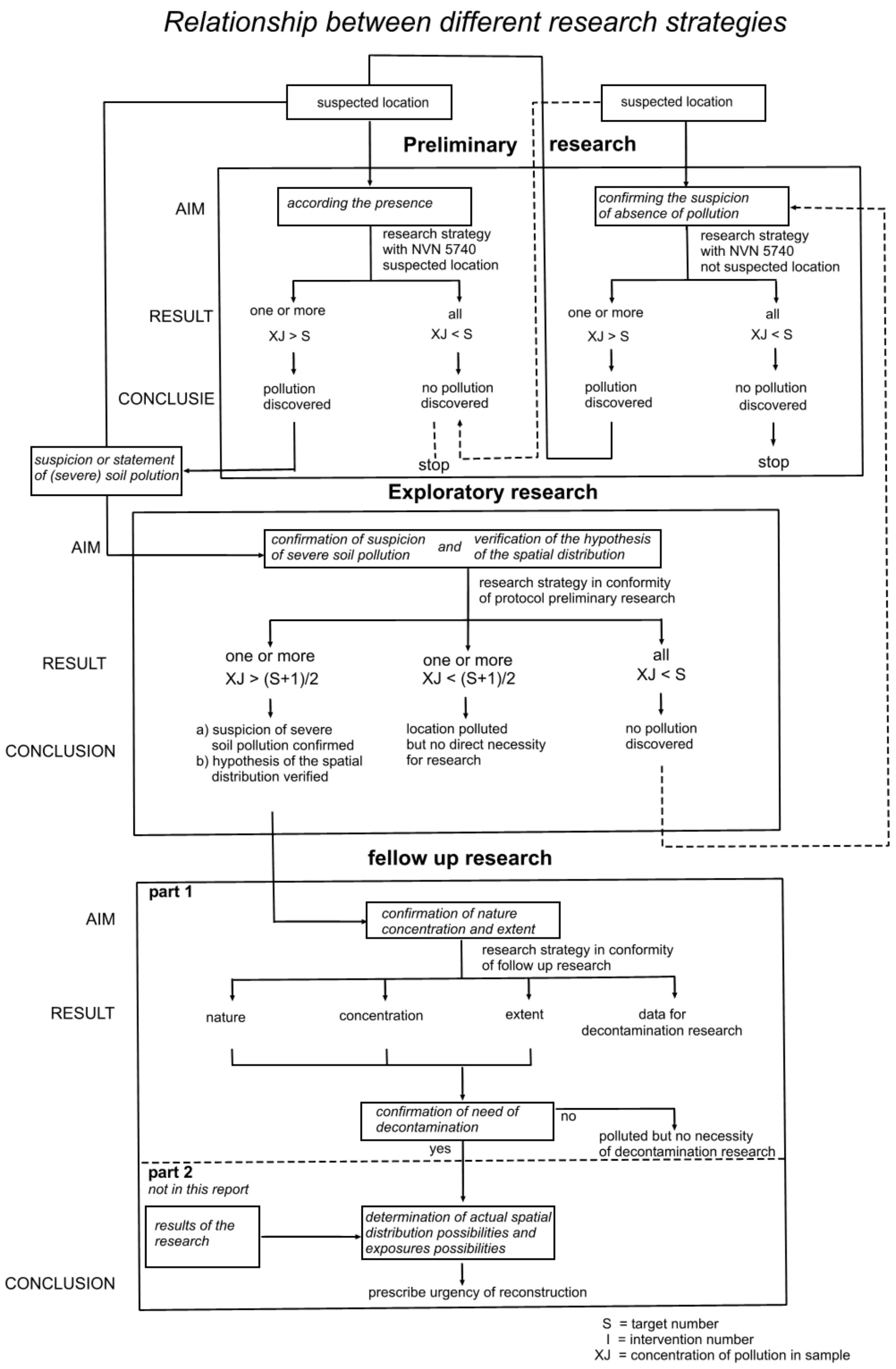
When drawing up his historic survey report, the investigator makes use of standardised survey setups, as well as municipal information and assessments. In many cases, the relevant council can provide information on behalf of the "historic survey". Based on the outcome of the survey, an exploratory investigation is instigated if serious contamination is suspected. The sole purpose of this investigation is to indicate the incidence of serious soil pollution.

Setup and criteria

The setup and criteria which the investigation must satisfy are laid down in two protocols:

- "Protocol voor het oriënterend onderzoek" (naar de aard en concentratie van verontreinigende stoffen en de plaats van voorkomen van bodemverontreiniging) ("Exploratory survey protocol" (into the nature and concentration of contaminating substances, and the location of soil pollution) SDU, The Hague 1993).
- "Protocol voor het nader onderzoek" (naar de aard en de concentratie van verontreinigende stoffen en de omvang van bodemverontreiniging) deel 1, SDU,'s Gravenhage 1993.
- ("Follow-up investigation protocol" (into the nature and concentration of contaminating substances, and the scope of soil pollution) part 1, SDU, The Hague 1993).

On the basis of both protocols, an overview is included of the survey methods to be deployed, including information relevant for building contractors. If you wish to carry out this survey yourself, you will be required to comply with these protocols.



The exploratory research in confirmity of NVN 5740 refer only to the research of a land soil.

Fig. 1039 Research strategies in protocols[a]

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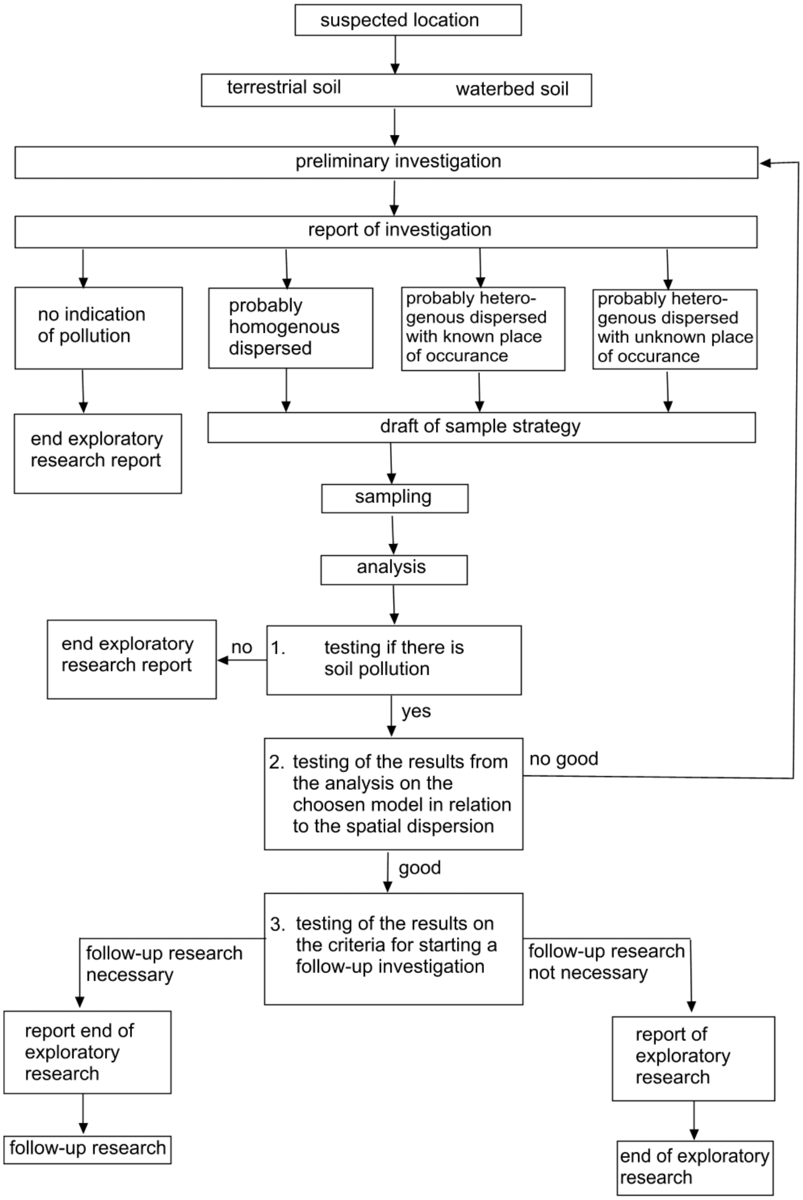
[a] F.P.J. Lame and R. Bosman (1994)

6.6.4 Exploratory survey



The structure of the exploratory research is the same for terrestrial soils as for waterbed soils; the strategy for sampling can differ on certain parts.. The soheme should be executed seperately for both soil's.

F.P.J. Lame and R. Bosman (1993)

Fig. 1040 Exploratory survey protocol[a]

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[a] Lamé and Bosman, Protocol voor het oriënterend onderzoek, SDU, Den Haag 1994

Terrestrial soils and waterbed soils

As demonstrated by the above diagram, the exploratory survey is divided into terrestrial soils and waterbed soils, while the survey itself is divided into an exploratory investigation with a concluding report, and a more detailed investigation in the event of soil pollution. This investigation is also concluded with a report.

Exploratory survey

An exploratory survey must be carried out at all times to obtain a suitability certificate to commence building work. This process involves collecting information and data on past and present use of the site, as well as the soil conditions, soil composition and the (geo)hydrologic setting. This might also involve the pollution crossing terrain boundaries, from the location "outwards", and "outwards" towards the location. Pollution might also concern the ground beneath the buildings, in particular if we are dealing with a permeable soil such as sandy ground.
The investigation includes an on-site visit. During this visit, soil drillings can be carried out to gain an impression of the soil composition and the likely contamination detected through sensory perceptions (colour and odour).

Please take your own safety into consideration; be careful when inhaling and touching substances. If you need to smell and/or touch something, please do so in small quantities at a time.

Terrestrial soils

The sampling strategy of the follow-up investigation is based on information obtained from this "field visit" – such as location and structural condition of the buildings.
With regard to construction work, we will confine our research to terrestrial soils. In cases of contaminated subaqueous soils, readers are referred to the research methods detailed in the above literature.

Information required for exploratory survey

As previously mentioned, this information needs to include details on:

- past and present use of the site
- the soil composition and geo-hydrologic settings of the site.

As a minimum, information on past and present use of the site must contain the following details:

- past purpose(s) of the location and immediate surroundings;
- location of occurrence of possible sources; for example legal or illegal dumping and discharging, leaking (underground) pipes and tanks. Council registrations of pipes and storage tanks are a useful tool in detecting the source of contamination.
- information on potentially contaminating activities, such as production processes, storage and transfer locations. Remember also to draw up an inventory of the relevant substances. An indication of the location of these activities, if possible, will simplify inventory activities and the investigation.
- methods and materials used in the past for preparing a site for building, including opening up the site.
- details of in-situ cables, pipes, debris, consolidations.
- past and present activities on adjoining terrains.
- investigations into soil pollution on neighbouring or adjacent terrains
- inventory of past users of the terrain, with their activities from approx. 1900.

Information on soil composition and geo-hydrologic settings of the site

As a minimum, this information must encompass the following:
- on-site soil composition, both shallow and deep (over 10m); information obtained from soil drilling tests and drilling;
- depth of the ground water
- horizontal and vertical movements of the ground water (effluent seepage, seepage and groundwater flows)
- position of water channels and other surface water (also drained)
- presence of groundwater sources and groundwater drawoff
- prevention of brackish and/or salty ground water
- results of earlier soil surveys on-site or in the immediate surroundings; also include past surveys into soil pollution.

Adding contaminating substances and microbiological activities

It is advisable to incorporate into the survey research into the properties of contaminating substances and microbiological activities. Although it is not compulsory to include this information, it can provide a valuable insight into the problems, and assist in selecting an investigation strategy and, if need be, determining the remediation method.

Past and present use

The information on past and present use of the site, as well as the information on soil composition and geo-hydrologic settings of the site, needs to be incorporated into the exploratory survey report, including relevant sources.

How to obtain information for an exploratory survey

How can we obtain the relevant information?
- use recent maps: topographical, from the land registry and maps of pipelines and mains, as well as soil and geological maps including legends. The local council office can usually provide historic data.
- use of old and recent aerial photographs, which can be obtained from the municipal topographic service and numerous aerial photography firms. Additional tools include infrared and other recordings falling under the heading of ‘remote sensing images’.
- exploratory visit to the site, carrying out field observations and soil drillings to take samples.
- investigation into archives, permits and dossiers (under the Nuisance Act) relating to past and present use of the terrain
- interviews with (former) employees and the local community
- use of archives of different municipal, provincial and government institutes
- branch-information concerning past use of the terrain in relation to possible contamination
- historical information from council and water boards.

This information must be incorporated in the report, concluding the exploratory survey.

Provisional conclusion

If all (writing desk) investigations indicate the likelihood of soil pollution, the survey must be extended to include information on the nature and concentration of the contamination collected on-site and laboratory analyses. This effectively is the start of the exploratory survey; a certain degree of in-depth research is required. A section of the preceding research must be expanded and deepened, as the results of the exploratory survey indicate a suspected case of soil pollution and a rough understanding of the contaminating substances. The distribution of these substances has also been mapped out in outline. On the basis of this information, a strategy is developed for the research methodology in general, and samples taken. The selected method(s) are subjected to tests, essential for eliminating potential mistakes and focussing the investigation, if need be.
This survey reveals whether we are actually dealing with soil pollution, and is concluded with a report, indicating the presence of soil pollution and recommendations for "further research".

Additional notes concerning the exploratory survey

In the event of a contaminated land soil, it is not necessary to examine the groundwater, provided the mobility of the contaminating substances is negligible. It would however be wise to do so, as most contaminating substances are either soluble in water or present in liquid form in the ground.

Sensory perceptions of contamination – by smell and/or perception or the identification of something "different" in the ground - is not really objective, but rather indicative. In addition, complicating factors must be taken into consideration, such as potential health risks for the observer.
Visual perceptions can also be clouded by the natural colour of the soil.

With regard to safety, VROM (Environment Ministry) has produced a series of publications. When carrying out a soil sample, a certain degree of care must be taken, not only by those taking the sample, but also by onlookers. As a minimum, warning signs must be displayed in the event of assumed contamination. Even better would be to temporarily close off the site.

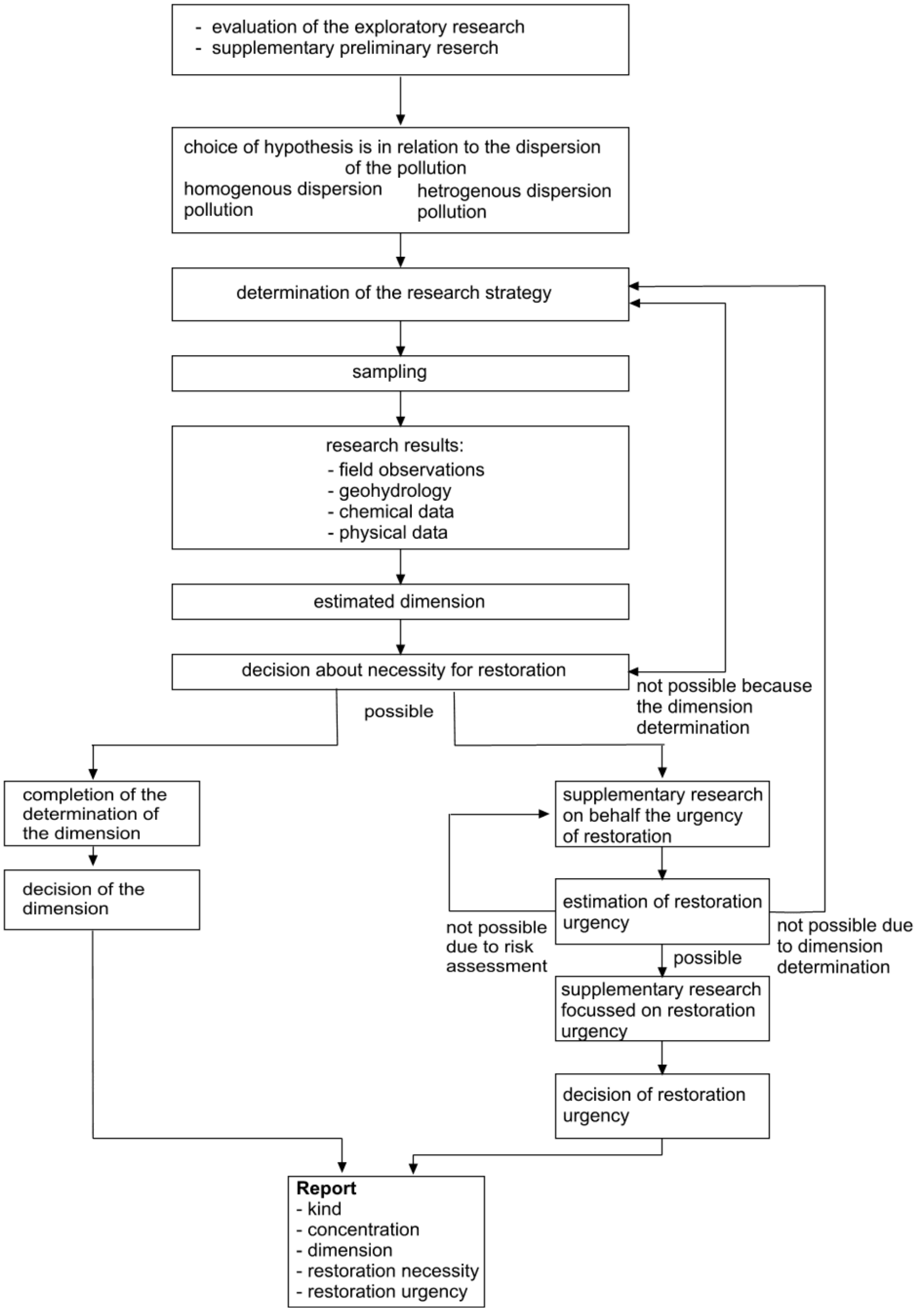
Sampling strategy

In principle, there are different contamination types and therefore different sampling strategies.
Homogenously spread contamination requires evenly distributed sampling. This is based on 1000 m2 spatial units (RE) in the horizontal plane. Per RE, 3 drills must be carried out, whereby the resultant ground samples are put into a mixed sample of the suspect layer and analysed.
An alternative sampling method is used for heterogeneously distributed contamination in known and unknown place of occurrence. As the preceding investigation has determined the type of contamination and its spread, a specific sampling method can be drawn up.
Needless to say, research results will need to be tested.
The exploratory survey is concluded with a report. In the event of actual soil pollution, a follow-up investigation will be carried out in accordance with the applicable norms.

Carrying out the investigation

In principle, anyone can carry out the survey, provided the details on past and present use have been incorporated in the final report. The same applies to information on soil composition and the geohydrolic setting. Soil samples that require analysis can be carried out in a specialist soil analysis laboratory on the instructions of the researcher.
The exploratory survey can also be entirely outsourced to a specialist research agency.

6.6.5 Follow-up investigation



F.P.J. Lame and R. Bosman (1993)

Fig. 1041 Protocol for follow-up investigation[a]

The follow-up of an exploratory survey

Having completed the assessment of the exploratory survey, plans are now drawn up for a follow-up investigation (including additions to the exploratory survey).

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[a] Lamé en Bosman, Protocol voor het nader onderzoek, SDU, Den Haag 1994

The aim of this investigation is to establish the nature and concentration of the contaminating substance(s) in both the horizontal and vertical plane.
An insight into the local soil composition is essential, as is soil sampling. Regulations have been drawn up for this purpose. Soil sample analyses and results interpretations must be carried out in accordance with the protocol.
A follow-up report is drawn up on the basis of the results.

The contents of a follow-up investigation

This report must comprise the following information[379]:

- nature of the pollution
- concentration of the pollution
- extent of the pollution
- need for remediation
- urgency of remediation

N.B. this report does not offer advice on whether remediation is required, nor on the remediation method. These decisions are taken by the relevant institutions.

Implementation of the investigation

In principle, anyone can carry out this follow-up investigation. However, due to the substantially more complex nature of this investigation – in particular with regard to the behaviour of substances and pedologic research, it would be advisable to enlist expert help.

Determining the level of urgency for soil remediation

A systematic approach has been drawn up to determine the level of urgency for carrying out soil remediation work. This approach is partially based on the existence of unacceptable risks in the event of serious soil pollution. The eventual decision to carry out remediation work is taken by the competent authority.
This problem falls outside the scope of this dissertation.
Further information is contained in the Urgentie van bodemsanering (urgency of soil remediation), published by the SDU.

6.6.6 Causes of soil pollution

Industrial sites

In view of the fact that most incidences of soil pollution are likely to occur in industrial sites, we have confined our research to these areas. It must however be noted, that these terrains are also found in built-up areas, and that a petrol station and garage in a residential area may also be a potential contributor to soil pollution.

Causes

In general, the causes of pollution on industrial sites include[380]:

- leaking (underground) storage tanks and company sewers. These types of leaks are frequent occurrences, spanning longer periods. In addition, the replenishment of tanks can cause numerous problems.
- Old storage tanks for central heating oil are often located in the vicinity of residential buildings
- discharges directly into the ground of the industrial site
- dumping company waste on own site
- land fills containing own company waste and/or waste matter such as ash, waste products and cinders from incinerators.
- calamities such as fire, explosions, floods, pipe fractures etc.

Ignorance, mistakes, leakages and accidents

Many contaminating substances have entered the ground in the course of time due to ignorance, mistakes, leakages and accidents such as spillages when transferring material or fuel.
The absence of clear operational regulations governing the handling of raw materials and the end product with regard to storage, transfer and carriage, as well as the disposal of waste matter, have almost certainly contributed to soil pollution.

The often lackadaisical attitude of managers and operational staff is a further culprit.

Terrains other than industrial sites

In addition to industrial sites, soil pollution regularly occurs in waste dumps (rubbish tips), storage yards of (polluted?) ground, mines, quarries, gas and oil rigs and salt extraction areas etc. Pollution may also be generated by the re-use of, for example, previously contaminated building materials, as concrete aggregate. In Rotterdam for example, contaminated debris of WW2 aerial bombardments is still causing significant problems. Agriculture and horticulture are also potential polluters due to their use of pesticides and fertilizers.

Standardisation of A, B and C values

The standards governing the most frequently occurring forms of soil pollution are drawn up in a "test table" for ground and groundwater in the Leidraad Bodemsanering (Soil Clean-up Guidelines). These standards are subject to alterations, and can be amended in line with recent surveys. As such, it is essential that the most recent tables be used. It seems best therefore to use the term "indicative target values", which are divided into A, B and C values.

- The A value is the reference value. If this value is exceeded, we are dealing with contamination381. The A value differs per soil types, as adsorption processes are particularly relevant in clay and peat grounds. In other words: if this (contaminated) ground has an A value, it is suitable for all purposes.
- The B value is an indicator of contaminated soil; it does not reveal to what extent the soil is contaminated. Further research is required in accordance with the “exploratory survey” protocol.
- The C value is the actual test value. In this case, soil remediation is required in accordance with the “follow-up investigation” protocol.

The system of A, B and C values was replaced in 1995 by a system of clean soil target values[382] (new A value) and soil remediation intervention values[383] (C value). The intervention values are based on risk assessments, highlighting risks to the eco system as well as risks to man.

Relationship industrial sector and soil pollution

Industrial sites are categorised as follows in soil pollution surveys:

- former gas factories
- former and existing industrial sites
- former and existing car and machine wreck depots
- former and existing tips in general
- former and existing goods transhipment sheds
- former and existing borrow areas (coals, oil, salt, gas, clay, rocks etc.)

Costs

In 1991, soil remediation costs amounted to approximately 84 billion Dutch Guilders, and primarily concerned remediation of former industrial sites.

Company operations

The relationship between soil pollution and industrial sector is self-evident. The risk of soil pollution is effectively dependent on company operations[a] [384].

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[a] De tabel is ontleend aan het boek "Bodemsanering van bedrijfsterreinen", praktijkboek voor bedrijf en beroep van Ing.J.Verschuren (ISBN 90-9003485-4) geeft enig inzicht in deze relatie.

Business operation	Pollution
metal and galvanic industry	all kind of heavy metals, cyanids aromates and chlorinated solvents (Tri and Per)
paint and dye industry	all kind of heavy metals, PCB’s, aromates and chlorinated solvents (Tri and Per)
graphic industry	idem
textile industry	chlorinated solvents (Tri and Per)
chemical lavendaries and textile cleaning service	all kind of heavy metals, pak’s and chlorophenol
carpentry and wood preserizing	
tanning and leather working industry	hydrocarbons and chromium
petrol stations	mineral oils, aromatics and lead
garages	mineral oils, aromatics, lead and battery acid
breaker’s yard	all kind of heavy metals
pesticide industry	halogenated, hydrocarbons, aromatics, mercury, tin and arsenicum.

Fig. 1042 Overview of prominent forms of soil pollution per operation[a]

Pollution types and occurrence in the soil

Soil pollution can take on different forms, depending on chemical composition, phase (gas, liquid, solid) and ground type. Clay ground particles for example can be contaminated through adsorption, immobilising the particles. The intervention values (previously B and C values) differ for clay grounds and sand grounds. Sand ground is unable to form a compound with contamination particles.

Types of form

Incidences of pollution:

- solid form – solid particles: metals, compounds of heavy metals and metalloids
- adsorption - cation: adsorption of soluble salts of heavy metals to clay particles and organic components of the ground (humus or peat)
- adsorption - molecule: molecule adsorption of aliphatic and aromatic compounds to organic components of the ground
- liquid phase (insoluble or poorly miscible in water): mineral oil, petrol and organic solvents. Liquid occurs in the soil in droplet form or as a film surrounding the ground particles. In this type of pollution, the specific weight of the liquid plays an important part. Liquids that are heavier than water will form a layer above a poorly permeable layer, while liquids lighter than water will form a layer on the ground-water table.
- soluble in water: occurrence in groundwater
- gas phase: aromatics (BTEX), volatile components of petrol, diesel oil and other mineral oils, volatile chlorinated hydrocarbons.

Types of content

The above pollution types can be divided up into a number different categories, which in turn can be categorised per industry sector.

Pollution types:

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[a] J. Verschuren (1993)

- heavy metals and metalloids: chrome, cobalt, copper, cadmium, nickel, arsenic, zinc, tin, mercury, lead and antimony. Occur as metal and as oxide, sulphate, nitrate, halogenated, carbonated or silicate forms.
- complex cyanides and free cyanides
- aliphatic and aromatic hydrocarbon and mineral oils.
- volatile halogenated hydrocarbon: Trichloroethylene, Perchloroethylene
- non-volatile halogenated hydrocarbon: Polychlorobiphenyl (PCB), different types of pesticides
- other compounds: ammoniac, acids, lye, phosphates, sulphates, nitrates

6.6.7 Remediation methods

Remediation techniques have been under development in the Netherlands since 1980. As soil remediation is a relatively new technology, large-scale techniques are still being developed. Remediation methods can be categorised into two main groups, with a third group acting as a combination of the main groups[385].

- soil recovery
- isolating the pollution
- combination of isolation and recovery.

Soil recovery

Soil remediation by excavating, followed by soil purification or tipping.
The primary purification techniques[386] involve:

- thermal and extractive methods for removal and
- biological methods for alteration.

Tipping must be considered, if there are no adequate soil purification techniques for this specific situation[387]. Temporary storage is considered if the purification plant has a limited capacity[388].
Soil remediation through in situ purification is currently under development. In addition to not having to excavate the ground, other advantages of this method include its relatively low costs and no interruptions to the company operations[389]. The techniques applied include flushing out the contaminated soil ("washing"), extraction of polluted air streams, chemical or biological conversion and removing pollution via an electric field.
Most contaminated soils are cleaned up by excavating, followed by soil purification. In situ soil purification occurs on a limited scale, but will become increasingly commonplace in future.

Isolating the pollution

This process effectively involves containing the spread of the pollution. This can be achieved in a number of different ways[390]:

- installing vertical and horizontal screens, such as sheet piling, building plastics, mastic layers, bentonite-cement slurry walls etc.
- pumping up groundwater and/or infiltration water.
- using fixation techniques; immobilising the pollution.

Isolation is primarily used in cases of extensive pollution, where "hot spots" – places with the highest pollution levels - are isolated in order to prevent further spread before complete remediation, or in order to be cleaned up first[391].

Combination of isolation and recovery

In cases, where it is not (yet) possible to recover the soil for all types of pollution, the unrecovered areas are isolated.

6.6.8 Soil purification techniques

Soil purification methods are aimed at removing the pollution or converting the pollution into components that pose a minimal, or acceptable, risk to man and the eco system[392]. The latter method comprises biological degradation and conversion of the pollution. The characteristics, on which the soil purification process is based, are determined by the specific (chemical) properties of the pollution.
The most prominent properties are:

- phase: gas, liquid, solid (volatility, boiling point)
- solubility in water or in another solvent
- adsorption/absorption (electric properties)
- chemical stability
- thermal stability
- magnetic properties
- biodegradability/convertibility
- weight and form of the particles
- size and shape of the particles.

Information needed for soil purification

In addition to the soil purification technique, the "remediability" of the ground also plays an important part, as soil purification comes with a price tag attached. Soil remediation experts will need specific information, such as the nature and concentration of the pollution, the presence of other contaminants and debris, plastic, cinders, vegetation remnants etc. Knowledge of the soil in terms of grain-size frequency distribution, organic dust content and moisture content are also essential factors in the world of soil purification.

This chapter will focus on the following purification techniques:

- techniques for excavated grounds;
- in-situ soil purification techniques;
- isolating contaminated sites.

Thermal soil purification of excavated grounds

Thermal soil purification involves increasing the temperature of the ground to such an extent, that the contaminating substances are evaporated and/or decomposed and evaporated. The techniques used during this process fall outside the scope of this dissertation.

Application: all types of organic contaminations.
In principle, this method can also be applied to heavy metals and their compounds, provided temperatures reach approx. 800^{o} C.
Thermal soil purification can be applied to any type of ground. However, grounds with (a high content of) organic material will be susceptible to burning. Clay and loam grounds require more energy for this process than sand ground. Furthermore, measures must be taken to guarantee a uniform ground supply.
In thermal soil purification, the contaminated substances are evaporated, and the vapours filtered. The resultant emissions are subject to severe criteria under the Wet op de Luchtverontreiniging (Air Pollution Act).

Purification through extraction of excavated grounds

The extraction process is divided into a number of phases:

- putting the contaminated ground into contact with extracting agent (dissolved in water)
- separating extraction particles from the clean ground through rinsing out
- purifying the (contaminated) extract

Application: suitable for removing heavy metals, metal compounds and organic pollution.
This method is ideal for purifying sand soils, due to the proportionately low adsorptive forces between sand grain and contaminant. Due to the relatively high adsorptive forces of clay and loam grounds, this method is unsuitable, or less suitable, for these ground types.

Biological soil purification of excavated grounds

In this process, organic contaminants are decomposed or converted by micro-organisms into compounds that are not harmful, or virtually harmless, to man and the eco system.
A distinction is made between a mineralisation process with anorganic end products, and degradation with incomplete mineralisation.
These biological processes are however known to cause highly toxic inorganic compounds such as chlorinated derivatives due to the decomposition of organohalogens. It is of vital importance that employees working on site be adequately protected.
This biologic soil purification method is based on landfarming and bioreactor techniques.

In landfarming, the contaminated ground is spread in a thin layer across a suitable terrain and cleaned by natural microbiologic processes. The degradation process is stimulated by adding oxygen, cultivating the ground (ploughing), adding lime and nutrients for the decomposing organisms, and by proper water management.

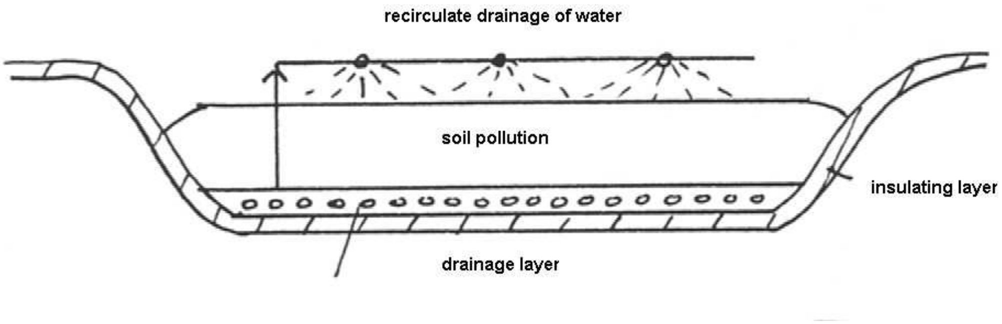


Fig. 1043 Landfarming diagram

Bioreactor techniques of excavated grounds

We can identify two bioreactor techniques: a dry form, comparable with composting solid waste, and a wet form in so-called soil slurry reactors.

This technique can only be applied to organic compounds.
In principle, this method is suitable for all ground types, but is usually applied to sand grounds due to its high permeability and ease of cultivation.

The disadvantages of this method include the long duration of the soil purification process, and difficulties in reaching the target values.

In-situ soil vapour extraction

Volatile compounds are removed by extracting soil vapours, and subjecting them to surface clean-up. This process is known as soil vapour extraction, and is solely applied to volatile substances such as perchloroethene, trichloroethylene, petrol, benzene, toluene, xylene, ethylbenzene and methylene chloride.
This method can only be applied to permeable grounds such as sand.

Disadvantages include difficulties in reaching the target value, longevity of the process (can take several years) and, in the case of mineral oil, the leftovers of heavy components.

In-situ bio restoration

The process of bio restoration consists of optimising the conditions for micro-organisms responsible for ground purification.

This method is primarily applied to sand grounds, as the contaminant must be easily degradable. As a result, this method is mainly used in pollution types involving mineral oil and low molecular weight polycyclic aromatic hydrocarbons.
This method also has its disadvantages: it takes a long time to achieve the target value, if it is achieved at all.

In-situ liquid extraction

Contaminants are extracted from the ground through the infiltration of a water-based extracting agent, causing a chemical reaction. The extracting agent, containing the dissolved contaminants, is then pumped up and cleaned above ground. Liquid extraction can continue until the desired target value has been reached.

Application: primarily in easily permeable grounds such as sand grounds. This method is suitable for all pollution types that are soluble in extracting agents, including heavy metals, low molecular weight polycyclic aromatic hydrocarbons, low molecular weight halogenated solvents, phenol and benzene.

The total duration of this process ranges from several months to several years. It is not always possible to achieve the target value.

In-situ electro reclamation

The method of electro-reclamation is based on three direct current transmission lines: electro-osmosis, electrophoresis and electrolysis.

Ions or ion complexes are transmitted through liquid between the soil pores under influence of an electric field. This causes the polluting ions to be carried to the electrodes and removed via a pumping system.

Application: this method is ideal for purifying clay soils contaminated by heavy metals. Its main disadvantage however is its energy inefficiency.

Conclusion in-situ soil purification techniques

The above in-situ soil purification techniques are currently operational in the Netherlands. A certain degree of experience has been gained with most of these techniques, in particular underground contamination and polluted petrol stations. At present, it is virtually impossible to achieve the A value using these techniques. Furthermore, they are only suitable for homogenous areas. The remediation methods take a relatively long time to implement. Having said that, these in-situ soil purification methods also have a number of advantages, including underground remediation, tackling deep contaminations without the need for earth moving, and causing minimal disruption.

It is clear from the above, that researchers in the Netherlands are currently on a steep learning curve in terms of remediation techniques, learning from every new piece of technology, unveiling new and at times unexpected information. In my opinion, promoting in-situ soil purification is highly desirable, given its advantages. One solution would be to increase the costs of tipping, and inspecting tipping activities. It might also be useful to carry out a feasibility study into the use of A-value as a follow-up remediation value. Greater flexibility in remediation policy would promote the use of these relatively simple techniques.

Isolating the contaminated sites

A polluted soil is screened off, thus containing the spread. This method can involve closing off the site and preventing potential spread via soil vapours.

Civil-engineering isolation techniques.

This civil-engineering isolation technique is based on the erection of impermeable walls of steel, bentonite-cement slurry walls and grout curtains. Preventing sideward spread alone will not suffice, as the upper surface and lower surface must also be isolated.

This technique can be applied to all areas. Disadvantages include the behaviour of isolation walls in the course of time. Only steel walls are moveable.

Geo-hydrologic isolation

Geo-hydrologic isolation involves pumping up the groundwater of a contaminated site, preventing the spread of pollution in the groundwater. This pumping action can be combined with water infiltration from an adjacent area.

Application. This technique is difficult to apply in built-up areas, as soil layers are generally prone to settling during water drawoff. The degree of settlement depends on the ground type.

This technique releases (lightly) polluted water that needs to be discharged. This cannot simply be done into a sewer or open water, so the water has to be cleaned prior to discharging.

Site management and inspection

All the above isolating techniques require adequate site management and inspection, even in the event of (partial) failure of the technique.

Living layer in urban areas

A special isolation method is being applied to a number of urban areas. Ground that is proving difficult to clean due to the surrounding buildings, is isolated from all sides. The overburden is partially excavated and isolated. A layer of clean ground, known as the living layer, is applied on top of the insulating layer. When using this terrain for building work, care must be taken that this upper insulating layer is not "infiltrated". This method is currently being applied in the city centre of Amsterdam.

General conclusion remediation and soil purification techniques

One of the biggest problems associated with contaminated sites is that they contain a significant amount of urban, industrial, building and demolition waste in addition to polluted ground.
Pollution is rarely of a singular nature; it is usually characterised by a combination of contaminating substances, which frequently need to be extracted in different ways from the ground.
Some substances are impossible to extract from the ground, or require extraction methods that have not yet been discovered. In this case, isolation is currently the only solution available.

Combining soil purification and site preparation

Purification of contaminated soil requires a lot of shifting of the ground. As such, might it not be wise to draw up a plan of approach for preparing the site, as well as a soil purification plan, and effectively combine these two plans? The underground infrastructure can be installed during or immediately after clean-up.
In instances, where a site is located in the middle of a remediation area, where space is at a premium, this combined approach can yield some surprising results.

Involvement of experts

The follow-up investigation can be carried out by anyone, provided this is done in accordance with the exploratory survey and follow-up investigation protocols, and the requisite details and documents have been submitted in report form to the relevant municipality. It is however recommended that the relevant surveys are carried out by an expert. Soil samples may prove problematic; these can be analysed by specialist laboratories in accordance with the methods indicated. (A list of ground survey laboratories has been included.)
Technical laboratories carrying out these surveys have acquired a certain reputation in this field and are therefore often readily accepted as authoritative by local authorities. These laboratories usually include an executive body, leading to a conflict of interests.

6.6.9 Appendix saneringsregeling wet bodembescherming P.M. (remediation regulations under the Soil Protection Act)

7 Legends for design

Contents

7.1 Mapping

7.1.1 Introduction

Outline

The concept of mapping is basic to the visual representation of the earth. Maps used to be dominated by a strategic and military use, nowadays the use of maps has extended to use for quite different types of applications like wayfinding, tourism, travel and also spatial planning.

In urban design and landscape architecture, we see maps as a form of visual representation of the landscape be it urban, rural or infralandscapes. Maps can also be looked at from an artistic point of view. Especially old maps are sometimes pieces of art. Landscape architects and urban designers cannot work without maps; an striking difference with architects. It is not only important to learn how to read and interpret maps; the relation between map image and field image needs special attention and takes time to learn. In the design process it means that abstraction and reduction play an important role in urban design and landscape architecture due to sheer size and scale. So maps and cartographic techniques are basic for the representation of study areas and design interventions alike. Finally you should be able to make use of cartographic information in your drawing of plans at different levels. Problems of reduction and enlargement, of representation of hierarchy and of a 2D-representation of spatial situations should be basic knowledge for a designer.

'Mapping' is not always referring to making maps. It can also be used in a metaphorical way. In this context for instance 'cognitive mapping' (Downs & Stea, 1973) is used but also in expressions like 'mapping the city' that has nothing to do with maps as such but with a way of visualising urbanity.

Cartography and maps

What is a Map? A map is a graphic representation or scale model of spatial concepts, a means for conveying geographic information. Maps are a universal medium for communication, easily understood and appreciated by most people, regardless of language or culture.

Basic to the understanding of the concept of maps is that it is a "snapshot" of an idea, a single picture, a selection of concepts from a constantly changing database of geographic information.

Modern Maps

Maps became increasingly accurate and factual during the 17th, 18th and 19th centuries with the application of scientific methods. Many countries undertook national mapping programs. Nonetheless, much of the world was poorly known until the widespread use of aerial photography following World War II. Modern cartography is based on a combination of ground observations and remote sensing.

Cartography or mapmaking (in Greek chartis = map and graphein = write) is the study and practice of making maps or globes. The cartographic process rests on the premise that there is an objective reality and that we can make reliable representations of that reality by adding levels of abstraction. Maps are basically geographical or topographical models of the land. Maps function as visualisation tools for spatial data. Spatial data is acquired from measurement and can be stored in a database, from which it can be extracted for a variety of purposes. Current trends in this field are moving away from analogue methods of mapmaking and toward the creation of increasingly dynamic, interactive maps that can be manipulated digitally.

Standard features on modern maps are: a scale that is used for precise interpretation of phenomena, conventional signs with legends, a table that contains supplemental information about the specific places on the map, and the practice of orienting maps so that North is at the top and East to the right of the map.

Cartography and communication

Maps are a universal medium for visual communication about the earth. Cartography is related to, but different from other forms of visual communication. Cartographers must pay special attention to coordinate systems, map projections, and issues of scale and direction that are in most cases of relatively little concern to other graphic designers or artists. But, because cartography is a type of graphical communication, some basic insights to the demands of cartography can be learned from the practice of graphical communication and statistical graphics.

7.1.2 Types of maps

Maps are traditionally subdivided into topographic and thematic maps.

Topographic maps

Topographic maps are meant to give the most accurate as possible description of the surface of the earth and the objects that are on that surface like roads, rivers, buildings etc. and their names. Topographic maps are general reference maps showing coastlines, cities, and rivers and use contour lines to show elevation differences. All topographic maps have a military origin; they were first of all made for military use. Nowadays this has changed — military still use topographic maps — many other people make use of topographic maps, realtors, hikers, geographers etc. Nowadays most topographic maps are made on the basis of aerial photographs.
In Holland topographic maps are called 'Topografische kaarten', in Britain 'Ordnance Survey Maps', in France 'Cartes IGN'. Note the difference with a 'topological map'!

A topological map is a very general type of map that show relations but not exact locations, the kind you might sketch on a napkin. The maps of the Metro in Paris, the Underground in London and the railway maps of the Dutch Railways are examples of topological maps.

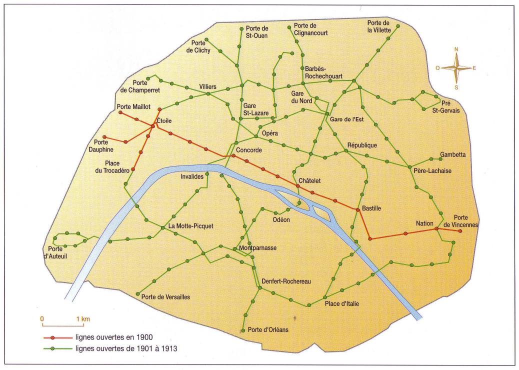


Fig. 1044 The topographic positions of the Metro stations

Fig. 1045 The topological representatin. To see the differences, focus on one line for instance line 1; Porte de Vincennes to Étoile on both maps

Thematic maps

soil maps, geological maps, census maps, historical maps show only a certain aspect like soil types, geology, distribution of population, history of places or events are thematic maps.
Census maps focus on population characteristics of a country. Census maps are thematic maps focusing on population distribution as well as data on such items as age, ethnicity, and income. Census maps help governments provide services to its citizens and plan for the future.
Types of maps being used in urban design and landscape architecture are — besides topographical maps — soil maps, land use maps, historical maps, road maps, hydrological maps etc.

A more modern division can be made between 'map sorts' and 'map types'

Maps sorts

Maps sorts refer to how maps are used; the function of maps. The most important use of maps is orientation. Whether to get across town or across the world, maps are crucial for navigation. They can help us discover the distances between objects and their relative orientation to one another.\

There are:

1. Orientation maps
2. Planning maps
3. Maps for prognosis
4. Management maps
5. Educational maps, atlases

Map types

Map types refer to the different methods of mapmaking. There are nine 'map types':

1. Chorochromatic maps
2. Choropleths
3. Isoline maps
4. Point distribution maps
5. Diagram maps
6. Dot maps
7. Movement maps
8. Spatial models

The types of spatial information on a map

Any map contains different types of spatial information:

1. Topographic; defines the location (where?)
2. Thematic; defines the attribute or quality of the information (what?)
3. Thematic cartography involves maps of specific geographic themes oriented toward specific user groups.
4. Temporal; defines the time (when is topographic and/or thematic information defined?)

Use of maps

The predominant use of maps is for orientation and way finding. Maps can also be used to analyse the land, the topography or any geographical phenomena represented on maps. Designers and planners use maps as basis for their work: to study the form of the land, occupation and land-use, spatial developments and change. This is done by map analysis, for instance by comparing maps from different time periods. A special topic in urban design and landscape architecture is to study the relation between field image and map image. That is part of the visual research of the site. You should always use topographic maps as a basis for your work; no road maps, no city maps (unless you are analysing the road system)!

Geographical information systems (GIS)

Nowadays GIS is an important part of map production, mapping and geographical research. GIS is a digitally based system that adds content to the visual representation on the map. Note that this is different from labeling. For instance the green colour on the map can refer to grassland but in a GIS-system any surface on a map can contain information about that surface. This information can be updated, changed and extended easily. So it offers a possibility for a wide range of applications. The software of ESRI — like ArcInfo, ArcView — is still most used and more or less a standard (www.esri.com).

Learning GIS takes quite some effort and time. There is no way we can teach GIS in the context of this course, this is only a short course on visualisation in urban design and landscape architecture. GIS is a specialist tool that has a different scope and content; it is one of the many research tools for urban designers and landscape architecture. Unfortunately we don't have a structured introductory course in GIS in the department yet, it will definitely come in the future. Steffen Nijhuis (S.Nijhuis@tudelft.nl) is one of the specialists at GIS and its applications in the department of Urbanism.

Types of maps in the Netherlands

The Dutch government is responsible for the production of maps of the country. In former days the Topographic Survey, and nowadays the land registry (*kadaster*), is officially assigned the task of producing topographic maps on the scales 1:10,000 1:25,000 1:50,000 1:100,000 and 1:250,000. Other standard maps include soil maps, geomorphological maps and geological maps. These maps do not cover the whole country. Soil maps, geomorphological maps and geological maps have a standard scale of 1:50000. These maps are based on 1:50,000 topographic maps, which are printed in grey on these maps.

Other maps

There are several other maps, such as historical maps, older topographic maps (the most important is perhaps the topographic military map dating from around 1850 on a 1:50,000scale), waterway maps, sea charts, water board maps, motorway maps, cycling maps, maps showing administrative boundaries, maps illustrating demographic spread, etc.

All topographic maps are based on a grid of 1:50,000 (see Fig. 1), from map 1 in north-western part of the country to map 62 in the south-eastern part of the country. These 1:50,000 maps are subdivided into Western (W) and Eastern (O) maps, for example : in Amsterdam no 25 O, the O stands for east. The same system is used for larger scales and is further subdivided (see *Fig. 1046*).

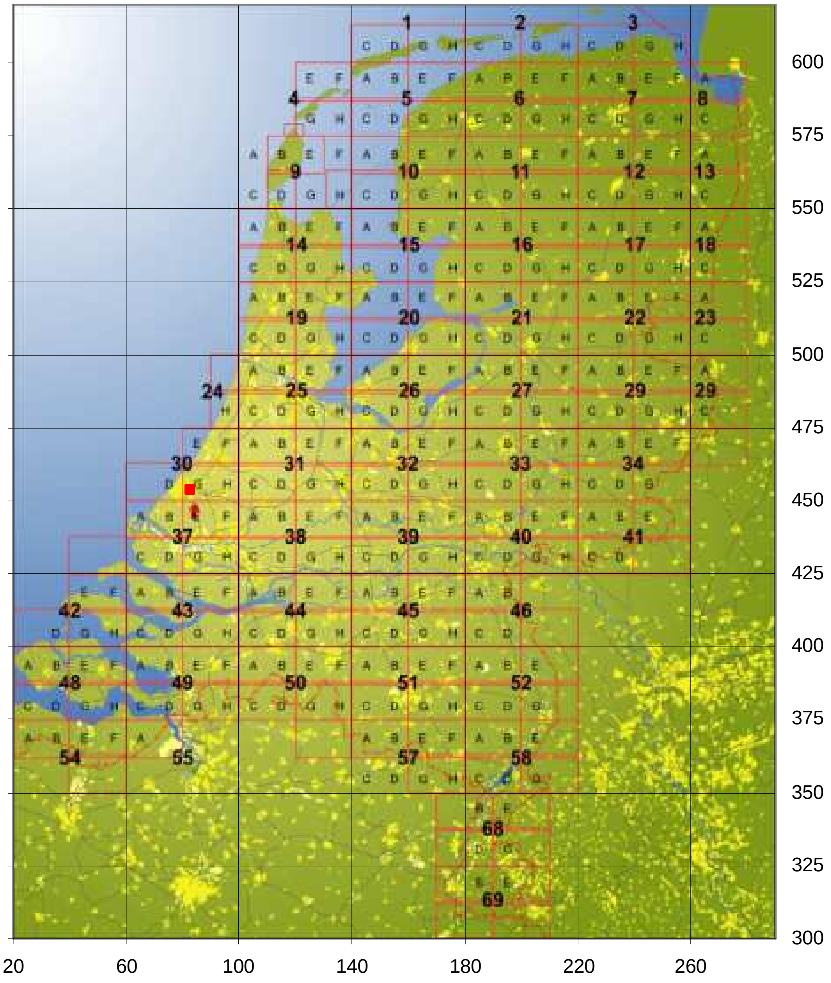
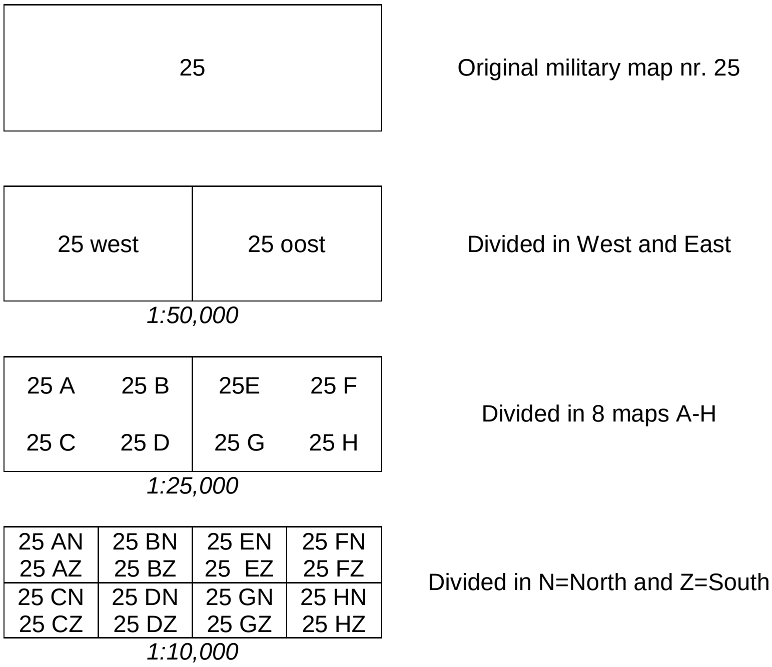


Fig. 1046 Subdivision of topographical maps 1:50,000



25

Original military map nr. 25

25 west	25 oost

Divided in West and East

1:50,000

25 A	25 B	25E	25 F
25 C	25 D	25 G	25 H

Divided in 8 maps A-H

1:25,000

25 AN 25 AZ	25 BN 25 BZ	25 EN 25 EZ	25 FN 25 FZ
25 CN 25 CZ	25 DN 25 DZ	25 GN 25 GZ	25 HN 25 HZ

Divided in N=North and Z=South

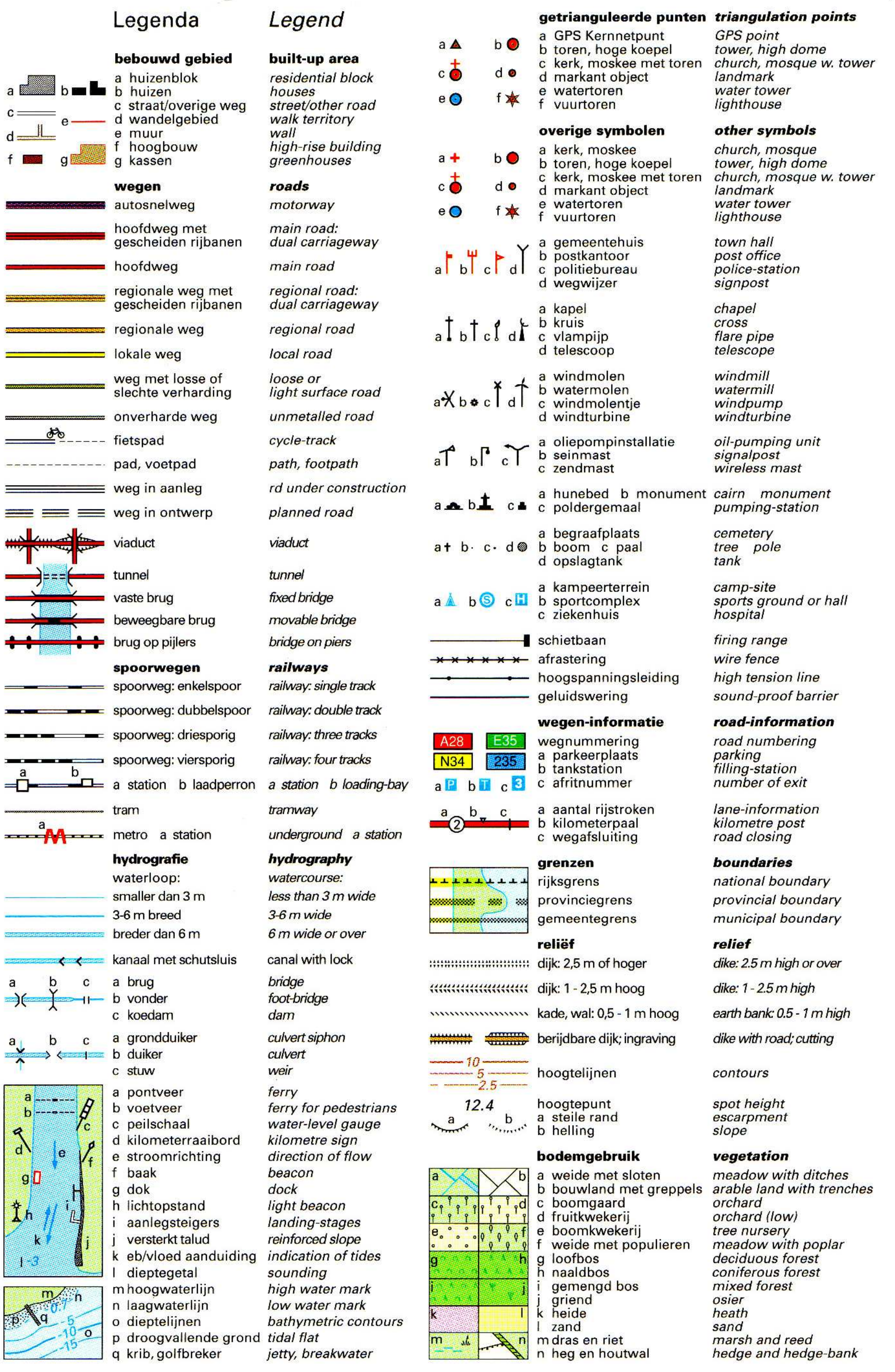
1:10,000

Fig. 1047 Coding of Dutch topographical maps on different scales

7.1.3 Perception and reading of (topographical) maps

Map reading; from form to content.

Reading maps is for a great deal a matter of pattern recognition and being able to see structure. A map is in some or another way a model of reality that is reduced to the structure of that reality that is represented. Map reading includes the capability to read: longitude and latitude, relief or elevation, land use, hydrological system, administrative boundaries etc. Map reading, therefore, means the interpretation of various symbols, colours or grayscales, type of lines.



Legenda	Legend
bebouwd gebied	***built-up area***
a huizenblok	*residential block*
b huizen	*houses*
c straat/overige weg	*street/other road*
d wandelgebied	*walk territory*
e muur	*wall*
f hoogbouw	*high-rise building*
g kassen	*greenhouses*
wegen	***roads***
autosnelweg	*motorway*
hoofdweg met gescheiden rijbanen	*main road: dual carriageway*
hoofdweg	*main road*
regionale weg met gescheiden rijbanen	*regional road: dual carriageway*
regionale weg	*regional road*
lokale weg	*local road*
weg met losse of slechte verharding	*loose or light surface road*
onverharde weg	*unmetalled road*
fietspad	*cycle-track*
pad, voetpad	*path, footpath*
weg in aanleg	*rd under construction*
weg in ontwerp	*planned road*
viaduct	*viaduct*
tunnel	*tunnel*
vaste brug	*fixed bridge*
beweegbare brug	*movable bridge*
brug op pijlers	*bridge on piers*
spoorwegen	***railways***
spoorweg: enkelspoor	*railway: single track*
spoorweg: dubbelspoor	*railway: double track*
spoorweg: driesporig	*railway: three tracks*
spoorweg: viersporig	*railway: four tracks*
a station b laadperron	*a station b loading-bay*
tram	*tramway*
metro a station	*underground a station*
hydrografie	***hydrography***
waterloop:	*watercourse:*
smaller dan 3 m	*less than 3 m wide*
3-6 m breed	*3-6 m wide*
breder dan 6 m	*6 m wide or over*
kanaal met schutsluis	canal with lock
a brug	*bridge*
b vonder	*foot-bridge*
c koedam	*dam*
a grondduiker	*culvert siphon*
b duiker	*culvert*
c stuw	*weir*
a pontveer	*ferry*
b voetveer	*ferry for pedestrians*
c peilschaal	*water-level gauge*
d kilometerraaibord	*kilometre sign*
e stroomrichting	*direction of flow*
f baak	*beacon*
g dok	*dock*
h lichtopstand	*light beacon*
i aanlegsteigers	*landing-stages*
j versterkt talud	*reinforced slope*
k eb/vloed aanduiding	*indication of tides*
l dieptegetal	*sounding*
m hoogwaterlijn	*high water mark*
n laagwaterlijn	*low water mark*
o dieptelijnen	*bathymetric contours*
p droogvallende grond	*tidal flat*
q krib, golfbreker	*jetty, breakwater*

getrianguleerde punten	***triangulation points***
a GPS Kernnetpunt	*GPS point*
b toren, hoge koepel	*tower, high dome*
c kerk, moskee met toren	*church, mosque w. tower*
d markant object	*landmark*
e watertoren	*water tower*
f vuurtoren	*lighthouse*
overige symbolen	***other symbols***
a kerk, moskee	*church, mosque*
b toren, hoge koepel	*tower, high dome*
c kerk, moskee met toren	*church, mosque w. tower*
d markant object	*landmark*
e watertoren	*water tower*
f vuurtoren	*lighthouse*
a gemeentehuis	*town hall*
b postkantoor	*post office*
c politiebureau	*police-station*
d wegwijzer	*signpost*
a kapel	*chapel*
b kruis	*cross*
c vlampijp	*flare pipe*
d telescoop	*telescope*
a windmolen	*windmill*
b watermolen	*watermill*
c windmolentje	*windpump*
d windturbine	*windturbine*
a oliepompinstallatie	*oil-pumping unit*
b seinmast	*signalpost*
c zendmast	*wireless mast*
a hunebed b monument	*cairn monument*
c poldergemaal	*pumping-station*
a begraafplaats	*cemetery*
b boom c paal	*tree pole*
d opslagtank	*tank*
a kampeerterrein	*camp-site*
b sportcomplex	*sports ground or hall*
c ziekenhuis	*hospital*
schietbaan	*firing range*
afrastering	*wire fence*
hoogspanningsleiding	*high tension line*
geluidswering	*sound-proof barrier*
wegen-informatie	***road-information***
wegnummering	*road numbering*
a parkeerplaats	*parking*
b tankstation	*filling-station*
c afritnummer	*number of exit*
a aantal rijstroken	*lane-information*
b kilometerpaal	*kilometre post*
c wegafsluiting	*road closing*
grenzen	***boundaries***
rijksgrens	*national boundary*
provinciegrens	*provincial boundary*
gemeentegrens	*municipal boundary*
reliëf	***relief***
dijk: 2,5 m of hoger	*dike: 2.5 m high or over*
dijk: 1 - 2,5 m hoog	*dike: 1 - 2.5 m high*
kade, wal: 0,5 - 1 m hoog	*earth bank: 0.5 - 1 m high*
berijdbare dijk; ingraving	*dike with road; cutting*
hoogtelijnen	*contours*
hoogtepunt	*spot height*
a steile rand	*escarpment*
b helling	*slope*
bodemgebruik	***vegetation***
a weide met sloten	*meadow with ditches*
b bouwland met greppels	*arable land with trenches*
c boomgaard	*orchard*
d fruitkwekerij	*orchard (low)*
e boomkwekerij	*tree nursery*
f weide met populieren	*meadow with poplar*
g loofbos	*deciduous forest*
h naaldbos	*coniferous forest*
i gemengd bos	*mixed forest*
j griend	*osier*
k heide	*heath*
l zand	*sand*
m dras en riet	*marsh and reed*
n heg en houtwal	*hedge and hedge-bank*

Fig. 1048 Different legend units in a Dutch topographic map

Legends; the reading of maps

You cannot 'read' a map without legend and scale. Sometimes the legend is also called the 'key'. You can distinguish three types of legends on topographic maps:

1. Labels; e.g. a colour green means 'forest'
2. Symbols or icons; e.g. a pumping station is represented by a symbol that is identical anywhere on Dutch topographic maps even though all pumping stations have a different form.
3. Scale representations; e.g. parcels do have the same form as they have in reality, but are scaled down.

Scale; determining size and distance

Scale is relative size. A map or relief model, to be most useful, must accurately show locations, distances and elevations on a given base of convenient size. This means that everything featured on the map or model (land area, distances, rivers, lakes, roads, and so on) must be shown proportionately to its actual size. The proportion chosen for a particular map is its scale.

The scale of a map can be defined simply as the relationship between distance on the map and the distance on the ground, expressed as a proportion, or representative ratio.

Different scales
1:50.000 scale
1:25.000 scale
1:10.000 scale
1:5.000 scale

Scale means relative size; for instance on a 50.000 scale, 1 cm represents 50.000 cm or 500 m.

Different scales of the same area

Fig. 1049 - Fig. 1052 show the Faculty of Architecture building and surroundings. The parcelling and form of the buildings is according to the real form; scale representations.

Fig. 1049 1:50.000 (2x2 cm= 1km2)

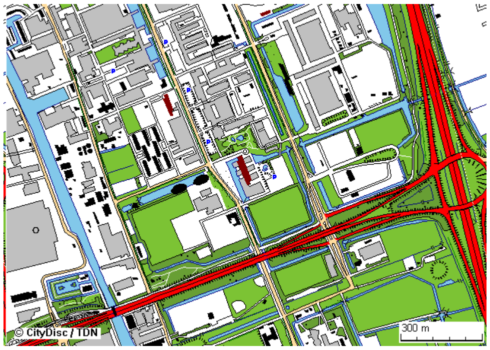


Fig. 1050 1:25.000 (4x4 cm= 1km2)[a]

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[a] CDROM 'The Dutch national street guide with maps of the National Topographic Map Service, Emmen' (The Hague) Citydisc

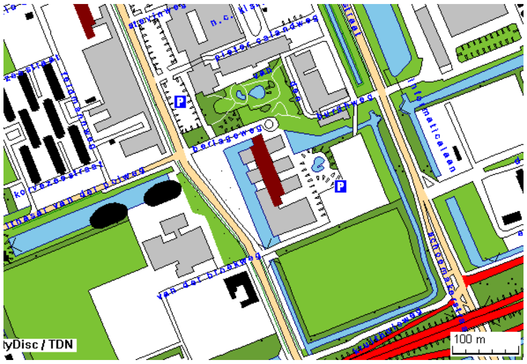


Fig. 1051 1:10.000 (10x10 cm= 1km2)

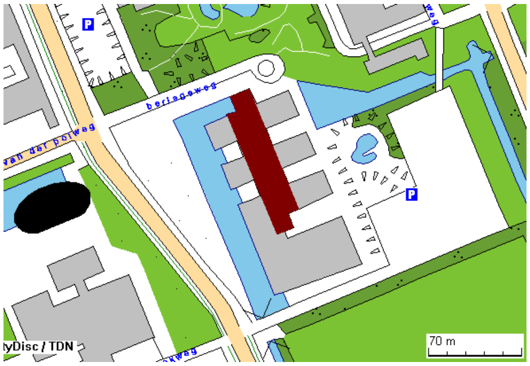
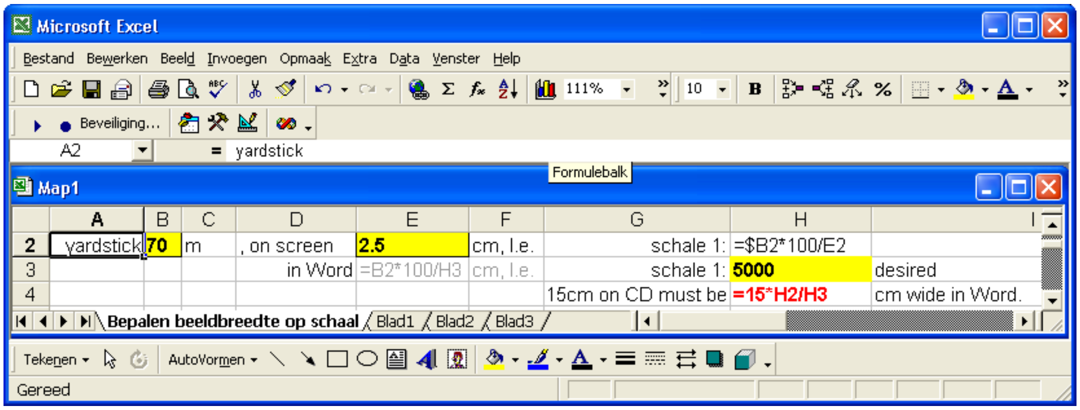


Fig. 1052 1:5000 (20x20 cm= 1 km2)[a]

Importing images from an electronic source at the appropriate scale

Importing the image of an area from an electronic source with a yardstick at the appropriate scale into a word processor similar to Fig. 1049 – *Fig. 1052* could be done as follows. Make the image in the window of the electronic source exactly 15 cm wide (and for example 10 cm high). Copy the map to the clipboard (Ctrl+C). Note the name of the place, district and street. Note the nominal size of the yardstick in m (for example 70m like *Fig. 1052*) and the size on the screen in cm (for example 2.50 cm.) measuring it with a real ruler from screen. Put these measures and the desired scale in an Excelsheet with formulas as given in *Fig. 1053*.



A2 = yardstick

	A	B	C	D	E	F	G	H	I
2	yardstick	70	m	, on screen	2.5	cm, I.e.	schale 1:	=$B2*100/E2	
3				in Word	=B2*100/H3	cm, I.e.	schale 1:	5000	desired
4							15cm on CD must be	=15*H2/H3	cm wide in Word.

result:

70	m	, on screen	2.50	cm, I.e.	schale 1:	2,800	
		in Word	1.4	cm, I.e.	schale 1:	5,000	desired
					15cm on CD must be	8.40	cm wide in Word.

Fig. 1053 Calculations to import an image at the appropriate scale in a word processor

Put the map in the wordprocessor using Ctrl+V. Keep the image selected. Select ‘lay-out’, ‘image’, ‘width’ and enter at ‘width’ according to ‘cm wide in Word’ (8.40 in Fig. 1053). Press ENTER. The figure has the desired scale when you print it. Don’t forget to quote the source under each map used because of copy rights. Don’t make more than one hard copy and only for personal study purposes.

Screensize and printsize

However, the screen you are looking at right now is often not A4. To check that you can adjust the zoom percentage of the screen until you have an A4 of 21,1cm width (for example 95%, dependent on the type of screen). Click ‘Image’ and ‘Ruler’. Check the number of centimetres above the text on screen with a real ruler. Measure from the centre line of the surrounding streets the size of an urban

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[a] CDROM ‘The Dutch national street guide with maps of the National Topographic Map Service, Emmen’ (The Hague) Citydisc

island. Check with the yardstick in the image whether you have done it properly! Note attributes such as in this example: there is a public space at the rear and a park on the edge of the urban island. Add photographs if you have.

Why do we need to adjust the planimetric scale?

The smaller the scale of a map is, the fewer the features that can be accommodated. Obviously, therefore, the larger the scale the more comprehensive the map.

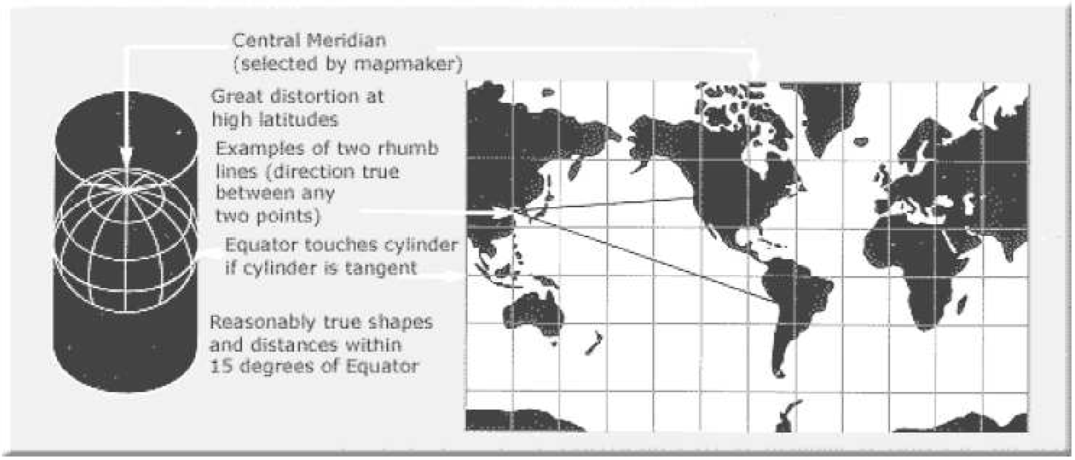
Conversion table

0.001 km = 1 m = 100 cm
0.1 km = 100 m = 10.000 cm
1 km = 1000 m = 100.000 cm

1 km^2 = 100 ha = 1.000.000 m^2
1 ha = 10.000 m^2

Map projections

A map projection is any of many methods used in cartography (mapmaking) to represent the three-dimensional curved surface of the earth or other body on a plane, a two-dimensional space. The term "projection" here refers to any function defined on the earth's surface and with values on the plane, and not necessarily a geometric projection.



Source:

Fig. 1054 A map projection

This process always results in distortion to one or more map properties, such as area, scale, shape, or direction. Because of this, hundreds of projections have been developed in order to accurately represent a particular map element or to best suit a particular type of map. Data sources for maps come in various projections depending upon which characteristic the cartographer chooses to represent more accurately (at the expense of other characteristics).

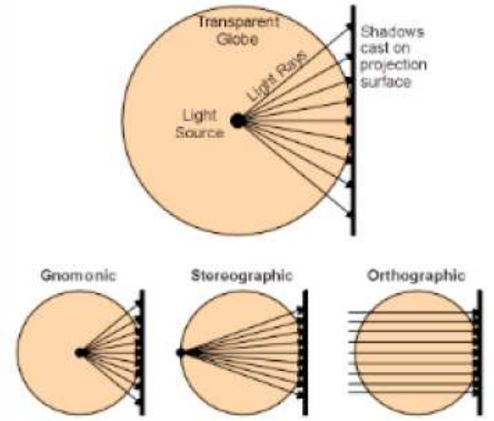
Different types of projections

In the case of the 'Mercator projection', it preserves the right angles of the latitude and longitudinal lines at the expense of area, which is distorted at the poles, showing the land masses there to be larger than they actually are.

Flat maps could not exist without map projections. Flat maps can be more useful than globes in many situations: they are more compact and easier to store; they readily accommodate an enormous range of scales; they are viewed easily on computer displays; they can facilitate measuring properties of the terrain being mapped; they can show larger portions of the earth's surface at once; and they are cheaper to produce and transport. These useful traits of flat maps motivate the development of map projections.

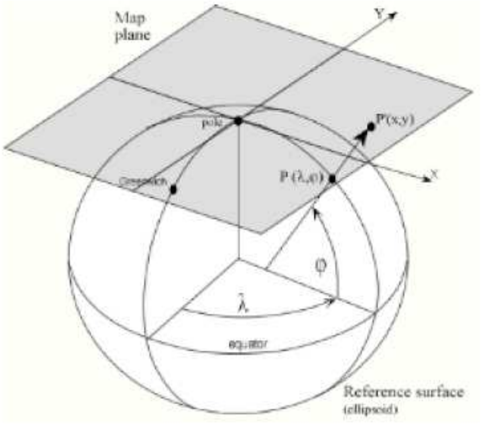
Coordinate system; the defining of location

A coordinate system is just a way of systematically denoting and labeling points in space. Numbered aisles in supermarkets, grids on road maps, and lines of latitude and longitude on the Earth are all coordinate systems which we use every day. Coordinate systems are usually based on two lines, or axes, which are most often perpendicular to one another. In a city, for instance, one building may be "two blocks north and four blocks east", from another, in which case the compass directions of north and east are used as a basis for the grid of the city.



Source:

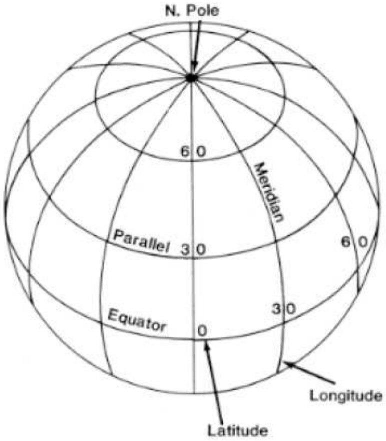
Fig. 1055 Projecting on a plane



Source:

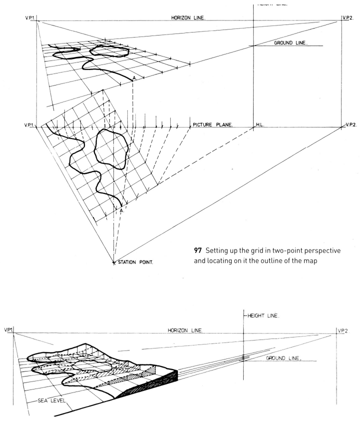
Fig. 1056 Calculations

The dawn of the Great Age of Discovery, some five hundred years ago, greatly increased the demand for accurate maps and charts. The explorers needed maps which covered areas much more vast than those we have yet constructed; they required maps of nothing less than the entire world which they were exploring. Indeed, much of the work of these early explorers involved making newer, more accurate maps of little- or never-traveled regions.



Source:

Fig. 1057 Latitude, longitude



Source:

Fig. 1058 Elevation

Even still, it was not until about a century ago that a standard coordinate system to describe locations on the Earth's surface was adopted. An international convention devised the now-familiar system of latitude and longitude and fixed its reference points. A line of longitude (a meridian) passes through both the North and South Poles. They are labelled according to their angular distance from the prime meridian which passes through Greenwich, England by international agreement. Meridians are labelled between 0° and 180° East or West of the prime meridian. Lines of latitude (often called "parallels") are parallel to the Equator, and are labelled according to angular distance from the Equator- between 0° and 90° North or South. Any point on the surface of the Earth can be uniquely specified by just these two coordinates, latitude and longitude.

The lines of latitude and longitude are not straight, since they are on the surface of a sphere. Nevertheless, if one looks at a small enough region, like a city or a town, that region of the Earth is nearly flat, so the lines of longitude and latitude appear straight and seem to form a square grid. Note that close to the Poles, where the meridians converge, the slant of the meridians is quite noticeable, even on small scales, so even if they appear straight, they won't form a square grid.

GPS (Global Positioning System)

What is GPS? The Global Positioning System (GPS) is an American worldwide radio-navigation system formed from a constellation of 24 satellites (space vehicles) and their ground stations. It is built and operated by the US Dept. of Defense for military use.
Europe is working on its own system called 'Galileo'; it will be available in a couple of years and will be more accurate. GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter!
GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. And that makes the technology accessible to virtually everyone. These days GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, even laptop computers. Soon GPS will become almost as basic as the telephone; part of 'ubiquitous computing'.

The GPS User Segment consists of the GPS receivers and the user community. GPS receivers convert satellites' signals into position, velocity, and time estimates. Four satellites are required to compute the four dimensions of X, Y, Z (position) and Time. GPS receivers are used for navigation, positioning, time dissemination, and other research.
> Navigation in three dimensions is the primary function of GPS. Navigation receivers are made for aircraft, ships, ground vehicles, and for hand carrying by individuals. All navigation systems in cars are based on GPS. In sports like sailing GPS is used to determine positions and navigation.
> Precise positioning is possible using GPS receivers at reference locations providing corrections and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are examples.

Elevation

In geography, the elevation of a geographic location is its height above mean sea level (or some other fixed point). Elevation is mainly used when referring to points on the earth itself, while altitude is used for points in the air, such as an aircraft. Difference in elevation is also called 'relief'. Relief is in general the showing of a three-dimensional surface on a map; the showing of hills and valleys is not substantially different from that of representing a statistical surface such as the rainfall distribution. People are notoriously poor at reasoning in three dimensions and so it is no surprise that many people find relief harder to interpret than most other information on a map. There are more than a dozen distinct methods for showing relief and so the map designer has a wide choice.
It is more or less a convention in cartography to use darker tones/colours for higher elevations and lighter for lower.

Making 3-D models of topographic maps

Still a comprehensive work, making a 3-D map on the basis of a topographic map.
Haaften (2001) gives a short outline how to do this. Gill (2006) is more extensive in that sense.

The ‘Meetkundige Dienst’ RWS[a] measured the elevation of The Netherlands every 5 metre. It resulted in a database called ‘Algemeen Hoogte Bestand’ (AHN) with X, Y and Z coordinates for every measure point to be imported in a CAD or GIS application[b]. The database is divided in smaller parts than *Fig. 1046* because of its enormous size (>50Gb). To get grip on this incomprehensible multitude of figures you can get some of the databases and load them one by one in Excel using an application developed for that purpose (*Fig. 1059*).

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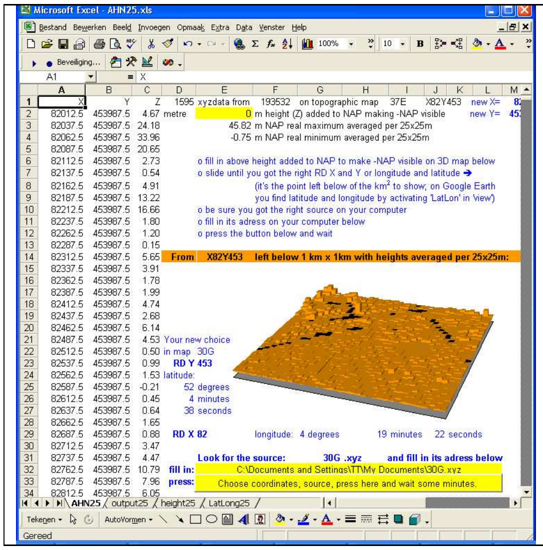
[a] http://www.neonet.nl/browse/dcn.waterland.net/neonet/Organisation/AGKYQJSWOPUBOTRJVEEXOQTVO.html

[b] available in the map library of the Faculty of Architecture TUD



X	Y	Z
82012.5	453987.5	4.67
82037.5	453987.5	24.18
82062.5	453987.5	33.96
82087.5	453987.5	20.65
82112.5	453987.5	2.73
82137.5	453987.5	0.54
82162.5	453987.5	4.91
82187.5	453987.5	13.22
82212.5	453987.5	16.66
82237.5	453987.5	1.80
82262.5	453987.5	1.20
82287.5	453987.5	0.15
82312.5	453987.5	5.65
82337.5	453987.5	3.91
82362.5	453987.5	1.78
82387.5	453987.5	1.99
82412.5	453987.5	4.74
82437.5	453987.5	2.68
82462.5	453987.5	6.14
82487.5	453987.5	4.53
82512.5	453987.5	0.50
82537.5	453987.5	0.99
82562.5	453987.5	1.53
82587.5	453987.5	-0.21
82612.5	453987.5	0.45
82637.5	453987.5	0.64
82662.5	453987.5	1.65
82687.5	453987.5	0.88
82712.5	453987.5	3.47
82737.5	453987.5	4.47
82762.5	453987.5	10.79
82787.5	453987.5	7.96
82812.5	453987.5	6.05

1595 xyzdata from 193532 on topographic map 37E X82Y453 new X=
metre 0 m height (Z) added to NAP making -NAP visible new Y=
45.82 m NAP real maximum averaged per 25x25m
-0.75 m NAP real minimum averaged per 25x25m

o fill in above height added to NAP to make -NAP visible on 3D map below
o slide until you got the right RD X and Y or longitude and latitude ➔
(it's the point left below of the km² to show; on Google Earth
you find latitude and longitude by activating 'LatLon' in 'view')
o be sure you got the right source on your computer
o fill in its adress on your computer below
o press the button below and wait

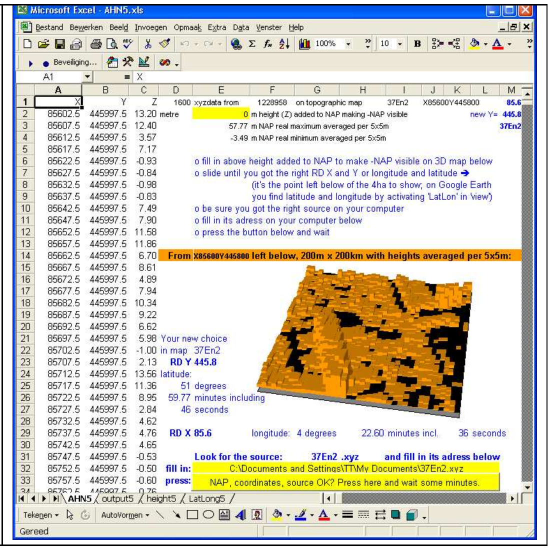
From X82Y453 left below 1 km x 1km with heights averaged per 25x25m:

Your new choice
in map 30G
RD Y 453
latitude:
52 degrees
4 minutes
38 seconds

RD X 82 longitude: 4 degrees 19 minutes 22 seconds

Look for the source: 30G .xyz and fill in its adress below
fill in: C:\Documents and Settings\TT\My Documents\30G.xyz
press: Choose coordinates, source, press here and wait some minutes.

Fig. 1059 AHN 5x5m



X	Y	Z
85602.5	445997.5	13.20
85607.5	445997.5	12.40
85612.5	445997.5	3.57
85617.5	445997.5	7.17
85622.5	445997.5	-0.93
85627.5	445997.5	-0.84
85632.5	445997.5	-0.98
85637.5	445997.5	-0.83
85642.5	445997.5	7.49
85647.5	445997.5	7.90
85652.5	445997.5	11.58
85657.5	445997.5	11.86
85662.5	445997.5	6.70
85667.5	445997.5	8.61
85672.5	445997.5	4.89
85677.5	445997.5	7.94
85682.5	445997.5	10.34
85687.5	445997.5	9.22
85692.5	445997.5	6.62
85697.5	445997.5	5.98
85702.5	445997.5	-1.00
85707.5	445997.5	2.13
85712.5	445997.5	13.56
85717.5	445997.5	11.36
85722.5	445997.5	8.95
85727.5	445997.5	2.84
85732.5	445997.5	4.62
85737.5	445997.5	4.76
85742.5	445997.5	4.65
85747.5	445997.5	-0.53
85752.5	445997.5	-0.50
85757.5	445997.5	-0.60

1600 xyzdata from 1228958 on topographic map 37En2 X85600Y445800 **85.6**
metre 0 m height (Z) added to NAP making -NAP visible new Y= **445.8**
57.77 m NAP real maximum averaged per 5x5m **37En2**
-3.49 m NAP real minimum averaged per 5x5m

o fill in above height added to NAP to make -NAP visible on 3D map below
o slide until you got the right RD X and Y or longitude and latitude ➔
(it's the point left below of the 4ha to show; on Google Earth
you find latitude and longitude by activating 'LatLon' in 'view')
o be sure you got the right source on your computer
o fill in its adress on your computer below
o press the button below and wait

From X85600Y445800 left below, 200m x 200km with heights averaged per 5x5m:

Your new choice
in map 37En2
RD Y 445.8
latitude:
51 degrees
59.77 minutes including
46 seconds

RD X 85.6 longitude: 4 degrees 22.60 minutes incl. 36 seconds

Look for the source: 37En2 .xyz and fill in its adress below
fill in: C:\Documents and Settings\TT\My Documents\37En2.xyz
press: NAP, coordinates, source OK? Press here and wait some minutes.

Fig. 1060 AHN 25x25m[a]

However, it is still difficult to recognise the topographic features, because incidental vegetation disturbes the image. So, the database is aggregated into another database with 25x25m cells (see *Fig. 1060*). But even then it is difficult to recognise the Mekelweg in Delft.

Learning to read maps by combination of sources

The more you know about the background of an area in terms of soils, geology the better you will be able to understand the form of the landscape and what you see on the map. Nonetheless all urban designers and landscape architects should be able to read and interpret maps of areas, even though you have never been there or you are not familiar with.

Learning to read maps is a matter of doing; only by experience you gain more insight. The legends and scales as such are not very difficult to understand but the interpretation is the tricky thing. Reading and interpreting contour lines is even for experienced map readers difficult. In Holland we have the disadvantage of not having any mountainous region so there is less possibility to practice that aspect of map reading.

7.1.4 Map analysis and interpretation

Reduction and analysis

Analysis of maps always needs reduction. Reduction of maps (Leupen et al., 1997) is a basic technique in map analysis. Reduction is based on abstraction but is not the same. When you reduce information on a map, it might be one aspect. For instance when you want to analyse the water system, you could leave out the road system in order to focus. Depending on the purpose you leave out information in order to emphasise other information. In case of abstraction you generalise, that is you lower the scale and depending on the size you leave out detailed information. For instance on the map 1:400.000 of Holland, the city of Delft is represented by a small point or circle whereas on the scale 1:25.000 you can distinguish the street patteren, main plaza's etc.

Working with layers

The working with layers is very well known technique in map analysis. Formerly with (transparent) paper, now with digital layers like they can by used in Illustrator. Say you want to research the relation between occupation pattern and elevation of a certain area. You then first make one layer with only the dwellings of that area. Then you do the same for the elevation. By comparing the two you might find a relation; for instance at Walcheren, in the province of Zeeland, you will find that the occupation pattern is related to the higher areas; the ridges of the former creeks. Like in statistics; finding relations

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[a] http://team.bk.tudelft.nl/ > Publications > 2006

is one, secondly you will have to research whether these relations have also causal relations or are haphazard. These research by means of layers can be done in an analogue way (mostly with transparant paper) or digitally like the layers in Illustrator.

The principle here is that you research vertical relations in the landscape.

Still one step further is to make use of GIS. Nowadays analysis of maps is more and more done with GIS. The digital analysis of geographical information and cartographic information is not only cheaper as soon as information is available in digital form, it gives also opportunities for larger scale research with almost infinite amount of data.

Comparing maps in time

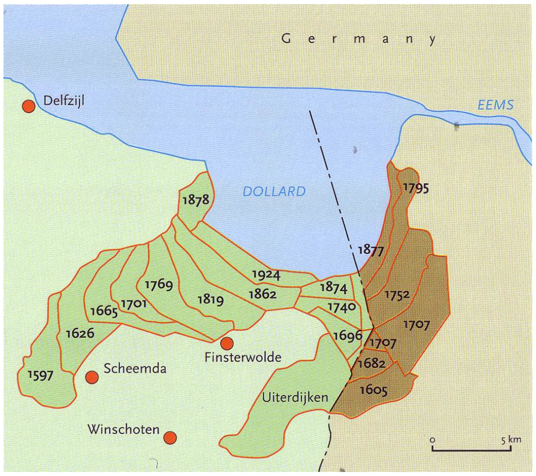
Analysis of maps by comparing maps of the same area from different time periods. Historical development can be analysed by comparing maps from different time periods of the same site. For the city of Delft, Geurtsen (1988) did such a study for the urban development of the city.

Fig. 1061: The development of the city of Delft according to Geurtsen[a]

Source:

Fig. 1062 Compare this historical analysis with the present situation!

It can also be shown in one map, like Ven (2004) did for the polders around the Dollard, up in the north in the eastern part of the Province of Groningen.



:

Fig. 1063 Showing the process of landscape development; the making of polders in the Dollard area in the northeastern part of Holland, the process of the subsequent polders in time[b]

Source:

Fig. 1064 The topographic map of the area.

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[a] *Geurtsen ()*

[b] *Ven, 2004*

Analysing of places by means of maps

Analysis of maps by comparing different aspects of the map. Maps represent spaces, places by horizontal and vertical elements. Horizontal elements are: roads, roadsystems, watersystems, parcelling. Vertical elements are: built structures, differences in elevation, plantation. This we call a spatial and/or visual analysis.
By adding the flows of people, material, energy and information you can get an idea how a place works and functions.

In most countries the relief is much more outspoken than in Holland. Formally Holland does not have 'hills' and 'mountains'; the highest point in the South (Vaals) is less than 400 m above sea level. Even though the differences in elevation are not outspoken, in Holland small differences in elevation can make great differences in occupation and land-use.
The only way to analyse the basic topography is to make an analysis on the basis of contour-lines.

7.1.5 Making of maps and communication

Cartographic drawing

Maps can be seen as a form of visual communication — a special-purpose language for describing spatial relationships. Although it is perhaps unwise to draw a direct analogy between cartography and language, concepts such as "grammar" and "syntax" help to explain, at least metaphorically, the sorts of decisions cartographers make as they compose maps. Cartographers seek to make use of visual resources such as colour, shape and pattern to communicate information about spatial relationships. The analogy with language also helps explain why training in principles of effective cartography is so important — it allows us to communicate more effectively.
Drawing maps — cartographic drawing — is a specialist activity. Urban designers and landscape architects should have a basic understanding and insight in cartographic principles.
Keep in mind that cartography in whatever form is a way of communication. What you want to communicate defines the way you are going to work on maps.

Making maps; from content to form

1. Classification and typology. You start out with a classification and typology of the geographical information you have. It is clear that this distinction forms a direct relation with the legend.
2. Generalisation and reduction of maps. Sometimes information is too detailed and needs to be generalised into more global classes or types. Any change in this sense refers at the same time to scale and legend. Every scale has its own legend.
3. Abstraction and diagrams. Any cartographic representation as a map can be considered as a form of abstraction. Sometimes it helps to add diagrams to give additional information next to the map.

Upscaling and downscaling

Re-scaling; upscaling and downscaling. In general downscaling is easier than upscaling. If you compare in an atlas the same area at different scales, you can see the effect of downscaling and upscaling. A different scale shows a completely different image, not just diminishing in size. So every scale has its own image and its own legend.
Technically, downscaling is always always possible as long as you adapt the legend and reduce information, whereas upscaling is only possible if you add new information. In practice you can always 'diminish the size' of maps but not 'enlarge' them. You cannot enlarge or reduce maps without changing the legend! A number of factors influence the options for re-scaling. First you have to identify and measure the area you want to reproduce. For your ease, you will select a rectangular shape including the core area (e.g. protected area, watershed, ancestral domain, or other) and its environs of ecological, cultural and economic significance. If the core of a protected area is a mountain, the rectangle will include the downhill catchments and possibly the settlement areas where most dependent communities reside.

Making cartographic models

The choice of the scale and hence the size of the model should take into account the need for accuracy as well as the need for enough space in which physically to construct and store the model.

Maps and mapping in Holland

Holland has a long cartographic tradition. From the 16th century on Dutch cartographers made maps, not only of Holland but also of other parts of the world. In many cased there were military uses for maps; sea maps, maps of fortifications and topographic maps of an early stage. At the end of the 18th century the first ‘Topographic office’ was established based on French ideas and models. The main goal was a military cartography of the whole country. In 1932 the ‘Topographic service’ was formally established still under military rule. Between 1876 and 1953, a series of 25.000 maps was produced of the whole country; the so-called ‘Bonne-sheets’.

Gradually this series was replaced by a series on 25.000 based on the stereographic projection. In 2004, a new organisation was set up; the ‘Topographic service Kadaster’. This organisation is a formal part of the government service that has independent tasks of producing basic maps, of registration of real estate. It is a public service open to everybody. Nowadays most topographic information is digitally-based information.

In Holland we now have basically three scales in topographic maps; 50.000, 25.000 and 10.000.

The TOP10vector is the basis for all Dutch topographic maps. From this TOP 10vector, the 25.000 and the 10.000 scales can be directly derived. The 50.000 scale needs to be generalised otherwise it will be unreadable. This digital information forms the basis for the production of paper maps, for GIS information, maps for special purposes.

All topographic maps can be ordered at the website of the topographic service; www.tdn.nl

GoogleEarth and Web-mapping

Maps have traditionally been made using pen and paper, but the advent and spread of computers has revolutionised cartography. Most commercial quality maps are now made with map making software that falls into one of three main types; CAD, GIS, and specialised map illustration software.

'Web-GIS' is the culmination of what is regarded as a 'Geospatial Data Infrastructure' or 'GDI.' A GDI is a set of institutional, technical, and economical arrangements used to enhance the availability of correct, up-to-date, to-the-point and integrated geospatial data with regard to timeliness and price affordability, all of which combine to support efficient decision making processes. A GDI is composed technically of geographic information systems, networks, computers, and a plethora of software applications (Plewe, 1997).

Web-GIS consists of a sequence of geo-processing tasks that are distributed over server-side and client-side computer systems. A client is a Web browser. A server consists of a Web server and a Web-GIS software system. A client requests a map or makes a geo-processing request over the Web to a remote server. The Web server translates client requests into internal codes and invokes GIS functions by passing formatted requests to Web-GIS software. The later software returns results that are reformatted for interpretation by the client browser or with additional functionality from a plug-in or Java applet.

Maps generated by a Web-GIS are often called 'Web maps (Plewe, 1997).' They are an interface between a client and the GDI. The design of Web maps is critical for the correct communication of geospatial databases. Conventional and historical GIS analyses have traditionally evolved around constructions using paper maps. With the advent of the Internet, the practices of GIS had to be migrated into the Web environment.

GoogleEarth

GoogleEarth has really revolutionised web-mapping in every sense of the word. For the first time in history, maps of the entire world are available for all those who have internet. For urban design and landscape architecture the possibilities are hard to oversee; we still discover new types of use beyond the already existing of getting maps freely at almost every conceivable scale. Especially in the field of interpretation the possibilities are still to be further discovered. The development of GoogleEarth goes so fast, both in getting more detailed information and in the applications that you can use it for, that you have to keep track frequently to keep up to date. Do regularly download the user manual; it is also free and excellent.

At present, there are few formal standards for the design of Web maps. The visual perception of Web maps is decidedly different from paper maps. This perception is a fundamental consideration during a design phase for Web-GIS. Digital map authoring (i.e. cartography) tends to be more constrained in its available toolset than that used for paper map design. Subsequently, Web-GIS strive to 'emulate' paper map productions and presumably this weighs considerably in any Web-GIS selection. Web-GIS does offer an acceptable differentiation from conventional GIS through the use of animation, rotation functions, three-dimensional viewing, user interaction, and other multimedia presentations (Beddoe, 1997).

Representing objects, their environment and development

Specific problems associated with urban development within rural areas require knowledge of the city itself and of the surrounding countryside. This task needs up-to-date and reliable planning information, including development strategies, processes that take place in and around the city and the spatial spread of characteristic elements. Maps are a good method to lay down information and processes. For the town planner, analyses and interpretations are essential methods to identify and understand processes, and the possibilities and limitations of a region. Regional analyses and interpretations constitute the most important arguments and motives for a design.
Knowledge of the city and surrounding countryside can be derived from maps. When maps are not available or out-dated, aerial photographs and satellite images can be used.
Maps of the Netherlands are numbered according to grids.

INSPIRE is coming

The European Commission and the European Parliament have reached agreement about Guidelines for the set up of a foundation of infrastructure for Spatial Information in the European Community or Infrastructure for Spatial Information in Europe or INSPIRE. For the moment INSPIRE is targeting on the development and execution of environmental management. But the list of information belonging to INSPIRE is more extensive and will give information all kind of subjects belonging to the Spatial Sciences.

The more abstract language of the guideline should be translated into a more practical one for interpretation and definition of a number of specific standards and the description of a limited list of spatial data.

INSPIRE has five basic principles (INSPIRE 2007):

1. Data are once gathered and maintained where it is most efficient.
2. The possibility should be given to combine data of different sources and that these data can be consulted by many users for different purposes.
3. Spatial data should be gathered on one level of the government and it should be possible to use these data on all levels of the government.
4. Spatial data that are necessary for a good public policy should be available without any restriction.
5. It should be easy to discover what spatial data are available, the suitability of these to evaluate and what kind of conditions are committed to it.

There are no specific guidelines or techniques to translate the information to the practice. Accessibility should be guaranteed by internet and by an EU-internet portal for all publicly available information of the EU-member states and the guarantee of the interchangeability of the information.
Spatial data belonging to INSPIRE:

Since 2010

- Geographical names
- Administrative units
- Traffic networks
- Hydrographic data
- Protection zones
- Altitudes
- Identification of ownership
- Cadastral register of land plots
- Groundcover
- Ortho photographs

Since 2013

- Spatial definitions of statistic units
- Buildings

- Soil
- Geology
- Land use
- Human health and safety
- Public services
- Environmental security services
- Production and industrial facilities
- Facilities for agriculture and aquaculture
- Demography
- Registered regions for waste, groundwater, zones of nuisance, mining etc.)
- Regions with natural risks
- Atmospheric circumstances
- Meteorological characteristics
- Oceanography
- Sea regions
- Habitats and biotopes
- Distribution of species.

More information is to be found on website *http://inspire.jrc.it/*

7.1.6 Legends for municipal zoning plans

The Law on spatial Planning 2008 prescribed colours symbols and codes for municipal zoning plans summarised in the tables below[a].

code	Dutch	English	R	G	B	C	M	Y	Pantone
	Grens	boundary	255	255	255	100	100	100	
A	Agrarisch	agricultural	235	240	210	10	5	20	7485U
AW	Agrarisch met waarden	agricultural with values	210	225	165	20	15	35	580U
B	Bedrijf	business	180	095	210	35	60	00	258U
BT	Bedrijventerrein	industrial estate	200	160	215	20	30	00	522U
BO	Bos	forest	100	170	045	55	10	100	369U
C	Centrum	center	255	200	190	00	20	15	706U
CO	Cultuur en ontspanning	culture and entertainment	255	060	130	00	90	35	Rubine Red U
DH	Detailhandel	retail	255	160	150	00	40	30	1625U
DV	Dienstverlening	provision of services	240	145	190	05	40	05	701U
G	Groen	greenery	040	200	070	50	00	80	360U
GD	Gemengd	mixed	255	190	135	00	25	45	156U
H	Horeca	hotel and catering industry	255	105	035	00	70	90	Orange 021U
K	Kantoor	office	235	195	215	05	20	05	250U
M	Maatschappelijk	social	220	155	120	05	35	50	157U
N	Natuur	nature	130	165	145	40	15	40	557U
R	Recreatie	recreation	185	215	070	20	05	85	380U
S	Sport	sports	130	200	070	45	05	90	3B2U
T	Tuin	garden	200	215	110	15	05	65	584U
V	Verkeer	traffic	205	205	205	20	20	20	427U
W	Wonen	living	256	255	000	06	00	97	102C
WA	Water	water	175	205	225	25	05	10	290U
WG	Woongebied	residential area	255	255	180	00	00	30	600U
	Overig	remaining	235	225	235	05	10	10	663U

Fig. 1065 Legally prescribed colours for main uses in Dutch zoning plans

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[a] *http://www.helpdeskdurp.nl/infotype/webpage/view.asp?objectID=129*

code		**Dutch**	**English**
L	▒	**Leidingen**	**cables and pipes**
L-B		Brandstof	fuel
L-G		Gas	gas
L-H		Hoogspanning	high tension
L-HV		Hoogspanningsverbinding	high tension connection
L-L		Leidingstrook	strip for cables and pipes
L-O		Olie	oil
L-R		Riool	sewer
L-W		Water	water

WR	+ + + + + + + +	**Waarden**	**values**
WR-A		Archeologie	archaeology
WR-C		Cultuurhistorie	history of civilisation
WR-E		Ecologie	ecology
WR-G		Geomorfologie	geomorphologie
WR-L		Landschap	landscape

WS	≈	**Waterstaat**	**water management**
WS-WB		Waterbergingsgebied	water store area
WS-WK		Waterkering	dam
WS-WL		Waterlopen	watercourse
WS-WS		Waterstaatkundige functie	water management function

Fig. 1066 Legally prescribed patterns for main double uses in Dutch zoning plans

	Dutch and analogue representation		**English and digital representation**	**transp**
▥	geluidzone (R255 G155 B0)	⊥⊥⊥	noise zone (R255 G155 B0)	60%
▨	industrie			
▤	spoor			
▧	weg			
▥	luchtvaartverkeerzone (R155 G50 B205)	⊥⊥⊥	air connection zone (R155 G50 B205)	60%
▥	milieuzone (R0 G155 BO)	⊥⊥⊥	environmental zone (R0 G155 B0)	60%
▤	bodembeschermingsgebied			
▨	geluidsgevoelige functie			
▤	geurzone			
▥	grondwaterbeschermingsgebied			
▒	stiltegebied			
▨	waterwingebied			
▧	zones Wet Milieubeheer			
▥	reconstructiewetzone (R56 G133 B94)	⊥⊥⊥	Reconstruction law zones (R56 G133 B94)	60%
▧	extensiveringsgebied			
▨	landbouwontwikkelingsgebied			
▤	verwevingsgebied			
▥	veiligheidszone (R0 G0 B255)	⊥⊥⊥	safety zone (RO GO B255)	60%
▤	bevl			
▒	leiding			
▥	lpg			
▤	munitie			
▧	vervoer gevaarlijke stoffen			
▨	vuurwerk			
▨	windturbine			

	Dutch and analogue representation		**English and digital representation**	**transp**
▨	vrijwaringszone (RO G255 B255)	▲ ▲ ▲	protection zone (R55 G205 B0)	60%
▨	buisleidingenstraat			
▨	dijk			
▨	duin			
▨	molenbiotoop			
▨	radar			
▨	spoor			
▨	straalpad			
▨	vaarweg			
▨	weg			
▨	Wro-zone (R255 GO BO)	▲ ▲ ▲	Law of spatial planning zone (R255 G0 B0)	60%
▨ 1	moderniseringsgebied			
▨ 1	ontheffingsgebied			
▨	verwerkelijking in naaste toekomst			
▨ 1	wijzigingsgebied			
☐	overig (R100 G100 B100)	▲ ▲ ▲	remaining (R100 G100 B100)	60%

Fig. 1067 Legal and environmental zones

(bah)	(bah)	bedrijf aan huls	
(cw)	(cw)	cultuurhistorische waarde	
(iv)	(iv)	intensieve veehouderij	
(rw)	(rw)	recreatiewoning	
(-rw)	(-rw)	recreatiewoning uitgesloten	
(sdh-..)	(sdh-..)	specifieke vorm van detailhandel	
(-sdh-..)	(-sdh-..)	specifieke vorm van detailhandel uitgesloten	
	⬚	digitale grens	

Fig. 1068 Examples of functional indications

code	**Functieaanduidingen SVBP2008**	**Functional indications**
(as)	aanlegsteiger	jetty
(a)	agrarisch	agricultural
(ab)	agrarisch bedrijf	agricultural business
(al)	agrarisch loonbedrijf	agricultural wage labour business
(agw)	agrarisch met waarden	agricultural with values
(ak)	akkerbouw	farming
(abp)	ambachtelijke be- en verwerking agrarische producten	
(aqc)	aquacultuur	
(aq)	aquaduct	
(aw)	archeologische waarden	
(az)	asielzoekerscentrum	
(atl)	atelier	
(at)	attractiepark	
(ac)	autocircuit	
(bsd)	baggerspeciedepot	
(bb)	bed & breakfast	
(b)	bedrijf	
(bah)	bedrijf aan huis	
(b≤)	bedrijf tot en met categorie..	
(b=)	bedrijf van categorie ..	
(bw)	bedrijfswoning	
(bt)	bedrijventerrein	
(beb)	beeldbepalende boom	
(bp)	begraafplaats	

code	Functieaanduidingen SVBP2008	Functional indications
(be)	belwinkel	
(bh)	beroep aan huis	
(bi)	bibliotheek	
(bs)	bioscoop	
(bot)	bollenteelt	
(bm)	bomenteelt	
(bd)	bordeel	
(bo)	bos	
(bow)	bowlingbaan	
(brk)	brandweerkazerne	
(br)	brug	
(cs)	caravanstalling	
(ca)	casino	
(c	centrum	
(coc)	congrescentrum	
(cc)	creativiteitscentum	
(cr)	crematorium	
(co)	cultuur en ontspanning	
(cw)	cultuurhistorische waarden	
(dr)	dagrecreatie	
(da)	dansschool	
(dh)	detailhandel	
(dhg)	detailhandel grootschalig	
(dhe)	detailhandel in brand en explosiegevaarlijke goederen	
(dhp)	detailhandel perifeer	
(dhv)	detailhandel volumineus	
(dv)	dienstverlening	
(ds)	dierenasiel	
(dt)	dierentuin	
(di)	discotheek	
(db)	drafbaan	
(do)	drugsopvang	
(evz)	ecologische verbindingszone	
(ew)	ecologische waarde	
(ek)	eendenkooi	
(e)	erf	
(ev)	evenemententerrein	
(fz)	feestzaal	
(ft)	fruitteelt	
(ga)	garage	
(gs)	geluidscherm	
(gw)	geluidwal	
(gm)	gemaal	
(gd)	gemengd	
(gmw)	geomorfologische waarde	
(gz)	gezondheidszorg	
(gt)	glastuinbouw	
(go)	golfbaan	
(g)	groen	
(gr)	gronddepot	
(gv)	grondgebonden veehouderij	
(gh)	groothandel	
(ha)	haven	

code	**Functieaanduidingen SVBP2008**	**Functional indications**
(h)	horeca	
(h≤)	horeca tot en met horecacategorie	
(h=)	horeca van categorie..	
(hs)	houtsingel	
(hw)	houtwal	
(hv)	hovenier	
(ijs)	ijsbaan	
(i)	infrastructuur	
(ik)	intensieve kwekerij	
(iv)	intensieve veehouderij	
(ic)	internetcafé	
(iw)	internetwinkel	
(jh)	jachthaven	
(jo)	jeugdopvang	
(jop)	jongeren ontmoetingsplek	
(ji)	justitiële inrichting	
(kv)	kamerverhuur	
(kp)	kampeerboerderij	
(kt)	kampeerterrein	
(k)	kantoor	
(kab)	kartbaan	
(ks)	kas	
(kz)	kazerne	
(kb)	kinderboerderij	
(kijs)	kunstijsbaan	
(ll)	laad- en losplaats	
(lb)	landingsbaan	
(lw)	landschapswaarden	
(lbr)	leiding brandstof	
(lg)	leiding gas	
(lhs)	leiding hoogspanning	
(lhv)	leiding hoogspanningsverbinding	
(lo)	leiding olie	
(lr)	leiding riool	
(lwa)	leiding water	
(ls)	leidingstrook	
(lp)	ligplaats	
(lh)	luchthaven	
(lv)	luchtverkeer	
(m)	maatschappelijk	
(ma)	manege	
(mrk)	markt	
(me)	meer	
(mo)	militair oefenterrein	
(mz)	militaire zaken	
(mb)	modelvliegtuigbaan	
(mob)	monumentale boom	
(mc)	motorcrossterrein	
(md)	munitiedepot	
(mu)	museum	
(ms)	muziekschool	
(mt)	muziektheater	
(nso)	naschoolse opvang	

code	Functieaanduidingen SVBP2008	Functional indications
(n)	natuur	
(nlw)	natuur- en landschapswaarden	
(nw)	natuurwaarden	
(nb)	nutsbedrijf	
(nv)	nutsvoorziening	
(oe)	oever	
(on)	onderwijs	
(os)	ontsluiting	
(ov)	openbaar vervoer	
(ovs)	openbaar vervoerstation	
(od)	openbare dienstverlening	
(op)	opslag	
(pf)	paardenfokkerij	
(ph)	paardenhouderij	
(pd)	pad	
(pa)	park	
(pg)	parkeergarage	
(p)	parkeerterrein	
(pb)	partyboerderij	
(pah	passantenhaven	
(pp)	pitch & putt	
(ps)	plantsoen	
(pl)	plein	
(prr)	praktijkruimte	
(pr)	prostitutie	
(raamexploitatie)	raamprostitutie	
(rv)	railverkeer	
(r)	recreatie	
(rw)	recreatiewoning	
(re)	religie	
(ri)	risicovolle inrichting	
(rr)	rivier	
(sau)	sauna	
(shu)	schiphuis	
(si)	seksinrichting	
(sit)	sierteelt	
(sil)	silo	
(ske)	skeelerbaan	
(skb)	skibaan	
(sl)	sluis	
(sa-..)	specifieke vorm van agrarisch	
(saw-..)	specifieke vorm van agrarisch met waarden	
(sb-..)	specifieke vorm van bedrijf	
(sbt-..)	specifieke vorm van bedrijventerrein	
(sbo-..)	specifieke vorm van bos	
(sc-..)	specifieke vorm van centrum	
(sco-..)	specifieke vorm van cultuur en ontspanning	
(sdh-..)	specifieke vorm van detailhandel	
(sdv-..)	specifieke vorm van dienstverlening	
(sgd-..)	specifieke vorm van gemengd	
(sg-..)	specifieke vorm van groen	
(sh-..)	specifieke vorm van horeca	

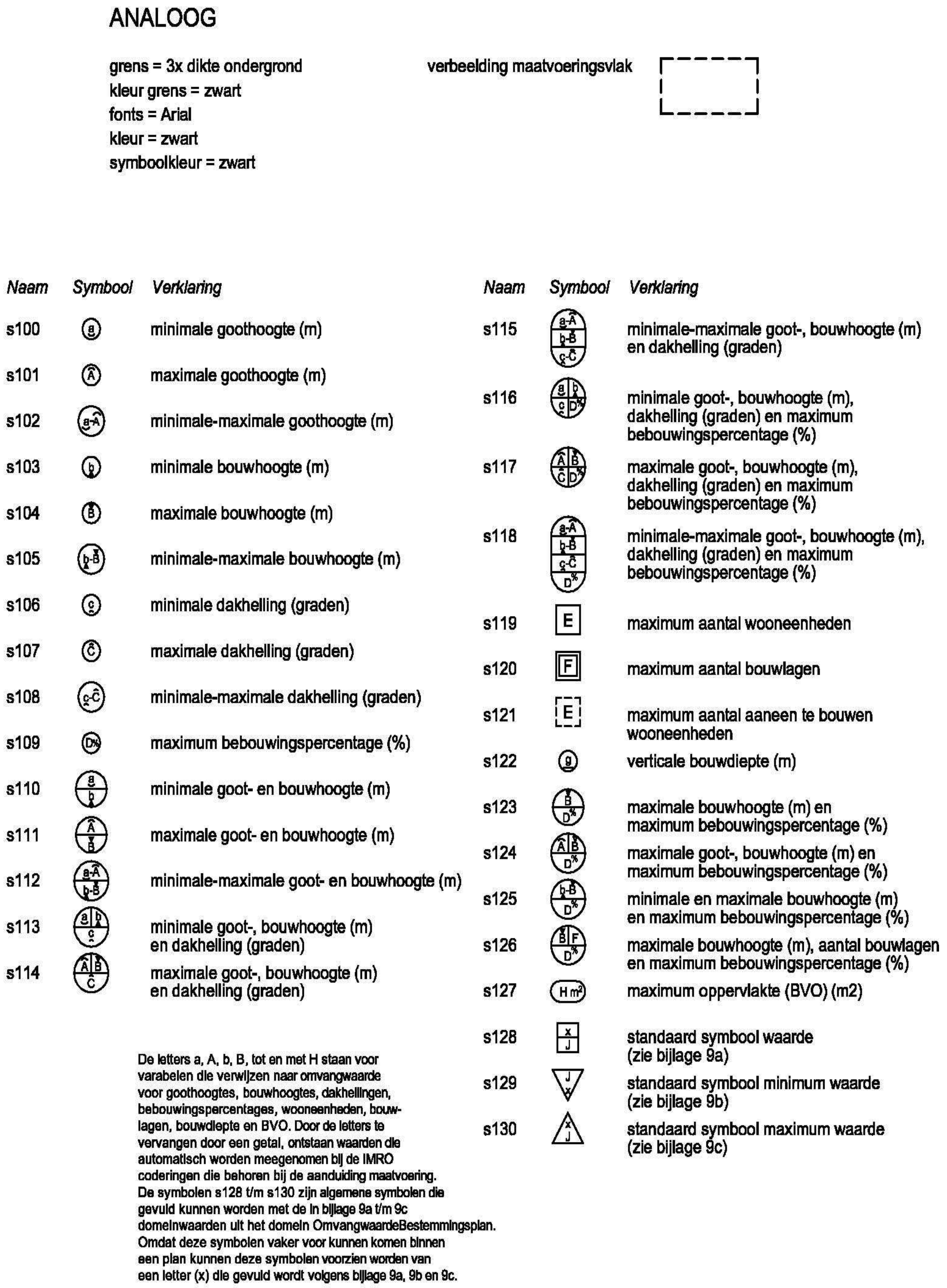
code	Functieaanduidingen SVBP2008	Functional indications
(sk-..)	specifieke vorm van kantoor	
(sle-..)	specifieke vorm van leiding	
(sm-..)	specifieke vorm van maatschappelijk	
(sn-..)	specifieke vorm van natuur	
(sr-..)	specifieke vorm van recreatie	
(ss-..)	specifieke vorm van sport	
(st-..)	specifieke vorm van tuin	
(sv-..)	specifieke vorm van verkeer	
(swr-..)	specifieke vorm van waarde	
(swa-..)	specifieke vorm van water	
(sws-..)	specifieke vorm van waterstaat	
(sw-..)	specifieke vorm van wonen	
(swg-..)	specifieke vorm van woongebied	
(spt)	speeltuin	
(sz)	speelvoorziening	
(sp)	spoorweg	
(s)	sport	
(spc)	sportcentrum	
(sph)	sporthal	
(spv)	sportveld	
(spz)	sportzaal	
(sq)	squashcentrum	
(sd)	stadion	
(ste)	steiger	
(str)	strand	
(shs)	strandhuis	
(sth)	studentenhuisvesting	
(stw)	stuw	
(su)	supermarkt	
(tn)	tennisbaan	
(tr)	terras	
(th)	theater	
(t)	tuin	
(tb)	tuinbouw	
(tc)	tuincentrum	
(tu)	tunnel	
(uv)	uitvaartcentrum	
(vw)	vaarweg	
(vh)	veerhaven	
(ve)	ven	
(vb)	verblijfsgebied	
(vr)	verblijfsrecreatie	
(vl)	verenigingsleven	
(v)	verkeer	
(vep)	verkoop eigen producten	
(vml)	verkooppunt motorbrandstoffen met lpg	
(vm)	verkooppunt motorbrandstoffen zonder lpg	
(va)	vertrek- en aankomsthal	
(vij)	vijver	
(vk)	viskwekerij	
(vt)	volkstuin	
(vu)	vulpunt lpg	
(wm)	waardevolle boom	

code	**Functieaanduidingen SVBP2008**	**Functional indications**
(wa)	water	
(wb)	waterberging	
(wk)	waterkering	
(ws)	waterstaat	
(ww)	waterweg	
(wz)	waterzuiveringsinstallatie	
(we)	weg	
(wel)	wellness	
(wei)	welzijnsinstelling	
(wn)	wielerbaan	
(wt)	windturbine	
(wtp)	windturbinepark	
(w)	wonen	
(wg)	woongebied	
(wl)	woonschepenligplaats	
(wp)	woonwagenstandplaats	
(zee)	zee	
(zo)	zend-/ontvangstinstallatie	
(zbo)	zorgboerderij	
(zoi)	zorginstelling	
(zw)	zorgwoning	
(zb)	zwembad	

Fig. 1069 Functional indications

code	**Bouwaanduidingen SVBP2008**
[aeg]	aaneengebouwd
[am]	antennemast
[bg]	bijgebouwen
[gs]	gestapeld
[kap]	kap
[ka]	karakteristiek
[nr]	nokrichting
[ond]	onderdoorgang
[pd]	plat dak
[tae]	twee-aaneen
[vrij]	vrijstaand
[sba-..]	specifieke bouwaanduiding

Fig. 1070 Building indications



ANALOOG

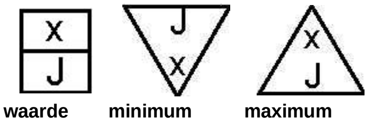
grens = 3x dikte ondergrond
kleur grens = zwart
fonts = Arial
kleur = zwart
symboolkleur = zwart

verbeelding maatvoeringsvlak

Naam	Symbool	Verklaring
s100	a	minimale goothoogte (m)
s101	Â	maximale goothoogte (m)
s102	a-Â	minimale-maximale goothoogte (m)
s103	b	minimale bouwhoogte (m)
s104	B̂	maximale bouwhoogte (m)
s105	b-B̂	minimale-maximale bouwhoogte (m)
s106	c	minimale dakhelling (graden)
s107	Ĉ	maximale dakhelling (graden)
s108	c-Ĉ	minimale-maximale dakhelling (graden)
s109	D%	maximum bebouwingspercentage (%)
s110	a b	minimale goot- en bouwhoogte (m)
s111	Â B̂	maximale goot- en bouwhoogte (m)
s112	a-Â b-B̂	minimale-maximale goot- en bouwhoogte (m)
s113	a b c	minimale goot-, bouwhoogte (m) en dakhelling (graden)
s114	Â B̂ Ĉ	maximale goot-, bouwhoogte (m) en dakhelling (graden)
s115	a-Â b-B̂ c-Ĉ	minimale-maximale goot-, bouwhoogte (m) en dakhelling (graden)
s116	a b c D%	minimale goot-, bouwhoogte (m), dakhelling (graden) en maximum bebouwingspercentage (%)
s117	Â B̂ Ĉ D%	maximale goot-, bouwhoogte (m), dakhelling (graden) en maximum bebouwingspercentage (%)
s118	a-Â b-B̂ c-Ĉ D%	minimale-maximale goot-, bouwhoogte (m), dakhelling (graden) en maximum bebouwingspercentage (%)
s119	E	maximum aantal wooneenheden
s120	F	maximum aantal bouwlagen
s121	E	maximum aantal aaneen te bouwen wooneenheden
s122	g	verticale bouwdiepte (m)
s123	B̂ D%	maximale bouwhoogte (m) en maximum bebouwingspercentage (%)
s124	Â B̂ D%	maximale goot-, bouwhoogte (m) en maximum bebouwingspercentage (%)
s125	b-B̂ D%	minimale en maximale bouwhoogte (m) en maximum bebouwingspercentage (%)
s126	B̂ F D%	maximale bouwhoogte (m), aantal bouwlagen en maximum bebouwingspercentage (%)
s127	H m2	maximum oppervlakte (BVO) (m2)
s128	x J	standaard symbool waarde (zie bijlage 9a)
s129	J x	standaard symbool minimum waarde (zie bijlage 9b)
s130	x J	standaard symbool maximum waarde (zie bijlage 9c)

De letters a, A, b, B, tot en met H staan voor varabelen die verwijzen naar omvangwaarde voor goothoogtes, bouwhoogtes, dakhellingen, bebouwingspercentages, wooneenheden, bouwlagen, bouwdiepte en BVO. Door de letters te vervangen door een getal, ontstaan waarden die automatisch worden meegenomen bij de IMRO coderingen die behoren bij de aanduiding maatvoering. De symbolen s128 t/m s130 zijn algemene symbolen die gevuld kunnen worden met de in bijlage 9a t/m 9c domeinwaarden uit het domein OmvangwaardeBestemmingsplan. Omdat deze symbolen vaker voor kunnen komen binnen een plan kunnen deze symbolen voorzien worden van een letter (x) die gevuld wordt volgens bijlage 9a, 9b en 9c.

Fig. 1071 Indicating measures in Dutch zoning plans



s128	x	s129	x	s130	x	J	betekenis x
s128a	a					aantal	aantal
s128b	b	s129a	a	s130a	a	aantal	bedrijven
s128c	c	s129b	b	s130b	b	aantal	bezoekers
s128d	d	s129c	c			aantal	bouwlagen
s128e	e	s129d	d	s130c	c	aantal	gebouwen
s128f	f	s129e	e	s130d	d	aantal	parkeerplaatsen
s128g	g	s129f	f	s130e	e	aantal	rijstroken
s128h	h	s129g	g	s130f	f	aantal	sporen
s128i	i	s129h	h	s130g	g	aantal	winkels
s128j	j	s129i	i			aantal	wooneenheden
s128k	k						maatvoering
s128l	l	s129j	j	s130h	h	m^2	bebouwd oppervlak
s128m	m	s129k	k			%	bebouwingspercentage terrein
s128n	n	s129l	l	s130i	i	m	breedte
s128o	o					graden	dakhelling
s128p	p	s129m	m			m	diepte
s128q	q	s129n	n	s130j	j	m	hoogte
s128r	r					m	bouwhoogte
s128s	s					m	goothoogte
s128t	t	s129o	o	s130k	k	m	hoogteligging vlak
s128u	u	s129p	p	s130l	l	m	lengte
s128v	v	s129q	q	s130m	m	m^2	oppervlakte
		s129r	r	s130n	n	m^2	vloeroppervlakte
s128w	w	s129s	s	s130o	o	m^2	bruto vloeroppervlakte;
s128x	x	s129t	t			m^2	bvo vloeroppervlakte;
s128y	y	s129u	u	s130p	p	m^2	netto vloeroppervlakte;
s128z	z	s129v	v	s130q	q	m^2	woning vloeroppervlakte;
s128aa	aa	s129w	w	s130r	r	m^3	volume
s128ab	ab	s129x	x	s130s	s		vrije tekst
s128ac	ac	s129y	y	s130t	t		vrije tekst
s128ad	ad	s129z	z	s130u	u		vrije tekst

Fig. 1072 Meaning of standard symbol values

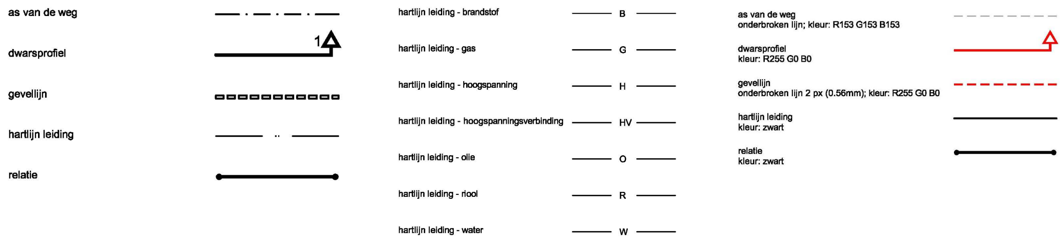


Fig. 1073 Examples of lines

7.2 Child perception

7.2.1 Introduction

Combining different sensory impressions

Experiments with babies, reported by Piaget and Inhelder (1947), keep me fascinated from the first time I read about them until now, because of the practical and design implications of the idea. Firstly, they gave the children an object to feel by touching behind a screen making sure they could not see it. Then they showed the same object, making sure they could not touch it. Piaget and Inhelder questioned at what age the children would combine these two totally different sensory impressions into one concept. On the average it appeared to be on the age of one and a half years old. These conclusions were criticized later (it happens earlier) but the idea has remained the same.

Concept formation

Combining different sensory impressions **synaesthetically** into a concept of any object involved, means more than a conditional Pavlov-reflex. Starting up your digestive system when a bell rings does not yet mean that you can imagine them as a concept, and they are not the same after all. It means that if you feel the object without seeing it, you can make a visual imagination of the object without seeing it. It is the very start of logical operations like ‘not’, ‘or’, ‘if … then’. It explains the fascination of young children for the game of peek-a-boo or hide-and-seek: mother hides herself and calls you. You can hear her voice, but you do not see her. You now are looking for her, because you have the visual imagination you like to check completing your concept.

Moving experience

In later investigations Piaget and Inhelder emphasized the importance of the **motoric ability** for imagination capabilities and learning. You can change your visual impression by moving physically. This possibility causes continuous experiments by children. I remember my niece celebrating her first birthday. Grandma held her on her lap saying ‘Quiet my darling, quiet!’. But she stayed crying all the time kicking her legs. I had been reading Piaget recently and said: ‘Give her to me’. Grandma handed me the child and I helped her kicking legs to move her body up and down to see my face alternating with the background. She started laughing! Grandma, somewhat embarrassed, thought she loved me more then her, but I explained her the baby was experimenting parallax: changing object and context by moving up and down. She did not see me as a person, she tried to understand the difference between my face and my background first. That is why moving on a seesaw is so fascinating for children.

Object constancy

She should have experienced **object constancy** earlier: mother is not there; she appears in the door and walks into your direction. Her face enlarges until it fills your total scope of vision: is that large object the same object appearing as a small face peeping around the door? You throw toys out of your box, they bring them back. Repeating experiences like that show constancy of changing objects: different, gradually enlarging impressions link up to one imaginable object. That is why swings and merry-go-rounds are important. Later on you run away from your mother and look back. She became very small and to regain your safety you run back to enlarge her. Your mother is not yet a person, but ‘something large and warm’, like my three years old daughters described their concept of ‘mother’ when I asked them ‘What is a mother?’. The other way round dangerous things are ‘large and cold’. A car is not dangerous when it is far away, because it is small.

Pain

There we are. The dangerous things at home are well known when you are three years old, because they are nearby and large, cold, solid and hard. They can hurt when you run too fast. You learn by collision. But once you are in the street you have to run faster to discern objects further away than at home and it takes years to learn that there are objects running faster than you, becoming large, cold, hard and painful very quickly. That is why playing tag is so important. Young animals are short-sighted to learn discerning objects nearby first by little movements causing parallax. The vision, radius of awareness and speed grow with the years of childhood. I think the radius of awareness grows exponentially, but it is a hypothesis.

Which programme of requirements we can conclude per level of scale?

7.2.2 The growing scale of perception

The radius of awareness

If the radius of awareness grows exponentially it could happen like *Fig. 1074* shows. The radius R should be interpreted elastically between its neighbors (R=10m means ‘between 3 and 30m’). If psychologists would study that relation and name the values children observe in every stage of their growth, it would be a great help for designers to determine their legend units and composition.

years old	m radius R	area of awareness
0	1	Action space
1	3	Room
3	10	House
5	30	Yard
7	100	Neighbours
9	300	Neighbourhood
11	1000	District
13	3000	Town

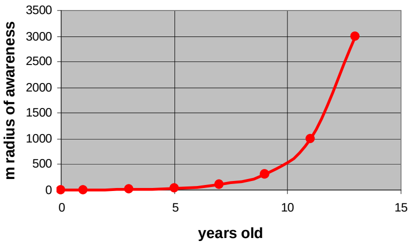
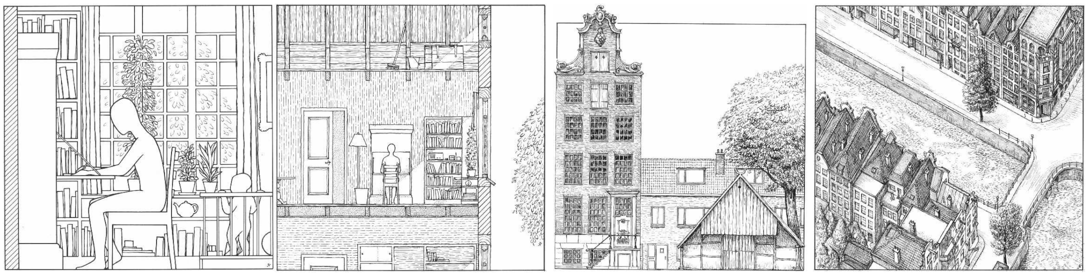


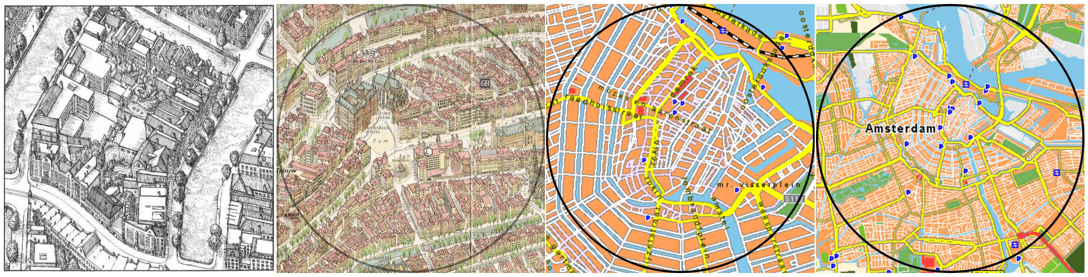
Fig. 1074 Hypothetical scales of awareness by age

Observable variables

To get an idea of the realities these measures indicate, see *Fig. 1075*. The question is: ‘Which observable variables vary on every level of scale?’.



0 year: R = 1m *1 year: R = 3m* *3 years: R = 10m* *5 years: R = 30m*



7 years: R = 100m *9 years: R = 300m* *11 years: R = 1000m* *13 years: R = 3000m*

Fig. 1075 Growing awareness by scale[a]

Let us first try to look as a child on different ages.

---

[a] Jong, T. M. de; 5 drawings by Jan Huffener (1978)

I am sorry in this text it's a boy like I was, rewrite it yourself for a girl if you think it's relevant.

A baby street like a room (3m)

You are one year old. The front door opens and they put you in a buggy. Suddenly at one side, all kind of unknown objects whiz by. Some objects on the far side stay longer. You don't have any influence, because *they* drive your car. You cannot stay to experiment parallax properly. So, you look forward. There, all kinds of objects enlarge, become dangerous, but they pass aside and disappear. Suddenly your driver turns. You shake in your buggy. The scene changes dramatically. They drive you in a dark hole. Slowly in becomes lighter. You hear voices, but you see dresses, trousers, legs, shoes and tiles as different colour surfaces. Looking upward you see bodies towering above you, faces and hands. Suddenly they shake you and drive you in a white hole with cars whizzing by. Another shake makes your scene well-known until they take you out of the buggy. They hold you before a wall that opens after some jingle with a turning hand. You smell something you are used to. You are 'home'.

A toddler street like a house (10m)

You are three years old. You can walk! That means, you can change the world around you by walking through a black hole. Sometimes the hole is gone, but in the mean time you learned to open the wall, standing on your toes and stepping back, pulling a handle down. There are several worlds, but there is one you can open by pulling a handle aside. In that room there is noise, wind, movement and very much space. You may run. They often call you back. If you fall, it's hard. Between the tiles there are blades and ants. Sometimes there is a drain cover with holes aside somewhat lower. But if you want to look inside they call you back: "dangerous!". You find pieces of soft brown clay, but they hold you back: "dirty!". You may not even step on it. They take you into another room by turning a corner. Suddenly you are standing in the sun. Here plants are huge and not standing on a windowsill, but in the ground. So, they can not fall down if you run through them. But they call you back: "dirty!". Some have prickles, so you stay walking on the pavement. There are several pavements: stepping down they are darker with smaller stones. But if you step down they call you back: "dangerous! We said that earlier!". Stupid: that was the drain cover.

A young child street like a yard (30m)

You are five years old. Your father takes you to school in the morning, your mother from school in the afternoon turning 5 corners. They moved into a house with a garden and a gate to a path, going to a playground and to a street with cars and large trees. You may not play in the sand around that trees, it is dirty. You've got marbles, but there are not much groves to play marbles. You like to go to the far side, but it is too dangerous. You've got a bike, but you may not leave the pavement with the large tiles. If you stay riding on that pavement, going around the corner three times, you come back from the other side! Your friend has no bike, so together you play on the playground. But it is too childish, your little sister plays there with your mother on the wipperchicken and the slide. My friend had a secret hut there, but they cut off plantation. So, it is not very secret anymore. But he has a *real* Play station on his computer!

A child street like a school (100m)

You are seven years old. You may cross the street in front of your house. Your new friend lives there. His neighbour has a motorbike. He is repairing it in front of his house. Round the corner lives an ugly man. You ring his bell, run away and look around the corner how angry he is. Your mother takes you to her work. You never knew she has a room there as well. Your portrait is on her desk, but you cannot play there. You get a chocolate in a café with strange people. Your father showed you how to go to Grandma by bus and you got a ticket to try yourself. The driver tells you where to go out. You see large buildings where people work, but they don't live there and there are no children.

A child street like a village or neighbourhood (300m)

You are nine years old. You may cross all the streets until the district way. You can go to school, the sports field, the hairdresser and to Grandma by bike. You've got roller skates on your birthday, but you only may skate on the skate ground at five minutes cycling. There are shops where you can buy stickers, but your new friend makes them on his computer. He takes you to the computer shop, but you like the car models you can buy next door. Your pocket money has doubled last year, but it is still not sufficient. If you help Grandma cleaning her house three times you can buy a Ferrari.

A child street to explore (1000m)

You are eleven years old. You climb the old church-tower and see your house from above, your school, your swimming pool and the fields outside the city where you cycled with your friends. You see your own daily life like a bird. Apparently there are many more districts in town. The city ends somewhere. Next year you will go to high school in another district. You will loose friends of your neighbourhood and find new ones from elsewhere.

A teen-ager street to meet (3000m)

There are students from other cities and countries in your class. In the geography class you learn countries and cities by heart. You visit them on holiday. You are not a child anymore. You have seen your city by night. There are right and wrong disco's. You have got a newspaper round to be able to pay for your girlfriend next time. You look at her lighted room from behind a tree in the street where she lives. Where could you make an appointment next week? She often goes to a volleyball ground hidden behind a large office building in her neighborhood. There you can sit, beyond neon lights, unnoticed by others, pretending to look at the games together.

7.2.3 Field of vision

Growth

From the second year on, children grow linear with their age to the adult stature of their nationality (see *Fig. 1077*). After 10 years old they outgrow a car (*Fig. 1076*). So, children have less overview than adults.

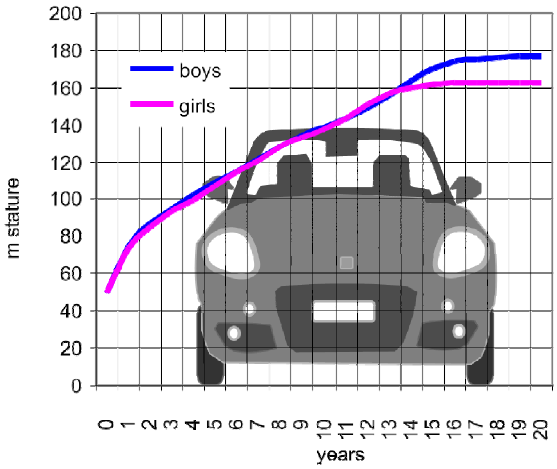


Fig. 1076 Growth of an average child in the USA[a]

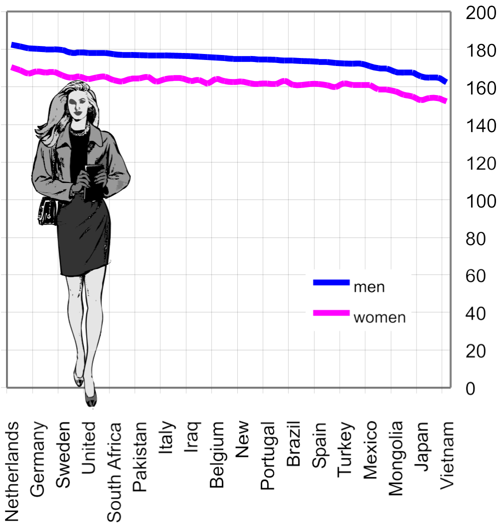


Fig. 1077 Adult length variation by nationality[b]

The growing eye

Moreover, their field of vision is smaller. So, their vision is closer to the fixation center with less attention to context. Context sensibility seems to be primarily the task of hearing. But, to determine the direction of noise is more difficult for children than for adults. Deaf people compensate their failing sense by developing a larger field of vision earlier.[c]

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[a] *http://kidshealth.org/parent/growth/growth/growth_charts.htm* l
[b] *http://en.wikipedia.org/wiki/Human_height*
[c] *http://www.shef.ac.uk/personal/l/lgf/visiondeaf/*

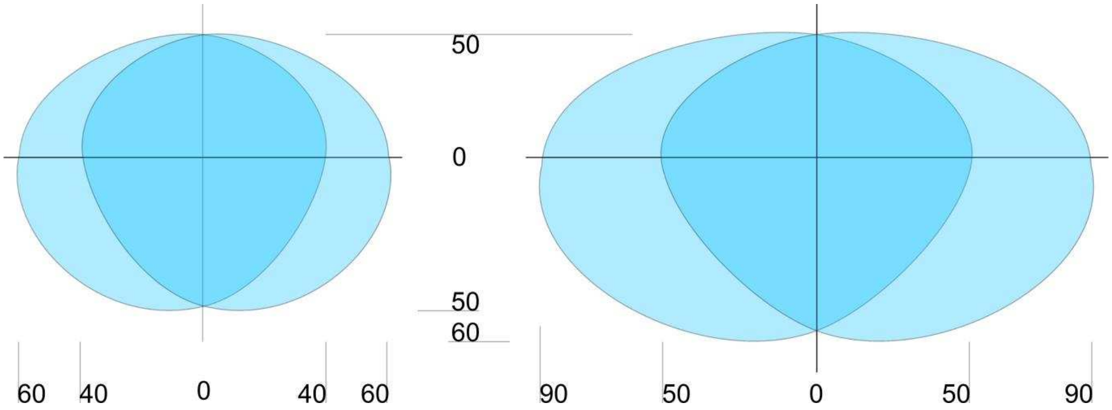

Fig. 1078 A child's average field of vision, and an adult's average field of vision in degrees from center[a]

Fixation point

Visibility is highest in the central fixation point, declining into the boundaries of the field of vision (see *Fig. 1079*).

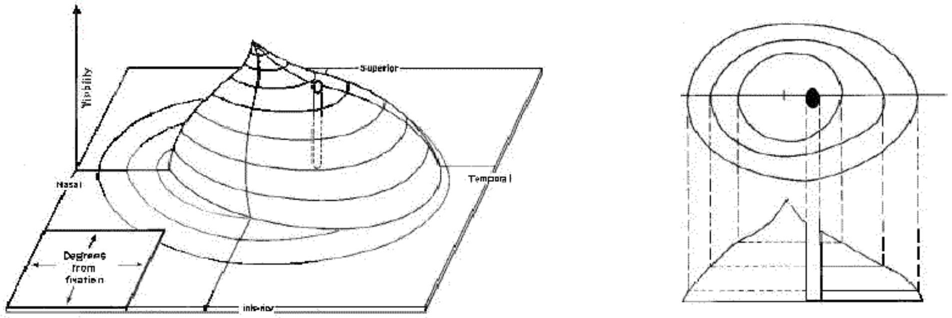

Fig. 1079 Visibility represented by Anderson (1984) as a third dimension in the field of vision[b]

Because of their limited field of vision children have to move their head more often than adults to build up a concept of context. Adults complain wrongly about lack of concentration then. They have to change focus themselves to understand the composition of a scene as well. Design helps to balance recognition and surprise. Too much recognition causes boredom, too much surprise chaos (see *Fig. 1081*).

7.2.4 The composition of a scene

Components and details

A scene comprises components and details. To design a quickly understandable scene we have to make larger components externally *different* from each other, but internally filled with characteristic details recognizably *equal* to distinguish the particular component from the other components with other characteristic details. That art is called composition.

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[a] *http://www.shef.ac.uk/personal/l/lgf/visiondeaf/*; *http://home.zonnet.nl/jcamps/gezichts.htm*
[b] *http://www.msac.gov.au/pdfs/reports/msacref13.pdf*; *http://www.msac.gov.au/pdfs/reports/msacref13.pdf*

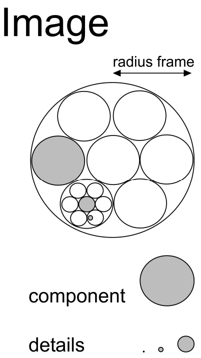

Fig. 1080 Components

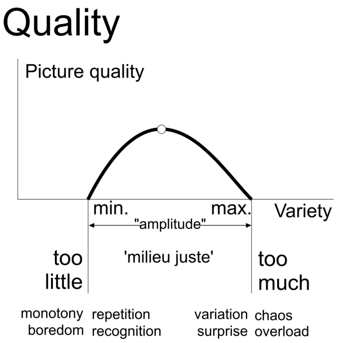

Fig. 1081 Quality as a working of variety

Fig. 1082 Design means of variety[a]

Any level of scale mentioned in *Fig. 1075* needs its own composition. On any level of scale components and details have new characteristics of categorization and orientation.

Observable differences

Your action space (R=1m) has hard and soft, movable and non-movable components in different colors. Your room (R=3m) has a door, corners to play, eat and store, different in light, material and visibility. These are the legends for designing a child street like a room.

Your house (R=10m) has differences of accessibility, control, light, noise, temperature, wetness, differently suitable for playing, personal care and rest. What could we use to distinguish the components of a child street like a house? Your yard (R=30m) is differently covered, planted and lighted by the sun. There are components of the house extending in the garden or the street (in-between realm). You behave differently at the back or front side. There are formal and informal places, hard and soft places, places of recognition and surprise. What is the difference between lawn and pavement, terrace and walk? Are there in-betweens to hesitate where to go?

Your school (R=100m) has spaces to sit and to run, compete, watch, play and learn. Your village or neighborhood (R=300m) has spaces to buy, walk and ride a bike. Your district (R=1km) has spaces of living, business, traffic and parks. Your city (R=3km) has spaces to meet and retire, atmospheres and cultures to explore.

7.2.5 Conclusions for urban design

Resolution

A field of vision comprises a largest measure in reality (frame, expressed as R) and a smallest visible detail (grain, expressed as r). Both change the observed composition if you approach an object or a scene. The distance from the observed composition is approximately equal to its frame.
If the frame of a picture represents a reality of radius R = 10m and the grain a radius r = 10cm, the resolution r / R is 1%. You will call the result a ‘drawing’. If frame and grain differ less (say 3%), it is a rougher sketch, stressing the concept. If they differ more, it could be a more precise blue print (0.1%). Object and details of a blue print lay too far apart to understand the composition or concept immediately, they get their use primarily for realization.

Legends for design

On every level of scale the map you draw may have a different legend. For example, in a drawing with a frame R=10m, you can draw tiles in the pavement (10cm), the kind of plantation, the furniture of the street and the entries of homes. These are adult categories. Make a sketch to group them more roughly into less components, comprising child categories. But what do you choose as components and their legend units in other frames? You have to dissect or group them into components suitable for child perception on different ages. *Fig. 1083* gives an overview of variety per level of scale named in

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[a] Jong (2004)

this article. You could interpret it as guiding principle for design: try to change softness every meter, light every 3m and so on. However, for example light and shadow could be changed very successfully on other levels of scale as well. The table is only a starting point to be extended.

years old	**0**	**1**	**3**	**5**	**7**	**9**	**11**	**13**	
m Radius of frame	**1**	**3**	**10**	**30**	**100**	**300**	**1000**	**3000**	**learning**
differences to experience:									
hard-soft	x								danger
movable|non-movable	x								operational abilities
color	x								recognition
windows|doors		x							orientation
light|dark		x							imagination
shelter|corners		x							to escape adult movements
function|time		x							every time having its own place
visibility		x							hide-and-seek
accessibility			x						rules
control			x						other people
noise			x						context
temperature			x						kinds of clothes
wetness				x					hygiene
ceiling|shelter				x					in-betweens to hesitate, to decide
plantation				x					nature
sun				x					nature
formal-informal				x					different behavior
recognition|suprise				x					initiative
run|compete					x				ambition
watch, learn					x				to learn
possibility to buy						x			expensiveness
possibility to walk						x			interest
possibility to ride a bike						x			ride
urban functions							x		exploration
meet|retire								x	projection|identification
atmosphers|cultures								x	identity

Fig. 1083 Legends for design

A composition is not only determined by components, but also by details directing your fixation. We only mentioned characteristic details, determining components. But there are also marking details, determining boundaries, connecting details determining in-betweens and striking details labelling the whole scene.

7.3 Composition analysis

Establishing a legend by composition

Composition analysis is not only a research method for analysing the balance between repetition and diversity in existing urban architectural units, but also a design method to achieve this sort of balance and to explore its possibilities. In composition analysis, there appears to be an infinite number of possible types of balance. These extend artistic freedom by challenging the possibilities to their limits. Within this are boundaries of survival value, future value, practical value, and experiential value. Composition analysis is a systematic form of establishing a legend in the research and design process. Establishing a legend is an unexpressed supposition in every structure- and function analysis.

The composition analysis discussed here has been developed for the image-quality plan of the Amsterdam district '*De Baarsjes*'. by Jong and Ravesloot (1995). The following pages are an literal quotation taken from this document.

7.3.1 Variation

The starting point is that image quality is an outcome of variation in surroundings. Too little variation (monotony) results in boredom, and too much variation (chaos) in overloading (see *Fig. 1081*). For every individual, there are boundaries and optima of recognition by repetition and of surprise by change. This relationship says nothing about the importance of built-up surroundings, but rather about its potential to accommodate different sorts of meanings.

Scale

That this simple relationship has not been utilised earlier, even though much psychological research has a bearing on it, can be ascribed to scale problems at the time of implementation. For this reason, we will consider images on different scale levels separately (district image, neighbourhood image, block image, etc.).

Components and details

Within each image, we will make a scale differentiation between components and details (see *Fig. 1080*). We consider parts larger than one tenth of the image as components that define the composition. We will call everything smaller than one tenth a 'detail', for the time being.

Different components

The components of an image can be more or less alike (see *Fig. 1082*). If they are rather different, then the contrast is strong, otherwise it is weak. Between the most and the least similar components within an image, one can distinguish a smallest discernable and a largest discernable contrast. If all the components are similar (non-contrasting), then we call the composition homogenous, and if they differ, heterogeneous. One can observe a relationship between compositions of similar components, a relationship that can be either balanced or unbalanced. For the same contrast, the same composition and the same relationship, it is still possible to discern variation in composition. Similar components in a composition can be grouped in a more or less compact form.

Diversity and repetition on different levels of scale

Variation on one scale level (e.g. between the components) does not obstruct the occurrence of monotony on the other scale level (e.g. between the details within a component). In particular, it is the application of different principles on different scale levels that adds 'tension' to the image. One can now arrange the design strategies into scale levels in 'accords' between diversity (V) and repetition (R), for example:

ACCORDS	A	B
between buildings	Repetition	Diversity
between components:	Diversity	Repetition
between details:	Repetition	Diversity

Fig. 1084 *Variation accords*

Traditional and industrial accords

The traditional architectonic accord A (Repetition at the building and detail levels, but Diversity on the levels in between, 'RDR') differs from the modern accord B ('DRD'). After all, present architecture is mostly valued for the unique contour (D) of the building as a whole and for the originality (D) of the details, while between both these scale levels, repetition (R) is valued as 'architectonic clarity'.

7.3.2 Scale levels

Three examples of style and scale

In Fig. 1085, three periods of architectural style, and, for the sake of brevity, the three scale levels linked to them are shown. A *tholos* for Asklepios in Epidauros, with a radius of 10 metres; Palladio's Villa Rotonda, with a radius of 30 metres; and Berlage's Mercatorplein in the district De Baarsjes, with a radius of 100 metres. In each period, and on each scale, components and details can be seen which indicate to what extent one can talk about diversity or repetition. [6]

Perceiving different compositions approaching a building

When we approach a façade, we first look at the composition of the different components and then at the details. By doing this, in each case, we have a different frame, depending on our distance away from that object. So, at a distance of 10 metres from our façade , when we turn our heads, the whole façade is within our vision (10-metre radius). Using a wide-angle lens, we can see our appartment (3-metre radius), and using a standard lens, a window or a door (1-metre radius).
To assimilate the total image of the street, we need to view it from a distance of about 30 metres. In each case, we position what we see within a larger frame. We see an image in a radius that is approximately the same as our distance away from that image.

Fading details by increasing distance

The more we extend that distance away from the image, the fewer details we see: the elements of façade are rougher than those of our house when we stand near to it. We only have an image of our block of houses thanks to the fact that we have walk around it at some stage. It is a conceptual image, but it is thereby no less important, because it helps us to find our way. This is also the case with our neighbourhood, district and urban images.

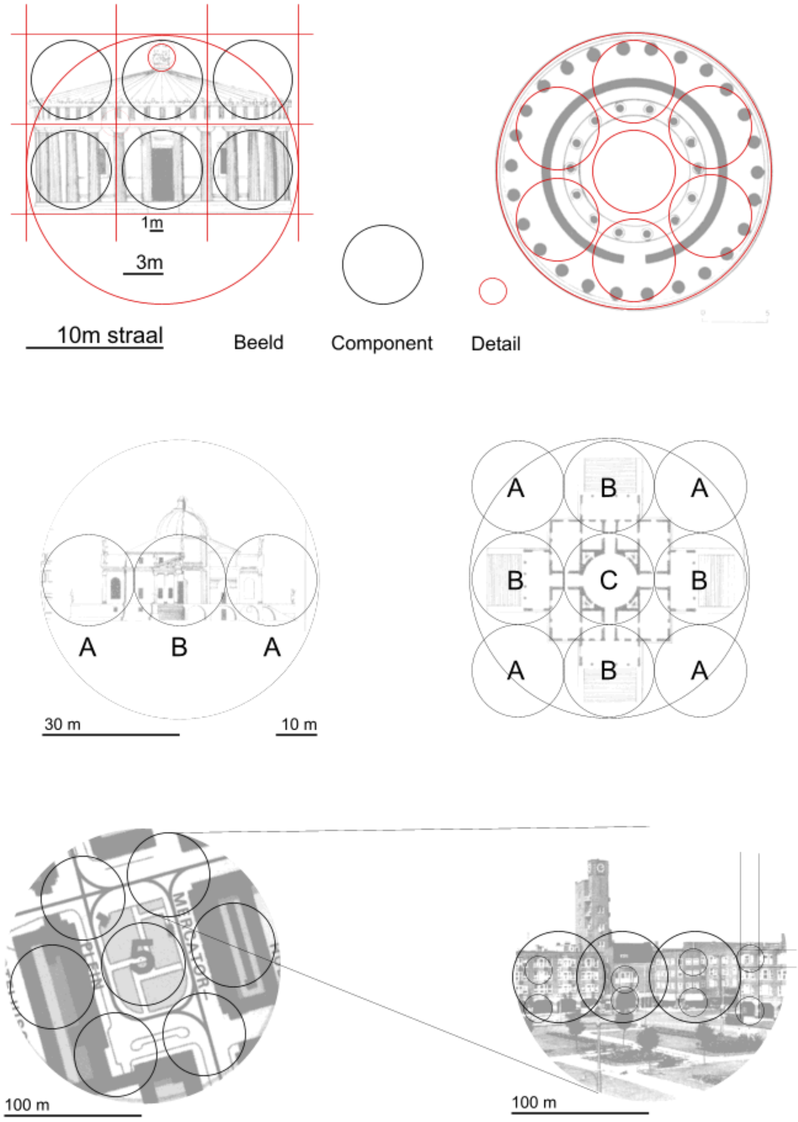

Fig. 1085 *Components and details of images in a radius of 10, 30 and 100 metres*.

By chance, the *tholos* has a diameter of 20 metres and thus a radius of 10 metres. The components of a radius of about 3 metres appear in the image of the map as the central *cella*and the components of the *peristyllum.*

Distinguishing components

When one looks at them, they appear to be an entrance section and the flanking parts of the pillared gallery, and the roof section and foreground laid out in a similar way. The division of the components of the same order of size is, of course, free and is not linked to an orthogonal or hexagonal grid. The capitals, triglyphs and other ornaments are contained as details in a frame of 1m radius.

The components of the Villa Rotonda differ more. The middle section is dominant. The special (B) according to Tzonis, Lefaivre et al. (1989) is flanked by the common (A) , repeating components following the classical scheme ABA.[7] On the map, a large central section C appears, flanked by similar ABA schemes, in which, this time, the peripheral area can be included as the most common component. In the image of Mercatorplein, the area *is* the central component (30m in radius), flanked by an approximately equally large groups of house façades in the corners and along the lengthy sides. The details consist here of façade (10 m) window and entrance sections (3 m). The image of a block (of buildings) can also be described within a radius of 100 m.

Details, components and frame

For our analysis, we differentiate the following images by their details, components and frame (with radius expressed in metres):

	detail		component	frame	ACCORD
	<		>		BAARSJES
district image		100		1000	R
neighbourhood image		30		300	V
ensemble		10		100	R
street image		3		30	V
façade image		1		10	R
house image		0,3		3	V
finished image		0,1		1	R

Fig. 1086 Variation accord for *De Baarsjes*

Variation and repetition per level of scale

In *De Baarsjes* all the neighbourhoods within the district image look alike (R), but within each neighbourhood, the squares, and the block and street groups (‘ensembles’) vary greatly (V). Within each separate ensemble, the blocks and streets are again very similar (R), but within each block and street, the façades vary (V). Within the façades, appartments are repeated (R),[29] but within each house image, the finished image varies (V).

7.3.3 Focus

The primary difference in an image determines the dominant component

In the first instance, the variation in the district image is read against the variation among its components. As large units as possible are chosen as components within the image, wherein a maximal repetition of characteristic details can be found. It is as if one scans the image with a searchlight the size of a component, until one has caught the most repetitive part of the bundle. When, by doing this, one connects the definable diversity (between the components) and the repitition (within the components) so closely to the scale level of the district and its components, it becomes very important where one chooses to place (focus) the boundaries of the district components (and thus the boundaries of the formulated homogeneity).

Looking for internal homogeneity of components

To establish the remaining image-defining variations within each district component, a neighbourhood image can be formulated by looking for relatively homogeneous neighbourhood components that differ maximally among themselves at that level.

Symmetry of roads

If, for example, a road lies between two district components, then this road accentuates the difference between the district components, or, alternatively, the similarity within a district component. In the one case, that can lead to the establishment of an asymmetric street profile, and, in the other case, to a symmetric one. For instance, in the case of De Baarsjes, the focus determines the symmetry of the Hoofdweg. When one reaches the Postjes neighbourhood, we can distinguish, for various reasons, two different district components on both sides of the Hoofdweg. For this reason, the walls of the streets on the opposite side do not need to be the same (<>). Once past the Postjesweg, a striking symmetry between the street walls becomes evident (><). This gives the impression that one is entering a homogeneous neighbourhood.

7.3.4 Morphological reconstruction

Dividing and articulating

How, now, do we determine the focus? Following Van der Hoeven and Louwe's example, Hoeven and Louwe (1985) the urban area is 'morphologically reconstructed' (see the Fig. *1087*) First, the area covered by the district is divided as equally as possible in the two main directions, using the most characteristic repetitive detail: a building block of 72 by 360 metres. In this way, the present district image has been reconstructed with an accuracy of approx. 100 metres. This conceptual design intervention is called 'dividing'. Globally speaking, the second intervention, 'segmenting' or 'articulating', means connecting main roads and waterways to the surroundings and taking the consequences for the primary zoning. Thus, a more differentiated topological scheme arises that, in turn, is more closely aligned to present actuality.

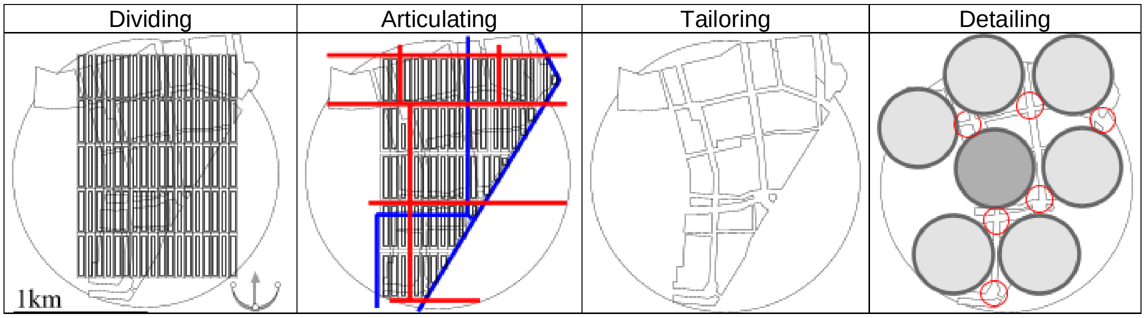
Dividing
Articulating
Tailoring
Detailing

Fig. *1087 Morphological reconstruction of the urban area De Baarsjes*

Tailoring and de-tailing

A third intervention cuts the otherwise homogeneous parts apart and 'adds' them to the existing topography. An analogy to the work of the tailor, the cutter, the couturier or dressmaker, this intervention is known as 'tailoring'. The next intervention, 'detailing', temporarily divides the area internally into components that are considered to be homogeneous, identified by characteristic internally repeating details. The connecting details can be found between the components, just where their differences culminate. These can be points or lines, which either represent the surrounding components or are in contrast to them.

7.3.5 Structure in terms of openness and closedness.

Divisions and connections

Structure (coherence) is the way in which grouped parts form a whole or the sum of divisions and connections. The concept forms a separate category between form and function, because the same structure can take on different forms and can have different functions, and *vice versa*. Coherence always arises between different parts; in the drawing, these are the legend units.

Cohesion and adhesion

One can refer to the coherence between one kind of legend unit as cohesion. The coherence between different kinds of legend units then has to be called adhesion.[8] Coherence can be stimulated by nearness in space and realised by separating or connecting infrastructure.

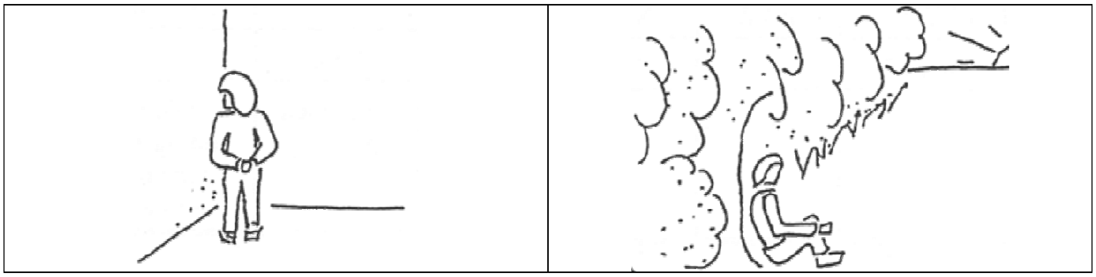

Fig. 1088 *Polarities 3m*[a]

Polarisation between open (α) and closed (β) sides

Spatial elements such as a neighbourhood, a house, a chair, a cupbourd, a television set, a person are often polarised, on the one hand, towards an open 'front' where the connections are concentrated and the communication with other elements takes place, and, on the other hand, to a closed 'back' in which the 'functions characteristic of the system' are concentrated where they can operate sheltered from the outside world. One cannot reverse this polarity with impunity without jeapodising the function. For example, it is pointless placing a TV set, a cupboard or a chair with their fronts against a wall. One only puts a person in a corner (with their front against a wall) if one wants to 'gag' them (Fig. 1088).

Scales of polarisation

One can recognise polarity between openness and closedness on different levels of scale and can give them meaning as 'structure' in design and research. The polarities at different scale levels influence each other. The polarity of a wall of a small room (3m radius) or of a forest edge (100m radius), interfers with human polarity (1m radius) by causing hinderance or back-coverage.[393]

Motoric and sensoric polarisation of rooms and houses

In the left hand Fig. 1089, a study has an 'open' window-side and an 'walled-in' door-side. This sensoric polarity is realised within a radius of 3m. If one considers accessibility as 'the distance to the front door" (radius 10m), then on a greater scale and in a motorical sense, the door-side is the most 'open' side of the room and the window-side is the most 'closed'. The polarities change meaning according to the scale and are directed antipodally ('contrapolar').

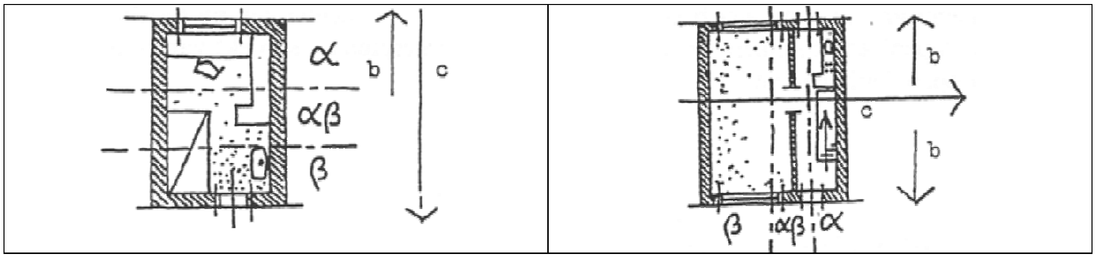

Fig. 1089 *Polarities of 3 and 10m*[b]

The right-hand Fig. 1089 is a sketch of a house with a through lounge in which the front door, back door, corridor, staircase, hall, cables, piping and wiring, in short the communication functions, are concentrated in the small aisle on one side, and the 'system characteristic' living functions on the other side , in the large aisle. This is the motoric polarity (c) from the left-hand drawing that extends for a distance of 10m. The sensoric 3m polarity that divides the house on two sides into a window side and a walled-in zone is here perpendicular ('orthopolar').

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[a] Jong (1978)
[b] Jong (1978)

Breaking boring polarisation by design

The three standard hobbies of 'creative' architects: 'the front door in the living room', 'the staircase in the living room', or 'the kitchen in the living room' all breach the 10m motoric polarity, so that the objections to them (draught, smells, people walking through) have to be solved mechanically.

Ensemble and urban island polarisation

The ensemble is polarised within a radius of 30m towards the open, communicative, public front and a more closed, protected 'private' back.

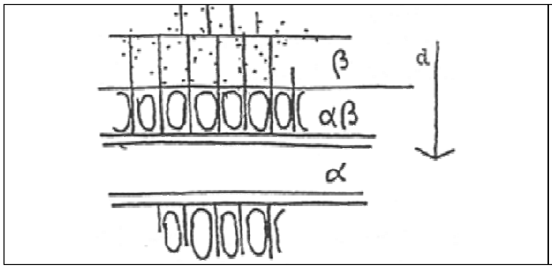

Fig. 1090 *Polarity 30m*

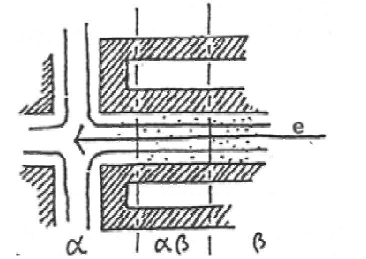

Fig. 1091 *Polarity 100m*[a]

Its most 'open' side is where the street crosses with another street or enters a more important street or square; its middle is the most 'closed' part.

Polarisation on higher levels of scale

This polarity can be spread over more than 100m. Within the radius of 300m, one can be polarised towards 'neighbourhood centre' and 'neighbourhood green'; within a radius of 1000 metres towards 'district centre' and 'district green'. In a similar manner, within a radius of 3 km, the town has an open 'town centre' and a more closed 'periphery'. However, this is a motoric interpretation of 'open' and 'closed'. A more sensoric interpretation talks about closed 'inner city' and open 'outside areas'[394].

7.3.6 Functional differentiation

Function as values of use on different terms

The built-up and unbuilt upon surroundings have different values, such as short-term experiencial value, medium-term practical value, long-term future value and extremely long-term survival value. By definition, this has to do with the value for people, including the value for plants and animals, in sofar as we, as people, recognise that value.[395]

For experiencial value 'shape' is enough; one doesn't need much structure for this. For the other values, increasing amounts of structure are needed. These have to be designed in that way, because structure is the 'condition' for these values.

Practical values

Practical values can be subdivided into economy, culture and administration. [9] These can be recognised in the medieval town (see the market square of Delft) as the following:

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[a] Jong (1978)

Social differentiation	Urban differentiation
administration (aristocracy)	castle, palace
culture (spirituality)	church, cloister
economic basis (citizens, serfs)	market, shops, dwellings, small traditional trade businesses

Fig. 1092 *Trias urbanica in the Middle Ages*

Trias urbanica

Pierre George's definition George (1961can be called '*trias urbanica'*. By subdividing further, as a result of social differentiation, it is possible using Jakubowski's (1936) [10] and Parsons(1966 and 1977) systematique to imagine a '*trias politica'* from Montesquieu and Derathé (1973), a '*trias cultura'* and a '*trias economica'*.

Social differentiation	**Urban differentiation**
Politics	
legislative power	town hall
legal/administrative	law court/government services
executive power	police station, prison, barracks, military training ground
Culture	
religion/ ideology	churches, monuments, signs
art/science	museums, institutes, libraries
up-bringing/education	socio-cultural facilities, schools
Economy	
production	firms, banks, offices
exchange	distribution points, infrastructure
consumption	living, health service, recreation

Fig. 1093 *Social and urban differentiation in modern times*

Concentration and centralisation

Functions can be concentrated or deconcentrated spatially, but apart from that, each function can also be centralised or decentralised in a hierarchical order.[396]

So, there are 4 possibilities of form related to function:

		FORM	
		concentration	deconcentration
FUNCTION	centralisation	Concentration of centralised functions	Deconcentration of centralised functions
	decentralisation	Concentration of decentralised functions	Deconcentration of decentralised functions

Fig. 1094 *The difference between concentration and centralisation demonstrated*

In the concept of 'centre' a morphological and a functional meaning have to be discerned.

7.3.7 Intention

Desirable possibilities

Intentions can range from tradition-oriented to opportunity-oriented. They are proportioned as are probability and possibility within what is desirable.[397]

More than a programme of requirements

A design is traditionally preceded by a programme of requirements, compiled according to the wishes of the commissioning body. In order to meet these requirements, the designer has to create the conditions in his proposals that will lead to the fulfilment of these requirements. In doing this, he himself sets additional requirements based on past experience and on his expectations regarding future use and perception.

Robustness

The finished design will be used and perceived in a different way than the commissioning body and designer had envisaged. A design to be used in different ways and contexts we call 'robust' That quality often leads to a plea for flexibility, 'leave possibilities open'. This means making fewer design efforts.
However, from that point of view, one can also defend an environmental diversity that offers freedom of choice and with which one not only makes allowance for the unsuspected, but also facilitates it. This means putting more effort into design.

Art and kitch

A painting such as 'the child with a tear' that prescribes emotions in us, emotions that we have to feel every time we look at it, is no more art than sentimentality (kitch). A true piece of art enables one to feel different emotions every time we look at it.[398]

Unexpected use

Nature has no wishes. Nevertheless, we try, as people, to make a programme of requirements for nature development.[23]. That is as paradoxical as the order 'Be spontaneous'. We do that based on a primitive and often inaccurate picture of how plants, animals and human beings will use the environment that we design. We are repeatedly surprised by the way in which the surroundings that we have designed are put to use by nature.

Unintended possibilities

We cannot make a programme of requirements for nature: each species has its own programme of requirements, about which we have little understanding and there are at least 1,500,000 species in addition to *homo sapiens*. All we can do is to create environmental diversity and wait to see what use nature will make of it. While ever one is unable to base the programme of requirements on prognoses, diversity remains a form of risk coverage for perceptive-, practical-, future- and survival values. This design intention seems to me to be important, not only for nature, but also for human beings, as long as we believe in their freedom of choice. Image quality can be related directly and in a design-oriented way to variation in surroundings.[399]

7.4 Legends

7.4.1 Resolution and tolerance

The vocabulary of design

The legend is the vocabulary of design. A legend unit is a type and any legend is a result of (sometimes hidden) typology (for example living, working, recreating, travelling in CIAM's functional typology). According to Jong and Engel (2002) typology in design study is not the same as top-down categorizing in empirical research. A type is not a category, a model or a concept but the raw material for design. A type combines incomparable categories. For example form and colour are incomparable: you can not speak about redder than round. A type has to be designed to become a model, a design that can be realised. Types are chosen because of their potential for design. They seldom lack aspects of form. So, a design legend often can not be explained by words.

Resolution, the distance between frame and grain

That is why design sometimes begins with a collage assembling reference images into a larger composition (collage, montage). In that case the reference images are the legend, sometimes even summarised and explained apart from the composition. The reference images should not be taken litterally then, but interpreted as general types. In a later stage the composition becomes a realisable design and the legend transforms in homogeneous lines or surfaces indicated by form or colour. Their external form in the drawing is its smallest detail, its 'grain', supposed to be homogeneous inside. Compared with the measure of the composition as a whole ('frame') the grain determines the resolution of the drawing. The measure in reality of frame and grain could be expressed in their rough radius R={…1,3,10,30,100m….} and r={…1,3,10,30,100mm….}. So, a resolution r/R=0.1 may concern a sketch, r/R=0.01 a drawing, r/R=0.001 a very precise blue print.

Tolerance, the preciseness of the drawing

Apart from the concept of *resolution* you have to consider the *tolerance* of a drawing. For example, if in an early stage of design you sketch a line indicating a road your intention is an approximate location, though it may be drawn in high resolution. Discussing the drawing with parties concerned a tolerance of 10m from the core of the line may be supposed. A drawing entails often different tolerances. The existing objects you want to keep in the design could be drawn with a small tolerance. Their exact location is determined. However, the designed lines start with a large tolerance and in the course of the design process their location is more and more precise; the tolerance decreases. If you draw the existing objects by narrow lines and the designed objects by thick lines your most important message comes to the fore best, while the objects everybody knows already shift to the background.

7.4.2 Scale-sensitivity

Frame and grain

Your legend is scale sensitive. For example, using the CIAM typology of living, working, recreating and travelling for a regional sketch (R=30km and r=3km) tacitly supposes design decisions like dividing living, working and recreational areas concentrated within a radius of 3km. However, using it for a district sketch (R=1km, r=100m) hides other design suppositions[400]. So, frame and grain (scale) determine the meaning of your design vocabulary (legend).

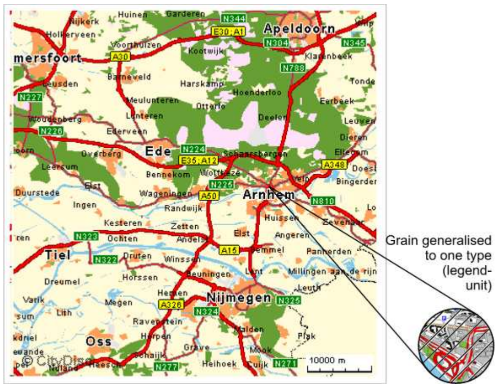

Fig. 1095 *The region Veluwe-Arnhem-Nijmegen 60x60km*
The radius of its grain is R=300m in reality; on scale 1:25 000 it is r=1.2cm

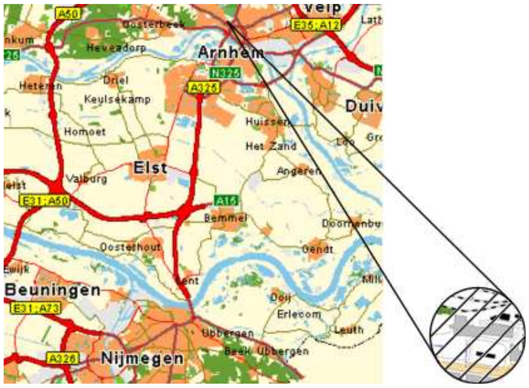

Fig. 1096 *The sub-region Arnhem-Nijmegen 20x20km*
The radius of its grain is R=100m in reality: on scale 1:10 000 it is r=1cm[a]

From sketch into blue print

In Fig. 1095 the radius of the smallest legend unit (grain) covers 1% of the radius of the whole map (300m) and a surface of approximately 30ha. So, it is not a rough sketch or precise blue print, but a drawing. Fig. 1096 is a drawing as well, but with a smaller frame and grain. In both representations the legend distinguishes built-up area, forest, heathland, agriculture, water and highways. What kind of legends you would choose planning the area? There are infinitly more possibilities than the CIAM legend, topographical and density stereotypes. They all introduce hidden design decisions.
A legend in grain spots of the same surface makes the produced map countable as a surface programme. Such quantity and surface sensible spots can be grouped together into larger surfaces or subdivided into 10 smaller spots each, increasing resolution eventually into that of a photograph at last. However increasing resolution makes the map less accessible for analysis.

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[a] *CDRom 'de nationale Stratengids van Nederland met kaarten van de Topografische Dienst te Emmen' (Den Haag) Citydisc*

7.4.3 Unconventional true scale legend units

Design principles as a legend

Steenbergen and Zeeuw (1995); Steenbergen and Reh (1996); Steenbergen (1999) and Reh discerned principles of landscape design as legend units (types) for the national planning agency of the rural area: urban nodes, rural estates and castles, plantations, landscape theatres and streamlands. In 2003 students tried to find them on a large 1:10 000 map of Fig. 1095 (Fig. 1098) and glued them as spots of two sizes (300m and 1000m) from Fig. 1097.

Grain				Legend				
Radius real	surface real	radius on scale	diameter on scale	Red	Orange	Yellow	Green	Blue
m	ha	cm	cm	meaning				
300	30	1,2	2,4	urban node	rural estate	plantation	landscape theatre	streamland
1000	300	4,0	8,0					

Fig. 1097 *Legend-units landscaping r={300m,1000m} in a frame R=30km 1:25 000*

Existing urban nodes, rural estates and castles, plantations, landscape theatres and streamlands in the region of Fig. 1095 were glued in grey shade first, planned ones in clear colour later.

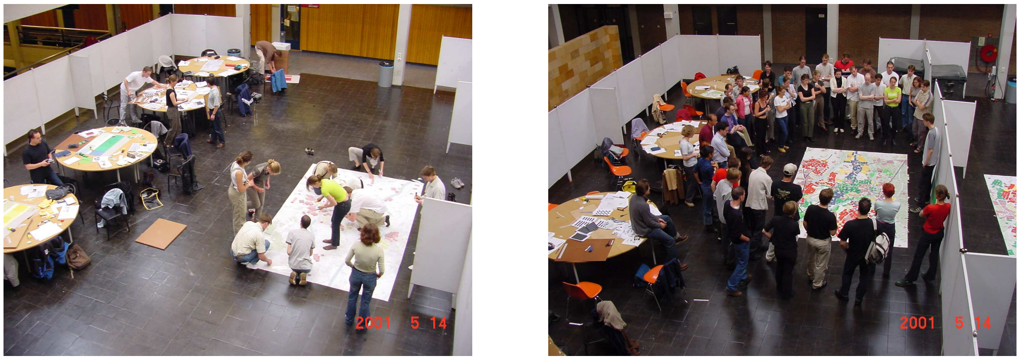


Fig. 1098 *Students making a map*

There are many existing rural estates and castles in that region. Vista's and other forms of accompanying landscapes were generalised in the glued spot. Plantations are colonised surfaces by which the programme is put on stage by intended or unintended grid like landscape architecture. They could be found not only in the rural, but also in the urban area, going beyond the stereotypic town-landscape dichotomy. Landscape theatres are recognisable natural, agricultural or urban systems of views and routes by which the physical, biological or cultural origin of the landscape could be experienced. Streamlands are locations where the dynamics of natural or urban life can be experienced.

Physical quantities as a legend

On every level of scale (R={30km, 10km, 3km, 1km, 300m, 100m}) such maps were made with shifting unconventional legends (Fig. 1099).

week 1 30km
Landscape

week 2 10km
Town and traffic

week 5 1km
Infrastructure

week 6 300m
Physics and soil

week 7 100m
Materialisation

Fig. 1099 *Exercises BkM1U 06 2002*

Quantified human activities as a legend

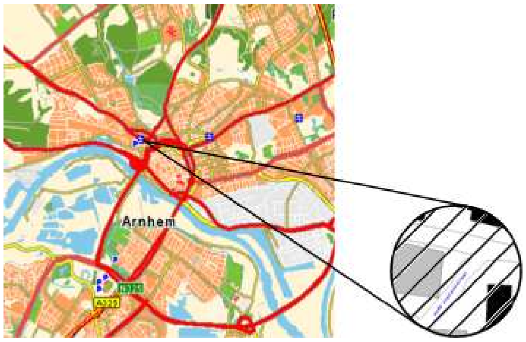
To indicate traffic in a frame R=10km (Fig. 1096) spots of Fig. 1100 were used.

Grain				Legend for a regular Monday				
Radius real	surface real	radius on scale	diameter on scale	Red: people average per hour using a station or motorway exit	Orange: people living at home	Yellow: people working	Green: people recreating	Blue: people caring or studying nature
m	ha	cm	cm					
100	3	1,0	2,0	100	1000	500	<100	<10
300	30	3,0	6,0	1000	10 000	5000	<1000	<100

Fig. 1100 *Legend-units town and traffic r={100m, 300m} in a frame R=10km, 1:10 000*

Different legends on different scales

Infrastructure was studied in a frame of R=1km, physics and soil in a frame of 300m.



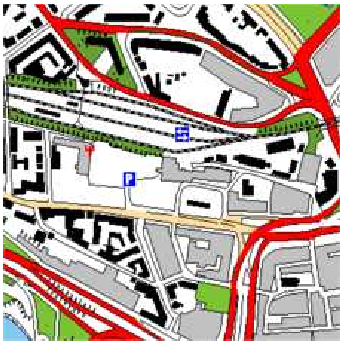


Fig. 1101 *The town of Arnhem 6x6km. The radius of its grain meets R=30m in reality; r=1.2cm on scale 1:2 500*

Fig. 1102 *The railway station neighbourhood 600x600m of Arnhem The grain is R=3m in reality, 1,2cm on scale 1:250*[a]

Money as a legend

Existing and planned infrastructure was studied in spots of investment according to Fig. 1103.

Grain				Legend				
Radius real	surface real	radius on scale	diameter on scale	Red investment crossing	Orange investment trace	Yellow investment multiple land use	Green investment milieu	Blue investment waterworks
m	m^2	cm	cm	meaning				
10	300	1.0	2.0	€ 10 mln	€ 10 mln	€ 10 mln	€ 10 mln	€ 10 mln
30	3000	3.0	6.0	€ 100 mln	€ 100 mln	€ 100 mln	€ 100 mln	€ 100 mln

Fig. 1103 *Legend-units infrastructure r={10m, 30m} in a frame R=1km, 1:1000*

Problems and opportunities as a legend

Physics and soil was studied by problem and opportunity spotting according to Fig. 1104.

Grain				Legend				
Radius real	surface real	radius on scale	diameter on scale	Red	Orange	Yellow	Green	Blue
m	m^2	cm	cm	meaning				
3	30	1.2	2,4					
first: problems				Safety	Noise	Light (sun/ artificial)	Ecotope	Wind
then: opportunities								
10	300	4.0	8,0					

Fig. 1104 *Legend-units physics and soil R={3m, 10m} in a frame R=300m, 1:250*

Creative design starts with doubting its most self evident supposition: its vocabulary.

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[a] *CDRom 'de nationale Stratengids van Nederland met kaarten van de Topografische Dienst te Emmen' (Den Haag) Citydisc*

7.5 Scales of separation

7.5.1 Potentials rather than functions

An important starting point for designing, forming policy on, and researching into legend units is the level at which one wants to separate or mix them. I deal with the scale-segmented approach here. However, the terms employed in this are only used here to indicate the extent of an area and thus have no functional meaning other than 'potentials' for functions.

Scale falsification

This approach is based on the discovery that 'scale falsification' (see Fig. 697) can occur in most urban architectural argumentations when one derives the argumentation from another scale level than that on which the inference is implemented. For example, this has been the case with the division between living and working. The radius within which the hinderance was determined was much smaller than the radius within which living was separated from working. In addition, the scale-segmented approach renders designers' paradoxical concepts, such as 'bundled deconcentration', understandable and acceptable. The same applies to the separation and mixing of red, green, blue and black.

The paradox of a homogeneous mixture

The concept of 'mixing', for example, of mixing built-up and vacant areas, is scale-dependent. What in a large radius is called mixing, can be segregation in a small radius. These conceptual confusions cannot arise any more in the legend proposed. Different principles for arranging can be recognised immediately on the map, according to scale.

Accords of distribution

The distribution of the urban area within a radius of 10 km has hardly any influence on the landscape around, if this is concentrated within a radius of 30 km. (see Fig. 702, the two upper variants CC and CD). However, the distribution within a radius of 30 km breaks the landscape around into landscape parks. Under that condition, the distribution within a radius of 10 km again becomes important: the landscape parks are further divided into urban landscapes. Until 1983,[13] the national strategy was DC (Bundled Deconcentration, see *Fig. 848*). After thatRPD (1983), the policy was changed to CC (Compact City/Town), but, in practice, the strategy was CD and even DD.

Shape, size and adjacent legend units

Shape and size do not in themelves give an indication of the probable function, but rather of possible functions; of functions such as nature and recreation (see Fig. 772 and Fig. 773).
Due to technical developments, some traditional urban functions (such as certain types of distribution) have become less dependent on the size of the built-up area around (the 'area capacity': the number of residents within a certain radius). Others (such as commuter traffic, public transport, urban nature and recreation) are still, or have become even more, dependent on that size. A table of potential functions could also be set up for each radius of the built-up area, even though it would have a more temporary character.

Value and adjacent legend units

The internet is used a lot by estate agents. This is one of their messages:

'... project developments of houses, appartments and detached villas will also be situated at the water's edge. In Almere, houses have been built at the edge of the lake, with a mooring place for a boat, so that one gets the idea of being on holiday in one's own house, whatever the season. Rotterdam makes use of its water-rich environment and Amsterdam is planning a new development at a location still occupied by water. Nieuwegein has its river bungalows along the banks of the Lek and there are many other locations where one can live at the water's edge. Who would not want to live at the side of the largest expanse of water in the Netherlands, the North Sea, and watch the sun sink into the sea every cloudless evening?
But, of course, we cannot all live at the water's edge, so some people go and live on it. Houseboats and boat conversions decorate the sides of the water in all shapes and forms, irrespective of municipal

and ministerial policies to discourage them. Hardly any new moorings become available, and permits are hardly ever issued for them any more. A boat conversion without a mooring permit is like a house without a building permit.

The remaining alternative is to live far away from the large areas of water and to buy a pleasure (!) yacht in which one spends as much of one's free time as possible. The yacht harbours on the Veluwemeer and the IJmeer, the Veersemeer and the Biesbosch, Nieuwkoop and Vinkeveen, Loosdrecht and the Sneekermeer offer these floating cabins, tired of tramping through the waterways all summer, places where they can hibernate through the winter en masse. Because another fact is that: it is nice on the water as long as it doesn't rain (too wet) and as long as it is not frozen over (too dry). But now let's return ... to the shore.

Because so many people are charmed by the restful effects and wide expanses of water, with the many additional recreational possibilities close at hand, these locations are more expensive than other spots.

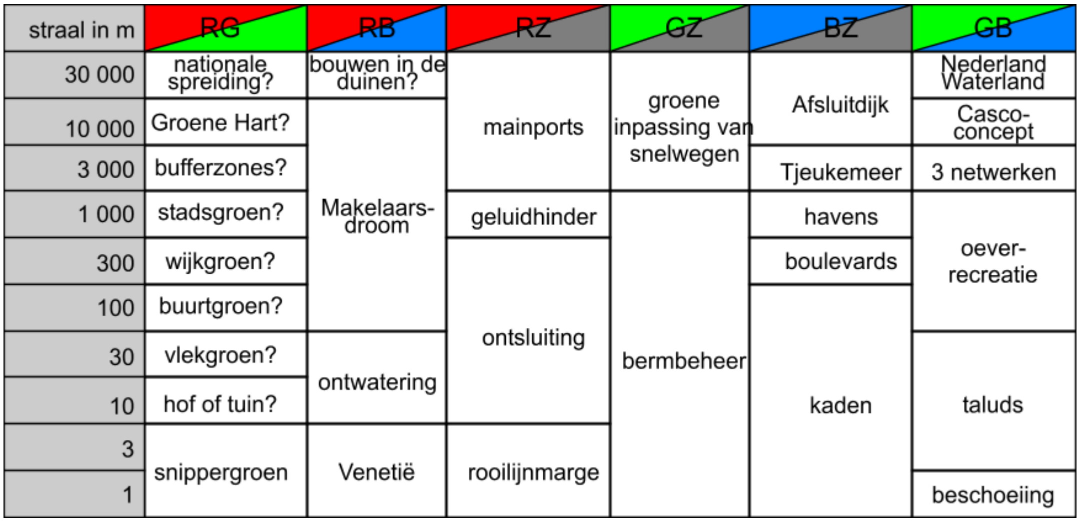
If living at the water's edge is restricted to the narrow ditch at the bottom of a back garden, then there are hardly any financial consequences. But if that narrow ditch becomes a stream, then the price of the plot is already higher. And should that stream broaden out into an often depicted slow-moving lowland river, flanked by summer and winter dykes, then the situation becomes very attractive for many people. Consequently, ... the more cubic metres of water that move along the banks of the waterway, the higher the square-metre price of the land becomes.

Maas van Vliet
Estate agent/ surveyor, Nieuwegein

Here, the economic function of the transition between buildings and water is defined. However, there are other functions and other transitions that must be valued and considered.

Boundaries between legend units

Apart from the colour combinations red and blue, one can distinguish on different scale levels the following margins between red, green, blue and black:



straal in m	RG	RB	RZ	GZ	BZ	GB
30 000	nationale spreiding?	bouwen in de duinen?	mainports	groene inpassing van snelwegen	Afsluitdijk	Nederland Waterland
10 000	Groene Hart?	Makelaars-droom				Casco-concept
3 000	bufferzones?				Tjeukemeer	3 netwerken
1 000	stadsgroen?		geluidhinder	bermbeheer	havens	oever-recreatie
300	wijkgroen?		ontsluiting		boulevards	
100	buurtgroen?				kaden	
30	vlekgroen?	ontwatering				taluds
10	hof of tuin?					
3	snippergroen	Venetië	rooilijnmarge			
1						beschoeiing

Fig. 1105 *Urban architectural agendas with respect to legend and scale*

Drawing creates boundaries. The decision as to where one draws a boundary, and why there, in particular, depends on the agenda.[401]

7.5.2 Conditional considerations

Each cell in Fig. 1105 has values and dilemmas that must be weighed up, not only economic, but also spatially, ecologically, technically, culturally and managerially. These considerations become simpler when one places those values in a conditional context (Fig. 1106).

Fig. 1106 *Urban operations arranged conditionally*

This figure shows, for example, that one cannot imagine management without culturally based collective concepts and shared presuppositions, but reversely, one can.
As a result, one cannot imagine culture without an economy that makes a decent existence possible, but reversely, one can. One cannot imagine economy without technical infrastructure: because, if the dykes break, the economy in the above-mentioned sense, does not exist any more. One cannot imagine technique without raw materials and raw materials cannot be imagined unless there is a time–space connection.

Weighting the uncomparable

Fig. 1107 gives an example of considerations using the above values, and summarized conditionally.

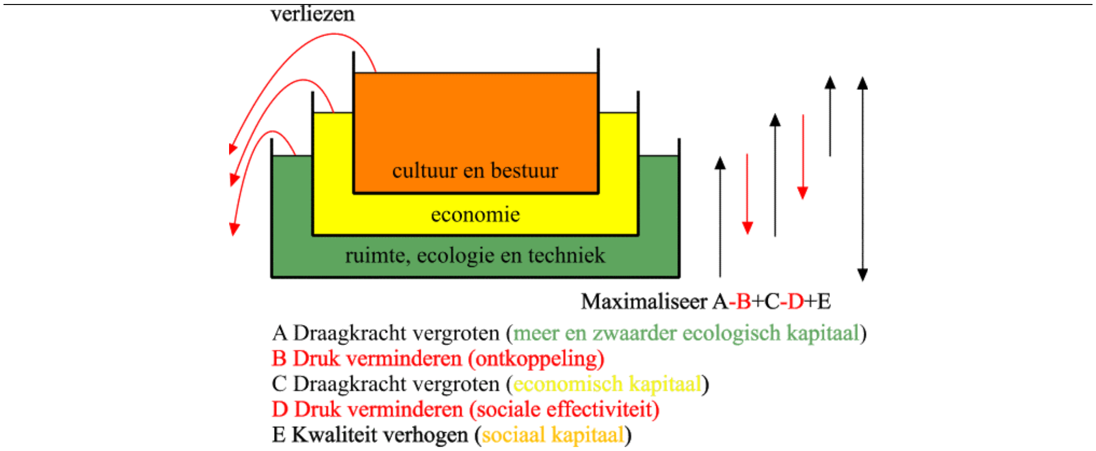
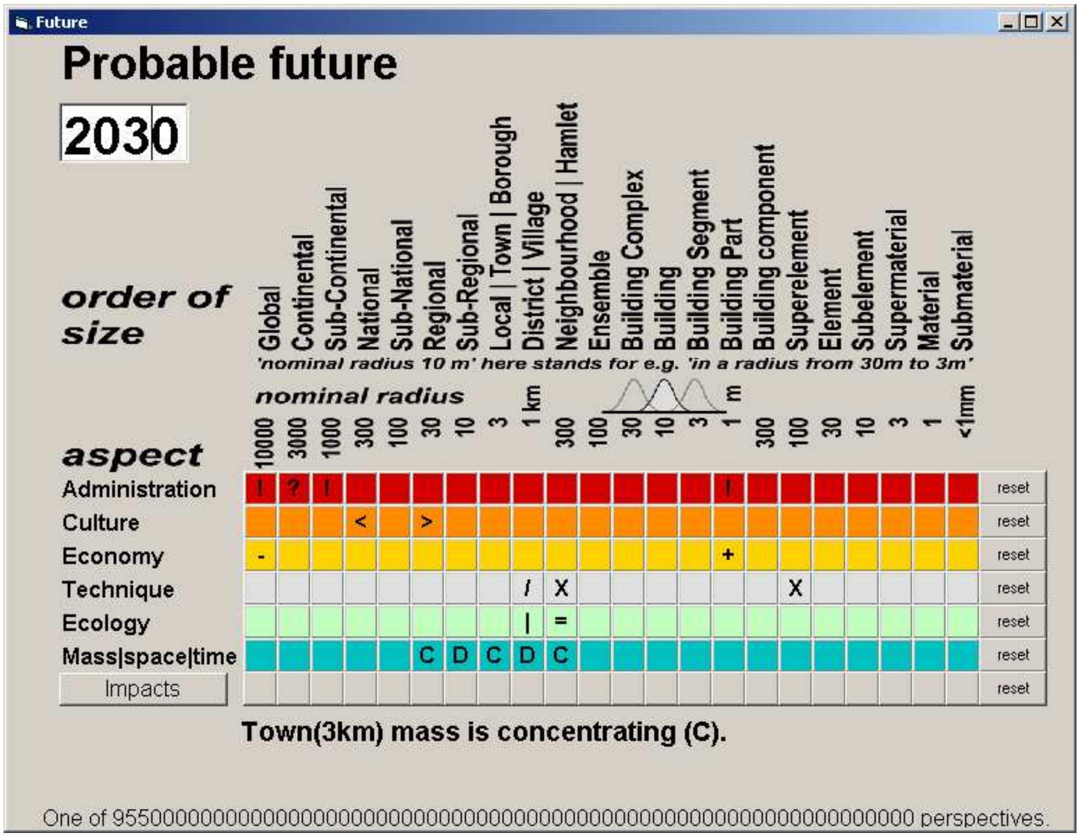


Fig. 1107 *Conditional assessments*

7.5.3 The context and perspective of consideration

Futures

Anybody has an implicit idea about the probable future. It directs your decisions. When somebody else judges your design (evaluation), (s)he can reject your design from another idea about the future.
So, it is important to make explicit your idea about the future for an honest judgement of your study.
Try *http://team.bk.tudelft.nl*, publications 2003, FutureImpact.exe (Fig. 1108) to make your ideas about the future explicit in a design relevant way.



Probable future

2030

order of size	Global	Continental	Sub-Continental	National	Sub-National	Regional	Sub-Regional	Local | Town | Borough	District | Village	Neighbourhood | Hamlet	Ensemble	Building Complex	Building	Building Segment	Building Part	Building component	Superelement	Element	Subelement	Supermaterial	Material	Submaterial	
nominal radius	10000	3000	1000	300	100	30	10	3	1 km	300	100	30	10	3	1 m	300	100	30	10	3	1	<1mm	
aspect																							
Administration	!	?	!												!								reset
Culture				<		>																	reset
Economy	-														+								reset
Technique									/	X							X						reset
Ecology									|	=													reset
Mass|space|time						C	D	C	D	C													reset
Impacts																							reset

'nominal radius 10 m' here stands for e.g. 'in a radius from 30m to 3m'

Town(3km) mass is concentrating (C).

One of 955000000000000000000000000000000000000000000000000000000 perspectives.

Fig. 1108 *Determining your probable future*[a]

In what kind of management, culture, economy you will have to operate?

The aspects 'management', 'culture' and so forth, are deliberately operationalised in an abstract way in extreme values (initiative(!) versus executing(?), traditional(<) versus innovative(>) and so forth), so that they mean something at each order of magnitude. Then they gain another working on each scale level, whereby their meaning shifts according to scale context.

Frame and grain of your object determine your context

Deciding among incomparable spatial, ecological, technical, economic, cultural and managerial values (evaluation) is dependent on the size of the project, the context within which the programme or intention is determined and the probable future in which the impacts of the intervention are anticipated within the term of a given planning horizon. In a second sheet of the computer programme you can fill in the frame(O) and grain(o) (size and resolution) of the object you have in mind. By doing so, the rest is context (see Fig. 1109).

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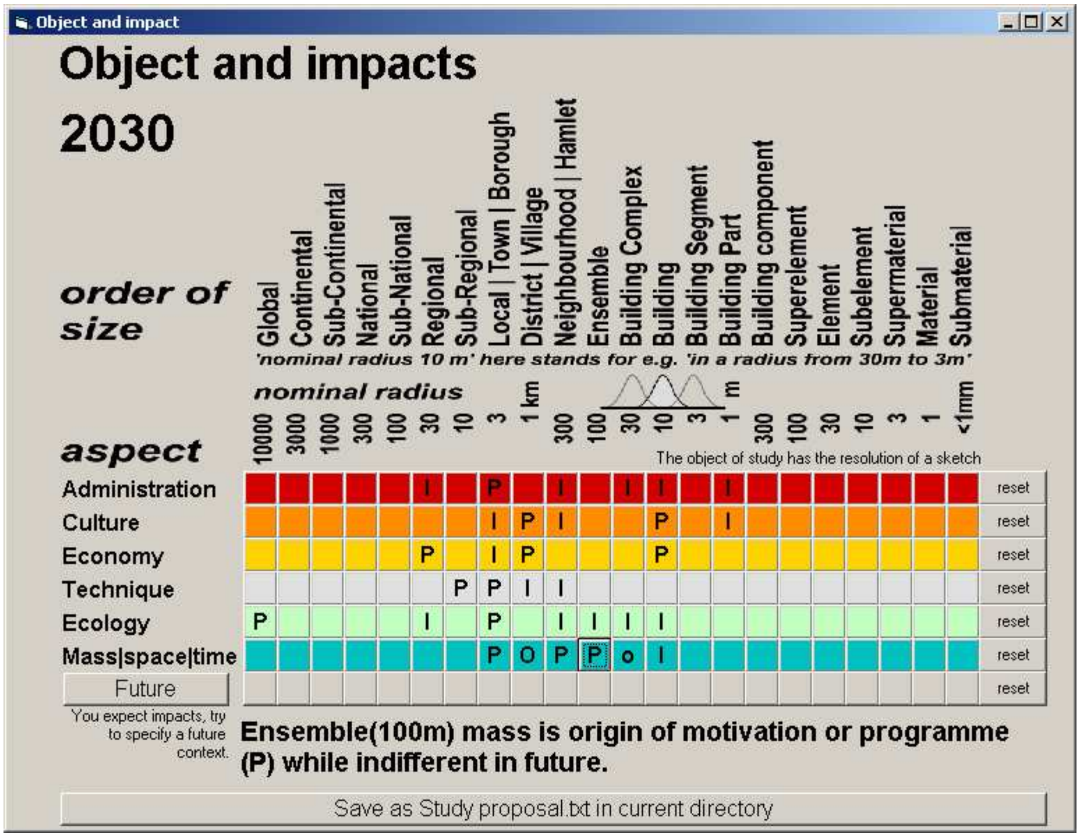
[a] Jong (2003) http://team.bk.tudelft.nl , publications 2003



Object and impacts

2030

order of size

'nominal radius 10 m' here stands for e.g. 'in a radius from 30m to 3m'

nominal radius

The object of study has the resolution of a sketch

aspect	Global 10000	Continental 3000	Sub-Continental 1000	National 300	Sub-National 100	Regional 30	Sub-Regional 10	Local | Town | Borough 3	District | Village 1 km	Neighbourhood | Hamlet 300	Ensemble 100	Building Complex 30	Building 10	Building Segment 3	Building Part 1 m	Building component 300	Superelement 100	Element 30	Subelement 10	Supermaterial 3	Material 1	Submaterial <1mm	
Administration						I		P		I		I	I		I								reset
Culture								I	P	I			P		I								reset
Economy						P		I	P				P										reset
Technique							P	P	I	I													reset
Ecology	P					I		P		I	I	I	I										reset
Mass|space|time								P	O	P	P	o	I										reset
Future																							reset

You expect impacts, try to specify a future context.

Ensemble(100m) mass is origin of motivation or programme (P) while indifferent in future.

Fig. 1109 *Determining object, local context and impacts*

What targeted (P) and non targeted (I) impacts you expect from the object you have in mind in that context? Once you have made explicit *where* you expect the object to have its impacts (not even specifying them), you can ask the computer programme to make the framework of a priliminary study proposal by pushing the button below (see Fig. 1109).

Planning horizon and changing perspective

The perspective determines the manner in which one guesses effects, and this perspective changes in a rather unpredictable way, for example, at national level, as follows,:

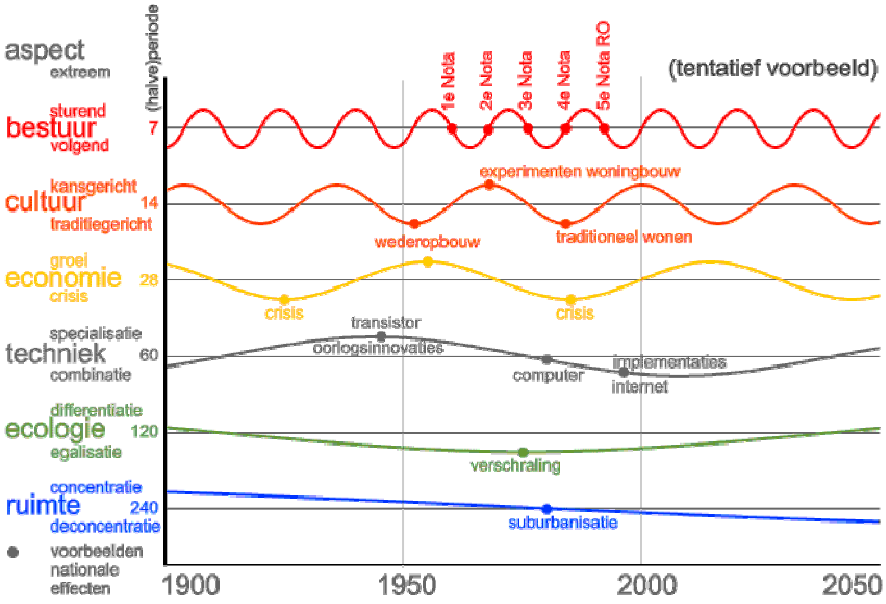


Fig. 1110 *Changing perspective*

The predictability decreases with increasing periodicity (in an upward direction).

Geographical and historical variation in context.

Fig. 1111 represent the same sorts of outside spaces in Venice, and are on the same scale as a ArchitectenCie’s design for the harbour island in IJburg Amsterdam. The extent to which the geographical and historical context can determine the outcome is obvious from this. From these images, the potential of exposure of stone to water also becomes evident, and the significance of the margin between built-up and vacant areas.

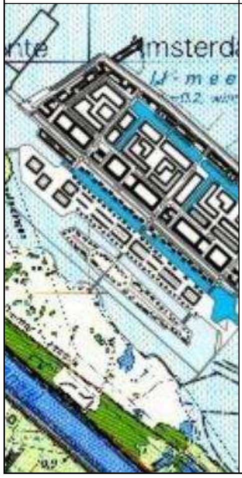
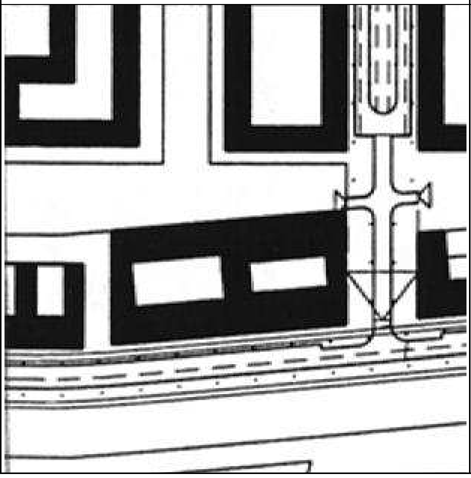
	Venice 1 x 2 km		Venice 200 x 200m radius 100m < canals every 100m < ⊥ streets every 30m < opened up internally by inner streets < occasionally with front to the water
Novelli (1989)			Venice 200 x 200m < interior < line of sight over the water < concave avenue
	IJburg 1 x 2 km		IJburg early design Harbour island 200 x 200m the same scale < interior < line of sight < more room to see < greater margin < convex avenue

Fig. 1111 *Geographical variation of conceptions*

7.5.4 Relief between built-up and vacant areas

A primary separation of legends

The examples of Fig. 1111 illustrate how important the margin is between built-up and vacant areas, and how much potential this margin has for a coherent urban image. Vertical segmentation on the façade surface gives motives for placing greenery, lighting, street furniture, pedestrian crossings and possibilities for interaction with adjoining water. In this way, public space is segmented by the façade in a manner that everyone understands. A number of examples are given below of this type of margin and the possibility for differentiating the outside space in relation to this with green and blue.

Inward and outward view

An urban architectural plan can be given shape starting from either the inside or the outside space. At the buildings level, the first principle starting with the outside is geared towards large, detached constructions that are expressive on all sides. Within this, as many external functions as possible (parking, traffic, light, air, greenery) are internalised. This leads to a relatively large outside area and so to large façades. Walled-in feelings are compensated by windows overlooking vacant and empty spaces, courtyards or inner squares within 10 metres from each room.

Outward extensions

Reasoned from inside outwards, a possible break in the building line is made in the form of 'cold extensions' such as platforms, balconies, galleries and oriels ('external margin' extensions) that leave the façade surface with a sudden jump in temperature (the skin) as undisturbed as possible. This is in turn, in itself, favourable for restricting the outside surface, although every extension also causes cold transition areas.

Inward extensions

In contrast, the second principle in the same scale tends towards the externalisation of functions, towards buildings that are less independent within themselves and with internal breaks in the building line (building backwards into an 'internal margin'). By doing this, the outside space gains more protected and covered external spaces such as inner corners, porches, arcades and walled-in balconies.

Recessing and extending parts of a façade

A systematic combination of both gives the façade a horizontal and/or vertical relief:

Horizontal relief	small space	large space	*vertical relief*	traffic space	lodging space
top floor	recessing	extending			
intermediate floors	extending	recessing	corner	recessing	extending
ground floor	recessing	extending	flank	extending	recessing

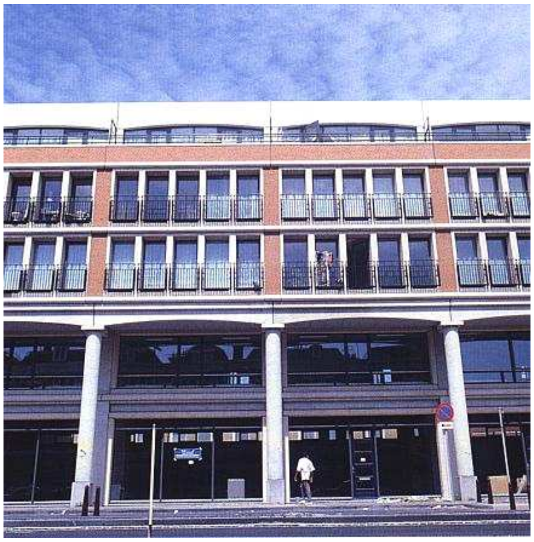
Fig. 1112 *Horizontal and vertical relief*

Systematically building recesses, setting the building back in an internal margin in a horizontal relief is appropriate mainly for the ground floor, at the level of public use, and – because of exposure to the sun – on the top floor. Building outwards can easily take place where there is unused space, so on the intermediate floors. Put the opposite way: platforms, ramps and extensions on the ground floor, recessed floors and overhangs on the top floor or roof (Wright effect), lends itself more to special locations and to large outside spaces. These accentuate the contours of the building.

Horizontal relief

Oud
Boven, Freijser et al. (1997)

15% horizontal extension
on the 1st floor



Coenen

Mecanoo

Fig. 1113 *Examples of horizontal relief*[a]

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[a] Freijser et al. (1997)

Vertical relief

To achieve a vertical relief in the façade, one can choose to recess the corners and extend on the sides of the building (for example, at the entrances to the building), extending both over the floors, or one can choose for the reverse: fortress-like extensions at the corners and recesses in the sides of the ground plan. The latter is less suitable because of traffic considerations and lends itself to special situations such as car-free streets.

Lourijsen

De Bazel

Greiner

Fig. 1114 recessed corner

Brandes

Brandes

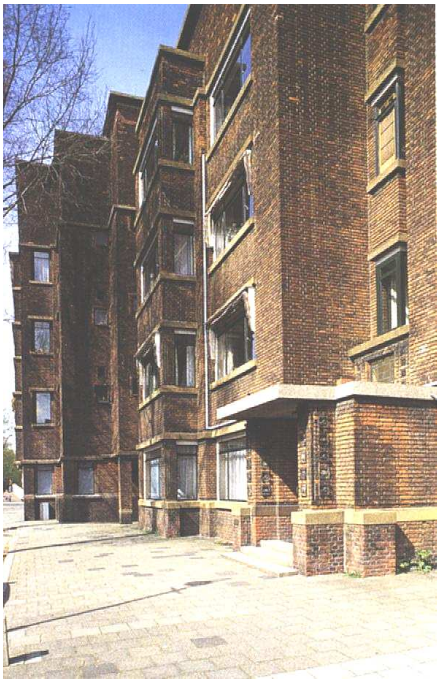
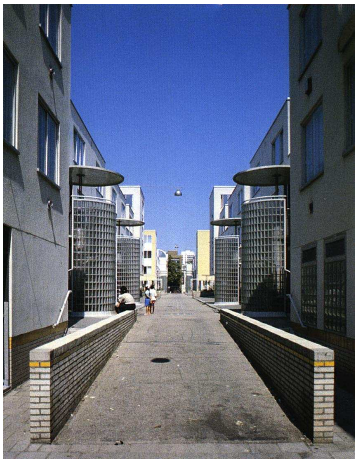


Fig. 1115 extended flank



< Atelier PRO

extension on the corner and flank

< Wils

extension on the corner, recess in the flank

< Wils
Boven, Freijser et al. (1997) page 65

30% horizontal recess on the first floor 1^{e}
40% horizontal extension on the ground floor.

Fig. 1116 *Combinations*[a]

Sculptural effect

Where there is increasing non-systematic variation in recessing and extending, the sculptural effect increases at first, but then it decreases again because of fragmentation.

Loerakker

Van Herk

Fig. 1117 *Examples of combinations of horizontal and vertical relief*

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[a] Freijser et al. (1997)

Structural effect

By, introducing a pattern on the smallest scale (internal or external balconies), from a distance, the façade gains a structural effect.

Mehrtens

Benthem en Crouwel

Fig. 1118 *Repetition 3m>30m*[a]

The recognisability of the ensemble

One can leave these choices entirely to the architect or, from the beginning, link it to the context in order to ‘add lustre’ to a special location. By doing this, an urban architectural ensemble (street, square, building complex in a radius of approx. 100 m) becomes more recognisable as an entity, compared with other ensembles. After all, such choices have a greater effect if they are repeated between the buildings themselves. For example, recessed corners of blocks of buildings (see Cerda’s Barcelona) only create a broadening urban architectural image if the same principles are used in the next and/or opposite block, also if the symmetry in which this occurs is incomplete.

7.5.5 Interaction with exterior spaces

Differences on higher levels of scale

When one lets such choices depend more on the context at a higher scale level, that requires an urban architectural typology of location variants in a broader context. One can then look for the context on the district level (1km◎) up to the European level (3000km◎).
The larger the context in which the location variants of open spaces and especially open water occur, the more scarce and thus the more precious they are. That applies to the corners of an island such as the south-west corner of the Harbour Island (Haveneiland) in IJburg, but also for IJburg as the inner corner of the IJsselmeer, or for Amsterdam as a corner of Europe, where lines from south and east converge on sea- and airports. One can leave such location factors for what they are, but one can also exploit them urban architecturally, and cash in on their scarcity.

Homogeneity by mixing places

In an age in which residents bring ideas back home with them from holidays spent in all parts of the world, reminders of Venice or St. Petersburg can also play a role, but by careful interpretation,

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[a] Freijser et al. (1997)

optimalisation, transformation and realisation, these must be adapted in such a way that they become rare in their own right. To what extent can the combinations that have come about in Venice, be used as a model for those in Amsterdam, and to what extent are they divorced from our time or place?

Interaction with sun, wind, water, earth, life, living outside

The effect of the outside space on the margin, and *vice versa*, is also connected here with climate (for example, with the amounts of sun and wind) and orientation (their direction), but, in particular, it is connected with the size of the open space along which the margins lie and the extent to which they are enclosed. Spaces that are totally, or for the most part, enclosed horizontally, such as empty spaces and voids (up to a breadth of 20m), courtyards and inner squares (20m or more in breadth) offer, in each case, another context for designing the margin. In the last two, it makes rather a lot of difference whether these are part of the through-traffic structure (outside courtyards and squares) or not (inner courtyards and squares).

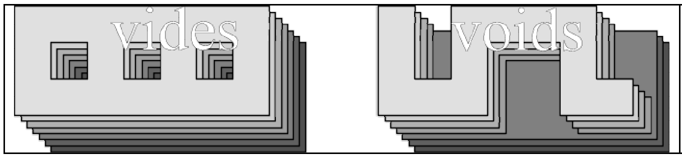
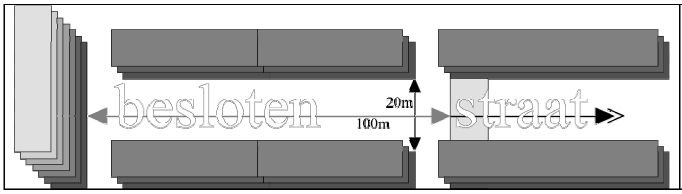
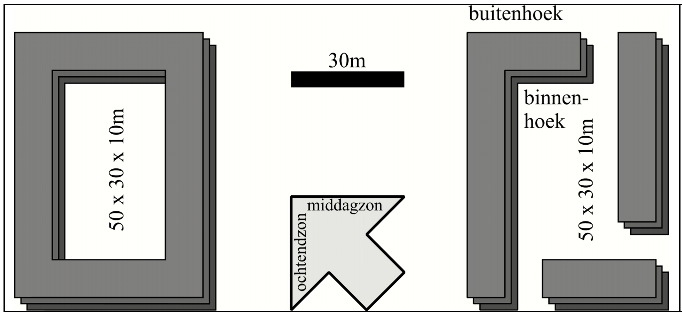
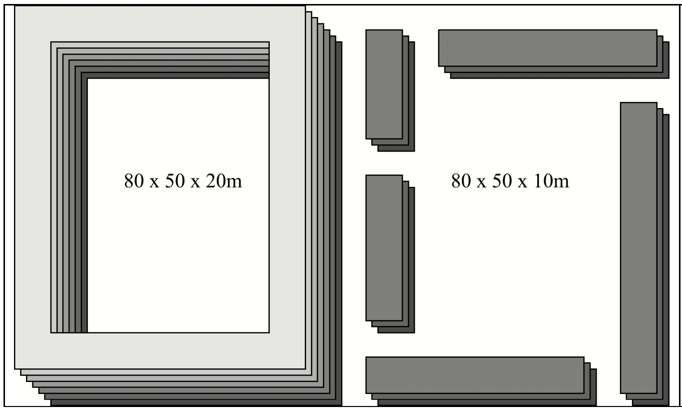
	incorporated up to 30 metres in a building empty spaces voids
	length smaller than 5 times the breadth: enclosed, otherwise through-going spaces: passages, streets, avenues
	up to 30m in breadth interior courtyards, small inner squares exterior courtyards and small outer squares
	more than 30m courtyards, inner squares courtyards, outer squares with less than 50% road surface: courtyard, otherwise a square

Fig. 1119 *Outside spaces*

Squares


market square for animals (Beestenmarkt) in Delft approx. 40 x 50m


Main market square (Grote Markt), Haarlem


Mercator Square (Mercatorplein), Amsterdam approx. 80 x 140m

Fig. 1120 Squares

Margins


Gouda Abken BV, approx. 20m

P.M.
Schiedam by Van de Seyp and Van Dijk, approx. 10m

Fig. 1121 Margins in courtyards and streets

Widths


EDE BRAUWERE
Fig. 1122 Small outside space with continual horizontal relief


Rotterdam Crooswijk Malschaert
Fig. 1123 Large outside space with vertical relief every 80m.

The depth of relief

Relief that has a rather small depth can, nevertheless, greatly influence the appearance of streets, as we know from experience in existing districts where plastic window-frames that have been moved to the façade surface interfere with the recognisability of the street.

The fequency of relief

The frequency of the relief is related to the length and height of the façade. The minimal frequency is 0. A small frequency is once per façade (e.g.once vertically between two side streets or once horizontally between the lowest and highest floors). Each frequency larger than that gives a more unrestful image and, in special cases, may be accepted or even requested.

7.5.6 An academic example of urban architectural rules.

The rules given here only apply to building lines (alignments) and façades. A distinction is made between ground-floor façades (BG), intermediary floors (TV) and the floor directly under the roof (DV).

1. The building lines are the outside boundary of the façade surface, unless it is established in the following rules that at a particular depth, over a certain area, and at a certain frequency, it is permitted to extend and/or recess a building with respect to the building line.
2. The particular characteristic of the planning area within a town is ‘powerful and urban’. This leads to the general rule that deviations from the building line should strengthen the vertical character of the buildings and, with a view to this, must extend above each other over a number of floors.
3. Acceptability and the desirability of having differences between the façade surface and the building line is established by four fixed characteristics of the urban architectural plan. These are:

   a. the position of the building with respect to water;
   b. the position of the building within the urban district;
   c. the position of the façade with respect to the public space that borders it;
   d. the position of the façade with respect to the sun.

Each of these characteristics leads to a series of different public spaces. Each series is divided into a series of types (rules 5-8). For each of the four characteristics in each series a general rule is given (rules 8-12).

5. Water in the planning area is divided into four types on the basis of breadth, as follows:

   W1 >100m : external water
   W2 50-100m : internal water
   W3 25-50m : waterways
   W4 <25m : canals

6. The planning area is divided on the basis of centrality in three types of urban area, as follows:

IJ1	centre, up to 300m from the southernmost point of the harbour
IJ2	central area, 300-1000m around the centre
IJ3	periphery, urban areas around the central area

7. Public space in the planning area is divided into ten types, grouped into streets (S), squares (P) and courtyards (H), as follows:

S1	1>10 b, where b is 24–48m: main street
S2	1>10b, where b is 12–24m: street
S3	1> 5b, where b is 4–12m : lane
S4	1> 5b, where b is <4m : passage
P1	built-up on one side, remaining sides W or S
P2	built-up on two sides, remaining sides W or S
P3	built-up on three sides, remaining sides W or S
P4	built-up on all four sides.
H3	built-up on three sides, remaining side W

H4 built-up on all four sides.

8. The façades are divided according to their position in relation to the sun's orbit (Z), by the hours of the day, as follows:

Z1 0–6 hrs : night façade (N–E)
Z2 6–12 hrs : morning façade (S–E)
Z3 12–18 hrs : afternoon façade (S–W)
Z4 18–24 hrs : evening façade (N–W)

9. Because of traffic, the corners between S1 and S2 are recessed from the corner to 3m.
All the other corners are built along the building line to at least 5m from the corner.
The rules below only apply then to the remaining surface of the façade.

10. The general rule for recessed building surfaces with respect to the building line in connection with their location with respect to the sun's orbit is that the less exposure to the sun, the smaller the percentage of the façade surface that is allowed to deviate from the alignment of the building. For Z1, the desired deviation from the remaining façade surfaces according to rule 10 is 20%, for Z2 this is 40%, for Z3 60%, and for Z4 80%.

11. The general rule for the depth of the recess with respect to the alignment of the building in connection with location by water and public space is that from at least 1% of the bordering public space in the south-west of the planning area (*luw*) to at least 5% of it in the north-east of the planning area (*ruw*) are recessed inside the building alignment.

12. The general rule for the frequency of recessing with respect to the building alignment is that the nearer one comes to the centre, the 'liveliness' of the façade increases. In the connection with the above sentence, the frequency with which recessing occurs amounts to a maximum of 3 times for each 100m of building alignment on the north-west side to at least 9 times for each 100m of building alignment on the south-east side.

7.6 Boundaries of imagination

7.6.1 Creativity

Creativity means leaving out at least one self evident tacit supposition. We found a systematic way to examine *hidden presuppositions* in science and technology. We provisionally call it '*conditional analysis*' and use it in ecology, design, education and in making computer programs. It has more to do with possibilities than with probabilities or necessities[a]. It gives some insight in the boundaries of imagination and thus design.

Conditional analysis

It is based on the simple comparison[b] of two concepts A and B, putting the question 'could you imagine A without B?' and the reverse question. Temporarily we take in consideration only the pairs of concepts that make possible a different answer on both questions.
As soon as we can imagine A without B but B not without A we call A a (semantic) condition for B. As soon as we find a concept C that we cannot imagine without B but B without C we can, we have semantically a '*conditional range*' of concepts ABC out of which the hypothesis emerges that we cannot imagine C without A, but in the reverse we can. Though introspective, these comparisons turned out to give consensus based on a possibility of falsification[c].

Culture supposes life, life supposes matter

Let us for instance conditionally compare the ecological concepts *Abiotic*, *Biotic* and *Cultural* phenomena (A, B and C). I cannot imagine cultural phenomena without biotic (because culture presupposes at any time living people and functioning brains), but biotic phenomena without cultural I can (for instance plants[d]). I cannot imagine biotic phenomena without abiotic phenomena, but abiotic phenomena without biotic I can (for instance light, air, water, soil). So the hypotheses to be controlled are: 'I cannot imagine cultural phenomena without abiotic phenomena, but abiotic phenomena without cultural I can.'. If we confirm that hypotheses we can draw a conditional scheme like this:

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[a] Some presuppositions of normal logic lack that seem to stagnate the development of drawing theory, design theory and ecological theory. Though we, Jong, T. M. d. (2002) Verbal models in: T. M. d. Jong and D. J. H. v. d. Voordt *Ways to research and study architectural, urban and technical design* (Delft) Faculteit Bouwkunde TUD did not examine it thouroughly, semantic conditions may be tacitly presupposed in normal logic. To formulate the function of a logical operator 'o', you first need to test the truth-value of 'PoQ' in four conditions (if P is true and Q is true, if P is true and Q is false, if P is false and Q is true, if P is false and Q is false). That conditional if..than.. test cannot be performed by the conditional operators (⇒, ⇐ and ⇔) to be defined by the truth-table itself. What kind of conditional comparisons are they than if they are tacitly supposed in formulating these well-known conditionals? Conditional analysis may also shed some light on the hidden propositions in the terminology 'true' and 'false' and the hidden propositions concerning restrictions on space and time in logical reasoning. For instance, the expression 'It rains and it rains not' is true on world-scale, but forbidden in formal logic as a contradiction. So the hidden supposition of formal logic must be that only local events could be logically expressed. A drawing containing different locations cannot be logic in this way.

[b] The expression 'comparison' is used here in an unusually broader sense than in formal logic or mathematics, but until now seemed to be correctly understood without explanation.

[c] Including the comparisons needed for the hypothesis, we needed 6 comparisons to make a conditional sequence of three concepts. The fourth one will need another 6 comparisons, the fifth another 8. We compared appoximately 200 crucial concepts in science and technology like 'set', 'pattern', 'structure', 'function' and the like (note 6). That required 39800 comparisons and resulted in a samantically conditional sequence of these concepts with one single condition at the beginning.

[d] This already says something about my preconception about culture: 'a plant has no culture'. Though the concept of culture is not yet defined by this operation, it is in any case 'placed' and the boundaries of many possible definitions are set.

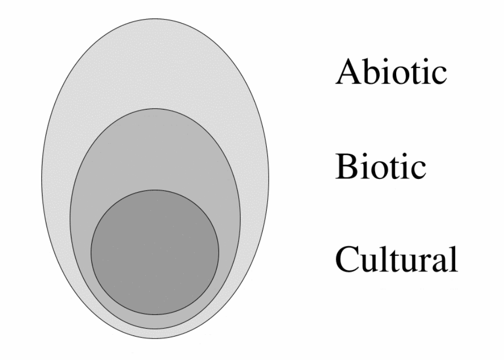

Fig. 1124 *The ABC model*[a]

It seems to be a *Venn diagram* out of set-theory. But it is not, because set-theory presupposes more than the concept of presupposition itself. It presupposes for example the concept of 'element' and any equality of the elements (according to the criterion of the set). Jong (1992) supposes less.

A *semantic Venn diagram* does not yet need these and perhaps other presuppositions. The drawn borders are no inward formulated borders of sets and elements, but outward boundaries of eventually vague and continuous conception.

The *ABC model* represents phenomena outside culture, but is itself a concept and thus culture.

This raises the philosophical question whether there is any difference between '*preconception*' (*presupposition*, *assumption*) and '*precondition*' (*prerequisite*) at all. The environmental crisis taught us however that there appeared preconditions for life we did not preconceive beforehand. We consider '*environment*' in an ecological sense as the set of conditions for life, known or yet unknown.

Nature a human concept or the reverse

In *Fig. 1012* two very different ecological presuppositions that have a direct influence on the way people design a landscape or townscape are drawn: 'Man is part of nature' and 'Nature is only a human concept' *ecocentrism* and *anthropocentrism*).

A paradox of argument

Both suppositions contain a paradox. The anthropocentric way of thinking would imply that physics and biology ('N') cannot find anything new from experiment or observation that is not already included in the existing set of concepts (C) or its combinations[b] (idealistic position). Wittgenstein (1919, 1959; Wittgenstein (1963; Wittgenstein and Hermans (1986) said: 'The boundaries of our world are the boundaries of our language.', and: ‘About which you cannot speak you have to be silent.’ It was a reason to suspect him of mysticism.
The ecocentric view however would imply that we cannot communicate such observations. To take these observations serious, we have to regard them as a not yet cultural part of the natural world N (materialistic position).

Logic as culture

Let us now consider culture (C) as an intermediate between the picture ('N') and the portrayed in the natural world (N). Wittgenstein supposes that the picture and and the portrayed have their 'logical form' in common. Formal logic however cannot cope with expressions like exclamations, questions, proposals (like designs) and orders: they have no logical form. That is what occupied the later *Wittgenstein (1953)*. In my opinion these linguistic expressions are the very solution to the paradox of ecocentric thinking. Questions are the definition of an emptiness at the boundaries of knowledge, proposals and designs are excursions in an unknown, but nevertheless imaginable and perhaps possible future world.

Culture as a set of suppositions

This brings me to a specification of culture, creativity, science and art. *Culture* is the set of suppositions in communication. Suppose we had to explicate all presuppositions of our communication before we could start with it, in that case we would seldom have time to communicate[c]. Fortunately we don't have to explicate every time all these preconceptions, we simply take them for granted and call them culture. That is easy, but it also keeps 'self-evident' concepts out of discussion. *Creativity* just

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[a] Jong (1972)

[b] Synthetic judgements a priori of Kant, I. (1976) *Kritik der reinen Vernunft* (Frankfurt am Main) Suhrkamp Verlag. .

[c] 'Suppose we are human, suppose we use a language, suppose we understand the same things using the same words, suppose this building does not pour down, suppose you don’t kill me for the things I say etceteras etcetera . . . than we could have a conference, shall we have a conference?'

starts with disclaiming these apparently self-evident preconceptions, *science* starts with doubting them.

Art as a ripple at the outside boundary of culture

Art is a ripple at the outside boundary of culture denying conventional and adding unconventional presuppositions by poièsis[a]. We need art or technique to make new concepts outside conventional language. Science on itself does not provide that.

7.6.2 Possible futures

Different futures

Probable ecological, economic and cultural *futures* are gloomy from a viewpoint of inevitable environmental developments. But are the probable futures the only ones that we have to take in consideration? *Empirical research* is limited to the probable futures. Design, or technical research is limited to the broader set of possible ones.
I cannot imagine the probable without the possible. The reverse I can.
What is probable must be by definition possible.

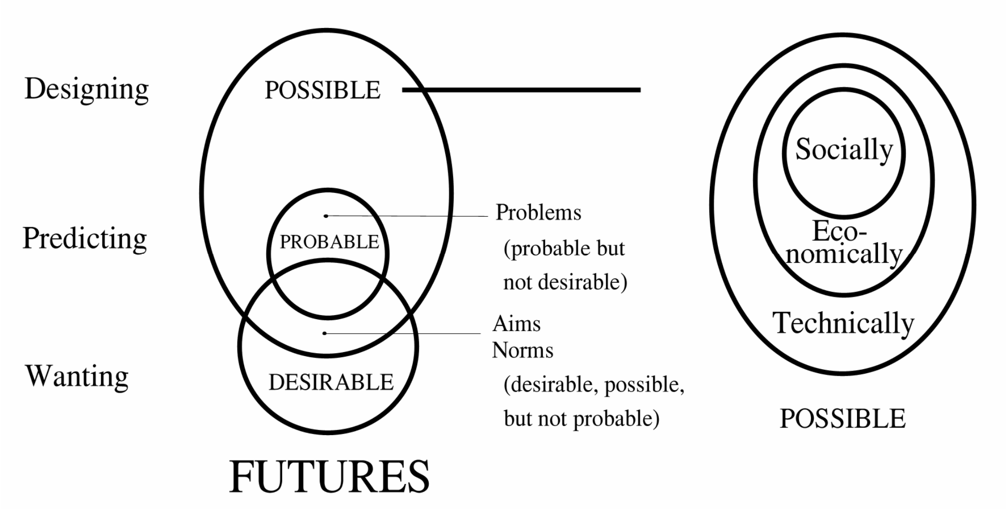

Fig. 1125 The modality of the possible

Boundaries of causal thinking

Predicting probable futures requires causal thinking on an empirical basis. We cannot predict possible futures as far as they are not probable: we have to design them. They are invisible for probability-calculations. They are fundamentally ab-normal, outside the 95%-area of probability. Designs cannot be calculated or predicted. If so, they would no longer be designs. Design produces possibilities, conditions, freedom of choice, difference.

Design does not cause futures, it makes them possible

Every line a designer draws is a precondition for further drawing, but not a cause for the rest of the design process. In the same way the performance of the resulting building, the behaviour of its inhabitants, is not caused or even necessarily aimed by the designer, but only made possible in a universum of possibilities opened by the design. Every line a computerprogrammer writes is a condition for the rest of the program, but not the cause of its performance. On the other hand one single missing line can 'ceteris paribus' be called the 'cause' of its break-down.

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[a] ποιησισ, manufacture, construction

Conditions of life

In the same way global life has no single cause, but many conditions of which lacking one on a single place and moment can indeed cause the death of an individual. Special conditions of sunlight, moist and minerals do not cause special life-forms (let alone that they can be aimed by norms of sunlight, moist and minerals per location), they only make different life-forms possible. The relation conditional <> causal has its analogies in the dualities possible <> probable, designing <> predicting, means-directed <> aim-directed, and probably ecocentric <> antropocentric.
What kind of thinking do we need for design study?

Causal and conditional thinking

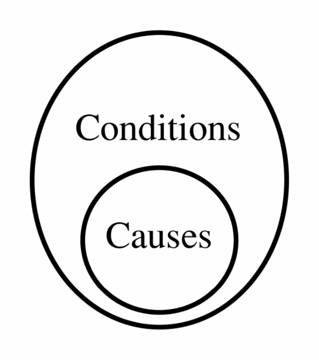

Fig. 1126 *Causes under conditions*

I cannot imagine causes without conditions, the reverse I can. We have to make a step back from *causal thinking* about probabilities into the broader area of *conditional thinking* about possibilities. Every cause is a condition for anything to happen, but not every *condition* is also a *cause*. The foundation of a house may be a precondition but not a cause of its existence. Causal thinking is conditional thinking, but conditional thinking is not always causal.
Suppose we read in the paper: 'The crash of the cars was caused because one of the drivers lost control of his wheel.' That sounds plausible until an extraterrestrial descends, saying: 'Nonsense, the collision was caused by two objects approaching eachother with great speed.'

If he is right, the paper is wrong, because if the cars would not have been approaching eachother and one of the drivers would have lost control there would have been no collision. So it is only a cause under the tacit precondition of approaching cars. Every causal conclusion is based on innumerable tacit conditions called '*ceteris paribus* presuppositions'.

Any cause supposes conditions

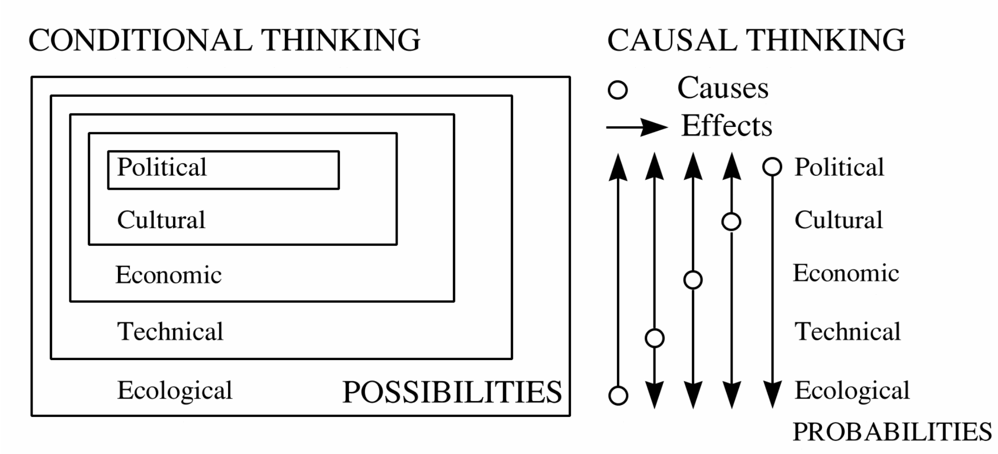

Fig. 1127 *Conditional thinking as a ceteris paribus environment of causal thinking*

I cannot imagine *social possibilities* without any *economic conditions*. The reverse I can.
I cannot imagine *economic possibilities* without *technical conditions*. The reverse I can.
This gives a semantic conditional sequence of possibilities. In stable technical conditions economic initiatives can cause technical or social change. But when the dikes burst the technical 'ceteris paribus' for economic determinism are lacking.

Changing conditions

The ceteris-paribus presuppositions of causal explanations also change on different levels in time. That means changing causal explanantion. They also can be changed by design forcing shifting explanation about the effects. Innovative design implies removing some preconditions and making new ones. Design makes *ceteris* ***non*** *paribus*.

Innovative design implicates always removing suppressed conditions and making new ones. Loose from that conditions change in different wave-lengths:

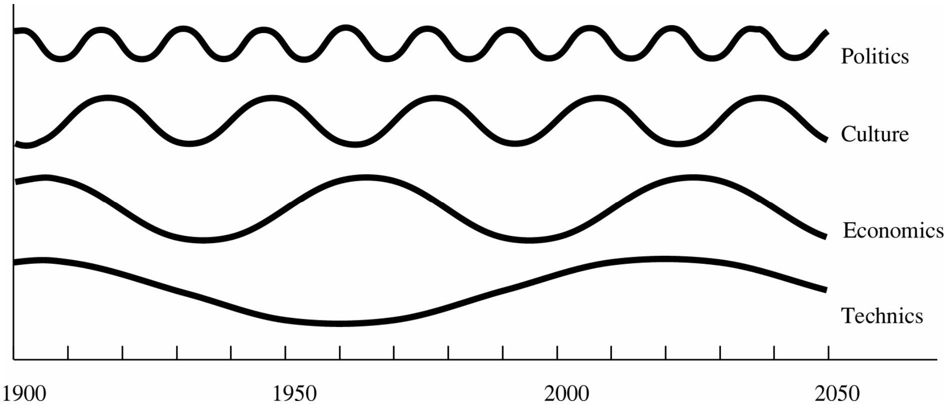

Fig. 1128 *Changing conditions for causal thinking.*

Now we can point out a week component in causal thinking. The ceteris-paribus presuppositions of causal explanations change on different levels and can be changed by design ... by us.

Comforting the causal trapped

Professor Helmar Krupp (1996), former director of the Fraunhofer Institut in Karlsruhe studied physics, pilosophy and sociology. He came to the conclusion that the individual no longer can influence the evolution of society. Society behaves as a system with its own dynamics. Individuals have to submit to this dynamics. In the conference 'The mind of technology', Delft, 27 november 1996, De Jong tried to comfort him by emphasising design. The limitations of research could be broken by design.
Probable ecological, economic and cultural futures are gloomy from a viewpoint of inevitable Schumpeter dynamics or Fukuyama-expectations. But are the probable futures the only ones that we have to take in consideration? Empirical research is limited to the probable futures, design, innovation or technical research to the possible ones. And that creates hope.

Form supposes a legend

I cannot imagine a *representation* or *drawing* without indicated differences, an (eventually tacitly presupposed) vocabulary or *legend* (key to symbols). The legend is the vocabulary of the drawing. Only by drawing differences one can make *forms* and only by making different forms one can make *structures*. *Function* presupposes a structure within which the function operates.

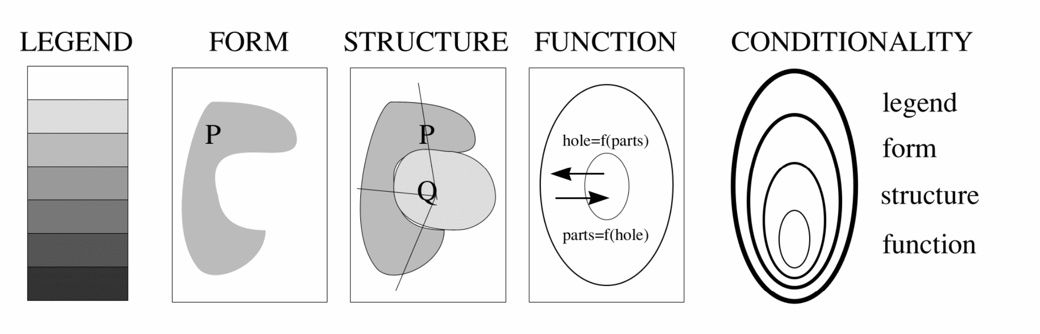

Fig. 1129 *The legend and its relation to form, structure and function*

The same form by different structures

Nevertheless, within one set of forms (for example a box of blocks) you can imagine different ways of connecting them (structures) and within different structures you can imagine different functions. In the reverse the same function often chooses different structures and the same structure is often built in different forms or materials. So where the design process lays the initiative is free. It can be either a causal, *aim-directed* (purposive) process starting with the function (*funcionalist* position) or a conditional, *means-directed* process (*formalist* or *structuralist* position).

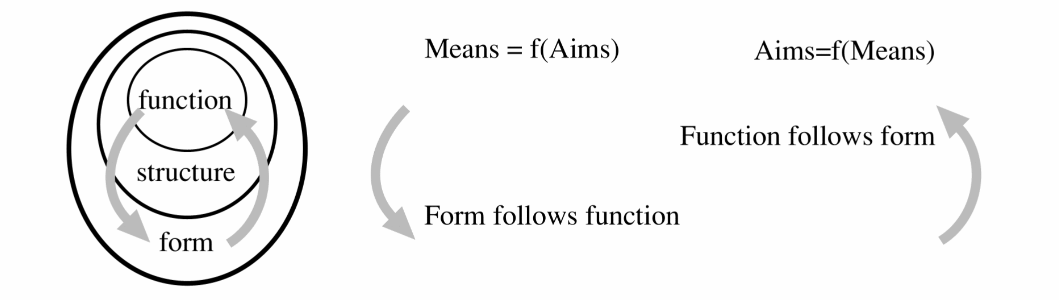

Fig. 1130 *Function, form, aims and means*

The sequence of aims and means

When the number of *aims* is smaller than the number of *means* you better can use aims as *independent variable* with the means as *dependent variable*. In architecture and certainly urban planning the number of means is smaller than the number of aims. In that case you better can variate the means to see what gives the greatest amount of possibilities for future generations.

7.6.3 Environment, the set of conditions for life

Environment in the technical and ecological sense of Hendriks (1993) is the set of conditions for life (see Fig. 1010). In this definition 'conditions' can be interpreted as ecological, technical, economic, cultural or administrative preconditions. These substitutions result in 5 different usual concepts of 'environment': the administrative environment, the cultural environment etc. The concept 'life' can be substituted in the same sense as 'social life, cultural life, life of men, animals, plants etc, multiplicating the meanings of the concept of 'environment'.

Building conditioning life

Building is a prerequisite for human and other life. Building and *urbanization* has ecologically more positive effects on the environment than negative. In contrast with other productive branches it produces more 'environment' than it costs. It produces an environment for humans without which they would not survive at the same rate. But it also could produce a better environment for a variety of plants and animals than many places outside the built-up area (see Fig. 768).

Making th city a source of life

Vos (1993) and Denters, Ruesink et al. (1994) reported that for instance in the Dutch cities Zoetermeer and Amsterdam, you can find 1/3 and 1/2 of the total amount of botanical species in the Netherlands. Within the city of Zoetermeer one square kilometre counts even 350 wild self breeding species outside the gardens. That is 7 times more species than an agricultural square kilometre in the direct surroundings and as much as a square km in the natural environment of natural reserves as the Dutch dunes. Of course we cannot say that the value of an urban ecosystem equals that of the dunes, but we signal a potential that we could improve. To improve the contribution of urban design to the solution of the ecological crisis we have to emphasize more the production of positive effects and its research than the reduction of the smaller negative effects.

The sun as source of the city

Let me give another example of environmentally decisive design. The development of *photovoltaic cells* can destroy many gloomy prophecies. The photovoltaic cell deminished a factor 14 in price since 1975 (see *Fig. 14*); another factor 8 and it outruns the economic efficiency of fossil fuels. The only problem is a cheaper way of slicing sand. The last two centuries technical problems like that never waited longer than 10 years for their solution.

Let's destroy **all** gloomy prophecies by design.

7.6.4 Starting by difference

Design makes a difference

The very beginning of any range of semantic conditions seems to be '*difference*'. Any concept presupposes 'difference'. Difference on itself cannot be defined because the concept of '*definition*' already presupposes making difference with the rest. But also the concepts of 'making', 'with', 'the', and 'rest' presuppose 'difference'. So in the sentence concerned, 'difference' was already at least five times presupposed! Even the concept of *equality* (as necessarily presupposed in the concepts of 'gathering' and 'counting' and therefore in set-theory and mathematics) presupposes difference. As soon as you accept that there are 'different differences', for instance more or less difference ('*variation*'), you have to accept that equality is a special case of difference.

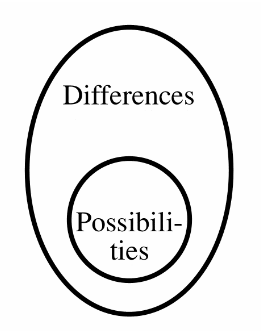

Fig. 1131 *Anything differs*

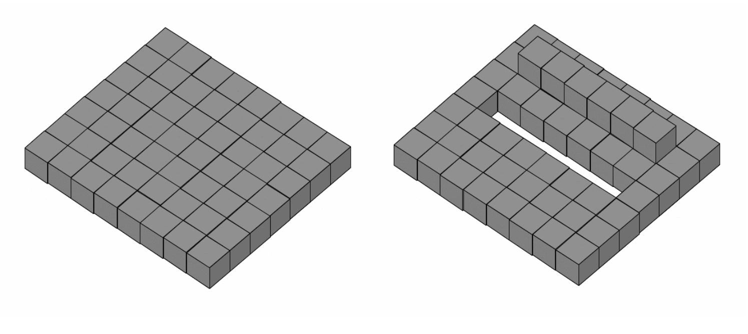

Fig. 1132 *Difference makes possible*

Difference makes possible

According to Fig. 1132 there should be a more specific relation between difference and possibility than the conditional one in Fig. 1131. However, I did not yet find a more convincing consideration than a picture like Fig. 1132.
Yet this question is essential for designers. If after all their profession as producers of possibilities has a specific relation with differentiation, than it has a difficulty with the accepted scientific practice of generalization*.*

Equality is a special kind of difference

Ashby (1960) and *Leeuwen (1971)* noticed that given a difference you always can imagine more difference, but not always less. The least kind of difference we call equality. Nevertheless, there must be a difference of place or moment left to establish that equality, otherwise the comparison has no sense. So we can draw an important conclusion: equality is a special kind of difference and not the opposite of it.

The search for equality ends somewere

Many scientists feel uncomfortable with that conclusion because their profession is based on equations that conceive regularities in sets of n>1 'comparable' facts. Designers on the contrary do not, because their profession is based on originality in every single n=1 case. Without that originality their design would not be a design, but a prediction. The very concept '*concept*' presupposes any equality in the observations conceived in the concept, but the concept '*conception*' presupposes something different from earlier observations. Conceptualization always needs a reduction of diversity.

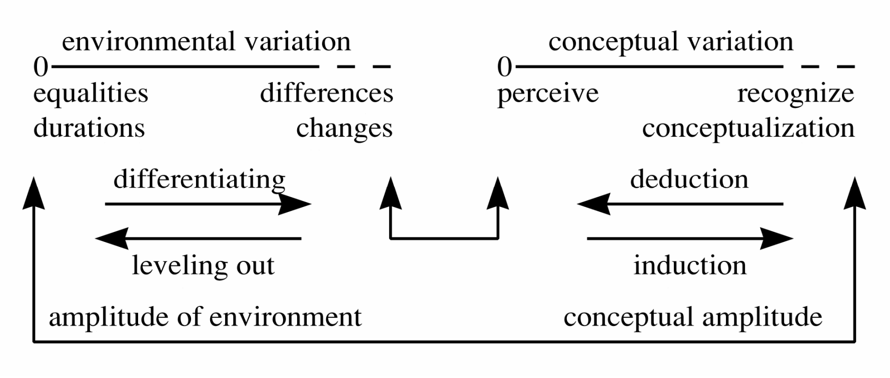

Fig. 1133 *Perceiving differences, recognising equaities*

The sense of difference

Vision, hearing, smelling, touching all need differences or changes in the environment. As soon as there is some repetition within these perceptions, we 'recognize' it, which is the basis of cognition and conceptualization. (Re)cognition however is only based on similarity, it **reduces** the differences that still can be perceived. So conceptualization changes sometimes chaos in surprize, sometimes surprize in recognition, sometimes recognition in boredom.

Deminishng returns of reductive science

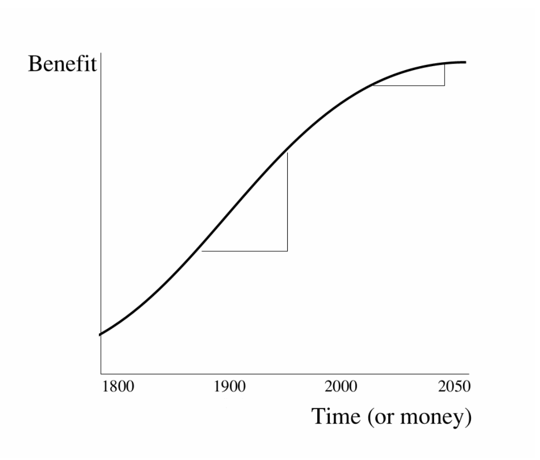

Fig. 1134 *Deminishing returns of monocausal (or paucicausal) research*

Causal thinking is a special way of reducing diversity. It reduces similarities in repeating sequences of phenomena to the more general concepts of cause-effect relationships. Causal explanation has the more value the more reduction of different cases is possible by abstraction.

Alas, nowadays there are not so much phenomena left that can be explained monocausally. They largely have been explained earlier. What is left are context sensitive effects that can be caused by many different 'causes' or causes that can bring about many different effects, dependent on small differences in the environment where the 'cause' is introduced. Striking a match can cause little damage here, and big damage there. So monocausal (or 'paucicausal') research shows deminishing returns, especially on environmental (context sensitive) issues.

Means and aims can only be chosen on the basis of a supposed causal relationship between both. Otherwise thinking about means and aims is senseless. The same means applied here have other effects as applied there. Apart from that they are also scale-dependent and therefore subject of misconceptions.

7.6.5 The importance of diversity in ecology

Ecological tolerance

The curve of *ecological tolerance* (see Fig. 695) relates the chance of survival of a species or ecosystem to any environmental variable, for instance the presence of water. In that special case survival runs between drying out and drowning.

A risk-cover for life

Variety is a risk-cover for life. This is not only true for the variety in the abiotic conditions, but also for the variety of ecosystems, species and of genetic possibilities within each species. Life survived many disasters thanks to biodiversity. In the diversity of life there was always a species to survive or within a species a specimen that survived. Survival of the fittest presupposes diversity from which can be chosen in changed circumstances. Deminishing biodiversity means undermining the resistance against catastrophes. From the 1.5 million species we know, this century we lost approximately 50000. So, we not only introduce ecological disasters, but also undermine the resistance of life against these disasters.

Biodiversity supposed in any quality of life

Biodiversity in mankind is a crucial value in our quality of life. As we are here we are all different and the very last comfort you can give a depressed person is 'But you are unique'. Diversity is also a precondition for trade and communication. If production and consumption would be the same everywhere, there would be no economic life. If we would have all the same perceptions and ideas, there would be no communication. It is an important misconception to believe that communication only helps bridgeing differences. Communication also produces diversity by compensating eachother and coordinating behaviour by specialization.

Freedom of choice supposes diversity

World commission on environment and development (1987, Committee Brundtland, see) summarizes the environmental challenge by stating sustainability as leaving next generations at least as much possibilities as we found ourselves. But what are possibilities? 'Possibilities' is not the same as economic supply. If our parents would have left us the same supplies as they found in their childhood, we would be far from satisfied. 'Possibilities' has to do with freedom of choice and thus variety. Our converging Schumpeter-economy described by Krupp (1996) and Fukuyama (1992)-culture leaves no choice. In our search for the alternative we find everywhere in the world the same hotels, the same dinners, the same language. This century, the last 'primitive' cultures are lost and with them an experience of life that no western language can express.

Trade and communication suppose diversity

The extremest consequence of this levelling out would be a world without economy and even communication. If there are no longer any differences in production factors, exchanging goods and services would no longer be necessary. If total world wide distribution of knowledge and consensus would be the result of our communication age, there would no longer be anything worthwile to communicate. These thought experiments show clearly that 'difference' is also a hidden presupposition in communication and economy.

Diversity and quality

Quality can be measured in terms of possibilities of use, experience and expectation for future generations. The way design can sustain a sustainable development in the sense of Brundtland is to produce more choices for man, animal and plant. If there were one best solution for all problems of architecture and urban planning, it would be the worst in the sense of choices for future generations! This paradox pleads more for diversity than for uniform solutions. Moreover, if there was an uniform solution, the designer would have no task.

Quality is always a function of variation (see Fig. 696). Quality of possible experience moves between diversity and uniformity, surprise and recognition. One step too far into both sides brings us in the area of boredom or confusion. This is a simple conception, already recognized by Birkhoff (1933) and Bense (1954) see also Koutamanis (2002), but why dit it not succeed, why is quality always posed as an unsolvable question?

Different diversities at different scales

Any discussion on variety and thus variables can fall prey to confuson of scale. That means that even logic and science as forms of communication are prey to the scale paradox. The paradox of *Achilles and the turtle* is a beautiful example of the scale-paradox in time. The turtle says: 'Achilles cannot outrun me when I get a headstart, because when he is where I was at the moment he started I'm already further, when he reaches that point I am again further and so on!'. This conclusion is only incorrect by changing the time-scale during the reasoning. Something similar is found by Russell on set-theory. Russell (1919) bans sets containing themselves and reflexive judgements as 'I am a liar'.

Premises of conclusions to be drawn at the same scale

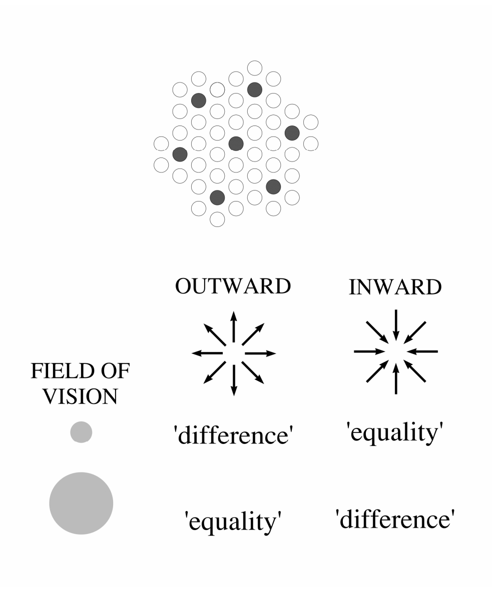

Fig. 1135 *The scale paradox*

The *scale paradox* means an important scientific ban on applying conclusions drawn on one level of scale to another without any concern. The picture shows the possibility of changing conclusions on a change of schale by a factor 3. There are 7 decimals between a grain of sand and the earth. That gives approximately 15 possibilities of turning conclusions. Between a molecule and a grain of sand applies the same. This ban is violated so many times, that this should be an important criterion on the validity of scientific judgements.

The scale-paradox is not limited on concepts of diversity. An important example of turning conceptions into their opposite by scale is the duality of aim and means. For the government subsidizing a municipality the subsidy is a means, for the municipality it is an aim. So the conception of means changes in a conception of aim by crossing levels of scale. The turning of '*Zweckbegriff*' into '*Systemrationalität*' by Luhmann (1973) may be a turning conception of the same character.
In growing organizations *integration* on the level of the organization as a whole means often *desintegration* of the subsystems and perhaps a new form of integration in the sub-sub-systems. This process is often called '*differentiation*'!

7.6.6 Conclusion

Obedience to nature called freedom

The computer sustains the design process and spatial design sustains or even enlarges our freedom of choice. Enlarging the diversity of inside and outside space offers after all new possibilities and thus new freedom of choice. Concerning the possibilities of future generations of world population since Bruntland, we call the maintenance of that freedom '*sustainable development*'. Environmental planning takes into account the simultaneously appearing loss of possibilities and freedom of choice for future generations.

Extending freedom of choice by design

The building process however has in this sense more positive than negative ecological effects. The best way design can sustain a sustainable development in the sense of Brundtland, is to produce more choices (possibilities) for man, animal and plant. If there were one scientificly tested best solution for all causally formulated problems of architecture and urban plaming, it would be the worst in the sense of choices for future generations. This paradox rises when we consider science only as a method of optimizing probable effects. I would like to state that technical science has more to do with possibilities than with probabilities.

Sutaining design by computing

Computerprogramming not only sustains design and freedom of choice, it also forces us to make clear hidden presuppositions and that is the traditional task of art and science.
In that perspective the task of technical science is to make clear the preconditions (or presuppositions) of technical performance, the task of technical ecology that of life performance.
The presuppositions about the design process, as they are differently hidden in a designers' mind and in design sustaining computer programs, have something in common with the preconditions of technical and biological performance. If our theory can cope with both, it will concern a more essential thing about design, building and ecology.

Designing the improbable

The *possibility* (the set of conditions) of an event is something different from a cause (and subsequently the probability) of an event. Every cause is a condition for something to happen, but not every condition is also a cause. The design of a house does not cause the behaviour of a household. It only makes more ways of behaviour possible than there would have been possible without a house. It allows freedom of choice, offers conditions. In the same way the design of a *computerprogamme* is no good when it forces the user into a specific way of thinking, it should give the opportunity for different ways of thinking. Ecology is the science of conditions, prerequisites for different life-forms. Global life by its enormeous differentiation is not monocausal and thus not predictable or 'aimable'. Death of individuals on the other hand, is predictable by pointing out any essential condition for life lacking. Man as a part of life is essentially not predictable as long as we believe in freedom of choice.

Sustaining the possible

In ecology, technology, design and computerprogramming conditional thinking is as important as the operational, aim-directed, causal thinking we are used to. The methodology of causal and probability thinking is largely developed. But what methodology do we need when we do not only ask questions about the cause or aim of a phenomenon, but about the conditions under which a phenomenon could possibly appear, its possibility?

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Key words

Questions

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[1] How does the SI system of units define energy and power?
[2] What is momentum?
[3] What is force?
[4] What is energy?
[5] What is power?
[6] In what units are energy and power expressed?
[7] What does peta mean?
[8] What is the energy content of 1 m^3 natural gas (aeq)?
[9] What is the energy content of 1 litre petrol?
[10] Give three expressions for the power of one watt *during* a year.
[11] Give three examples for the power of one watt *during* a year.
[12] Express 1 kWh in J.
[13] Give three examples of a power of 100W in every day life.
[14] Why is electric energy more expensive than the same energy from gas?
[15] What is the relation between entropy and efficiency?
[16] Which conversions are combined in an electric power station and which efficiencies are involved?
[17] How long could we maintain current energy use by fossile fuels?
[18] Name 3 drawbacks of the use of uranium for energy supply, explain every drawback with three elements.
[19] Where hides the danger of misuse of nuclear energy using a fast breeder reactor?
[20] What is nuclear fusion. What are the dangers of nuclear fusion?
[21] Which proportion of Dutch energy use is electric?
[22] What is the best alternative for future energy production?
[23] What is the largest flow of commercial energy through The Netherlands?
[24] For which applications is energy storage of decisive importance?
[25] Which kind of energy storage is most efficient. Why don’t we use it?
[26] When and at what time a building of 50m casts a shadow of 100m in North-Eastern direction in The Netherlands?
[27] What is a candela?
[28] What is a lumen?
[29] What is a lux?
[30] What is the name of the age 75 000 B.C?
[31] Where could you find daisies (madeliefjes) and from which month do they flower in the Netherlands?
[32] Which plants in The Netherlands start to flower in February as pioneering plants, in grassland and in forests?
[33] Why are flowering periods important for nature management? What types of biotope have an early flowering period and what types have a late one? What types of biotope have a limited flowering period late in the summer? To what extent can the daily variations in growing circumstances play a role in nature management?
[34] What is a key characteristic of plants in a built environment?
[35] What is 'screening' effect of plants?
[36] What is 'structure' in plantation?
[37] What can be the effect in time of planting schemes?
[38] What are restrictions in the choice of plant material?
[39] What is the primary factor that influences the planting of trees next to buildings?
[40] What are the climatic conditions for use of plantation?
[41] Which kinds of plantation are coloured or flowering in spring?
[42] Which kinds of plantation are coloured or flowering in summer?
[43] Which kinds of plantation are coloured or flowering in autumn?
[44] Which kinds of plantation are coloured or flowering in winter?
[45] Which are the physical conditions for use of plantation apart from the climatic ones?

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[46] Which kinds of plantation are applicable in coastal areas?
[47] Which kinds of plantation are applicable on clay/loam soils?
[48] Which kinds of plantantion are applicable on peat soils?
[49] Which kinds of trees are applicable on wet soils?
[50] Which water table is the best situation for trees?
[51] In ‘sinking’ areas (peat soils) in the West of the Netherlands the paving has to be raised every so often, even up to 30 or more centimetres at a time. As a result, many trees receive too little oxygen and die. Which kinds of trees will die?
[52] How is space in streets organised to enable tree planting?
[53] Which size classes are distinguished concerning trees?
[54] What is the minimum distance between the buildings and the centre of the stem of a size class 1 tree?
[55] What visual effects can be used in tree planting in urban space?
[56] In what ways can planting distances influence the urban environment?
[57] How can hedges be used in creating urban space?
[58] What is 1 bar air pressure?
[59] What is the mass of 1m3 of air on sealevel?
[60] Which relation exists between wind force and velocity?
[61] Why could you not multiply a locally measured wind force by the surface of a building to get the total force?
[62] In what order of magnitude air density decreases by altitude?
[63] How many turningpoints the air temperature counts in the atmosphere from ground level until 500km altitude?
[64] Why do cumulus clouds mainly have a flat bottom?
[65] Which length has the equator?
[66] Why is the atmosphere thicker at the equator than at the poles?
[67] What are 'trade winds'?
[68] How much energy non airtight houses in a moderate climate winter could loose by 5m/sec increase of average wind velocity?
[69] At which wind velocity a normal wind turbine has its maximum energy production?
[70] In what range the year average potential wind velocity varies in the Netherlands?
[71] What is an 'hour average wind velocity'?
[72] What is a 'year average wind velocity'?
[73] How can wind velocity statistics be reliably simulated?
[74] How is the energy in wind related to its velocity?
[75] What is best to decrease energy losses from buildings: sheltering form the coldest (NE) winds or from the most frequently appearing (SW) wind directions?
[76] From which wind direction a city in the Netherlands could best be sheltered to decrease comfort complaints about wind?
[77] What is the best place concerning all aspects of wind: Schiphol or Eindhoven?
[78] What is the standard class of roughness supposed in wind data?
[79] Which roughness class has obstacles of 10m < H < 15m: bottom regularly and fully covered by rather large obstacles with mutual distance not larger than 2x their height: regular forests, low rise buildings in villages, suburbs?
[80] How much could a windvelocity of 7m/sec on 20m altitude be reduced by 1km urban area?
[81] How much could a windvelocity of 5m/sec on 20m altitude be increased by a profile of 500m highway and railway?
[82] If there were no differences in temperature or ground level and water was equally dispersed over the Earth, how deep the ocean would be?
[83] Why is snow and ice in mountains important?
[84] As a very rough approximation, how much is the m^3/sec of discharge per km^2 catchment area?
[85] What is the ‘duration line’ of a river?
[86] How changes velocity downstream?
[87] Why are street patterns and artificial drainage systems in flat lands not like a tree but like a lattice?
[88] How large are the differences in sea water levels caused by tides in The Netherlands?
[89] Which Dutch weirs are closed successively to store enough fresh water in the IJssellake during warm and dry periods?
[90] How is salt water intrusion near Rotterdam reduced?
[91] What is the hydrological effect of climate change in The Netherlands?

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[92] Which four major systems of coast development can be distinguished in The Netherlands?

[93] Within which period a severe rainfall with critical intensity must be pumped out completely in Dutch populated and industrialised areas?

[94] The discharge of the river Rhine at Lobith in February 1995 was 12 000m3/sec. What is normal?

[95] Which general subsidence faces The West of the Netherlands until 2050?

[96] The Parliament of The Netherlands decided in 1960 to accept the risk of a disastrous flooding of rivers once in how many years?

[97] What is a Gumble graph?

[98] Give some norms for water storage in urban areas.

[99] Suppose the hierarchy of roads would follow a semi logarithmic sequence of meshwidths. Which nominal meshwidths (exit intervals) and widths (form facade to facade) would then approximately fit best residential streets, main streets, district roads, urban, local, regional and national highways on a Dutch topographic map?

[100] If a network with square meshes has a density of 2 km/km^2, what is then the mesh width?

[101] What is a normal network density of neighbourhood streets?

[102] The most efficient enclosure is made by surrounding the enclosed area with a minimum length of road. Which pattern of continuous network, fits that requirement best?

[103] Why is an orthogonal network pattern so often applied in an urban road network?

[104] If a rectangular network with square meshes is elongated into different widths and lengths keeping the same density (road investment), what happens to length of enclosing roads and the surface of the enclosed area?

[105] If a rectangular network with square meshes is elongated into different widths and lengths keeping the same density (road investment), which ratio of width and length is then the limit?

[106] If a rectangular network with square meshes is elongated into different widths and lengths keeping the same density (road investment), what happens to number of crossings per km2?

[107] Which effect has superposition of a higher order over the lower order in a road network, on the density of the lower order?

[108] Which kind of interference of two networks delivers the least crossings?

[109] Which kind of crossings give the least conflict points?

[110] What is the maximum span of a suspension bridge?

[111] What is the maximum span of a arch bridge in steel?

[112] What is the maximum span of a beam bridge in steel?

[113] What is the maximum span of a swing bridge?

[114] Suppose there is a highway on + 0.1 metre. If you want to make a tunnel for cyclists, what length of slopes you will need then on both sides?

[115] What is the average width of a car?

[116] What is the average width of a car parking place?

[117] Which width does a pedestrian need at least in a street profile?

[118] Which width does a cyclist need at least in a street profile?

[119] Which width does a car need at least in a street profile?

[120] Which width does a bus need at least in a street profile?

[121] Which width requires a normal residential street profile between the facades at average?

[122] At which speed a lane has its higest capacity for cars?

[123] What is the equivalent per day of 1000 cars per hour?

[124] What is the maximum capacity for cars of a lane?

[125] If three houses in one block are surrounded by roads, what is then the proportion of public pavement to the area between the centre lines of surrounding roads?

[126] What is a normal proportion of public pavement to the area between the centre lines of roads surrounding a residential building block with entrances at all sides?

[127] Which width requires a normal neighbourhood road profile between the facades at average?

[128] Suppose a residential building block surrounded by roads contains some 75 inhabitants going out 4 times a day of which 3 by car. Suppose in 1/3 of the car trips the driver is accompanied by a passenger. How many car movements per hour will the residential street count?

[129] If there are 1000 inhabitants in a neighbourhood how many car movements will there be per hour on a neighbourhood road?

[130] How much pavement surface you can save if approximately 200 inhabitants are willing to walk one minute longer into their parking space instead of parking in front of their home?

[131] How could you save pavement surface if approximately 2000 inhabitants are willing to walk ten minutes into their parking space instead of parking in front of their home?

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[132] How could you save neighbourhood pavement surface in a grid of 1x1km district roads filled in with a grid of 300x300 m neighbourhood roads?
[133] How was the principle named by Berlage not making X-crossings on central squares, giving access roads along the square a focal point on larger buildings located at T-crossing?
[134] Which traffic expert proposed a hexagonal grid in 1963?
[135] How does a regular grid of district roads and neighbour streets solve some problems arising if you look at an isolated neighbourhood only?
[136] What were the measures of urban islands Cerdà (1867) designed for Barcelona?
[137] How many urban islands contains a neigbourhood Cerdà (1867) designed for Barcelona?
[138] What was the width from façade to façade of residential, neighbourhood and district roads Cerdà (1867) designed for Barcelona?
[139] What are the advantages of a rectangular grid concerning its flexibility?
[140] Why did towns change from a spider into a fly in the regional web?
[141] 'Care for the pedestrian is the core of urban design.' In which Dutch publication this statement is supported most extensively?
[142] What causes deviations in a rectangular town grid?
[143] In what sense the lay-out strategy of public transport lines by busses changed at the beginning of the twentieth century?
[144] What are the km radius served area; km stop distance; km/h velocity; km average ride; minutes per ride; stops per ride; passengers per hour; passengers per stop of bus, tram, fast tram, (semi)metro or NS-sprinter?
[145] What is a light rail?
[146] If 14% of the inhabitants is expected to use metro if available, what density you need for anexploitable metro line?
[147] What is earth?
[148] What is ground?
[149] What is rock?
[150] What is soil?
[151] What is geology?
[152] What is plate tectonics?
[153] What is uniformitarianism?
[154] What is geochronology?
[155] What happened between Triassic and Permian?
[156] What is the duration of eons?
[157] What is the Phanerozoic Eon?
[158] How is the Phanerozoic subdivided?
[159] What are strata?
[160] What is the geological cycle and on which insights the concept is based?
[161] What is meteorology?
[162] Which major forms of ingenious rock can be found at the surface of the Earth?
[163] What are sedimentary rocks?
[164] What are metamorphic rocks?
[165] Which kinds of instruments are used by geologists?
[166] What is geomorphology?
[167] Which are the key concepts of geomorphology?
[168] Which are the main processe studied by geomorphology?
[169] What is the difference between weathering and erosion?
[170] Which kinds of weathering could be distinguished?
[171] What is abrasion?
[172] Give some examples of chemical weathering.
[173] Give some examples of biological weathering.
[174] What are the basic activities concerning topography and form of the land starting a design project?
[175] Which are the determining factors in the formation of rivers?
[176] Give some reasons to study river forms in a design project.
[177] Which kind of polders you can distinguish?
[178] What is soil science?
[179] Why is soil science important?
[180] How deep does soil science go?
[181] What is parent material?

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[182] Summarise five soil forming factors.
[183] Wich organic factors could have influenced the properties of the soi?
[184] Wich topographic factors could have influenced the properties of the soil?
[185] Name four phases of soil formation.
[186] Which soil horizons you can distinguish?
[187] What is the physical structure of sand, clay and peat?
[188] How could you identify the particle size of soil?
[189] Which zones of soil saturation by water can be distinguished?
[190] What is the difference between soil water and ground water?
[191] At what specific places in the western part of Holland, the influence of seawater is apparent and why is that?
[192] Hoe could you easily determine the depth of the groundater zone?
[193] Why is sand more easily drained than clay?
[194] What is a groundwater table and why is it important?
[195] What is seepage and at which places does it take place in Holland?
[196] Which characteristics of soil determine their use?
What is the main difference of using sand, clay and peat?
[197] What is the cause of the magnetic field of the Earth?
[198] Why is the composition of the Earth's crust different from that of the Earth as a whole?
[199] Why is the composition of the Earth's crust different according to its depth?
[200] Why are the minerals near the surface of the Earth mainly oxides?
[201] What is the difference between minerals and rocks?
[202] What is the difference between mafic and felsic rock?
[203] What is the most important mineral in igneous rock?
[204] What are two different approaches in preparing a site for development?
[205] Which site preparation methods can be distiguished?
[206] What is the number of kown species on Earth?
[207] Who called biodiversity 'a risk cover for life'?
[208] What is botanical taxonomy?
[209] What class of life forms counts the highest number of species in the Netherlands?
[210] What were the first organisms producing oxygen from carbon dioxide?
[211] When established life a foothold beyond the sea by which mosses and liverworts (Bryophyta) brought a green colour to the wet parts of the land?
[212] What is the evolutionary advantage of vascular plants?
[213] From which period we recognise ice ages (glacials) and warmer interglacials in the soil of the Netherlands?
[214] How is the last ice age named?
[215] In which period the higher parts of the Netherlands were formed?
[216] To which depth Holocene deposits under Delft reach?
[217] Where in the Netherlands is the sedimentation deposited since the last Ice Age the thickest? How thick is it there? How thick is it under Delft? From what period of time after the last Ice Age have human beings been present in the Netherlands? Did human beings live in the Netherlands before the last Ice Age?
[218] A year counts 8760 hours. How many hours per m^2 do people spend in shops, how many in home and garden?
[219] What is a curve of ecological tolerance?
[220] Who was Brundtland?
[221] What is 'sustainable develoment' in terms of the UN World commission environment and development (1990)?
[222] What are reflexive judgements and what kind of problems do they raise?
[223] What does the term 'scale paradox' emphasise?
[224] What is a 'nominal value'?
[225] How could you articulate a state of dispersion by scale?
[226] By whom ecology is defined as 'the scientific study of the distribution and abundance of organisms'?
[227] What is the difference between autecology and synecology?
[228] What kind of ecology is elaborated by Grime, Hodgson et al. (1988)?
[229] What is a biomen?

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[230] What are the average global life conditions of a desert, maquis, grassland, moderate decideous forests?

[231] What are the average global life conditions of the Netherlands?

[232] Welke Europese floragebieden zijn in Nederland vertegenwoordigd?

[233] Which vegetation areas are destinguished in the Netherlands?

[234] At which altitude approximately Holocene and Pleistocene are separated in the Netherlands?

[235] How many nature target types Bal, Beije et al. distinguished in 2001?

[236] Welke drie geologische eenheden onderscheidt men in Nederland?

[237] For which parts of the Netherlands respectively barley, wavy hair-grass, marram, greater burdock are typical?

[238] Which trees are general in the Netherlands?

[239] Which trees are specific for holocene and river grounds in the Netherlands?

[240] Which trees are specific for pleistocene and dunes in the Netherlands?

[241] Noem vier plantengeografische districten die in Nederland worden onderscheiden. Noem uit elk district twee kenmerkende bomen of planten.

[242] Where are Holoceneous willow and poplar forests (salicion) often found?

[243] Where are Holoceneous alder and ash forests with densely shrubs (alnion incanae) often found?

[244] Where are Holoceneous oak, ash (somtimes elm or maple, ulmion) forests often found?

[245] Where are holoceneous Hedges and thickets (sambuco-berberidion) often found?

[246] Where are pleistoceneous hedges and thickets (hawthorn, sloe, roses, blackberries, rubion) often found?

[247] Where are pleistoceneous oak, ash (sometimes maple or beech, carpinion) forests mostly found?

[248] Where are pleistocenious oak (seldom birch or beech) forests or coppice wood mostly found?

[249] Where are pleistoceneous oak (sometimes birch or beech, violeto-quercion) forests or coppice wood mostly found?

[250] Where are pleistoceneous oak (sometimes birch or beech, vaccinio-quercion) forests or coppice wood mostly found?

[251] Where are rarefied birch peat forests (betulon pubescentis) mostly found?

[252] Where are Birch (sometimes alder) peat forests (sphagno-alnion) with shrubs of alder buckthorn, willows, bog myrthle sometimes found?

[253] Where are Alder or willow (mostly coppice wood) peat forests (irido-alnion) mostly found?

[254] Waardoor draagt hetzelfde biotooptype niet altijd dezelfde levensgemeenschap? Noem twee klassen uit de klassificatie volgens Den Held (1989).

[255] Noem drie ecologische groepen die achteruitgaan.

[256] Waarom is de indeling naar biotooptypen van Runhaar, Groen, Van der Meijden en Stevers niet op oorzakelijke differentiatiefactoren zoals bodemtype en waterhuishouding gebaseerd?

[257] Wat zijn de voordelen van een zekere hiërarchie in de typologie?

[258] Wat betekenen in de Heukels' Flora bij een soort achtereenvolgens de volgende toevoegingen: W18sa, V11, H27, G23, P21, P28, H42, H47, G47kr, P41, P42, P43, P40mu, H61, H63, P63ro.

[259] Runhaar c.s. (1987) houden als criterium voor de indeling van soorten in biotooptypen en ecologische groepen aan. Welk criterium voor de indeling van soorten in biotooptypen houden Runhaar c.s. aan en waarom?

[260] Geef een voorbeeld van de causale samenhang tussen voedselarmoede en soortenrijkdom

[261] Op welke schaalniveaus en waarom is de herkenning van planten en dieren onderling en door elkaar van belang? Welke factoren spelen daarbij een rol? In welke fase van de voortplanting is deze herkenning belangrijk en welke fase volgt daarna? Welke betekenis heeft dit voor de planning van ecologische infrastruktuur?

[262] Welke overlevingsstrategieën onderscheidt Grime (1988)?

[263] Geef 5 verschillen tussen pionierstadium en climaxstadium volgens Odum (1971).

[264] Wat betekenen de strategieeën volgens Grime voor de eisen die de plant aan de bodem stelt? Naar welke categorie gaat de belangstelling van de natuurbescherming in het bijzonder uit?

[265] What is systems ecology?

[266] Give an indication in order of size of 6 claims on the surface of the Deltametropolis.

[267] How could you define an urban centre, an urban outskirt, a green urban area, a village and a rural living environment morphologically?

[268] Which 3 three robust connections counts Deltametropolis in the National Plan of NATURE POLICY [LNV, 2 000a #810]

[269] How does the National Plan of NATURE POLICY control the biological identity of areas?

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[270] Why is global biological diversity a basic criterion for ecological evaluation and how could you make it locally operational?

[271] The 4th National Plan of WATERMANAGEMENT POLICY [V&W, 1998c #829], and its last successor 'Anders omgaan met water'[V&W, 2 000b #832] mark a change from accent, just as the 4th National Plan of ENVIRONMENTAL POLICY [VROM, 2 001a #839] compared with its predecessors. Which change of accent is that?

[272] Which future problems in watermanagement and proposed solutions have a great impact on landuse in the Netherlands? Which solutions are proposed in the 4th National Plan of WATERMANAGEMENT POLICY [V&W, 1998c #829], and its last successor 'Anders omgaan met water'[V&W, 2 000b #832]?

[273] Which kind of ecology is human ecology?

[274] When lived homo habilis and which change of habitat accompanied its appearance?

[275] How old is the genus 'homo' and which capacity determines that distinction from other species?

[276] Noem 3 menselijke eigenschappen die wel worden toegeschreven aan het leven in een boom-milieu voorafgaand aan Homo Habilis.

[277] Schets enkele ergonomisch en architektonisch relevante kenmerken van het bosmilieu.

[278] In which biomen the highest human population densities are found? In which biomen the majority of people live?

[279] In which biomens most types of ancient economic household management are found?

[280] Welke relatie bestaat tussen huishouding en dichtheid?

[281] In what nominal radius 100 efficient ancient hunters and farmers could survive respectively?

[282] Which consequences the transition from gathering and hunting to agriculture have had?

[283] What is the neolithic revolution?

[284] How could the slowing down of world population growth around the beginning of the Christian era be explained?

[285] Around the beginning of the Christian era European population slowed down. By which mediaeval development a renewed growth was caused?

[286] To which ecological model war and illness, such as the pest epidemic around 1300 A.D., could be compared?

[287] By which economic factor in the past millennium decrease of population was often preceded?

[288] Where death rates vary per generation, there is also a variation in birth rates. How to contain these variations within one model?

[289] What is a logistic curve?

[290] Concerning limited availability of raw materials the growth of a technology or a population slow down after a period of exponential growth. However, a new technology can restore the growth of a population into exponential growth. How is the overall curve called?

[291] Which shapes the curve of a mathematical chaos function could produce?

[292] Wich population maxima for the Netherlands have been predicted by the CBS between 2002 and 2006?

[293] In which societies cases of birth control by infanticide, abortion and restricting coitus are confirmed?

[294] By which development the biggest mass migration ever was caused?

[295] Name some societal consequences of the industrial revolution.

[296] Which relation is found between increasing population density and differentiation of functions?

[297] Name some physical consequences of living in high densities.

[298] In which dimensions intensity of use can be measured?

[299] Which planning methods are available to avoid displacement and waiting?

[300] Why is intensity of use important for spatial planning?

[301] Why plays intensity of use seldom a role in spatial planning?

[302] Which urban space was the most intensily used in 1983?

[303] How much time urban inhabitants are since long prepared to accept for travelling twice a day between their homes and their work?

[304] Which remarkable developments in the Dutch landscapes could be mentioned in the periods of
1000 - 1100
1675 - 1800
1850 - 1960
1960 – 2000 A.D.

[305] Which ecologically relevant human activities can be distinguished on the lowest level of scale and what are its ecological effects?

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[306] How agriculture in the Netherlands until 1900 A.D. has increased the number of species?

[307] Give a schematic overview of the ecological influence of traditional and modern agriculture.

[308] How many m2 agricultural, natural and urban space the Netherlands counts per inhabitant?

[309] Which proportion of the urban area (industry and recreational areas excluded) is residential in the Netherlands?

[310] What is 'residential area' according to the CBS?

[311] How does the residential area vary in different parts of the Netherlands?

[312] Why the use of Planological Index Numbers for the amount of space needed for facilities should be put into perspective?

[313] By which factor you can derive the number of dwellings from population density?

[314] How did the average number of occupants per household in the Netherlands develop after the Second World War?

[315] Geef de namen van relatief bebouwde en onbebouwde gebieden in een semi-logaritmische morfologische reeks tussen 30km en 10m.

[316] Geef de namen van ontsluitingswegen in een semi-logaritmisch-morfologische reeks tussen 30m en 10km.

[317] Geef de namen van waterlopen in een semi-logaritmische reeks tussen 30m en 100km.

[318] Hoe kun je in een gestyleerd regionaal plan de planlaag onderscheiden van de reeds bestaande gebieden? Geef een voorbeeld van functionele inkleuring van legenda-eenheden voor bebouwd en onbebouwd gebied in een gestyleerd regionaal plan.

[319] How could the current definition of environment as ‘physical surroundings of society’ be changed to be part of a family of technically useful definitions?

[320] How could accomodation and adaptation be opposed?

[321] In which mode operate design, empirical research, policy and art respecitively?

[322] Which kinds of sources, emissions, transmissions and suffering objects can be distinguished?

[323] Which kinds of environmental standards can be distinguished?

[324] How could emissions of an area be estimated?

[325] Which compounds contains the largest amount of combustion and which process emissions?

[326] Give 3 examples of hydrocarbons and their impacts.

[327] In which measures standards for complex mixtures are given?

[328] Which kind of emission is most predictable, distance-sensitive and controllable within the framework of spatial planning?

[329] What contains transmission?

[330] What is ‘troposphere’?

[331] Warm air rises until the surroundings become warmer, but, in retaining its own heat content, rising air also cools off due to expansion. How much ℃ per 100 m it cools off?

[332] In which weather circumstances air pollution accumulates?

[333] What is an inversion? When does it occur and why? How does an inversion dissolve? In which circumstances it remains?

[334] Why is the underside clouds mainly flat?

[335] Why do the temperate climates often have turbulent wheathers?

[336] Which air streams meet in temperate climates?

[337] Which turning direction do whirling air movements have in the Northern hemisphere and why?

[338] How changes the wind direction in coastal areas after a sunny day and why?

[339] Welke beperking geldt voor de het voorspellen van verspreiding van luchtvervuiling in stedelijk gebied?

[340] Welke drie soorten verspreidingsmodellen bestaan er?

[341] Met welke 3 maten kan concentratie van luchtverontreiniging gemeten worden?

[342] Welke ontwikkeling heeft de transmissieberekening in water te zien gegeven vanaf 1960?

[343] Waarom gebruikt men bij de berekening van grondwaterstromen niet altijd driedimensionale modellen?

[344] Wanneer kan men ook met tweedimensionale modellen volstaan?

[345] Noem 5 bronnen voor een snelle orientatie omtrent de eventuele risico's van verbreiding van bodemverontreiniging. Waar moet men op letten?

[346] Wat betekent pH, Eh, k en CEC? Wat is in dit verband het verschil tussen zand en veen?

[347] Geef 3 benaderingen die ooit zijn toegepast om de prijs van een mensenleven te ramen. Is een van deze benaderingen naar Uw inzicht redelijk? Zo niet, hoeveel geld moet er dan naar Uw inzicht aan het herstel van het milieu worden uitgegeven wanneer U daarmee een mensenleven zou kunnen redden? Wie moet dat bedrag betalen wanneer de schuldigen niet kunnen worden aangewezen?

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[348] Which are the three approaches ever used to estimate the price of a human life? Is one of these approaches reasonable in your view? If not, how much money must then, in your view, be spent on the environment, to save one human life? If the guilty parties cannot be identified, who should then pay that amount?

[349] What is a dose-response relation? What does LD50 mean?

[350] Hoe zou men een dosis- effectrelatie voor materialen kunnen vaststellen?

[351] Hoe kent men de dosis- effectrelatie van een groot aantal stoffen bij mensen?

[352] Welke organen spelen een rol bij de opname en verwerking van vergiftigingen?

[353] Hoeveel % sterfte kan men ongeveer voorkomen door een reduktie in de luchtverontreiniging van ca. 10%?

[354] Why is the pollution prevention insufficient for retaining plant and animal species?

[355] Which individual chance of dying per annum caused by the totality of environmental risks to human beings is accepted by Dutch government; what is the maximal acceptable level for each single activity or substance?

[356] What is an environmental target value (streefwaarde) in the Netherlands?

[357] What is an environmental threshold value (drempelwaarde) in the Netherlands?

[358] What is an environmental limiting value (grenswaarde) in the Netherlands?

[359] What is an environmental guide value (richtwaarde) in the Netherlands?

[360] What is an environmental quality target (milieukwaliteitsdoelstelling) in the Netherlands?

[361] What is an environmental quality requirement (milieukwaliteitseis) in the Netherlands?

[362] How could an economic optimum of environmental quality be determinded?

[363] How does the strictness of environmental standards mainly vary with he area they apply?

[364] Wat betekent EPEL, MAC, TLV?

[365] Waarin schieten de bestaande milieudoelstellingen van het NMP tekort ten opzichte van ‘sustainable development’ bij verdubbeling van de bevolking?

[366] Welke direkte bijdragen aan de milieugebruiksruimte kunnen aan het bouwen worden toegewezen?

[367] Hoe kan men de eigen milieutaak van het bouwen in termen van milieugebruiksruimte formuleren?

[368] In hoeverre kan men de in het NMP+ opgesomde bijdragen van de doelgroep 'Bouw' ook aan andere doelgroepen toerekenen?

[369] Which environmental problems the NMP1 distinguished as global?

[370] Which environmental problems the NMP1 distinguished as continental?

[371] Which environmental problems the NMP1 distinguished as fluvial?

[372] Which environmental problems the NMP1 distinguished as regional?

[373] Which environmental problems the NMP1 distinguished as local?

[374] Which policy outlines the NMP1 used as an agenda to the discussions with target groups?

[375] Hoe zou men verschillende milieuthema's en -doelstellingen onderling kunnen wegen?

[376] Noem 5 'ver-thema's' uit het milieubeleid sinds het NMP.

[377] Welk thema is stilzwijgend verondersteld bij elk milieuthema sinds het NMP?

[378] What is a groundwater table and why is it important?

[379] What information must be incorporated into the “follow-up investigation” report?

[380] What are the causes of soil pollution in industrial sites?

[381] What is a reference value?

[382] What is a target value?

[383] What is an intervention value?

[384] Name at least 5 operational activities that can cause soil pollution.

[385] Which remediation methods have been identified?

[386] Name 3 purification techniques.

[387] When should contaminated soil tipping be considered?

[388] When is contaminated soil storage preferred?

[389] List 3 disadvantages of in-situ soil purification.

[390] List 3 advantages of in-situ soil purification.

[391] When is contamination isolated?

[392] What is the focus of soil remediation?

[393] What is structure and why can it be developed separately as a design category between form and function, and how can one recognise structure in the drawing?

[394] Give an example of polarity between ‘open’ and ‘closed’ on five different levels of scale. Are they positioned perpendicular to each other or equidistant? Are they motoric or sensoric?

[395] What is ‘function’ in the technical–ecological sense?

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[396] Give the main division of urban functions according to the concepts of George, Parsons and Jakubowski.

[397] On which variable should one be able to classify intentions?

[398] What alternative is there for freedom of choice by introducing flexibility into the design?

[399] What is the fundamental problem that comes to the fore when we want to make a ‘programme of requirements’ for nature and what is De Jong’s suggested way out?

[400] Which suppositions hides a legend using the CIAM typology of living, working, recreating and travelling for a district sketch (R=1km, r=100m)?

[401] Give a meaning to each cell in Fig. 1105 in words or in small illustrations. Make – whether on location or not – a design sketch in the five colours in which all transitions occur, each in at least four directions of the compass. Make a detailed design sketch of at least three transitions. Then characterise each area by means of its boundaries.

Page 380: [1] Comment [T.M. de15] **Jong**

Pagina: 468
Bovenste deel van hellingen in Zuid-Limburg, grensstrook tussen Ulmoin en Vaccinio-Quercion in geaccidenteerde zandgebieden, hoogste gedeelte van de oude strandwallen, op dunnen zankdgebieden, hoogste gedeelte van de oude strandwallen, op dunnen lagen dekzand op keileem, verlaten en beboste oude bouwlanden op zandgrond enz.

Page 380: [2] Comment [T.M. de16] **Jong**

Pagina: 468
Vlakke plateaus in Zuid Limburg, het grootste gedeelte van de pleistocne znadgebieden in Oost en Zuid Nederland, plaatselijk in het jonge en oude duinlandschap.

Page 380: [3] Comment [T.M. de18] **Jong**

Pagina: 469
Laagste gedeelten met slecht waterafvoer in de pleistocene zandgebieden, voedselrijkere delen van de veengebieden in Noord en Zuid Holland, Noord-West Overijssel en Friesland.