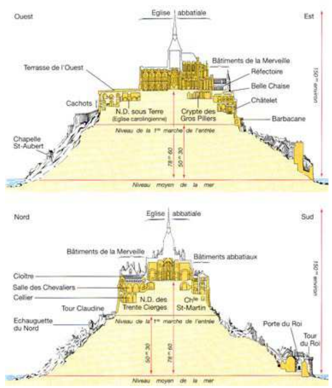
4 Earth and site preparation

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



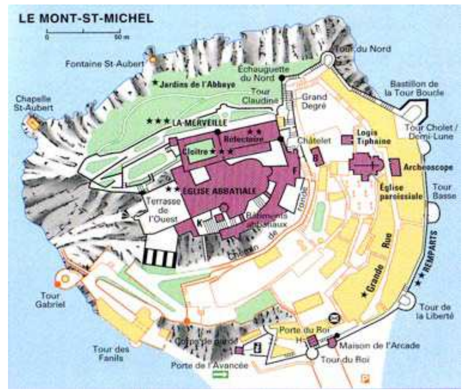


Fig. 620 Urban developement and geology; the Mont Saint - Michel in France. A small settlement around a monastry built on a rock in front of the coast. The settlement and the rock form a magnificent ensemble; the church and steeple enhance architecturally the verticality of the rock amidst the sea water. 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.

[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].

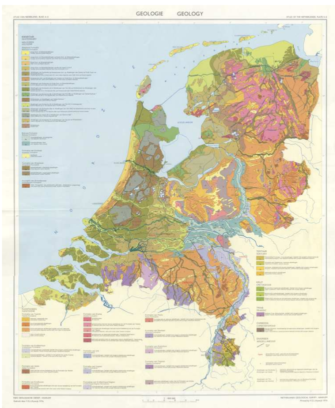


Fig. 621 The geological map of the Netherlands The main geological developments that have formed the country are visible; the river system with the delta, the coastal area with the dunes, the peat in the west and north east and the marine sediments in the north and south west

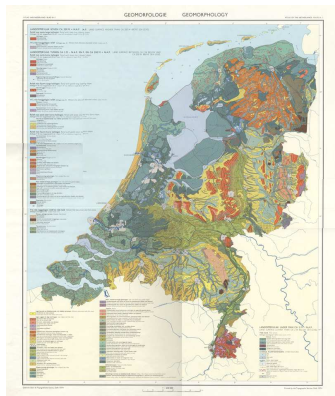


Fig. 622 The geomorphological map of the Netherlands Here the glacial influences are clearly visible in the centre of the country. Glacial ridges formed by the ice.

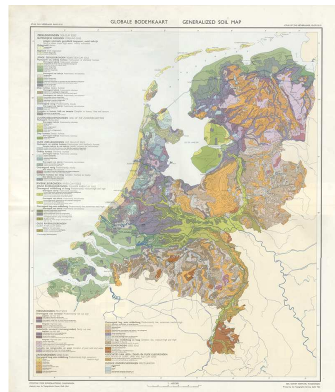


Fig. 623 The soil map of the Netherlands In the west you can see the peat and marine clays. In the east the sandy soils and in also here the river landscape can be clearly distinguished.

4.2.1 Geology

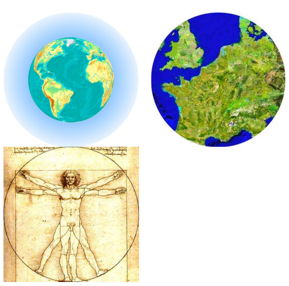


Fig. 624 R: 10 000km>1000km >1m

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.

[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.

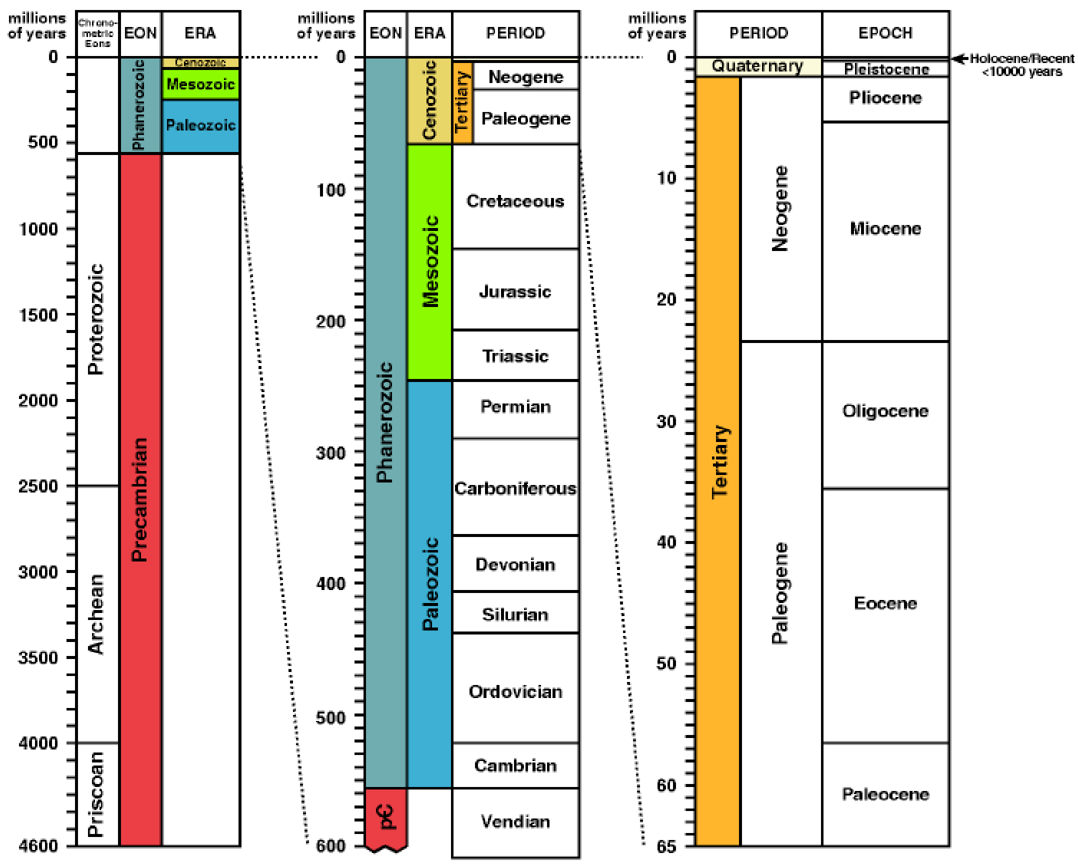


Fig. 625 Geological time intervals[a]

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.

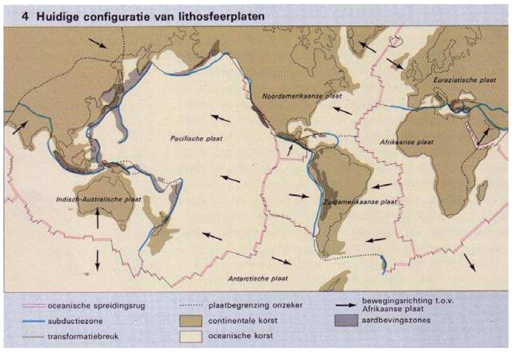


Fig. 626 Plate tectonics[a]

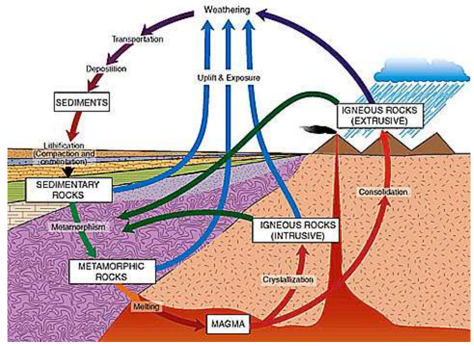


Fig. 627 Formation of rocks[b]

The atmospheric cycle

On the stage set by motion of the continents, the atmospheric cycle operates.

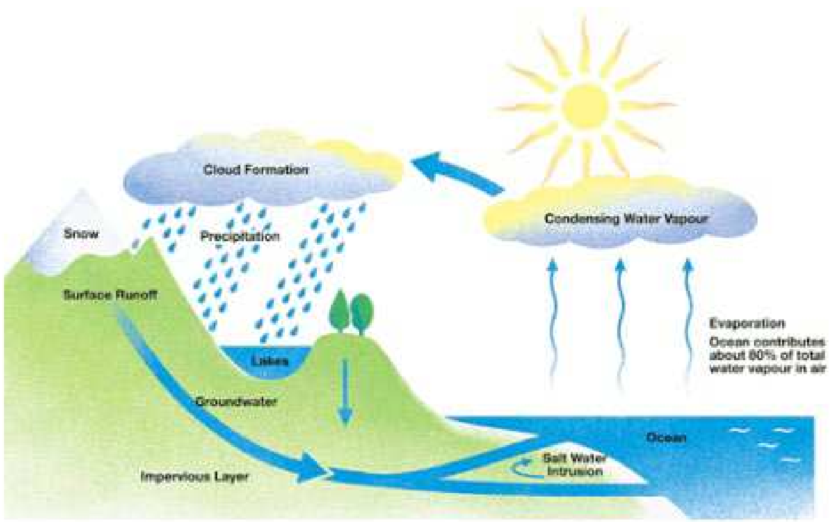


Fig. 628 The atmospheric cycle[c]

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.

a
b
c

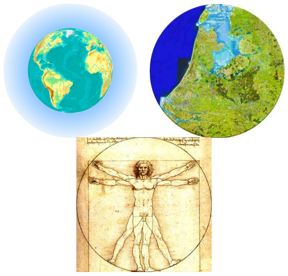


Fig. 629 *R: 10 000km>**100km** >1m*

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.

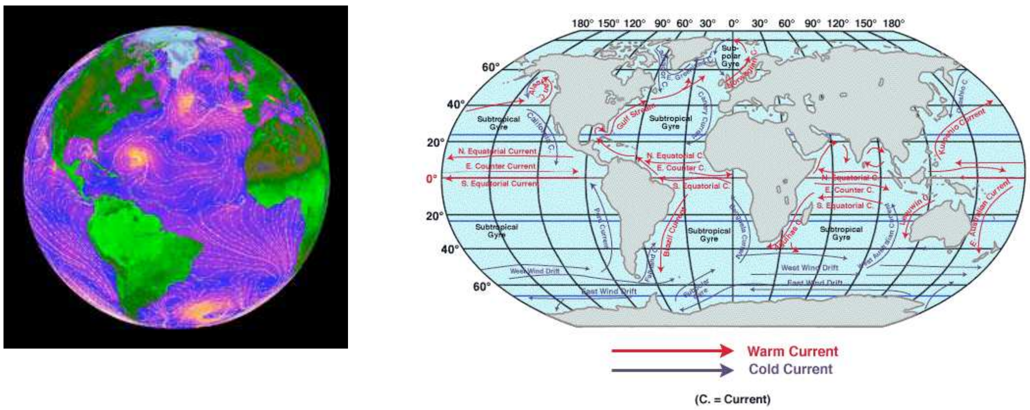


Fig. 630 Currents of the oceans[a]

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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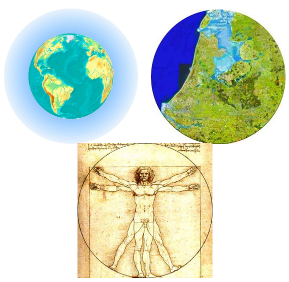
a

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]

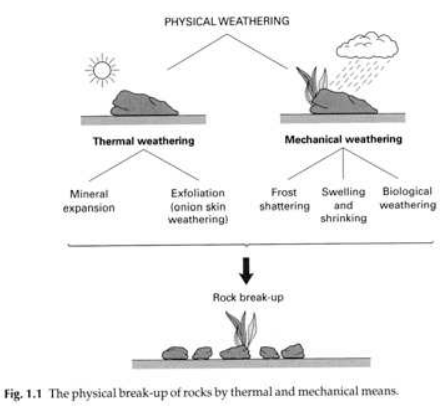
- Landform; an element of the landscape that can be observed in its entirety and has consistence of form
- Landscape; earth surfaces composed of an assemblage of subjectively defined, lesser surfaces including its vegetation and artifacts.
- Geomorphic system; a set of related landforms and processes, 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.

[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]



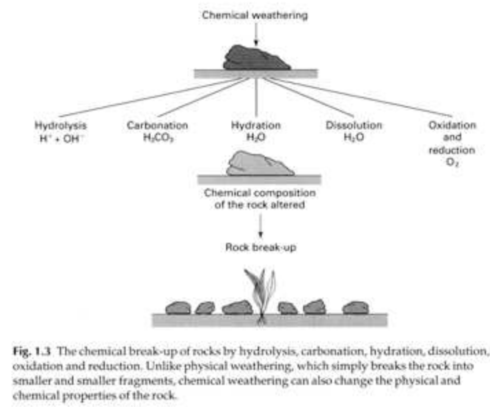


Fig. 632 Physical weathering

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.

a

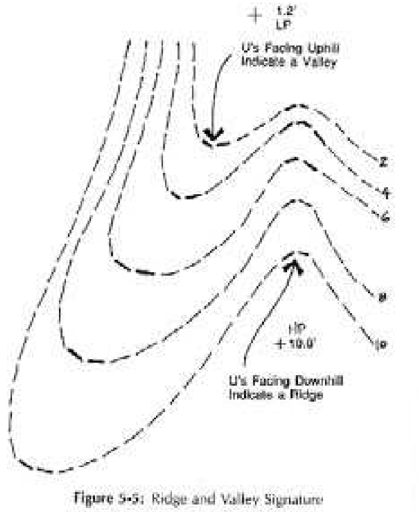


Fig. 634 Ridge and Vally signature

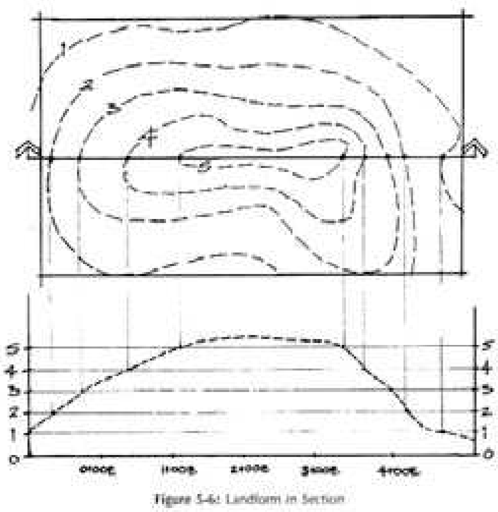


Fig. 635 Land form in section

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]

[a] Motloch (2001)

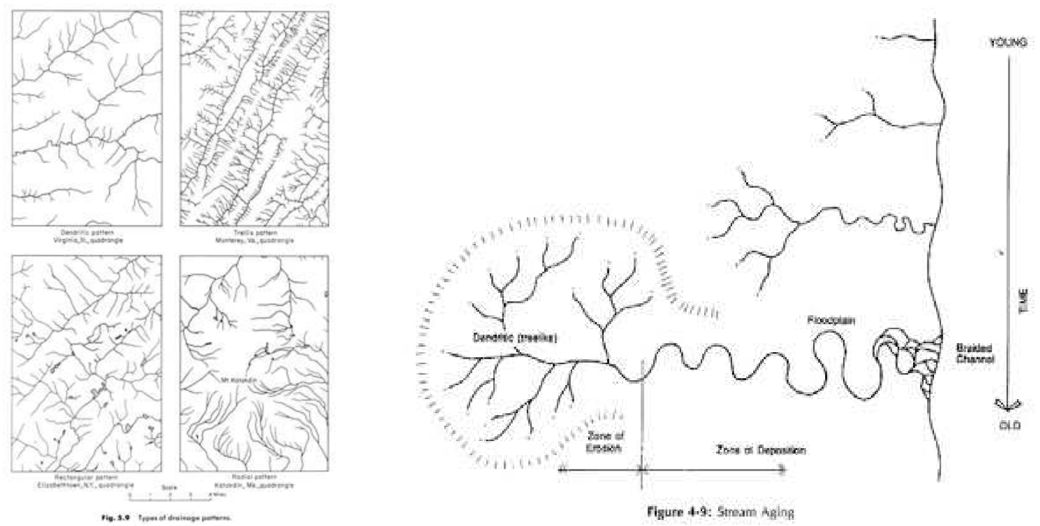


Fig. 636 River forms[a]

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]

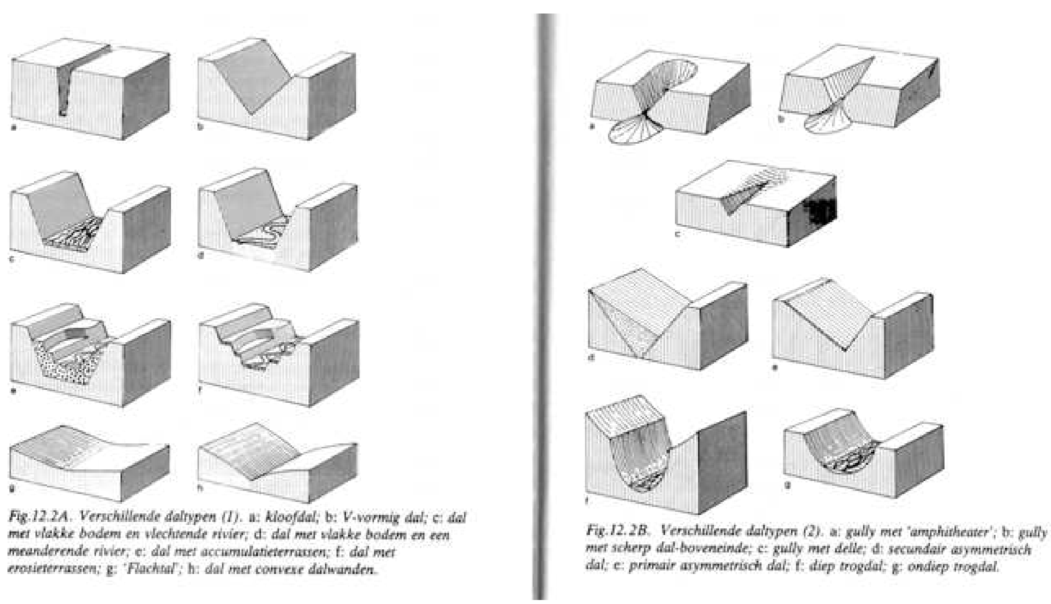


Fig. 637 Valley forms[b]

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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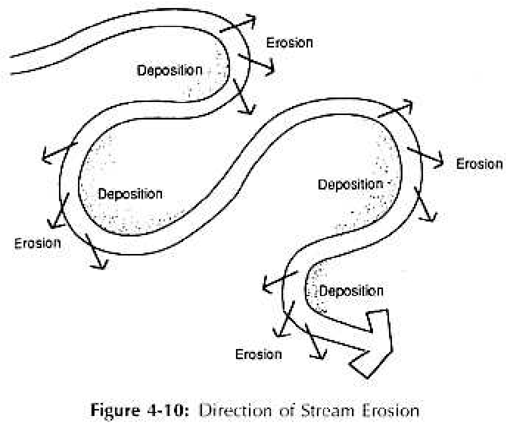
a

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*).



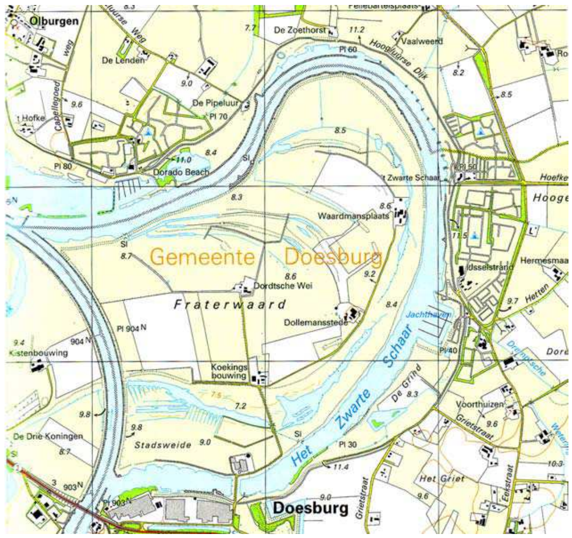


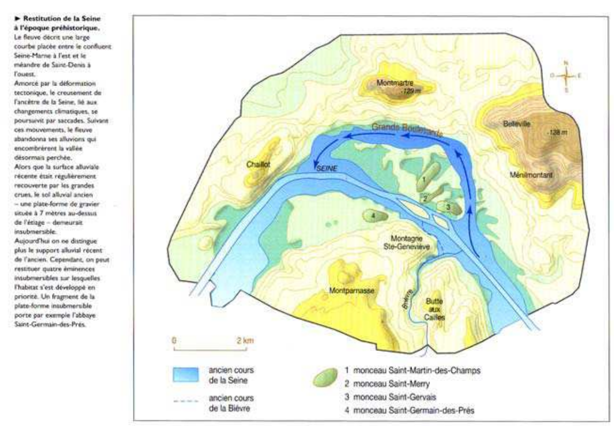
Fig. 638 Direction of stream erosion

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*).



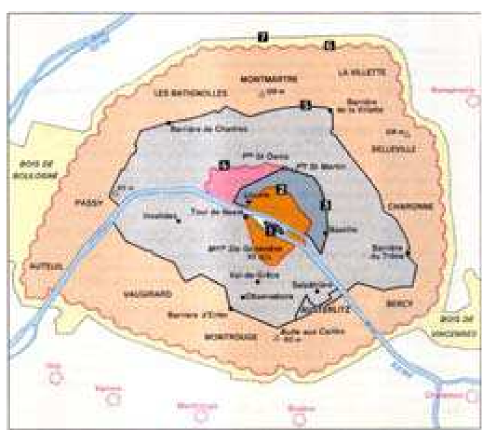


Fig. 640 The former course of the river Seine

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

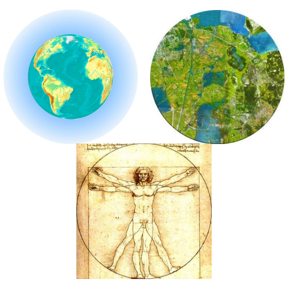


Fig. 642 *R: 10 000km>**10km** >1m*

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.

[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

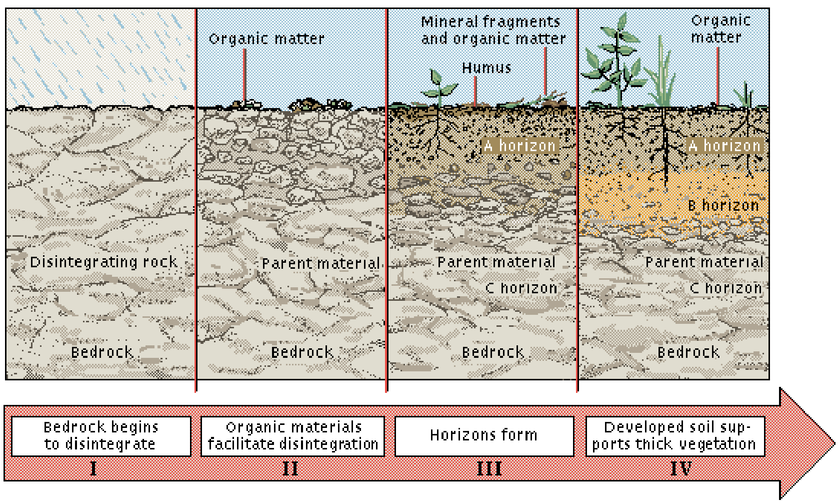


Fig. 643 R: 10 000km>*1m*

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.

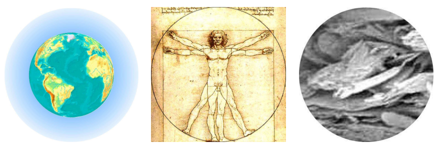


Fig. 645 R: 10 000km>1m>0.001mm=1µ (clay)[a]

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.

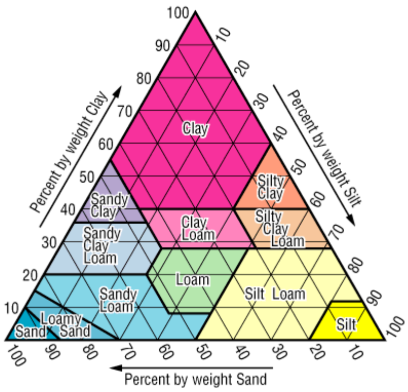
The surface of the particles per kg of dry matter is 10 m^2 for sand, 100 m^2 for silt and 1000 m^2 for clay. The size of the surface is relevant for the absorbing capacity of soil particles of nutrients on the one hand, and pollution on the other hand.

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]

[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

[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 …).

[a] Bogomolov (1958)

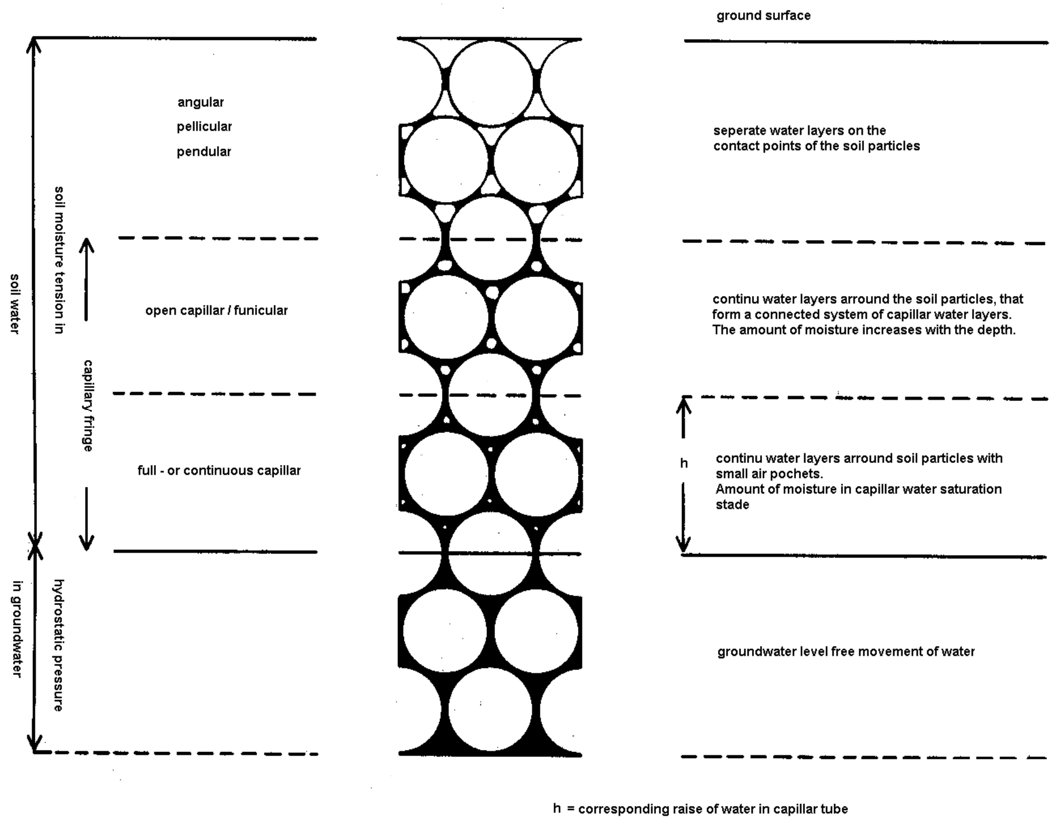


Fig. 648 Capillary action of the soil[a]

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 g roundwater 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.

[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.

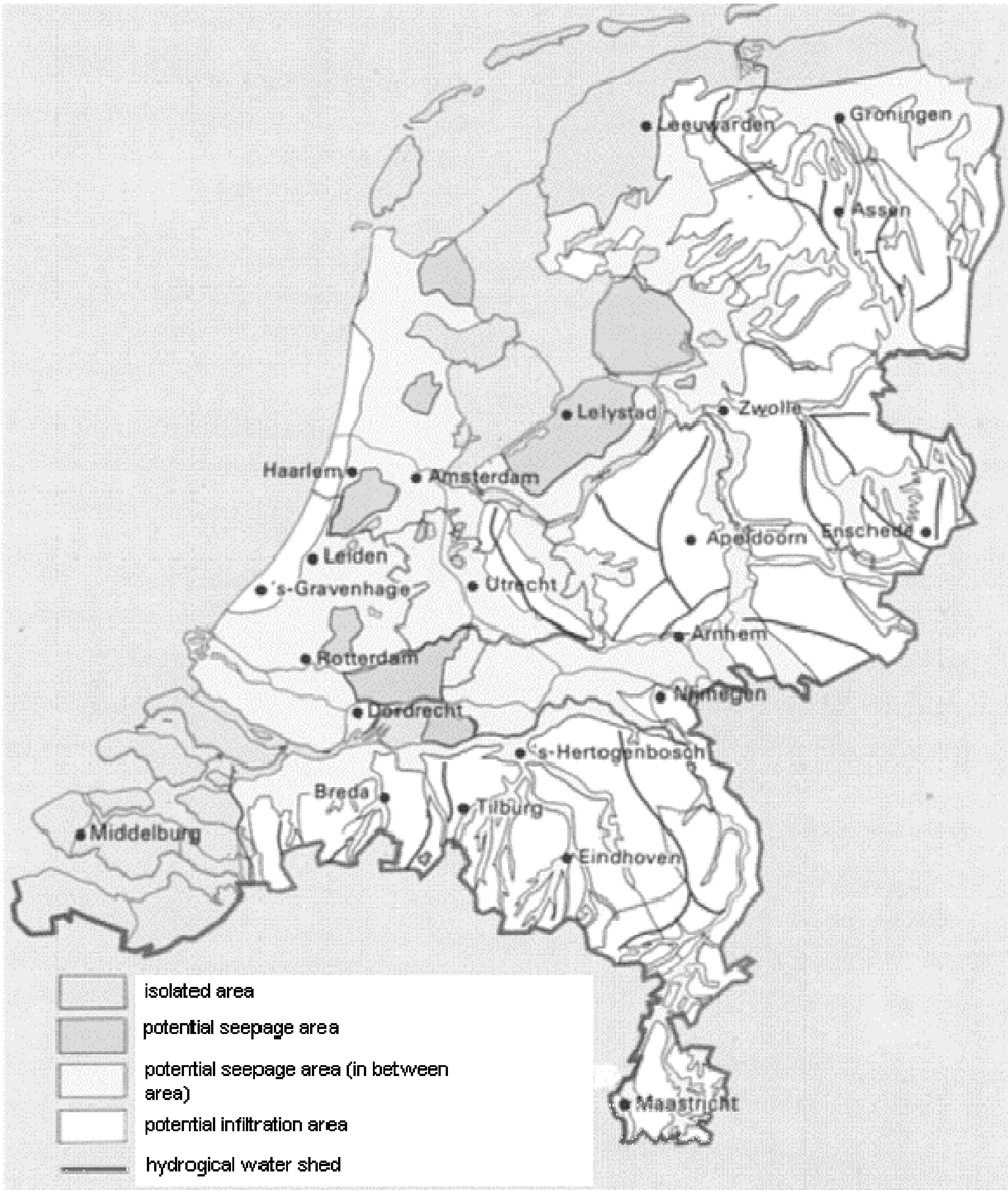


Fig. 650 Potential seepage areas[a]

[a] Sticht.Wetensch.Atlas_v.Nederland, v.d. Berg, Steur and Brus (1987)

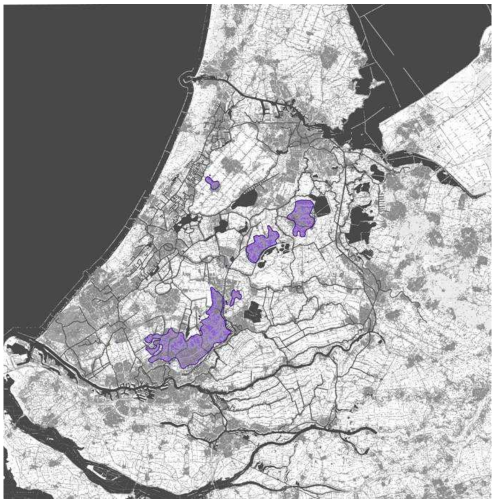


Fig. 651 Deep polders in the Randstad <5m-NAP

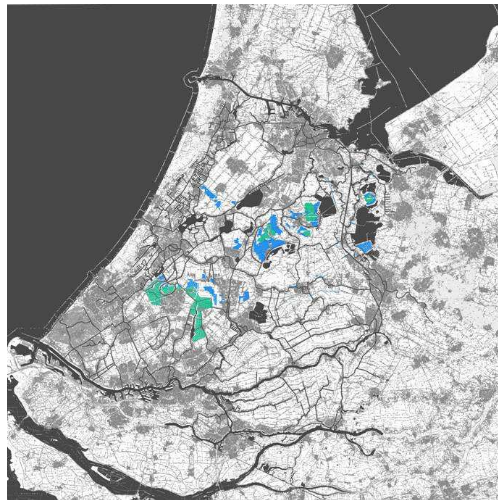


Fig. 652 Seepage areas in The Randstad

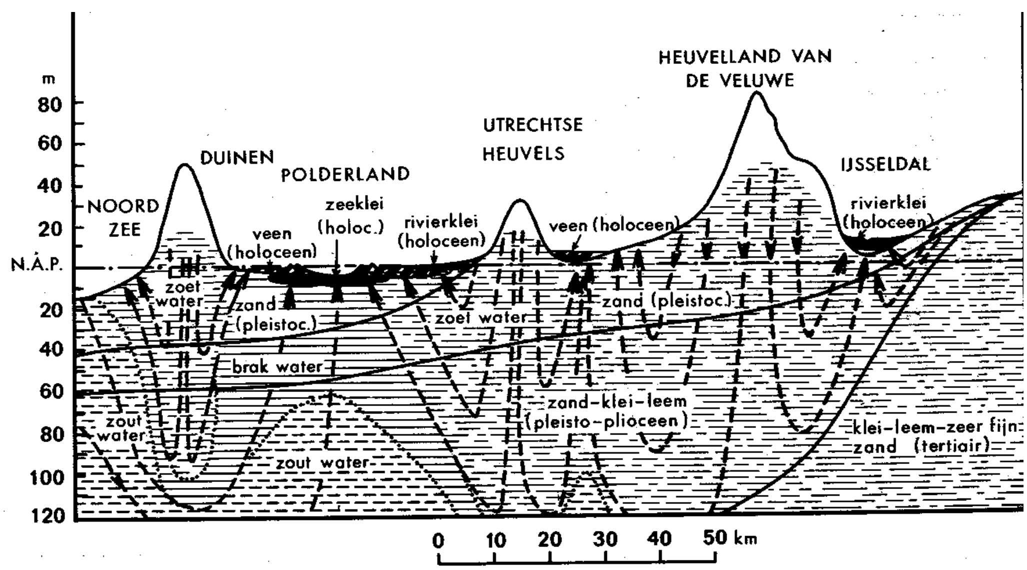


Fig. 653 Schematic hydrogeological cross-section of the Netherlands[a]

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 …

[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]

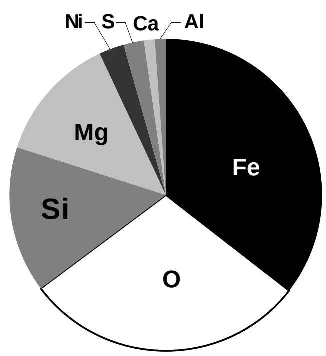


Fig. 654 Contribution of elements composing the Earth by mass (the darker the bigger the atomic mass)

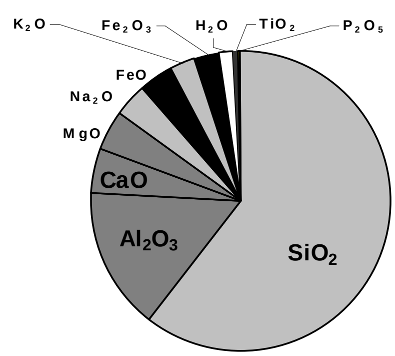


Fig. 655 Contribution of oxides composing the Earth's crust by mass (the darker the bigger the density on the Earth's surface)[a]

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

[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]

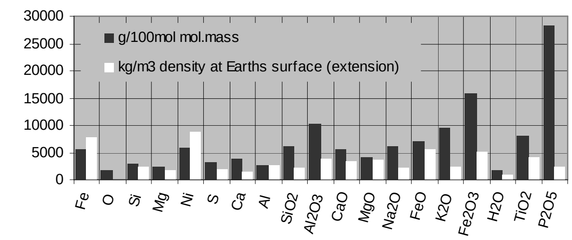


Fig. 656 Molecular mass and density (extension) at the Earth's surface of the most abundant elements and oxides in the Earth's crust

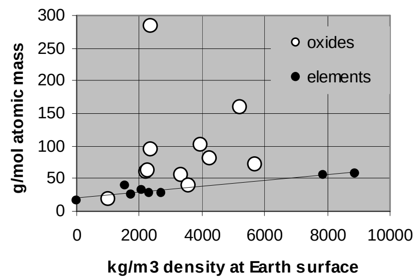


Fig. 657 Lower density at the Earth's surface of most abundant oxides compared to the main elements

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]

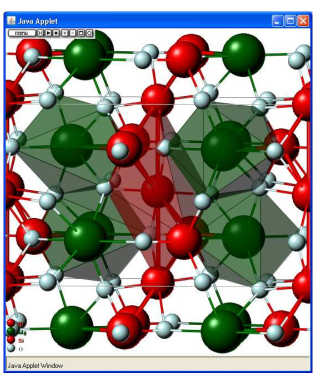


Fig. 658 The crystal grid of olivine

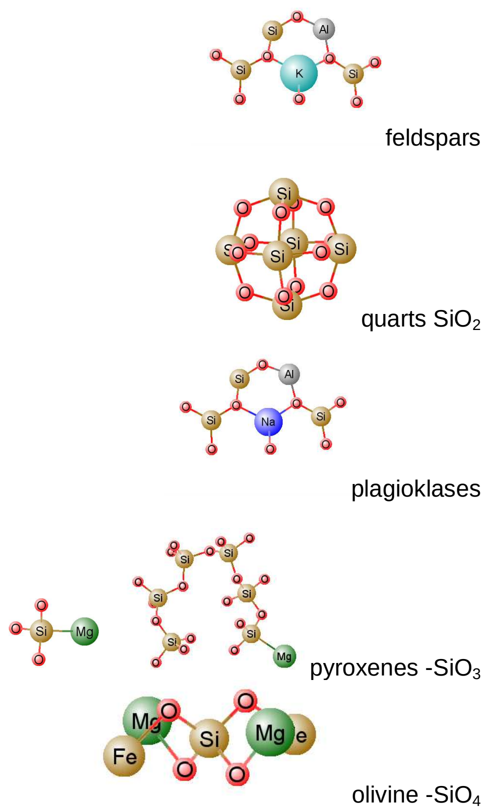
Fig. 659…and its green appearance as a crystal[c]

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!**

[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]



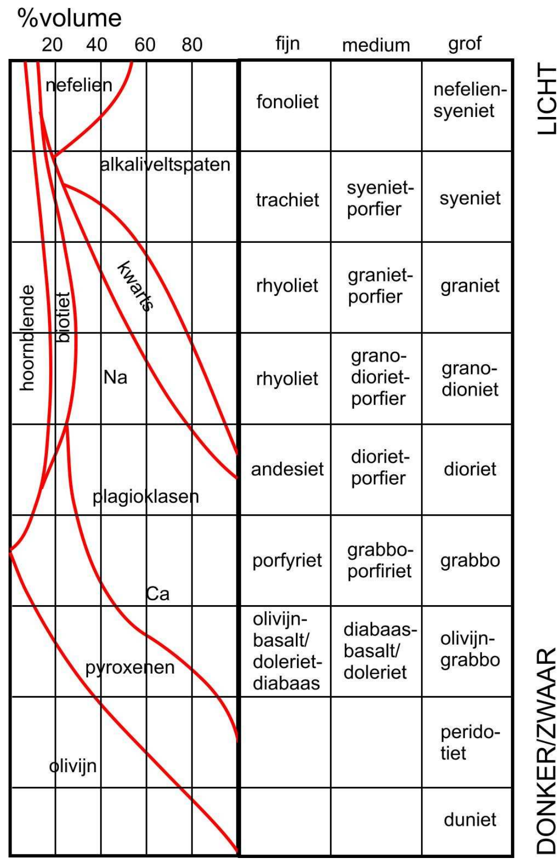


Fig. 660 Ideal typical parts of grids. *Fig. 661 Groups of minerals forming types of rocks*[c]

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]

[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.

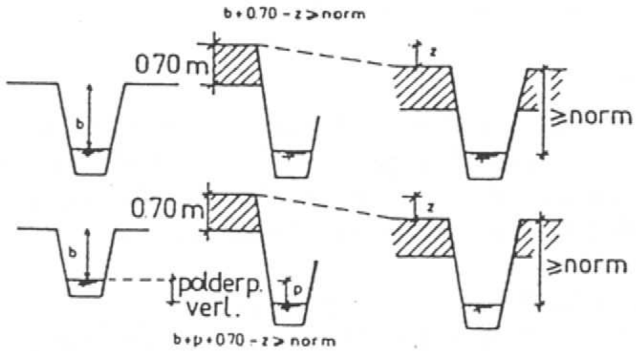


Fig. 662 Raising with sand and lowering polder level[a]

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.

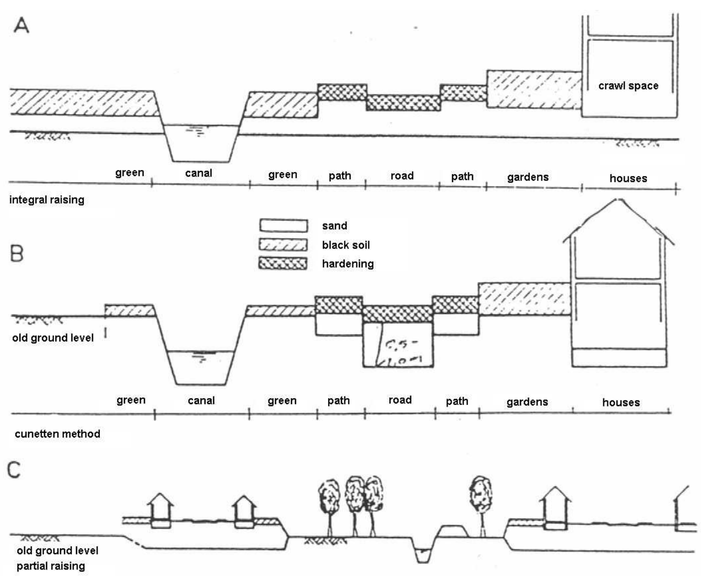


Fig. 663 Raising with sand[b]

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.

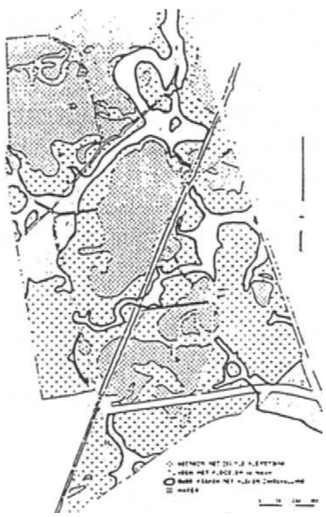


Fig. 664 Bijhouwer, soil map of Kethel and surroundings

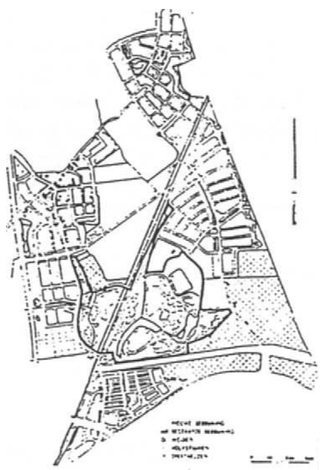


Fig. 665 Bijhouwer, development plan of Kethel and surroundings

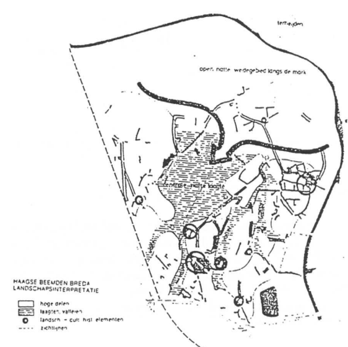


Fig. 666 Maas and Tummers Haagse Beemden

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]

[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.

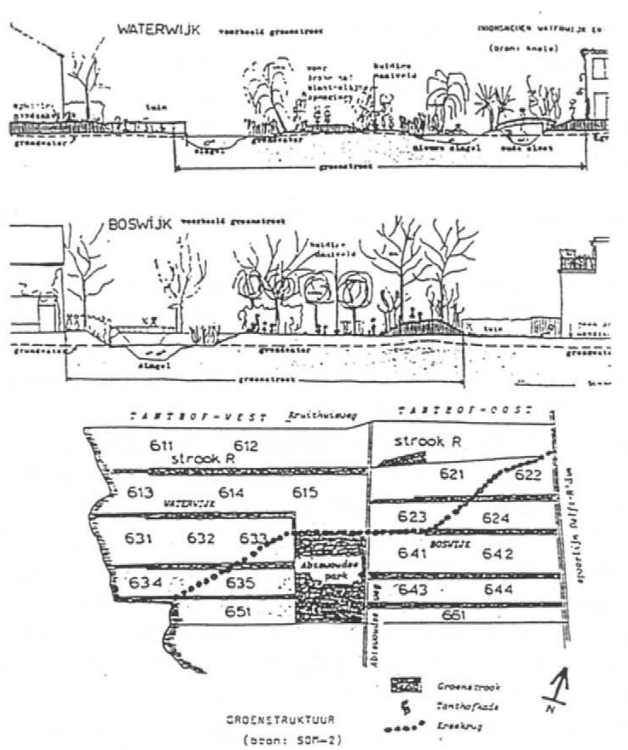


Fig. 667 Tanthof, Delft[a]

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

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.

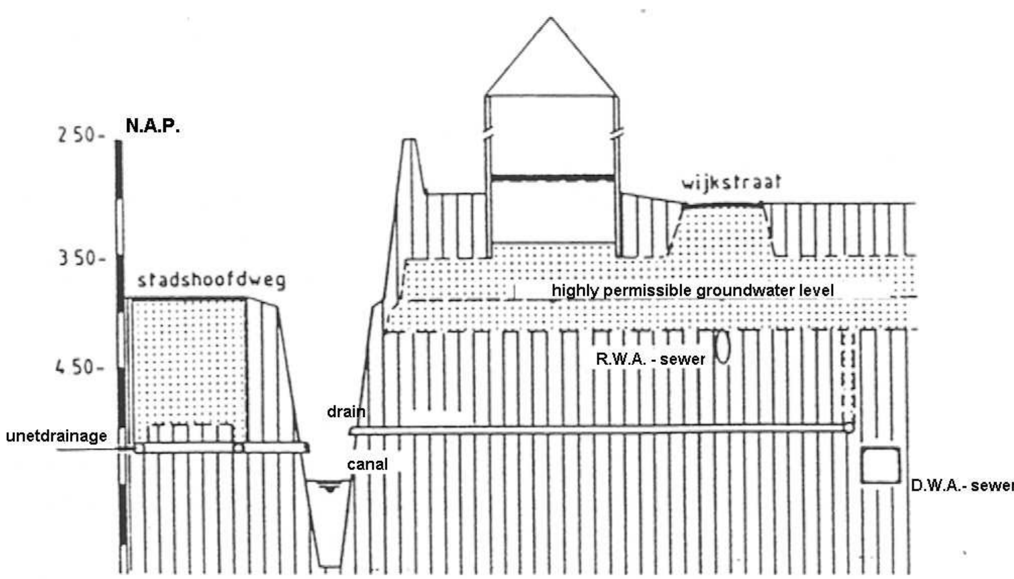


Fig. 668 Water control in urban areas

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.

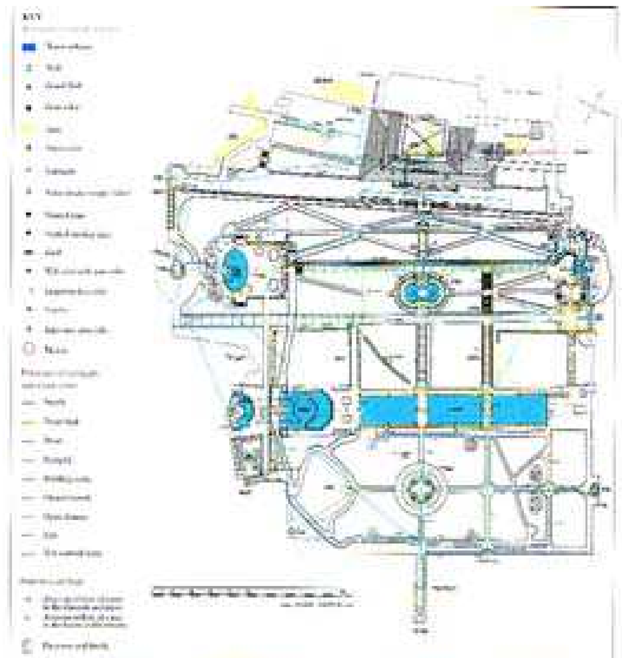


Fig. 669 Villa d'Este in Tivoli[a]

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
.

[a] *Barsi, 2004*

Parc de Sceaux in Paris

Sceaux is a relatively small ensemble compared to the other plans of Le Nôtre.

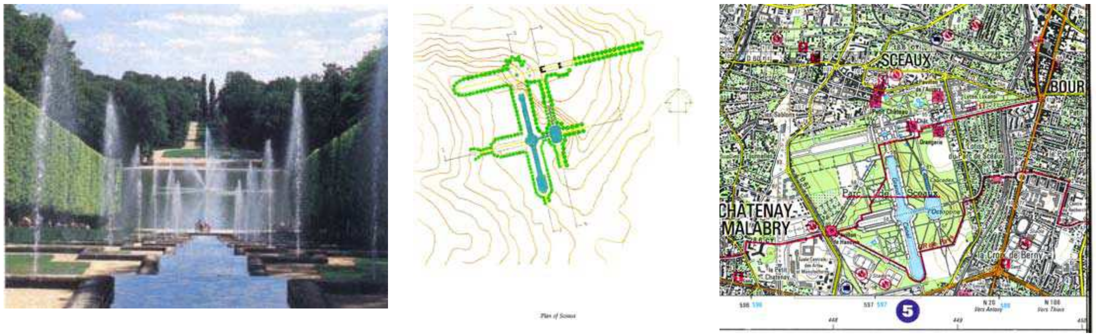


Fig. 670 Parc de Sceaux in Paris[a]

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.

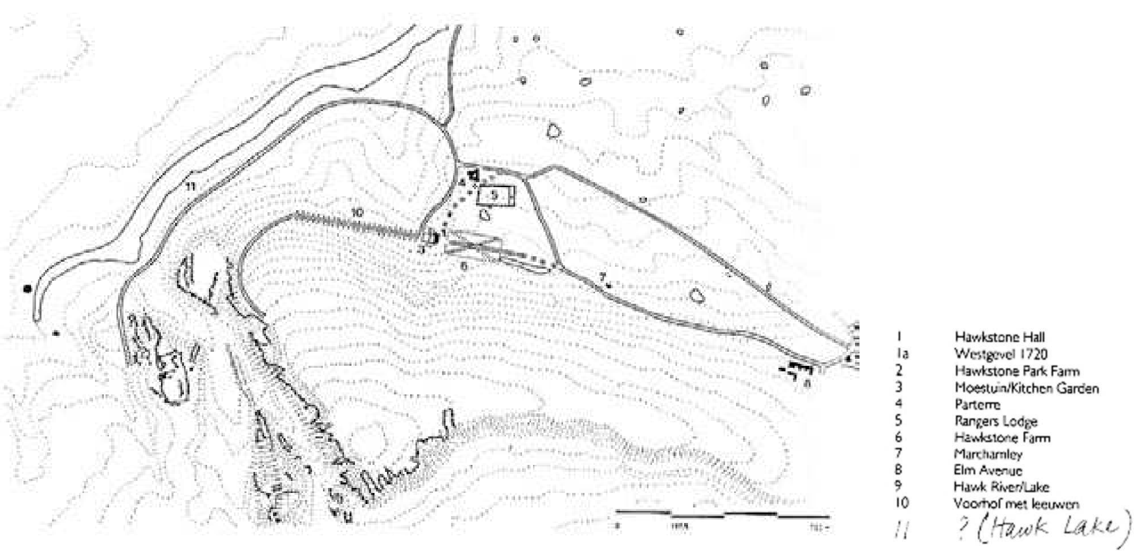


Fig. 671 Hawkstone, Shropshire, UK[b]

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.

[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