4 Earth, soil pollution and site preparation

Contents

4.1 Introduction

4.1.1 Span of view

Our spatial knowledge spans across the edge of the universe (10^{25}) to the inside of an atom (10^{-16}). Representative patterns of each spatial scale are depicted per factor of ten in the film "The powers of ten" and the eponymously titled book Morrison, Philip, Phylis Morrison et al. (1982; Morrison, Philip, Phylis Morrison et al. (1985). From the level of magnification 10^{25} to 10^{9}, all we can see is a “speckled” pattern (stars), before the earth comes into view. From powers 10^{8} to 10^{-8}, extremely distinct forms with relatively little repetition become visible. From 10^{-9} to 10^{-16}, thousands of repetitive speckles, spheres, clouds, nebula and fields of force are clearly visible.

Earth supporting life

The smallest abiotic element is the hydrogen molecule (H_2), and the biggest is the universe. By way of comparison: the smallest elementary life form is the virus (10^{-7} meter) while the biggest, according to the Gaia hypothesis (Lovelock, J.E., 1995) is earth (10,000 km). The Gaia hypothesis falls outside the scope of this dissertation.

The primary conditions for creating life on earth are the presence of solid (abiotic) matter as well as water and energy. The earth's temperature is determined by the distance between the earth and the sun. This distance is sufficient to keep water liquid.

Sun, wind, water shaping earth

Liquid water offers life on earth a chemical magic potion, as well as an excellent transportation and regulation system. Water evaporates in excessively high temperatures, and releases heat of condensation in excessively cold temperatures. In laymen's terms: it begins to rain or snow. On a global scale, the sun creates winds in the atmosphere, ranging from the warm tropics to the cold poles: the so-called big circulation. Due to unequal heating of the atmosphere on land and the oceans and the earth's rotation, this circulation is rather more complex than it first appears. Differences in temperature between the poles and the equator also create oceanic heat transport from the equator to the poles: the warm Gulf Stream.

Apart from the conditions created by light, temperature and water, we can limit the scope of our research to the 15 decimals of earth.

4.1.2 References Introduction

Lovelock, J. and Segeren, B.v. (1979) *Gaia, een nieuwe visie op de Aarde* (Utrecht/Antwerpen) Kosmos (Leerstoelbibliotheek).

Lovelock, J.E. (1995) *Gaia a new look at life on earth* (Oxford) Oxford University Press ISBN 0.19.286030.5.

Morrison, P., Morrison, P. and Eames, D.s.v.C.a.R. (1985) *De machten van tien* (Maastricht/Brussel) Natuur en Techniek ISBN 90-70157-48-9 (Leerstoelbibliotheek).

Morrison, P., Morrison, P. and Eames, T.o.o.C.a.R. (1982) *The powers of ten* (New York) Scientific American Books, Inc. ISBN 0-7167-1409-4 (Leerstoelbibliotheek).

4.2 Kilometres: Geomorphologic landscapes

Landforms

G e o m o r p h o l o g y is concerned with investigating the cause and changes of all topographic forms. This chapter focuses on the processes responsible for creating different landforms, and the regional spread of these landforms in the Netherlands.
Geomorphologic processes imply all physical and chemical changes affecting the earth's surface.

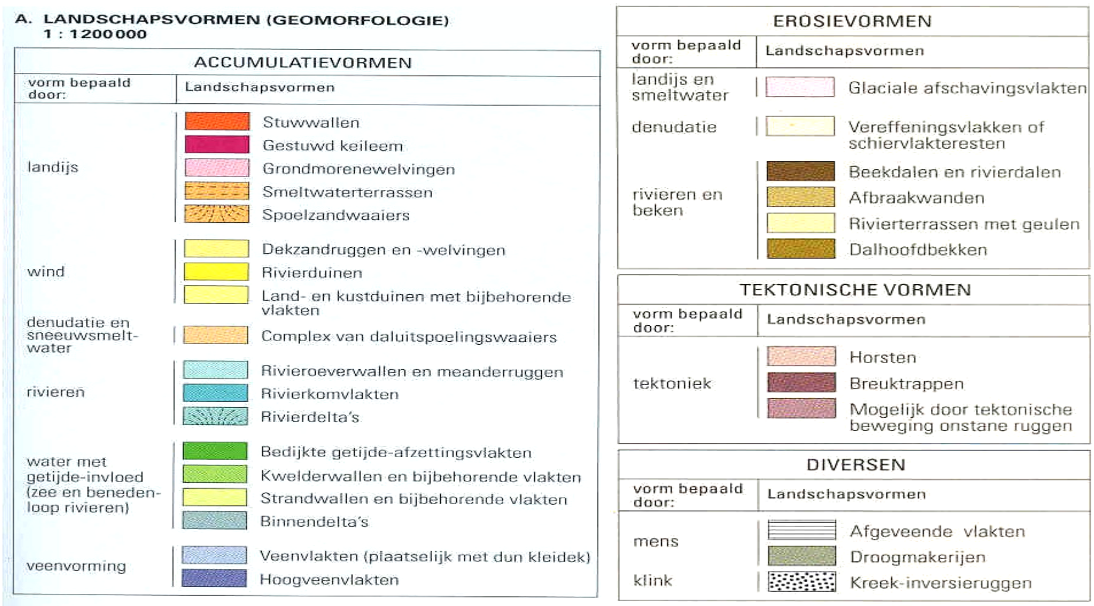
Geomorphologic processes

The main geomorphologic processes are:

- 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.

Epigenous processes

The Netherlands is primarily affected by epigenous processes like aggradation through deposition and degradation through levelling (‘accumulatie’ en ‘erosie’ in *Fig. 607*).



Sticht.Wetensch.Atlas_v.Nederland (1985, Sticht.Wetensch.Atlas_v.Nederland, v.d. Berg, Steur and Brus (1987)

Fig. 607 Legend to geomorphological landscapes of the Netherlands (Fig. 608)

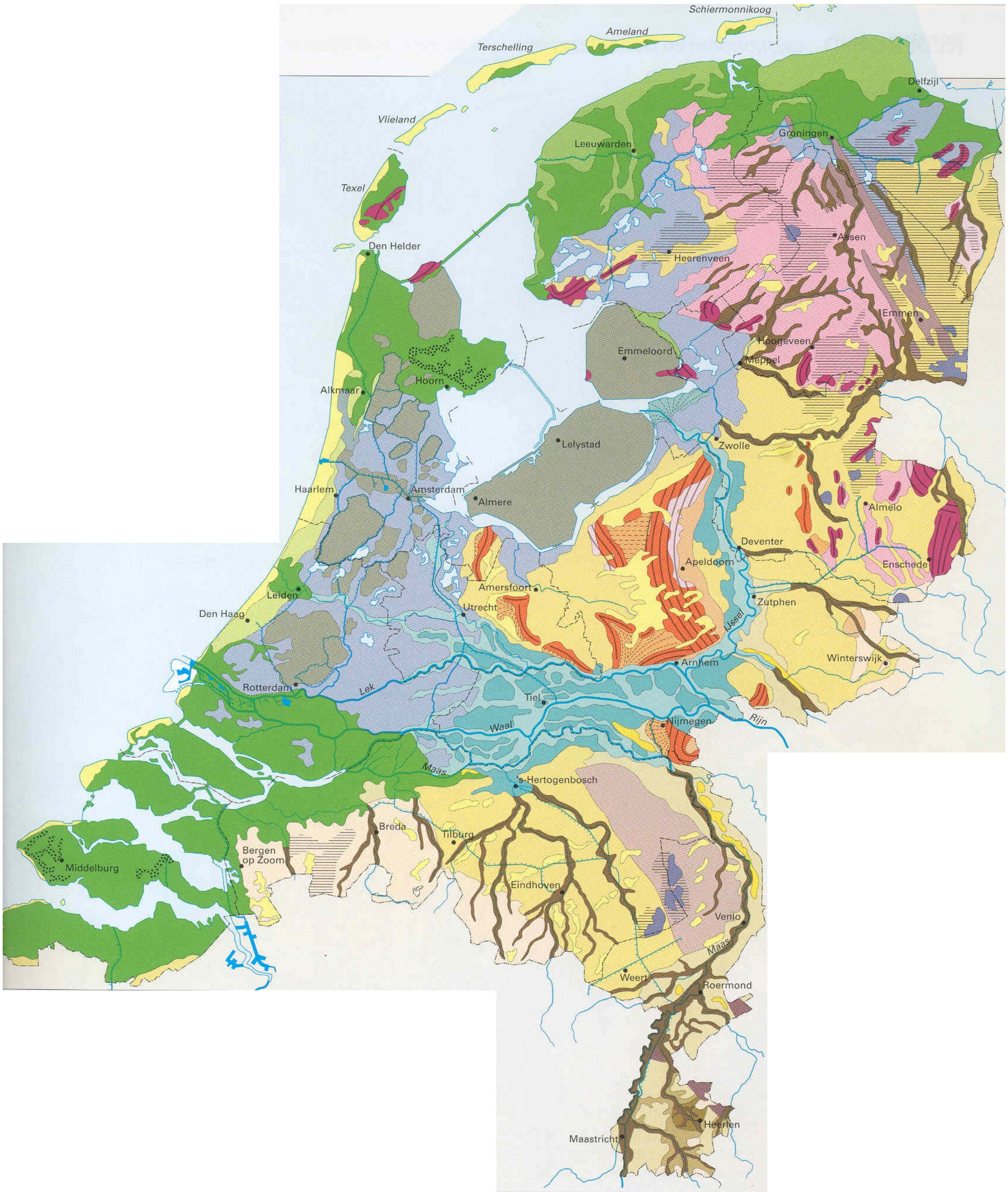


Fig. 608 Geomorphological landscapes of the Netherlands

Agents of geomorphologic processes

GEOMORPHOLOGIC PROCESSES are created by different agents. Aggradation through deposition and degradation through levelling both suppose vertical gravity, but water and wind bring horizontal differentiation (see *Fig. 609*).

PROCESS	AGENT
Mass wasting slope processes	Gravity
Degradation through levelling	1.flowing water 2.sea, waves, currents, tides 3.wind 4.ice, glaciers
Aggradation through deposition	1.flowing water 2.sea, waves, currents, tides 3.wind 4.ice, glacier

Fig. 609 Geomorphologic process and agent

A description and explanation of the following l a n d f o r m s , created by different agents (processes) and their regional spread (pattern) is included In this chapter:

- 4.2.1 Landforms created by water
- 4.2.2 Landforms created by rivers
- 4.2.3 Landforms created by ice
- 4.2.4 Landforms created by the wind
- 4.2.5 Landforms created by slope processes

This dissertation will focus solely on those landforms specific to the Netherlands. To enable a systematic approach and for the sake of completeness, context is provided in most instances.

4.2.1 Landforms created by water

To promote a better understanding of the landform patterns created by water, the relevant processes have been examined.
Water acts as an agent with all the corresponding movements such as waves, currents, tides and tidal currents.

General sea information.

Over two-thirds of the earth's surface is covered with water. In seas and oceans, s e d i m e n t a t i o n occurs more readily than e r o s i o n , compared to land, where erosion is more commonplace. The majority of the s e a f l o o r is covered with new sedimentary layers. This sediment consists primarily of lime, sand and clay. Over 90% of sediments found on land were originally formed in the sea, and this sedimentary rock was pushed onto land by mountain building and tectonics. Mountain chains such as the Dolomites in Italy, the Jura in Switzerland and France and large parts of the Alps are made up of this sedimentary rock.
Seawater contains practically every chemical element found on the earth's surface, including gas. The s a l i n i t y of the North Sea is approx. 35 g/l.

Classification of oceans and seas

Oceans and seas are classified, among other things, according to depth and flora/fauna.

Classification according to depth:

- continental shelf; maximum depth of 200 m; increase of slope towards the ocean; alternating width of the shelf bordering directly onto continents.
- continental slope; declivity from the continental shelf to oceanic depths; substantial relief (slope to 27o); width of 16-32 km.
- deep sea; predominantly horizontal; the deep-sea plains are characterised by trenches (long, narrow, deep depressions up to 10 km) and submarine mountain chains such as the Mid-Atlantic Ridge.

Classification according to flora and fauna:

- pelagic zone; the living space of swimming organisms or organisms floating in the water

- benthonic zone; the living space of organisms living on the sea floor.
- This benthonic zone is subdivided into:
  - littoral zone (part of the ocean closest to the shore)
  - neritic zone up to a depth of 200 m
  - bathyal zone depth between 200 and 1000 m
  - abyssal zone, the deepest portions of the oceans with the exception of the trench-hadal zone, the trench floor

Water movements in the sea
Landforms created by the sea are caused by water movements in the sea, the most important of which are:

- surface waves; wind-generated waves. The energy of the water particles decreases with depth. Only in relatively shallow waters, such as in most coastal zones, is it possible to transport material from the floor.
- tidal waves; movement caused by the gravitational attraction between the sun and the moon on the earth’s waters. This is a vertical movement of water around the earth, causing regular sea level rise and fall.
- tidal current; this is a horizontal movement of water associated with tidal rise and fall. This movement has an oscillating character (ebb and flow). In shallow waters, this current can reach considerable speeds.
- non-oscillating currents, such as the warm Gulf Stream generated in the tropics by Passat winds blowing over the water.
- tsunami; extremely high waves caused by disturbances on the earth floor such as earthquakes and volcanic eruptions.

Additional water movements include gradient currents and convection currents, which fall outside the scope of this dissertation.

Coast
The coast is an outstanding example of a landform created by the sea. The coastline forms the boundary between land and water. In coastal zones, the floor is clearly influenced by wave movements of high rising water. This applies both to water and land. Coastlines have a temporary nature. Onshore migration of the sea (transgression) is usually the result of coastal erosion caused by waves and a positive movement of the base level or flooding of a land area. Seaward movements are often caused by sediment supply by rivers, sea currents, waves and wind, as well as negative movement of the base level or raising of the land, known as regression. Neutral coasts are coastlines that have remained stagnant for longer periods.

Classification of coastal forms
Coasts are classified according to:
- sea movements relative to land
- coastal material.

Sea movements
- transgression coasts (submerged land)- submerged river valleys
  - - submerged glacial valleys (fjords)
  - - submerged valleys/sloping coast (ria coastline in Yugoslavia)
  - - submerged coastal plain with little relief
- regression coasts
  - - coastal plain with little relief (slow-ascending)
  - - coastal plain with terraces (in bedrock, easily identifiable)
- neutral coasts
  - - coasts composed of river sediments
  - - delta coasts
  - - coral coast (tropics)
  - - volcanic coast
- fault coasts; coasts influenced by tectonics

Coastal material

- rocky coasts
- coral coasts; coral reef surrounding the actual coast
- coasts made up of loose material such as gravel, sand or clay.
  This is the only coastal form prevalent in the Netherlands.

Coasts made up of loose material

As mentioned above, this is the only coastal form specific to the Netherlands.
In coastal zones, loose seabed material is carried into the sea through currents and waves, and by the wind above the waterline (on land, in fact). In itself, sedimentary supply by waves from deeper waters cannot cause the coast to expand seaward. The depth of the seafloor increases as a result of beachward wave movements. This creates an equilibrium, where no further sedimentation takes place. Continuous accretion is usually the result of sedimentary transport parallel to the coast.

Sedimentary transport parallel to the coast

This type of transport can be effected by waves and currents. It is crucial that these two movements work concurrently. Provided that wave movements are strong enough, even the weakest currents can transport material, as the material is mobilised by the waves. Coastal slips are known as beach drift, and as coastal rift when a certain direction dominates. Coastal drift plays an important role in the composition and decomposition of the Dutch coast. This drift must be taken into consideration when choosing coastal locations (such as the Waterman plan), and when carrying out dredging work and raising entire areas such as the Maasvlakte (Meuse deltaic plain). These activities can effect unforeseen coastal changes in the form of caving on the one hand, and sedimentation on the other.

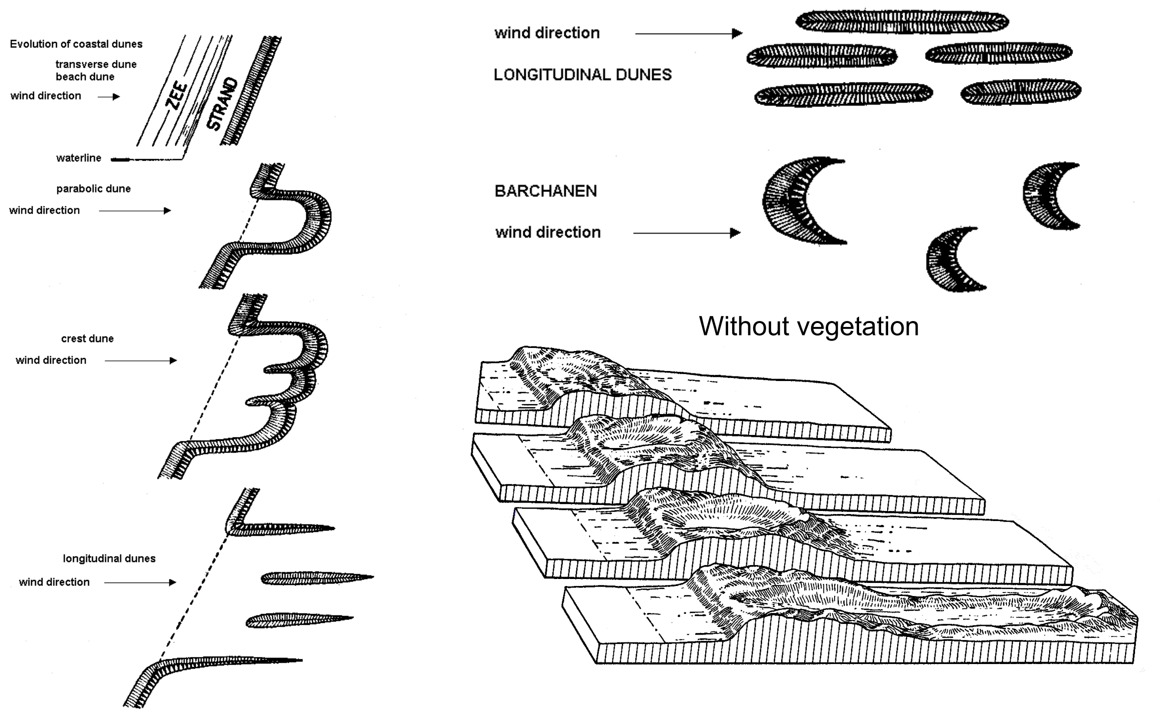
Influence of the wind on the coast

Shores extending along the coast are known as strand plains with barriers. This area extends beyond the scope of the sea, with the wind acting as the most important modeller. Dune formation is related to strand plain, where waves continuously supply new material, used as building material for dunes. The sand must be sufficiently dry to enable it to drift. Clay-like substances retain water and thus prevent drift. The sand of the North Sea coast satisfies these criteria, while the sand along the tidal flat side of the Wadden coast contains excessive amounts of pelagic ooze, virtually prohibiting dune formation.

It is universally accepted, that plants play an active role in coastal dune formation. The main flood mark operates along the coastline. Here, all manner of material such as weeds, driftwood, plastic and litter has been deposited, acting as "sand catcher". This deposited material offers a favourable environment both with regard to food and water management and micro climate, enabling the growth of plants and rush wheatgrass. The deposited sand enables the growth of rush wheatgrass (pioneer species) and marram grass (succeeding rush wheatgrass in the successional series), which in turn retain the sand against further drifting. Provided the circumstances remain favourable with regard to the supply of sand and plant growth, these series of small dunes with vegetation will turn into a foredune or transverse dune (dune perpendicular to the direction of the prevailing wind). If a blast inlet or blowout is created as a result of disruption of vegetation caused for example by coast erosion, trampling or holes (rabbits), drifting will create another dune form, namely a parabolic dune.

Dunes

Further deformation through sand drifts will create ridge dunes and eventually striation dunes. Dispersed layers that have reached a certain size are known as “duinpan” (flat bottomed depression amidst dunes) or dell. Meijendel is an example of such a layer. These layers can reach such a depth, that the ground water is accessed, forming a freshwater lake, used by many municipalities in the west of the Netherlands for drinking water. Due to the huge demand for fresh water, the current rate of supply is insufficient, necessitating the inflow from big rivers to supplement the water supply. This is external water, causing a disruption of the vegetation.
N.B. In the case of coastal dune formation, the forms are influenced by both the sea and the wind, as the sea provides the material, and the wind disperses it into a dune form.



With vegetation　　Diagrams of the evolution of coastal dunes

Escher (1962)

Fig.610 Dune forms

Lagoons, tidal-flat areas and estuaries

The outer boundary of marine sedimentation is not always formed by the sea beach. In certain areas, marine influence stretches to low lying areas bordering the landside of barriers. In most instances, the sea has access to these areas via (semi)permanent tidal inlets.
A distinction is made between lagoons and tidal-flat areas. Lagoons are mostly shallow bodies of water, while tidal-flat areas emerge at low tide, and the sea floor is only submerged at high tide. A lagoon floor is characterised by little relief, whereas the floor of a tidal-flat area consists of deep channels, as well as plates and banks raised above the low water level. In many lagoons and tidal-flat areas, water salinity differs little from that of the open sea.

Brackish water environments

Brackish water environments are predominantly found near river mouths such as estuaries and deltas. Estuaries are widened river mouths, where water movement is strongly influenced by the tides as well as the flow of river water. In the seaward parts of the estuary, the water moves seawards (ebb) and shoreward (flow). The amount of outflowing water (ebb) naturally exceeds the amount flowing in (flow). Further inland, currents travel permanently seawards, although the current velocity fluctuates under tidal influence, as does the water level. Due to the strong currents, estuary floors are characterised by strong reliefs with deep channels and, at low tide, emerging banks and plates. In terms of the nature of the relief forms and sedimentary deposits, estuaries are markedly similar to tidal-flat areas. They differ in terms of the orientation of the areas. Whereas estuaries more or less run perpendicular to the coast, tidal-flat areas run parallel to the coast. The differences are underlined even further by the absence (and presence) of barriers on the seaside and the resultant supply of river water.

N.B.Looking at the islands of Zuid Holland and Zeeland - the delta area-, we can conclude that these areas are more akin to estuaries than deltas in terms of their form and position. The islands are characterised by deep channels, plants and banks, all features of an estuary.

Sedimentation in tidal-flat areas and estuaries

The processes of sedimentation and erosion areas dominated by tidal currents. These currents are strongest in channels, although they prevail in the entire area at high tide, albeit less powerfully than in channels. The floors of those areas are subjected to constant change due to channel diversion as a result of current activity. In addition to channels, the area is also characterised by plates and banks, raised above the high tide level through sedimentation. Plants such as sand and silt catchers play an important role in this respect. The resultant vegetated terrains are known as “schorren” (salt marshes) in Zuid Holland and Zeeland and as “kwelders” in the Wadden area (tidal-flat areas).

Deltas

Deltas are sedimentary deposits created by streams in large basins containing stagnant water, lakes or seas with little tidal differences. Sedimentation is caused by a rapid decline of current velocity, “depositing” floating particles in the water. Sand is deposited first, followed by silt and eventually the finest material, clay. If the strength of the sea current renders sedimentation of finer particles impossible, these particles will be carried away and deposited elsewhere, as is the case at the mouth of the Rhine. The speed of growth of deltas varies tremendously: the bigger the sedimentary supply of the river, the smaller the depth of the (sea) floor bordering the river mouth, and the weaker the influence of erosion as a result of wave activity and tidal current, the greater the speed of growth.

The position of the Rhine delta is relatively stable, while the Rhone delta is growing at an approximate rate of 20 m per year, and the Volga delta at approximately 170 m per year.

4.2.2 Landforms created by rivers

The landscape of river areas

A considerable portion of the Netherlands has come about as a result of the Rhine and the Meuse, our two biggest rivers. The process of deposition or sedimentation has been ongoing for millions of years. The Netherlands is located in a so-called area of subsidence.
An excellent example of an area formed by rivers and their sedimentary deposits is the central area of the Netherlands. The pattern of recent river deposits reveals all the hallmarks of a meandering river. Meandering rivers flow slowly into a relatively flat area, creating a multitude of curves - meanders. The river bed is relatively narrow in summer. In winter and spring however, the rivers are prone to flooding, causing them to overflow the mean-water bed. Normal annual fluctuations, where the river does not overflow excessively, create a deposition of coarse material immediately bordering the bed as a bank - the natural levee - and, further away from the river, layers of fine material (clay) - the flood basins. Natural levees mainly contain meadows and orchards. Ancient civilisations were known to inhabit natural levees, and old roads have also been found. The big open pastoral areas are based on flood basins, which remained largely uninhabited, with few or no roads. Recent land development plans as well as re-allotment have rendered the majority of these old patterns virtually unrecognisable. Since the Middle Ages, river courses in the Netherlands have been fixed by the creation of dykes; as a result, all material is deposited on flood plains.

Flooding

Flooding occurs due to extremely high water, and is caused by heavy downpours or sudden thawing. Flooding is promoted through river canalisation - increasing the discharge velocity of the water - and soil erosion in the drainage basin through changed land use, greatly reducing the buffering capability of the soil or even reducing it to nil.
In terms of the natural levee, land parcels are largely divided into blocks on the eastern river banks, while the flood basin is characterised by meander land division. The villages on the eastern side show marked similarities with elongated *esdorpen*.
Heading further west, land parcels are gradually divided into strips with no inhabitation. The area where rivers enter the Dutch moorland pool is also characterised by strip land division. This area however is inhabited, partly as a result of special land reclamation contracts known as “cope-ontginning”. Villages in this area have an elongated, linear shape.

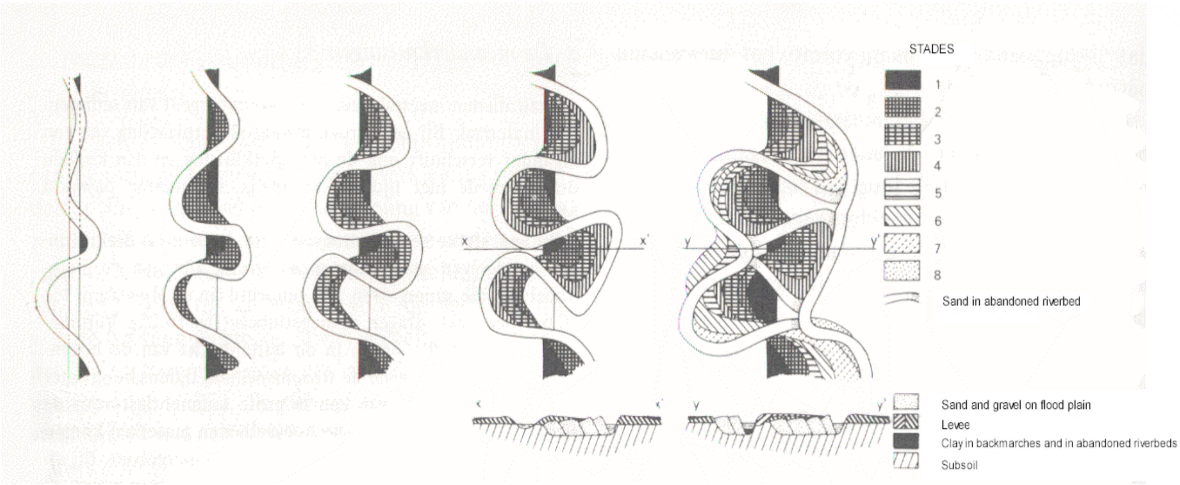
Classification of rivers.

River classification is based on a number of different criteria, including:
- form and course

- river source
- runoff fluctuation

Form and course

A distinction is made between v a l l e y - f o r m i n g r i v e r s , m e a n d e r i n g r i v e r s (see *Fig. 611* and Fig. 404) and anastomosing or b r a i d e d r i v e r s (see *Fig. 612* and Fig. 405). The Netherlands only has meandering rivers. A meandering river is characterised by more or less regular curves in a flat area and a relatively regular supply of water. Meandering rivers turn into braided rivers with an excessive influx of water. Braided rivers are characterised by a system of many small, medium wide and shallow watercourses, repeatedly dividing and converging.



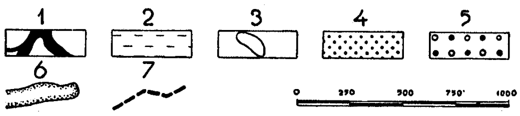
Present riverbed of the Mississippie

Riverbed 200-2000 years old

Riverbed 2000-3000 years old

A.J. Pannekoek (1973)

Fig. 611 Meanders



1. Former river beds of braided system, partly filled with peat
2. Late-glacial fluvial loam on fluvial sand and gravel
3. Thin cover of fluvial loam
4. Inland dunes, partly covering the fluvial loam
5. Fluvio-glacial outwash
6. Water
7. Roads

A.J. Pannekoek (1956) after Pons, from: C.H. Edelman (1950)

Fig. 612 Detail of fluvial loam landscape, south-west of Nijmegen.

Source of water supply

Depending on the water supply source, rivers can be classified into s n o w , g l a c i e r - , r a i n - , s o u r c e - a n d c o m b i n e d r i v e r s . The water of combined r i v e r s , which encompasses all big rivers, usually consists of all four types. The Rhine is a combined river with snow, glacier and snow as its water supply source, while the Meuse contains no glacial water. As a result, the Meuse is characterised by bigger fluctuations in water supply than the Rhine.

Runoff fluctuation

The amount of water runoff fluctuates greatly. During the ice ages, both the Rhine and the Meuse were braided rivers, as the amount of water depended primarily on ice melt, while precipitation in the form of rain was virtually non-existent. A distinction is made between intermittent (periodic), permanent and interrupted rivers. Dutch rivers are permanent rivers.

Water balance or regime.

The term water balance or river regime implies the quantity of water (d i s c h a r g e) passing through during the course of a year or several years, and the influencing factors.
Rivers are part of a r i v e r s y s t e m consisting of main streams and tributaries. This system is usually arborescent or d e n d r o i d . As smaller rivers converge into bigger rivers, the discharge increases downstream. The area where useful precipitation flows into a river, is known as the reception basin or drainage basin, while the boundary line between drainage basins is known as a watershed.

Runoff

River r u n o f f is determined by
- permeability of the rock floor
- climate
- vegetation

Permeability

P e r m e a b i l i t y In impermeable ground or rocks, all precipitation flows immediately from the surface to the river, creating big fluctuations. Compare this to the absorption of rainwater in an urban area, which has no water buffering or absorbing capacity in place.

Climate
Climate is not only affected by the amount of precipitation, but also by temperature, as this determines what form it takes - snow, ice or rain - and evaporation. The spread of precipitation during a year or several years is of greater importance than the average annual precipitation.

Vegetation
The flow of rainwater is hugely dependent on vegetation. Where vegetation is in place, water hits the leaves first before entering the ground and being absorbed along the root canals. In areas with little or no vegetation, there is a significant chance of the water not being absorbed fully into the soil, causing soil erosion or clogs up as a result of the rain.

Current velocity
In a straight channel with a symmetric cross section, the highest current velocity is in the centre or just beneath the surface. All rivers are curved. In a river bend, the water will attempt to flow in a straight line, creating an accumulation of water on the concave bank and a shortage on the convex bank.

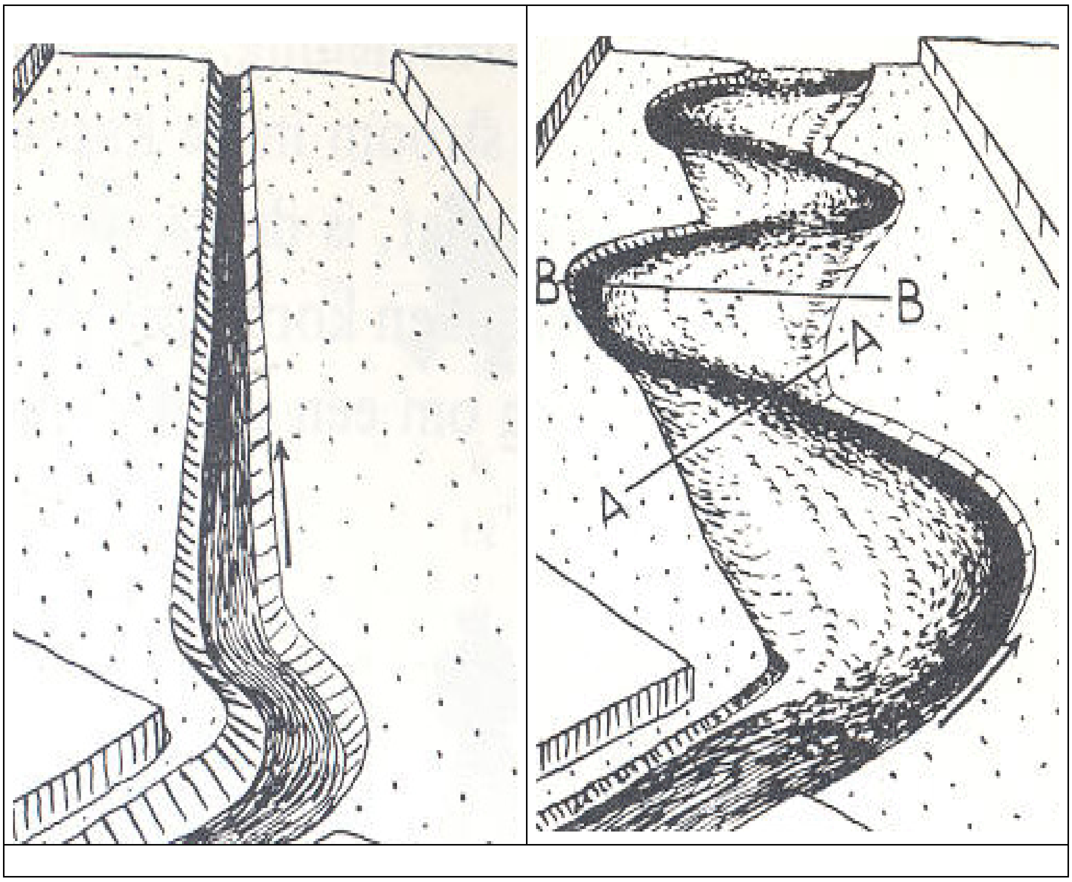


Fig. 613 Convex and concave bank (A.J. Pannekoek(1973)

Water velocity is greater in concave banks than in convex banks, resulting in bed erosion and deepening. Concave bank erosion automatically causes the river to transport the curves downstream.
The line connecting points of greatest current velocity are known as the thread of maximum velocity.

Longitudinal profile
The ideal longitudinal profile of a river is characterised by a steep upper part and an increasingly flat bottom part; the curve resembles a parabola. Most rivers have not yet reached this ideal form or lost it due to tectonics, landslides, lava flows etc.

Sedimentation
A distinction is made between material, transport and deposition.

P.M.

4.2.3 Landforms created by ice

Ice periods in The Netherlands

The Netherlands has been covered in a continental ice sheet at least once in its recent geological history. In addition to this ice period, our country has also experienced numerous cold periods, which have left their mark on the landscape. During these cold periods, the original landscape was covered with ice, as well as being shaped by frost and transformed from a flat area constructed by rivers to a hilly area. As a result, original river deposits were heavily disturbed, and partially covered with moraines to the north of the Haarlem Nijmegen line.

The course of ice sheets

On its journey though the Netherlands, the continental ice sheet made use of existing river valleys. These valleys were extremely deep, with valley walls pushed up by the ice.
Big ice-pushed ridges usually consist of bow-shaped elongated hills with reasonably steep slopes on the inland ice side and slight slopes on the other side. The area north of the Haarlem-Nijmegen line is characterised by bigger and smaller ice-pushed ridges, with altitude variations of 50-100m for the bigger ridges, and 5-10m for the smaller ones.
The material transported by the continental ice sheets, the moraines (known as boulder clay in the Netherlands), is also found above this line. These moraines form flat plains such as the Drents Plateau. In the (earlier) river valleys, shaped by the ice, the boulder clay is situated deep beneath the present-day surface.
In the periods following the ice ages, the land was shaped by other agents. As a result, remnants of the ice age have been levelled or even virtually disappeared.

Glaciers and inland ice

Glaciers are divided into reception basins of snow and areas of melting ice.
There are different types of glaciers:

- continental ice sheet, partly or completely covering the land, irrespective of the form and altitude of the subgrade; for example Greenland and Antarctica, and, during the ice ages, Scandinavia and the Alps.
- a catchment basin (firn plateau) with different glacier tongues; the melting area surrounds a communal intake area (continental ice sheets cover a huge area, while this form is modest in size)
- valley glacier; this type of glacier follows the course of a valley and is fed from different catchment basins; the mountain chain protrudes above the actual intake area and the glacier, for example many glaciers in the Alps.

Glaciers are constantly on the move as a result of accumulation of snow and ice and gravitational force. This movement cannot be perceived with the naked eye, and is measured using reference marks. Alpine glaciers move at a rate of 30-150m a year, while glaciers in Greenland and Alaska can travel up to 30-50m a day.
The glacier's journey across the subgrade causes erosion. The ice exercises an abrasive and grinding pressure on the subgrade due to the presence of glacial rock in the glacier, creating U-shaped valleys or so-called trough-shaped valleys, and depositing moraines in the process.

Moraines

The sediment deposited by glaciers is known as moraine. A distinction is made between lateral moraines, end moraines, recessional moraines and ground moraines.
In principle, the Netherlands contains all moraine types. However, due to later erosion, the majority of this sediment has been cleared. The most prevalent and easily identifiable moraine type is ground moraine. It consists of slightly rounded debris and fine material, eroded and transported by the glacier travelling across the subgrade. This combination of debris and finer material has been blended into a reasonably homogenous mass.
Pleistocene ground moraine is known as boulder clay in the Netherlands and can be found in the north and east of our country. The area also contains a variety of big boulders, used by the *Hunnebedbouwers* (megalith builders) to build their graves. Rock composition indicates that the ice originally came from Scandinavia.

Ice-pushed ridges

Glaciers, when moving across loose subgrade, have the ability to transform this material into a ridge. The cross section of this ridge has an imbricate structure.

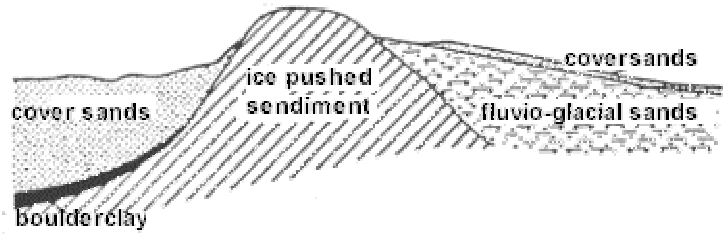
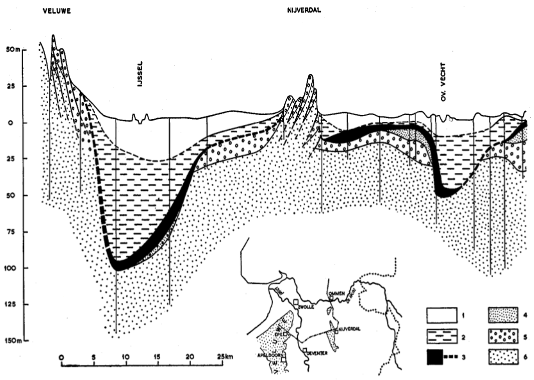


Fig. 614 Ice-pushed ridge
Kuipers p. 141: Edelman (150) Inleiding tot de bodemkunde van Nederland (Introduction to pedology in the Netherlands)



1. Eemian and younger
2. Fluvio-glacial younger than ground moraine (Drenthian)
3. Ground moraine (boulder clay) (Drenthian)
4. Fluvio-glacial older than ground moraine (Drenthian)
5. Brown sands with gravel (Needian Drenthian?)
6. White sands with gravel (Taxandrian and older?)

Thin vertical lines: bore holes

A.J. Pannekoek (1956)

Fig. 615

This imbricate structure of older river deposits distinguishes ice-pushed ridges from terminal moraines (glacially deposited materials found near the end of a glacier).
Intermediate forms of end moraines and ice-pushed ridges are also possible.

Fluvioglacial deposits

In addition to sediments deposited directly by ice, we can also distinguish sediments deposited by ice and water (rivers). These are known as fluvioglacial deposits. We can distinguish the following forms:

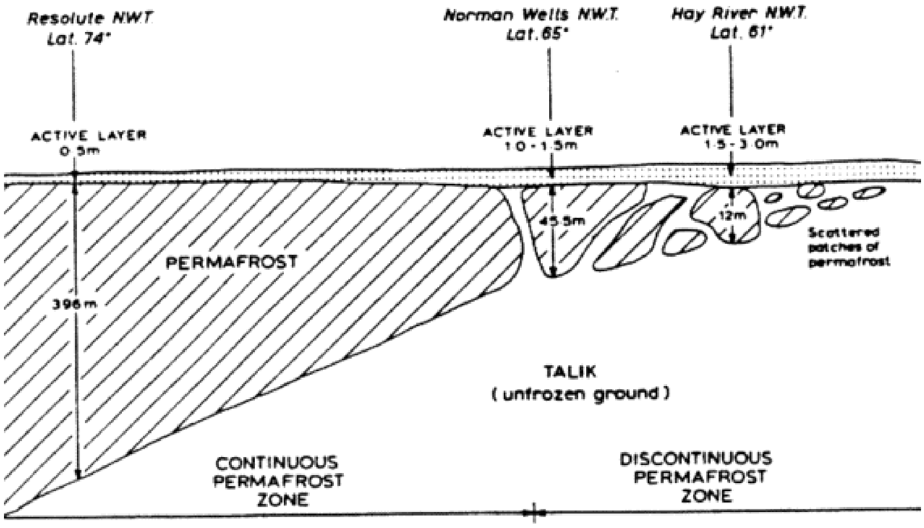
- extremely flat debris/sand till (sandr) deposited by the ice front
- elongated winding ridges of relatively uniform width (known as esker in the Netherlands). These were created in glacial tunnels situated in or beneath the glacier. They can be hundreds of kilometres long and dozens of metres high.
- fluvioglacial deposits in the form of terraces between the glacier and the adjacent valley wall of the ice-pushed ridge, deposited by supraglacial streams on and along the surface of the glacier. No sedimentation occurs in the ice blocks (so-called dead ice) of a kame terrace or sands. Ice melts create depressions, as is the case in the Uddelermeer and the Zuidlaardermeer.

Periglacial phenomena

The continental ice sheet did not reach the Netherlands during all ice ages. Nevertheless, the temperatures in our country were low enough to cause ground to freeze, in turn producing special periglacial forms. These structures are dependent on long-term exposure to sub-zero temperatures, the presence of soil moisture and little or no vegetation. Different forms of periglacial phenomena can be distinguished, namely permafrost, front mounds or pingos and frost cracks.

Permafrost

The term p e r m a f r o s t denotes ground that is subjected to subzero temperatures for more than a year. In general, this stratum consists of an active layer, which thaws during the warm season and freezes during the cold season. This alternating process of freeze-thaw creates special forms; non-hardened layers are deformed, in particular alternating layers of coarse-grain and fine-grained material. This phenomenon is known as c r y o t u r b a t i o n , and is quite a common phenomenon in many subgrades in the Netherlands.
The permafrost layer can be several hundred metres deep in the coldest areas, decreasing to 10-20 metres towards the edge. The frozen parcels disintegrate into blocks of differing dimensions.



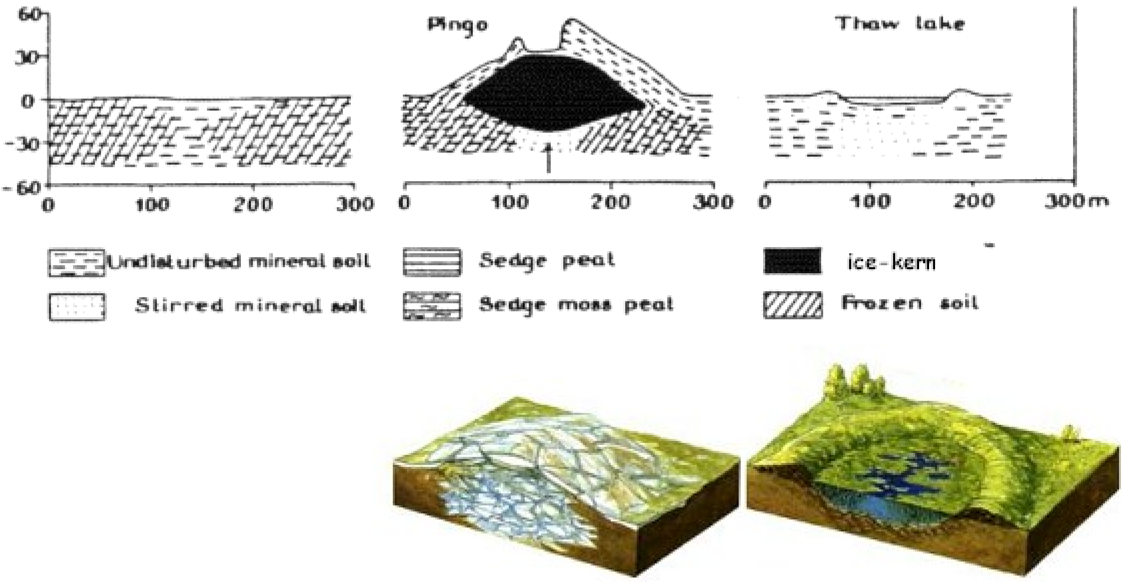
Cooke and Doornkamp (1974) *Geomorphology in environmental management (Oxford*) p.22

Fig. 616 Permafrost

We are all familiar with the process of frost and thaw during a frosty winter, when roads are broken up through "surface thaw". It is important that wires and buildings in areas prone to permafrost are insulated to eliminate heat transfer of buildings to the surrounding area, and to prevent subsidence caused by melting.

Frost mounds or pingos

P i n g o s are ice-cored mounds that have domed up from beneath. They occur exclusively in permafrost areas. The growth of this ice core can cause the surrounding stratum to break up and the mound to "cave in".



Hails (1977) Applied geomorphology (Amsterdam) Elsevier, p. 26;
Deinema, J. ed. (1996) Brussel en Wallonië (Antwerpen) Standaarduitgeverij, p. 245.

Fig. 617 Pingo

The same phenomenon occurs when the ice core melts, leaving all but shored circular lakes, ranging in size from several metres to several hundreds of metres. These predominantly peat-filled lakes are a common occurrence in the Netherlands, and are known as *dobben*, ranging in dimension from 150m for round types and 250m for oval lakes.

Frost cracks

A sudden drop in temperature of 20o or more can create splits or cracks in the ground due to ice volume changes. These splits and cracks can be filled with other material from the surrounding area. These f r o s t c r a c k s occur throughout the Netherlands.

The ice ages

Numerous phenomena have occurred in areas (far) removed from present-day glaciers and continental ice sheets. This can only be explained by assuming that glaciers and continental ice sheets had a wider spread in recent geological history than is currently the case. These phenomena are characterised by the presence of glacial erosion and glacial and fluvioglacial sedimentation, as well as periglacial circumstances, plant and animal migration, sea level fluctuations etc.
These cold periods are localised stratigraphically in the P l e i s t o c e n e e p o c h .
Significant processes of glaciation are referred to as an i c e a g e or g l a c i a l a g e . A succession of glacials with intermittent warm periods is known as i n t e r g l a c i a l , while warmer periods (of shorter duration) during an ice age are referred to as i n t e r s t a d i a l .
In the Netherlands and surrounding area, glacials are characterised by arctic or subarctic vegetation. This can be determined through a pollen analysis (p a l y n o l o g y). In the Netherlands, the term interglacial is applicable when denoting long-term climate improvement, enabling vegetation establishment that is comparable with present-day vegetation.

Time scale	*Geological periods*	*Sediment*	*Archeological periods*
	SUB-	Younger young sea clay	
+ 1200			dikes around old kerns
	ATLANTICUM		Carolingian settlements
		Young dunes	
		Older young sea clay	
+ 300			
+ 100			Roman settlements
± 0			
		First young sea clay deposits	
- 700			Iron Age
			Bronze Age
	SUBBOREAAL	Bog/peat	
- 300			Neolithicum / Young Stone Age
		Old dune landscape	
	ATLANTICUM		
		Old sea clay	
- 5500			
	BOREAAL	Bog at large depths	
- 7500			Mesolithicum (homo sapiens)
	PRE-BOREAAL	idem	
- 8000			
	LATE GLACIAL (Young-pleistocene)	Cover sand and loess	
- 20 000			
	WÜRM ICE AGE	Cover sand and loess	Paleolithicum (Neanderthal)
-200 000	RISS ICE AGE	Ice-pushed ridges, boulder clay, boulders, fluvio glacial sand	
	OLD PLEISTOCENE	Gravel. sand and loan deposited by the old rivers (pre-glacial sand etc.)	
- 1.000.000			

S.F. Kuipers (1972) *Bodemkunde (Culemborg) Tjeenk Willink*

Fig. 618 Geological time scale

4.2.4 Landforms created by the wind

The Netherlands has two distinct landscapes, formed primarily by the wind, namely the coastal dunes and the cover sand and loess areas found in the eastern and southern provinces of the country. Dunes are prevalent in all sand areas of the Netherlands, including river areas.
In other words, dunes are created in all areas characterised by sand drift and the absence of "sand retaining" vegetation.
The processes of erosion, transport and deposition are all influenced by the wind.

Wind erosion

In wind erosion, a distinction is made between the lifting and removal (deflation) of material by the wind and material abrasion or damage caused by sand drifts (compare sandblasting of buildings, metals, glass etc.) Both aspects usually occur concurrently. Limiting factors for deflation or drift include:

- shortage of material
- ground water (wet sand is incapable of drifting)
- gravel bars (gravelly layer with ventifacts)

- podzol soil profile, containing hardened B horizon.

Wind transport or Aeolian transport

A e o l i a n t r a n s p o r t is comparable with transport in flowing water. As the speed of fall of a material particle is far greater in the air than in water, the wind is capable of transporting smaller particles faster than flowing water. A particle with the same diameter requires greater current velocity in the air than in water.

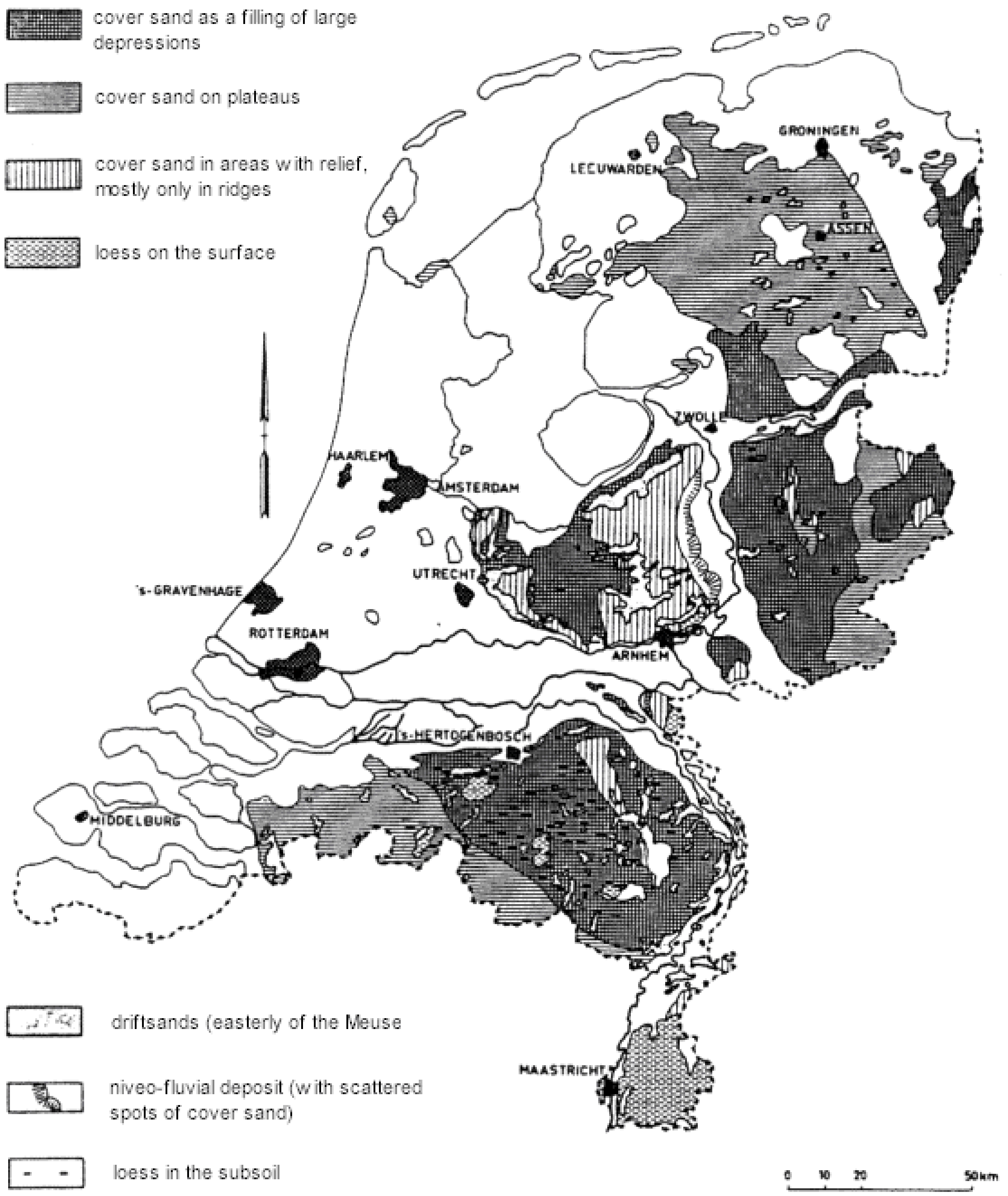
Aeolian accumulation or deposition

Wind-borne material, be it close to the surface or transported high up in the air by turbulent air currents, is deposited in a random location. Aeolian deposits have a relatively wide spread across the earth's surface. Depending on particle size, they can be categorised into two main groups: sand and loess.

Sand deposits

Wind-borne sand particles can be deposited in several ways, for example in front of and behind an obstacle, on an open plane as a blanket. It can also be "caught" and retained by vegetation.
This creates d u n e forms, including river dunes, free dunes and phytogenic dunes, cover sand and Aeolian sand.
Phytogenic dunes predominantly occur along the coastline, caused by deposition through vegetation.
Free dunes are created on an open sand plane and repeatedly migrate and change location and form.
Examples include c r e s c e n t i c d u n e s of b a r c h a n , transverse dunes and longitudinal dunes.

- River dunes are situated along rivers; the sand originates from dried-up riverbeds. In the Netherlands, a large percentage of dunes were created alongside rivers during the ice ages. A river dune surrounded by later river deposits is known as a donk in the Netherlands.
- Cover sand envelops large surfaces like a blanket, covering all original forms. These cover sands were deposited in the Netherlands during the ice ages.
- Aeolian sand is created by local drifting in a sand area caused by disruption of vegetation. As previously mentioned, sand drifting can result from any disruption of vegetation in wind-borne material.



Stiboka (1962) Bodem van Nederland (Wageningen) p.189

Fig. 619 Aeolian deposits

Loess deposits

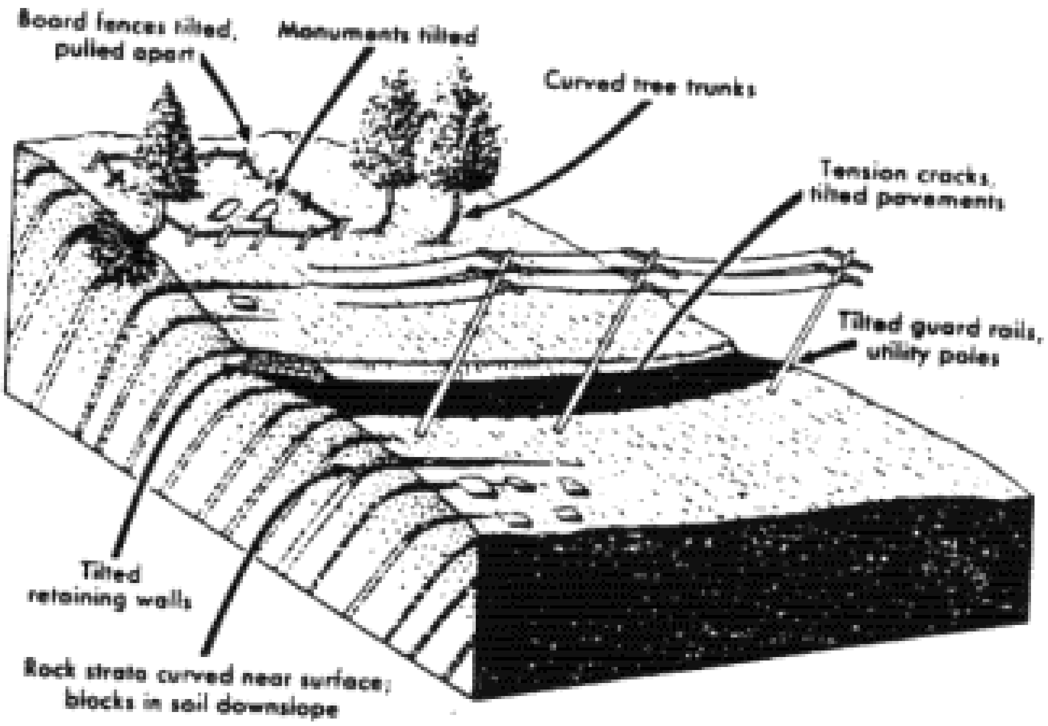
Particle size analyses of l o e s s have revealed a domination of the soil fraction of 16-50 micron.
A distinction is made between desert loess (continental loess) and loess originating from earlier periglacial areas: glacial loess. Continental loess is deposited on the leeward side of deserts (compare loess found in China with that of the Gobi desert). Glacial loess originates from areas bereft of vegetation during the ice age, with sufficient fine and loose material to enable deflation.
It is generally accepted that there is a correlation between the northern boundary of Pleistocene loess deposits and the vegetation boundary of the last cold period, i.e. the northern boundary of the cold grass steppe.

4.2.5 Landforms created by slope processes

Gravity and abrasion

Slope material loosened through w e a t h e r i n g is prone to movement under the influence of gravity (it must be noted that this also depends on the material's ability to overcome the abrasive effect exercised on it).
Abrasion is dependent on a range of factors including sloping, form and roughness of the terrain, as well as form and roughness of the loosened material. The greater the slope angle of a terrain and the steeper the slope, the easier rock will move. It is generally assumed that critical slope angles depend on the roundedness and the weight of the material. In practice, this means that the critical slope angle must be taken into consideration when constructing banks for roads and railway lines, dykes, dunes, river shores, streams, channels and ditches and lakes and ponds, as well as reserving slope land to prevent mass movement along the slip plane.

Recognising slope processes

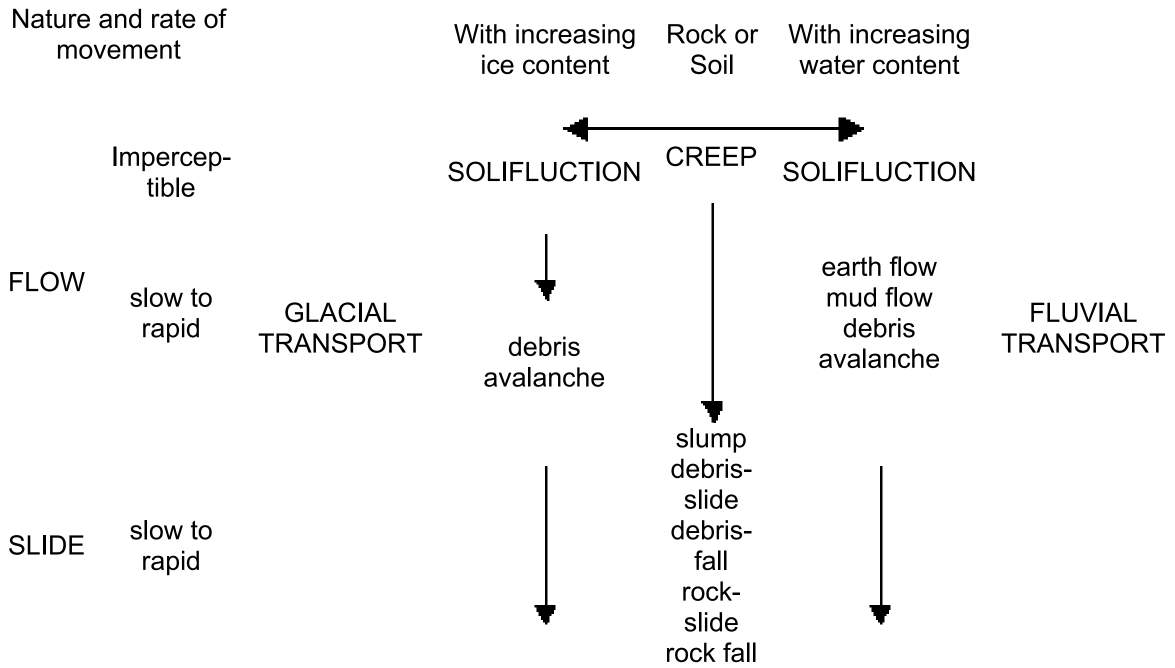


Cooke and Doornkamp (1974) Geomorphology in environmental management (Oxford) Clarendon Press, p. 146
Fig. 620 Recognising slope processes

Classification of slope processes

The following slope processes have been identified:
- falling and rolling of stones under the influence of gravity; limited to steep slopes - rock fall, stone avalanches.
- sliding or slipping; the downward slipping or sliding of rock debris or ground mass sliding, retains its original form; landslides
- creeping (soil creep); slow movement of ground mass downslope due to the alternating process of expanding and shrinking (wet-dry; frost-thaw). (this is a common process in the Netherlands)
- flow; mass obtains a plastic consistency and begins to flow as a result of saturation of slope material with water; the internal cohesion is lost; (this is a common process in the Netherlands)
- surface wash; in this process, loose material is transported downslope through rainwater; if this water accumulates in streams and rivers, this process is fluvial. (this process is commonplace in the Netherlands)

- soil creep; (extremely) slow downslope movement (creeping) under the influence of gravity; mass cohesion is maintained. (this is a common process in the Netherlands)
- solifluction; see creep. In this process, water and/or ice act as lubricant.



After Bloom (1973) The service of the earth (London) Prentice Hall International, p.42

Fig. 621 Classification of slope movements

Water

Water plays a vital role in mass movement. F l o w a g e p r o c e s s e s are created as the quantity of water in the groundmass of the slope increases. The water acts as a lubricant for the groundmass.
As the amount of water increases and begins to dominate, we are no longer dealing with slope processes but with fluvial processes; i.e. processes influenced by flowing water in the form of rivers, streams etc

Vegetation

Slope vegetation encourages slope stability, as plants are able to retain soil through their root system. In addition, precipitation does not enter the soil directly, but is absorbed by the plant first, enabling it to grow.
The stability of both natural and manmade slopes can be influenced by creating conditions for soil/slope vegetation (this explains why road banks in the Netherlands are often grass-covered). In areas with natural slopes such as mountainous areas, all steep slopes have been forested as much as possible.

Disasters

Compliance with this procedure could have prevented the disastrous floods in northern Italy in the spring of 1994. This natural disaster is additionally attributable to the construction of an increasing number of ski runs, some of which were built in wholly unsuitable areas, rendering water regulation extremely difficult due to disruption to, and subsequent absence of, vegetation. As the water is not absorbed by the soil first, heavy rainfall can have a catastrophic effect in the form of severe floods.

4.3 Metres

4.3.1 Pedological landscapes

Soil unit

Soil with virtually identical profile characteristics is known as a soil unit. These soil units are determined spatially and classified using soil drilling and landscape features. This work is carried out by the Stichting Bodemkartering (STIBOKA – Netherlands Soil Survey Institute). The downside of maps is that they only provide information on the top 1.20m, which is insufficient for urban development purposes.
To classify greater depths, use can be made of geological maps and soil drilling, the results of which are housed at the Rijks Geologische Dienst (Geological Survey of the Netherlands) at Haarlem.
A complete set 1:50,000 soil maps of the Netherlands is available. However, the geological and geomorphic maps covering the whole of the country are incomplete, and not all are 1:50,000 scale maps. More detailed information is available from some municipalities.

Soil group

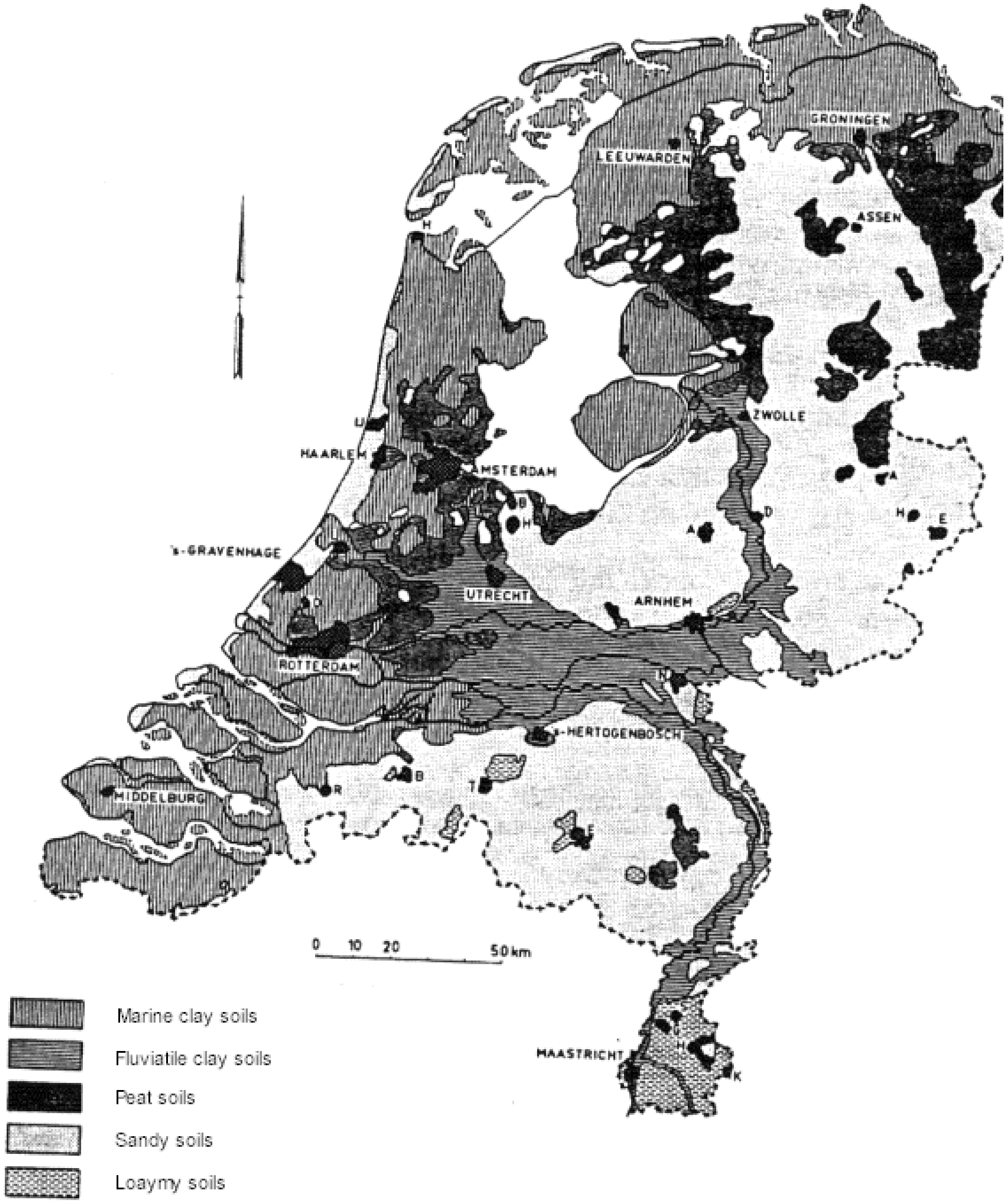
Soil groups can be divided into different types :

- clay soils
- loamy soils
- sand soils
- moorland soil

In principle, these soils have the same composition in terms of particle size. For further information on particle size and naming, please turn to page 368. Peat soil must contain 22.5% or more organic matter. Peat is formed locally from decomposed plants, unlike clay, loam and sand, which have been subjected to sedimentation or deposition.

Pedological landscapes

In addition to classification according to particle size, pedological landscapes are categorised according to sedimentation (clay, loam and sand) and/or origins (peat). This classification overlaps with geomorphology. Geomorphology is primarily concerned with interpreting topographic forms and their history.



STIBOKA (1965) De bodem van Nederland (Wageningen) p.3

Fig. 622 Pedological landscapes

4.3.2 Clay soils

Clay soils are deep-sea and river deposits, formed in calm water. The lighter soils border a stream or river, while heavier soils can be found further away.

We can distinguish the following types of sediments:

- Water deposits in tidal areas (ebb and flow);
- Washover deposits overlying peat;
- Coastal deposits;
- Subaquatic deposits;

- River deposits.

These different types of deposition have created different types of clay landscapes.

Water deposits in tidal areas.

We can distinguish three stages in this type of vertical accretion:
- sand flat or tidal-flat sand,
- ooze,
- kwelder (term used in North Holland for salt marsh) or schor (term used in province of Zeeland for salt marsh).

Vertical accretion in free water initially creates a sand flat or tidal-flat sand. Except at extremely low tides, this sand is usually below mean-tide level, and is barren of vegetation. Gradually, the area will rise above mean-tide level and produce vegetation, for example marsh samphire, decelerating the flow of sea water in the process. This encourages the settlement of finer muddy material as well as sand. The terrain usually rises above the mean-tide level at ebb. This is known as an ooze or tidal flat area.

Further vertical accretion

Gradually, this ooze is raised due to further vertical accretion, producing more vegetation such as marsh samphire, spartina and, lastly, salt marsh grasses. Areas with brackish water, for example the Biesbosch, a wetland area in the province of Brabant, are characterised by cane and wicker. The terrain is only submerged at high tide. This is known as a kwelder (salt marsh), a gors or a schor. High tide is characterised by extremely calm water, encouraged in part by the vegetation.
The end result of this process is deposition of clay particles out of the water.

Accretion and aggradation

In this type of vertical accretion, we can also identify accretion and aggradation.
- Accretion is characterised by silting up against the existing land, usually dyke land. Following dyking of this new accretion, heavier soils border the old dyke, and lighter soils the new dyke.
- A ggradation takes place in free water. The centre consists of a sand flat surrounded by streams. The heaviest soils are located in the aggradation core, while the lighter soils are found along the borders.

Polder landscapes

These free water deposits are responsible for creating the flat polder landscapes, such as in:

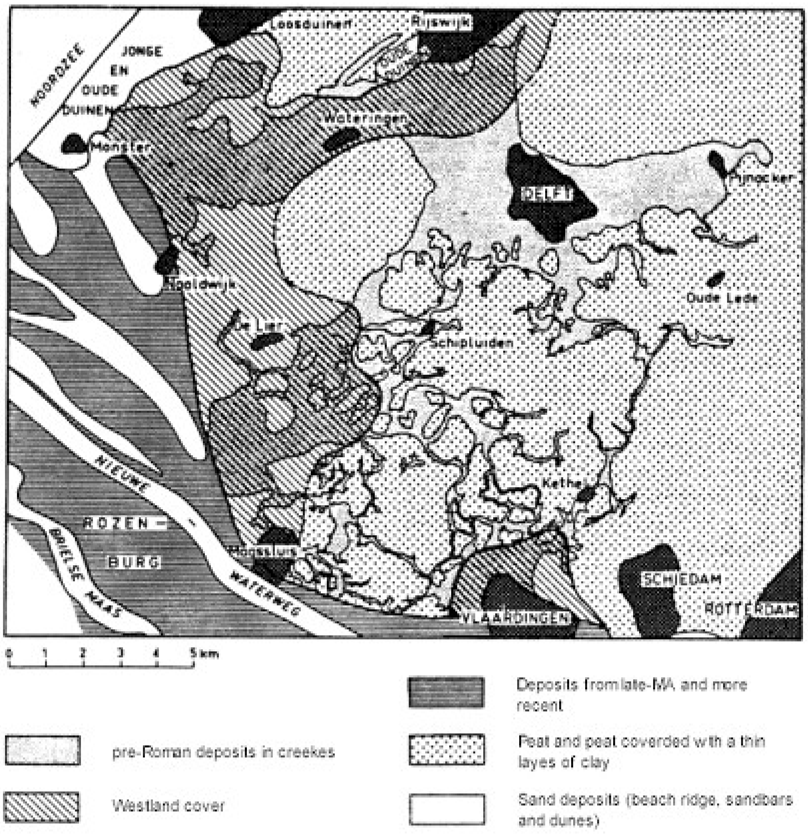
SOUTH-WEST NETHERLANDS	NORTH NETHERLANDS	OLD POLDERS
marsh soils	gors soils (salt marsh) young *kwelder* soils (high marsh) young sea bosom soils	tidal flat soils (‘wad’)
flat soils		*Kwelder* soils (high marsh)
stream bed soils		Moddergronden (mud soils)

Fig. 623 Deposits in free water

All the above listed soil types are clay soils with more or fewer good properties; sand does not penetrate too deep into the subgrade.

Washover deposits overlying peat

When the sea or a river penetrates a peatland area, the peat is stored in the breach channel. The remaining peat between the streams is elevated, and is subject to flooding from the streams at high tide. This occurs directly on the salt marsh, creating reasonably heavy clay blankets on the peat.



STIBOKA (1965) De bodem van Nederland (soil of the Netherlands) (Wageningen) p.41

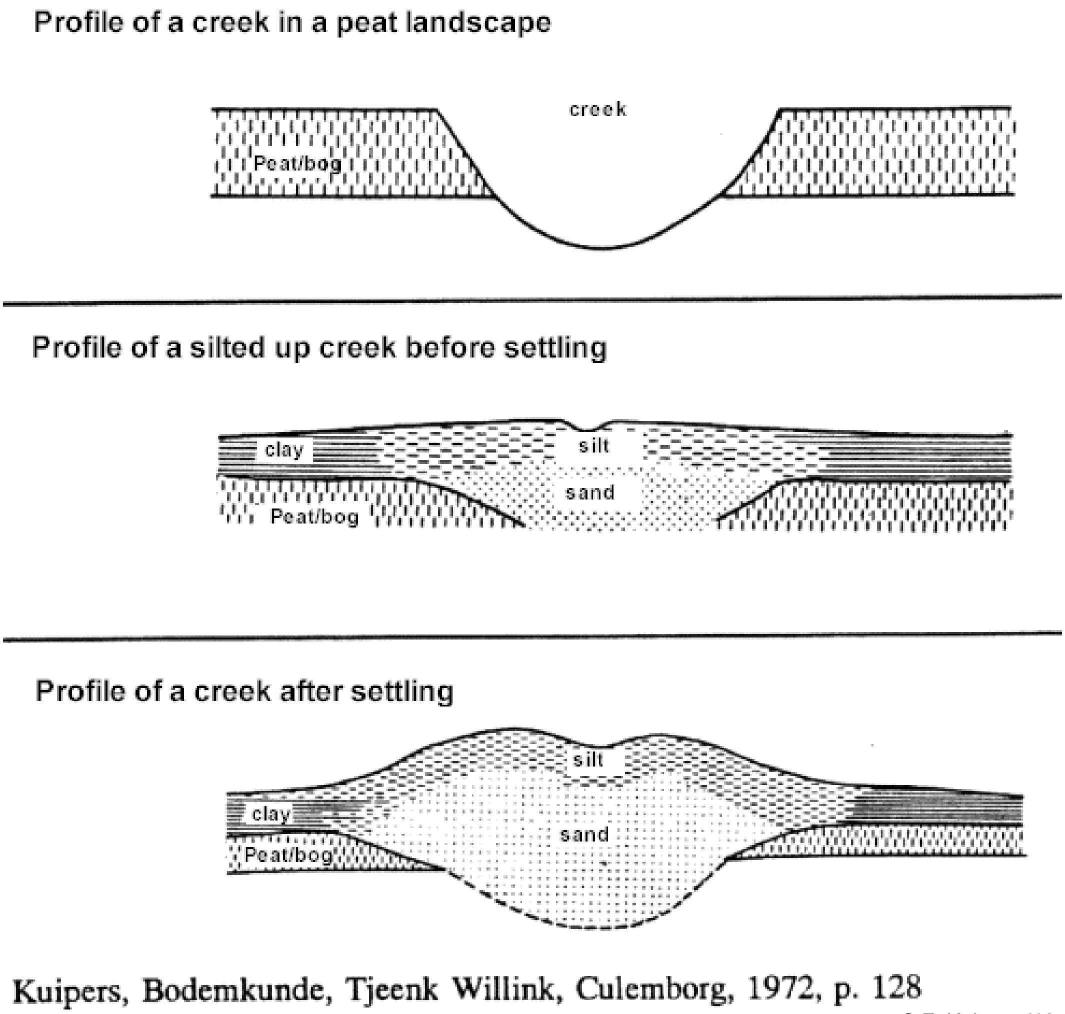
Fig. 624 Streams in the peat landscape of the Westland

Inversion of streams in a peatland area

The s t r e a m s themselves gradually silt up over time. Once the area is drained, the peat settles very quickly.

As earlier streams contain little peat, this area is subjected to significantly less settlement than the terrain beyond the streams. As a result, the earlier, silted-up streams create a r i d g e f o r m a t i o n in the landscape, while the intermediate clay-on-peat soils form the low areas, the so-called bogs.

This phenomenon is known as i n v e r s i o n of the landscape.



S.F. Kuipers (1972)

Fig. 625 Development of transverse profiles of a stream

In the north of the Netherlands, seawater entered peatland areas less forcefully, with the *waddeneilanden* (Wadden Island) bars and the coastal marsh bars acting as a protective barrier. As a result, the area is characterised by clay-covered peat and an absence of large inter-stream ridges. There are however slight altitude variations as a result of inversion.

Landscapes and soil series

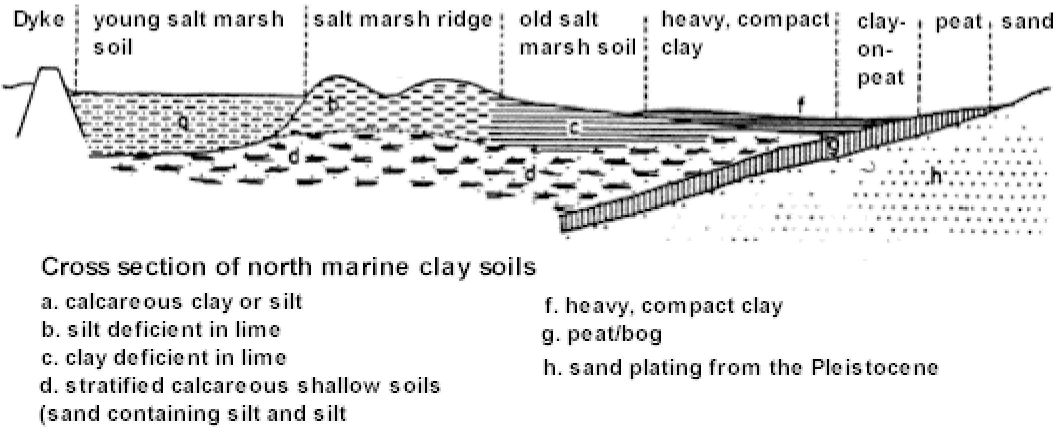
The following soil series can be distinguished in the inversion landscape of south west Netherlands:

- stream ridge soils, for example old stream ridge soils: these are elevated non-calcareous loam soils containing calcareous silted sand in the subgrade.
- bog soils, for example old bog soils: these are non-calcareous, reasonably heavy, low-lying clay soils with peat subgrade.
- clay flat soils. Clay flat soils: these are non-calcareous loam soils with an anomalous, extremely dense clay bank with poor subgrade.

The following soil series prevail in the north of the Netherlands:

- clay-on-peat soils,
- roodoorn soils, red-brown coloured, reasonably drained clay-on-peat soils, dusty and sandy in dry state,
- woodland soils,
- knipklei soils (clay-on-peat soil, known as knipklei in the Netherlands).

Woodland soils: clay soils with a higher organic dust content.



Kuipers (1972) Bodemkunde (Culemborg) Tjeenk Willink, p. 160

Fig. 626 Profile of the northern sea clay area

Coastal deposits

The daily ebb and flow movements create seaward and landward currents moving in a perpendicular direction to the coastline. The transition from ebb to flow is characterised by calm water, creating the right conditions for sand and silt deposits. This process explains the offshore bars that run parallel to our coastline, as well as the offshore ridges with intermediate strand plains. Sand drifting encouraged dune formation from and on these offshore ridges.
The process outlined above is also responsible for creating the marsh bars with intermediate kwelder (salt marsh), running parallel to the old Friesland-Groningen coast line.
Sedimentation occurred behind the *waddeneilanden* in a calmer environment, creating the marsh bars (made of light loam soils) and kwelder (salt marsh) basins (made of heavier soil).

Subaquatic deposits

In the Noordoostpolder (North-East Polder) and in Flevoland, most soils were created by silt sinking to the river floor of the former Zuiderzee and the later IJsselmeer as a result of extremely calm conditions. The heaviest soils are found nearest to the "oudeland" (old land), with the soils becoming gradually lighter towards the north. These deposits are characterised by a significant uniformity in a horizontal direction.
In vertical direction, i.e. in the soil profile, several layers can be identified. Humus rich material makes up the bottom layer, created at the same time as the Zuiderzee as a result of a large peat bog being affected by the sea (peat and detritus). The following layer contains deposits from the Zuiderzee period, and occasionally contains a thin depositary layer from the IJsselmeer period.

River deposits

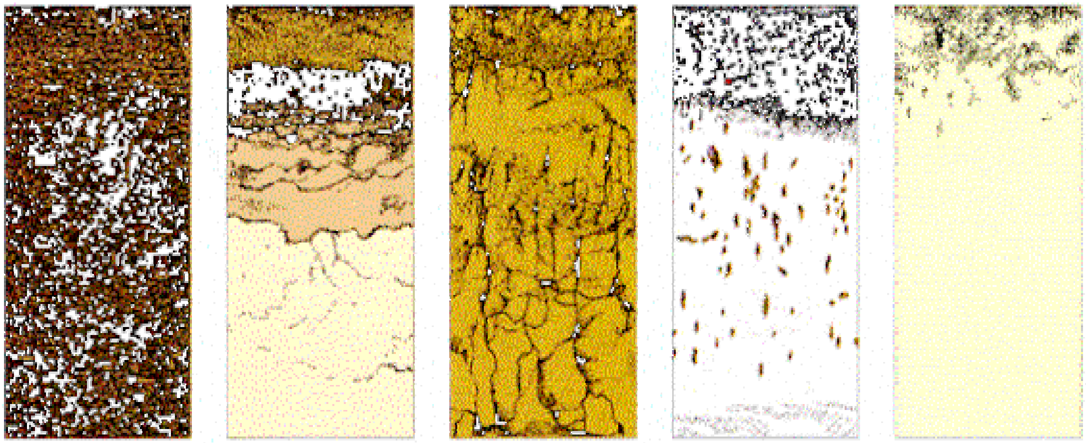
We can distinguish the following sedimentary processes:
- meandering rivers,
- tidal rivers,
- braided rivers (no longer occur in the Netherlands).

The soil series in the region of meandering rivers and tidal rivers are:
- Current ridge soils: elevated soils with a heavier overburden, gradually transformed into a lighter subgrade.
- Basin ridge soil: heavy to extremely heavy clay soils with occasional peat formation.
- Flood plain soils: created following river dyking.
- Storm soils: created by dyke washovers.

New classification and naming of clay soils.

- Illuviated clay soils: these occur in several older river deposits in Limburg and the Achterhoek (so-called river loams). These soils contain a heavier layer, an illuvial horizon of clay in the subgrade. This layer is known as clay plan or textural B horizon.

- Eerd soils: these occur in a limited number of clay areas of West-Friesland and the Old Polders. These soils have a thick, clearly dark, humus-rich overburden.
- Vague soils: all soils without a clear profile development, i.e. with no clear soil layers in the profile and no typically clear overburden. The majority of sea and river clay soils fall belong to this order.



moorland soil podzol soil illuviated clay soil eerd soil vague soil

Sticht.Wetensch.Atlas_v.Nederland, v.d. Berg, Steur and Brus (1987) part 14 p.11

Fig. 627 Prototypes of soil classification

4.3.3 Sand soils

Classification of sand landscapes

While a portion of our sand soils is deposited by the sea and rivers, a significant percentage of sand is also wind-borne.
Due to the different geneses, we can identify several typical sand landscapes:

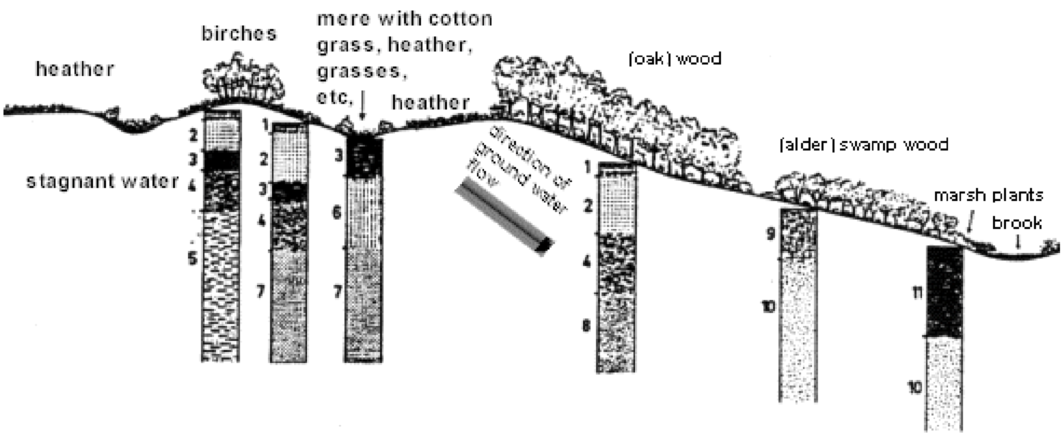
- coarse-grained sand, river terraces- and ice-pushed ridge landscape (see Fig. 629);
- cover sand landscape;
- drift sand landscape:
  - inland dune landscape or drift sand landscape
  - holocene duneand sea landscape.

Coarse-grained sand, river terraces and ice-pushed ridge landscape.

The flat-plain river terraces landscape is characteristic of several places in central Brabant and the Peelhorst in eastern Brabant. The ice-pushed ridge landscape (see *Fig. 629*) was created in regions where these coarse-grained and loamy deposits of pre-glacial rivers were pushed up by glacial mass during the third ice age (the Utrechts and Veluwse heuvelruggen (hill ridge), Montferland, Overijssel, Rijk van Nijmegen, het Gooi). These soils, originally river sands and loams, are generally chemically richer than cover sands.
However, from an agricultural point of view their quality is poor, due to their susceptibility to drought. As a result, they tend to be characterised by woodland and heathland.

Cover sand landscape

Cover sand landscape embraces the majority of our Pleistocene sand soils. As previously mentioned, the pure cover sand landscape is neither entirely flat, nor characterised by significant altitude variations. It is relatively undulating. Sand composition is generally uniform; it was deposited by the wind on a subgrade of older deposits of divergent character. It is finer than sand found in ice-pushed ridge landscape. There is however a slight variation in soil texture (biggest soil fraction 105-150 mu).

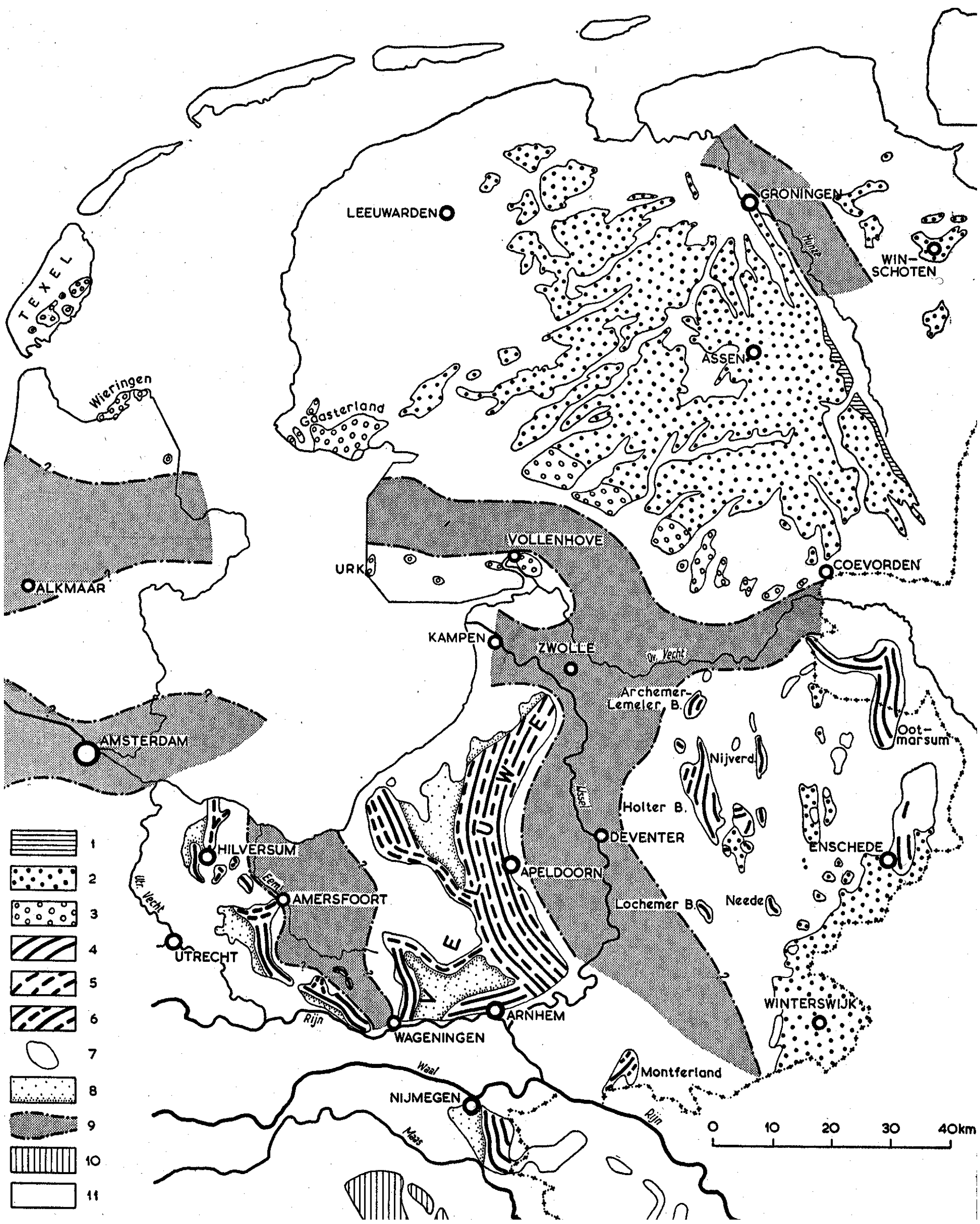


1 heather sods
2 bleached layer
3 iron pan
4 iron pan
5 yellow-brown sand with brown fibres
6 brown sand
7 yellow sand
8 red or yellow sand
9 humus-rich sand
10 grey sand
11 peat/bog.

(…)

Fig. 628 Profile of plateau brook valley with vegetation

The cover sand landscape incorporates relatively wide s t r e a m v a l l e y s ; these were created in earlier times, when large water masses had to be discharged. The width does not correspond with the size of present-day streams. The area is additionally characterised by many continuous valleys, made up of the intermediate layers of c o v e r s a n d r i d g e s .



1. Fluvio-glacial older than ground-moraine
2. Ground-moraine (boulder clay) at the surface or under thin coverzand
3. Ground-moraine of great thickness (terminal moraine according to A. Brouwer)
4. Ice-pushed ridges, phase A (after Maarleveld)
5. Ice-pushed ridges, phases B + C (after Maarleveld)
6. Ice-pushed ridges, consorted in phases A and B + C
7. Ice-pushed ridges, strike not indicated
8. Main fluvio-glacial deposits (after Maarleveld)
9. Buried valleys with deep boulder clay
10. Uncontorted fluvial Needian-Drenthian
11. Deposits younger than Drenthian

STIBOKA (1962) *Bodem van Nederland* p. 184

Fig. 629 Ice-pushed ridge landscape

Original vegetation of cover sand landscapes.

Traditionally, stream valleys have had a marshy character. The lowest layers provided ideal growing conditions for peat, while the more elevated terrains saw the growth of extremely dense, impermeable marshy woodland. Plant growth was encouraged by the relatively nutritious ground water flowing down

from the higher plains and stream water. Higher up, tall forests flourished along the borders of the elevated stream valleys.
The forested character of the area is characterised by the regional place names, such as the Friesche Wouden, Westerwolde in Groningen, Paterswolde, Ruinerwolde in Drenthe, Woudenberg, Renswoude in the Gelderse Vallei, and Sliebengewald in northern Limburg. All these places are situated on moist sand soils. The terrain beyond the stream valleys was reasonably flat, characterised by poor water runoff and nutritionally poor water, adversely affecting plant growth. The moist lowland areas were covered with heather, cotton grass, tubular straw, etc; while elevated areas saw the growth of ling, birch and pine.

Original habitation of cover sand landscapes.

Humans settled in the fertile, semi-moist areas, i.e. the shores of the streams or cover sand soils, protruding from the low sand soils. Here they cleared forests, built their settlements and developed their farmland (known as es, eng or enk). In the course of the centuries, these fields were considerably elevated as a result of regular supply of heather sods and sand, used as litter in sheep folds. Lower-level strips of land were cultivated and used as grassland. The terrain bordering the stream was too moist and inaccessible, making it temporarily impossible to clear the forests. This terrain was later turned into grassland.

Sheep and fertilisers on cover sand landscapes.

Sheep were set to graze on the poorer soils. This had an adverse effect on tree growth, thus creating century-old heathland. If the area was to be cleared of sheep, the area would soon revert back to pine and birch forests.
There was a strict correlation between the surface area of the field and the quantity of fertiliser and therefore the number of sheep and the area of moorland at their disposal. Farmers were therefore unable to cultivate heathland into arable land or grassland at will.
Since the advent of artificial fertilisers, from approximately 1900 onwards, these soils have been turned into large-scale farming land (so-called cultivated soils).

Drift sand landscapes.

Drift sand landscapes are spread across cover sand areas and can also be identified in the ice-pushed ridge landscape, for example along the shores of the river Meuse and the Overijsselse Vecht, in the area of the Meuse and Waal (the Drunense Duinen), on the Hoge Veluwe (for example near Kootwijk), and along the Hondsrug (Drouwenerzand), etc.
These drift sands are much younger than cover sands. They were formed in the Holocene epoch, when unvegetated soil became wind-borne as a result of man-made damage to natural vegetation (deforestation, forest fires, intensive sheep grazing). Other causes include drought or drifting of temporarily dry river beds. The wind-borne sand was deposited a little further afield, on lower and moist plains with sufficient vegetation, creating wind driven dunes. The original, humus-rich soil profile can often still be found at the bottom of drift sand profiles. The once elevated, dry regions from where the sand had originated, now became the lowest sections of the terrain. In terms of pedology, drift sand soils are relatively young, and are characterised by little profile formation.

Dune and sea sand landscape.

The soils of this holocene landscape are even younger than the above sand soils, and can be found along the North Sea coast.

Dune sand landscape can be categorised into:
- young dune sand landscapes
- old dune sand landscape.

Young dune sand landscapes

Young dune sand landscapes to the south of Egmond consist of calcareous sand, and to the north of non-calcareous sand. In principal, these landscapes incorporate the actual dunes. The average particle size of the sand is ? 200 u. There is virtually no sign of soil forming.

Old dune sand landscapes

Old dune sand landscapes consist of non-calcareous (decalcified) flat bars ('geest' - sandy soil between the dunes and the polder) with the intermediate low strand plains. This landscape dates from ? 2300 years BC.
Century-old forest vegetation has created a forest profile in the soil, especially in moist sections of this area.

Ground-water

There is a strong correlation between the quality of bar soils and ground-water table. This soil is ideal for bulb cultivation when situated at ? 50 - 60 cm below surface level, and is bereft of anomalous layers (for example silt- or humus layers). Pomology is also possible, although this requires good groundwater management (no strong fluctuations). This has been achieved in the province of Zuid-Holland by maintaining the polder level. Elsewhere, this has been the case by continuous water flows from the elevated dune complexes. However, this is usually insufficient; this reservoir was also depleted by dune water supply. In order to access groundwater, partial sand excavation was commenced in several dune sand areas. These are known as sand quarries.
Strand plains are usually characterised by clay deposits or peat formation. They are predominantly used as grassland, while marine sand soils are treated near the flat soils of the sea clay.

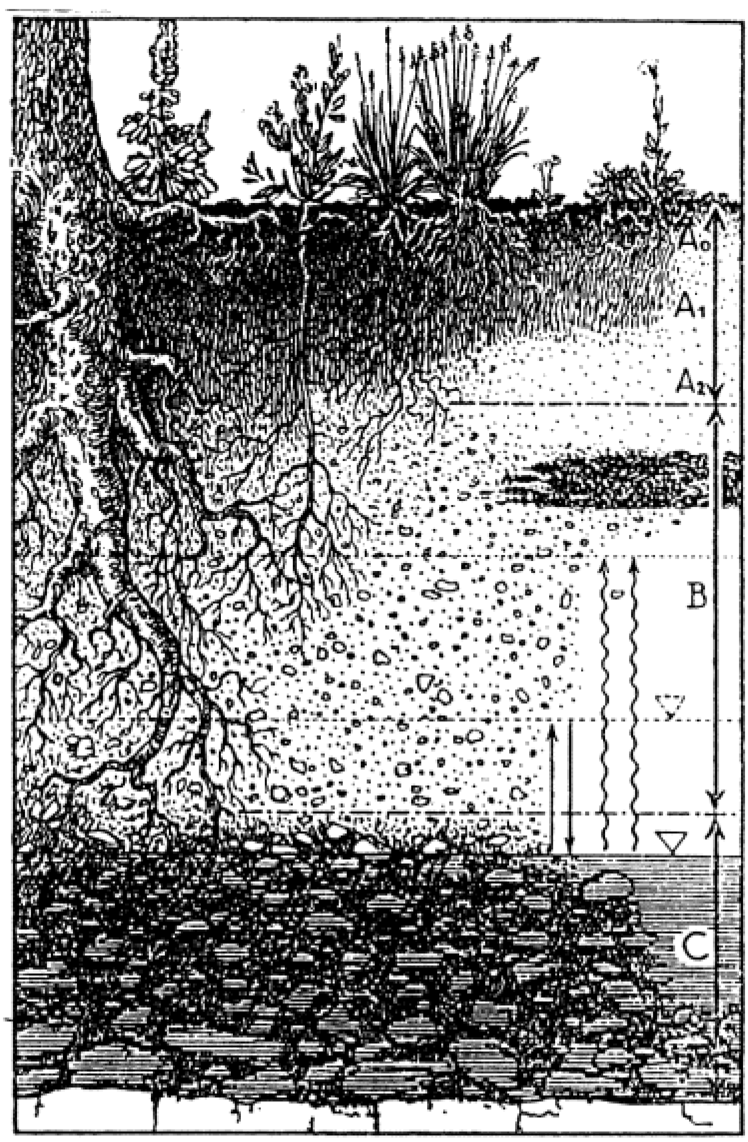
Soil-forming processes in sand soils.

As can be deduced from the above, the most highly developed soils were created by sand deposits, as these were exposed last to soil-forming processes. For sand soils, the most important processes are:

- illuviation and eluviation;
- accumulation of soil-organic matter.

Illuviation and eluviation

Sand soils can be subject to eluviation and illuviation of iron, aluminium and organic matter, creating podzol soils as a result . These soils contain A2-horizon, which is bereft of iron, aluminium and soil-organic matter, and is found directly the humus-rich overburden (A1 see *Fig. 21*). The layer below is known as the B-horizon, containing extra organic matter and occasionally iron and aluminium (B).



A.v. Kruedener (1951)

Fig. 630 Soil profile

A1 darker coloured layer, soil-organic matter accumulation
A2 layer, subjected to eluviation; usually lighter in colour than A1 to ash grey (podzol), eluviation consists of organic matter and/or minerals, such as calcium carbonate, iron, aluminium and silt
B illuviation layer; dark to black in colour, illuviation of matter mentioned under A2
C layer of unconsolidated material, also known as parent material
G this layer shows strong reduction.

The G layer is affected by ground water action; this layer can form the initial layer in all horizons. In A2G and BG for example, the reduced layer can be identified by its blue-grey colour, caused by a reduction in iron; the transition is known as the ground-water table. Above the ground-water table, the profile is initially characterised by alternating rust and grey spots with a uniform rust colour. (NB these colours only occur in iron-rich soils). In principle, each soil profile contains all soil horizons. However, due to a negligible period of soil-formation, they are not always identifiable as such. This is especially applicable to the situation in the Netherlands.

We can distinguish two types of podzol soils:

- mor podzol soils ;
- humus podzol soils,

Mor podzol soils were created on relatively mineral-rich sand soils, for example on the submerged pre-glacial Veluwe (impounded river sands) and loamy sand soils. Due to the slightly higher pH value of these soils, they were not subject to extreme forms of illuviation and eluviation. There are no clearly identifiable differences in A, B and C-horizons, i.e. there are no bleached layers and *orterde*. The A-horizon still contains traces of iron. The removal of organic matter from this layer through calcination produces a less red-brown colour than in the underlying, clearly reddish-brown B-horizon. The organic matter in this B-layer is made up of mor.
These soils were once referred to as humus-iron podzoil soils or brown forest soils. Ground water had no influencing role in the formation of these soils.
These conditions are ideal for the growth of richer vegetation, such as deciduous forests, creating a thicker humus-rich top layer than is the case in heathland.

In humus podzol soils, iron and soil-organic matter is heavily subject to eluviation. This process was possible on mineral-poor, acidic sand soil, and was enhanced by "acidic" vegetation such as heathland. These profiles are therefore far more prominent on heathland-reclamations of cover sands. Humus podzol soils can be found above and below groundwater level. In humus podzol soils, the A-horizon is yellow deferrized; a portion of this layer is usually lacking in humus (bleached layer). The B-horizon is fully or primarily deferrized and usually consists of a typical humus or humus iron bar. This humus is liquefied (amorphous humus), and sand particles are often bonded together. Deferrizing is easy to determine through calcination.

Accumulation of soil-organic matter

A significant percentage of sand soils consists of a distinctly dark overburden. This could be the result of supply of soil-organic matter by lush plant growth, medium decaying of this soil-organic matter (too wet, too acidic) or the supply of humus-rich soil by man (accumulation). In the new Dutch classification system, these soils are known as eerd soils. A1 layers thicker than 50 indicate thick *eerd* soils, including enkeerd soils (old farmland or ash soils). The humus-rich overburden was created by embanking with sod fertilizer, and stable sand in the fertilizer and drift sand. This humus-rich cover contains podzol soils (with bleached layer and orterde) as well as groundwater profiles. Provided the humus content is satisfactory and the humus-rich cover is sufficiently thick, these soils make good arable soil. The pH is frequently too low. We can distinguish black and brown enkeerd soils.
Black enkeerd soils were created in regions with exclusive use of heather sods. Brown soils indicate a nutritious soil and higher quality humus; they are elevated with forest litter or grass sods.

<table>
<tr><td rowspan="7">PODZOL SOILS</td><td colspan="3">Moder podzol soils Moder podzol soils - B</td><td>Woody podzol soil thin A1 (brown forest soil</td></tr>
<tr><td rowspan="6">Humus podzol soils humus podzol - B</td><td rowspan="4">Hydro podzol soils (wet)</td><td rowspan="2">Peaty podzol soils with peaty topsoil</td><td>Peaty podzol soil A1 (layers in low cultivated soils)</td></tr>
<tr><td>Dam podzol soil with humus sand cover (worn valley soil)</td></tr>
<tr><td rowspan="2">Ordinary hydro podzol soils</td><td>Field podzol soil thin A1 (low reclamation soil)</td></tr>
<tr><td>Laarpodzol soil thicker A1 (older reclamation soil)</td></tr>
<tr><td colspan="2" rowspan="2">Xeropodzol soil dry</td><td>Hair podzol soil thin A1 (high heathland reclamation soil)</td></tr>
<tr><td>Camp podzol soil thick A1 (older reclamation soils)</td></tr>
</table>

Fig. 631 *Podzol soils*

<table>
<tr><td rowspan="6">EERD SOILS</td><td colspan="2" rowspan="2">Thick eerd soils thick A1</td><td rowspan="2">Enkeerd soils</td><td>Brown enkeerd soils brown A1</td></tr>
<tr><td>Black enkeerd soils black A1</td></tr>
<tr><td rowspan="4">Thin eerd soils</td><td rowspan="3">Hydro-eerd soils no iron cutans or reduction within 80 cm</td><td>Peaty eerd soils (peaty eerd layer)</td><td>Bog eerd soil (lowest sections of stream valleys)</td></tr>
<tr><td rowspan="2">Ordinary hydro-eerd soil no peaty topsoil</td><td>Brown stream eerd soil brown A1 and rust spots (gley soils from stream valleys)</td></tr>
<tr><td>Black stream eerd soil black A1 further ditto</td></tr>
<tr><td colspan="2">Xero-eerd soils iron cutans</td><td>Border eerd soil thin A1</td></tr>
</table>

Fig. 632 Eerd soils

Loamy soils

Loamy soils are divided into loess soils and weathering soils. Loess soils are primarily confined to Zuid-Limburg and also occur in pockets in Noord-Brabant and Gelderland (including the Postbank). Loess is an Aeolian deposit characterised by uniform grain-size frequency distribution and a high percentage of loam. These soils have a clay-retaining horizon

caused by illuviation . Loess soils are the oldest arable soils in our country. The landscape is highly uneven and prone to water erosion.
Old weathering soils are confined to pockets in Zuid-Limburg. They occur on old geological formations such as chalk and clay with flints. These soils contain clear traces of different soil forming processes.

4.3.4 Peat soils and peat reclamation soils

Genesis of peat

Unlike clay and sand, most of the peat types in our country were not deposited. They were formed in situ from partially decomposed plants. This vegetation had failed to decompose fully due to extremely wet conditions (lack of aeration) and, sporadically, low pH values. This created an accumulation of organic matter, sometimes into extremely thick parcels.
Most peat layers have been temporarily subjected to decay, as they remained above the water surface for an indeterminate length of time, allowing oxygen to penetrate. This explains the presence of groundmass, containing remains of plants and clearly identifiable remains of carrots, twigs, seeds, etc.

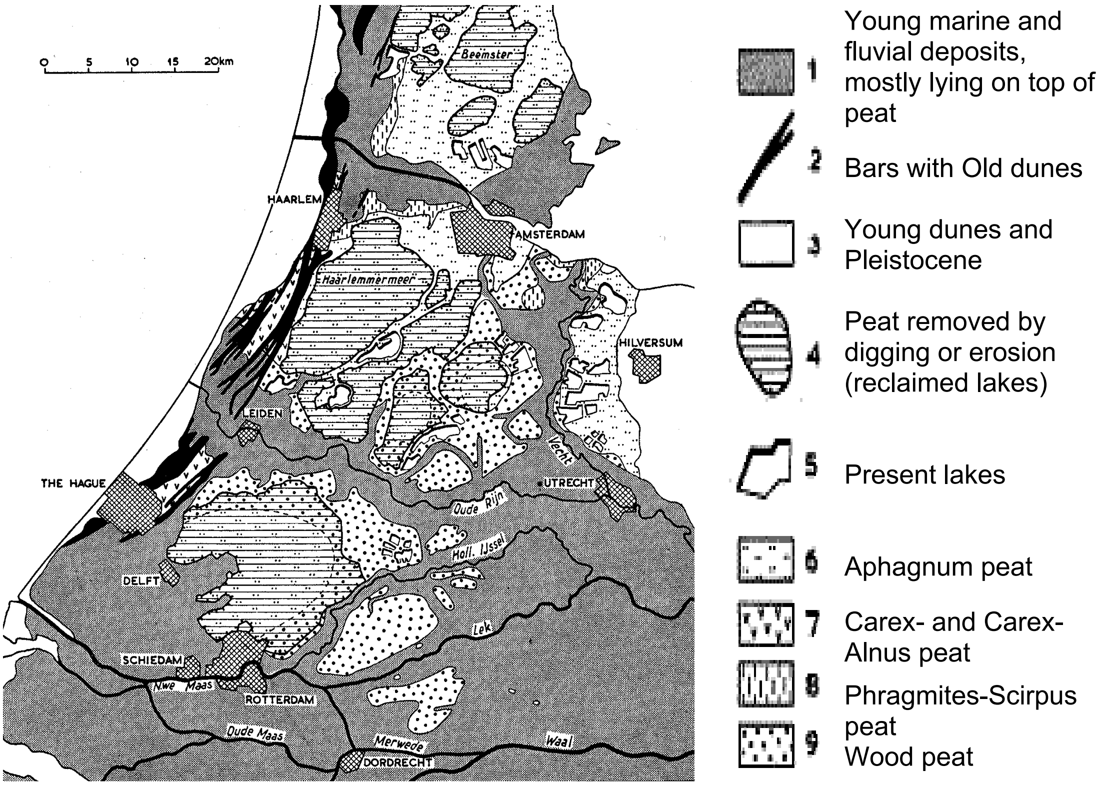
Peat types

The peat types we know are the result of different plant communities working together to form peat.
Peat can be divided into the following important groups:
- eutrophic peat : formed in water with a high nutrient content;
- mesotrophic peat : formed in water with a moderate nutrient content;
- oligotrophic peat : formed in water with a low nutrient content.

The most important peat types are:
- young sphagnum peat;
- old sphagnum peat;
- wood peat;
- sedge peat;
- reed peat.

Young sphagnum peat (bolster dusty peat).

(bolster dusty peat).This type of peat is light brown in colour. Its building blocks, peat mosses, are clearly identifiable.
Peat moss grows in a moist environment with a low nutrient content, i.e. in areas with a lot of rain water and an absence of ground, river and sea water. Young sphagnum peat is not suitable for reclamation. It is sold as mull or ground peat.



Stiboka (1965) Bodem van Nederland (Wageningen) p. 146

Fig. 633 Botanical peat types

Old sphagnum peat

Old sphagnum peat has a dark colour, and is well-decomposed peat, hence its popular name of black peat. Peat mosses are difficult to identify in the black groundmass, although we can still distinguish heather twigs and stalks, as well as fibrous cotton grass. Peat moss is found beneath the young sphagnum peat. This peat type is ideal for making turf. The genesis of old sphagnum peat is identical to that of young sphagnum peat. It is however much older: the growth of peat moss was repeatedly interrupted by sporadic dry spells, causing the formed peat moss to weather and darken in colour. These dry periods additionally encouraged a different type of plant growth, namely heather, cotton grass etc.

Wood peat

Wood peat is a highly decomposed peat type. Its building blocks, twigs and tree roots, are clearly identifiable in the darkly coloured groundmass. In the ground water zone, it is reddish-brown in colour. Wood peat is usually mixed with a percentage of ooze, as it is primarily formed in areas that are sporadically submerged by river water. This water provides much needed nutrition to encourage tree growth, while water runoff will aerate the soil sufficiently to enable root growth. This peat is not suitable for excavation. This explains why wood peat has remained unexcavated in the West of the Netherlands, as opposed to sphagnum peat.

Sedge peat

Sedge peat is also a darkly coloured, shapeless peat type. We can however identify numerous small, grey roots in the groundmass, and occasionally birch and gale twigs as well as reed. It was formed in a moist environment with a medium nutrient content, i.e. in areas characterised by ground water penetration.

Reed peat

Reed peat is a lightly coloured, somewhat layered peat type. It is easily identifiable by the multitude of coarse, flattened rhizomes of the reed. It usually contains a relatively high percentage of ooze; reed peat is formed in moist areas with a medium to high nutrient content, usually brackish water. These conditions are perfect for reed growth, and also explain the presence of ooze. It is often acidic, with yellow acid sulphate spots. Reed peat is most prevalent in the transitional process from peat to clay.

Dredge spoil and peat dust

D r e d g e s p o i l and l a k e p e a t d u s t are subaquatic deposits of organic matter in ponds, lakes, and occasionally old ditches. They were formed in water with a high nutrient content from the remains of lower plants and animals, such as marine algae, clams, and diatoms. It is usually mixed with clay or peat, reaching the lakes as a result of erosion. Gyttja in water with a high nutrient content, deposited dredge spoil or peat dust. Dy in acidic water, deposited dredge spoil or peat dust.

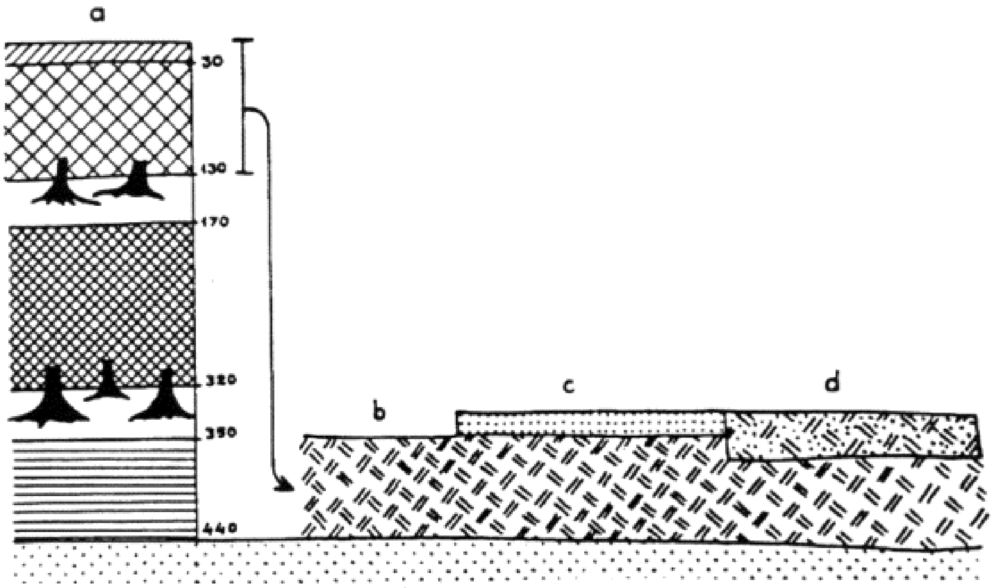
Low-lying peat soils

This category principally incorporates dry and wet p e a t s o i l s , composed of different peat types (along rivers and stream valleys, usually wood peat and bog peat with wood remains). At some distance from the river, these soils turn into reed and sedge peat, and a little further into sphagnum peat. These peat types are often found layered on top of each other in extremely thick parcels, including the presence of clay particles. Insofar as low-lying peat comprises sphagnum peat with a low clay content, this will largely have been dredged or dug for excavation purposes. This process formed the elongated lakes in the west of the Netherlands and in north Overijssel, the majority of which have been impoldered since the sixteenth century. Several of these lakes, such as the Haarlemmermeer, were already peat lakes before peat excavation activities began.

Surrounding the remaining peat lakes, such as the W e s t e i n d e r p l a s s e n , L o o s d r e c h t s e P l a s s e n and also in north western Overijssel and the Zaanstreek region, are large areas with p e t - or d i e h o l e s . These are the remnants of the times of peat excavation and consist of elongated channels, from which peat has been dredged or dug. These channels have been separated by strips of unexcavated peat, the ribs or embankments, onto which the turf was dried. The channels will gradually fill up, creating broads in different warping stages. Some complexes have been reclaimed into poor grassland and are referred to as manmade broads. The unexcavated section of the low-level bog consists of non-calcareous clay soils with a peaty top layer or peat soils with a thin clay cover. They were formed as a result of the gradual wedging out of sea and river clay across the peat, and are usually the transitional strips between sea or river clay soils and lowland peat soils with a low clay content.

Upland peat – and valley soils

U p l a n d p e a t is elevated in comparison with the sand soils of the surrounding area. It mainly comprises sphagnum peat with a low clay content. Unexcavated and partially dug upland peat only occurs in small pockets in E m m e n , V r i e z e n v e e n and the P e e l . They are the last remnants of elongated upland moors of the north-east and south of the Netherlands.



Stiboka (1965) DE BODEM VAN NEDERLAND (WAGENINGEN) P. 152

Fig. 634 Peat and valley soil

Peat excavation
Following drainage, the peat of these areas was cut for peat excavation, and the residual peat reclaimed into valley soil. The turf was usually carried by ship via channels, which doubled as drainage and outcrops. The peat of the younger valley soils was systematically removed, and the soil reclaimed into man-made land. The soil profiles consist of a humus-rich sand cover, resting on 15-50 cm recessed, young sphagnum peat (bolster). Below this layer are usually layers of solid peat and, occasionally, a spaded mixture of sand and peat.

Older valley soils
The peat of the older valley soils was removed in a similar fashion to that of the younger soils (albeit less systematically) and reclaimed. The soil usually lacks the bolster layer, essential to enable plant growth, or has disappeared altogether due to regular ploughing; these are known as worn valley soils. The irregular presence of solid peat layers seriously impedes the water movement of the valley soils.

Profile of low-lying peat in the West of the Netherlands
A typical profile of low-lying peat soil in the west of the Netherlands comprises the following:

0 - 30 cm	young sea clay,
30 - 45 cm	reed peat,
45 - 80 cm	sedge peat,
80 - 250 cm	young sphagnum peat,
250 - 280 cm	spalter peat,
280 - 400 cm	old sphagnum peat,
400 - 450 cm	sedge peat,
450 - 500 cm	reed peat,
500 -	old sea clay.

This profile is the result of the gradual closing off of the western old sea clay area from the sea. Salt water gradually turned into brackish and finally fresh water; this explains the initial presence of reed peat and sedge peat. The area was also subjected to warping, producing groundwater peat, rainwater peat and lastly sphagnum peat.
Lowland cracked peat was formed during temporary dry spells.

Sea effect on profiles in the West of The Netherlands
A typical feature of the peat types in the west of the Netherlands is that, unlike the high-lying peat in the east, they are "submerged". The sea became an increasingly influential factor, causing the groundwater table of this area to rise, encouraging new growth of groundwater peat on top of the rainwater peat (in other words, a layer of sedge peat on top of sphagnum peat). In some areas, seawater would submerge this peat, creating silted reed peat. This process continued: eventually, large sections of peat were covered with a small layer of young sea clay, or acquired a muddy overburden.

Bog peat in stream valleys
Bog peat was created in marshy areas, characterised by limited tree growth. It can be found for example in the centre of stream valleys of sand soils.

PEAT SOILS	Eerd peat soils mouldered overburden	Clay-like eerd peat soils clay-like A1	Aarveen soil thick A1 (peat soil from the wood peat area of Zuid Holland, horticulture)
			Koopveen soil thin A1 (peat soil from the wood peat area of Zuid Holland, grass land)
		Eerdveen soils with a low clay content A1 with a low clay content	Bosveen soil thick A1 (unexcavated upland peat with upper soil layer)
			Made peat soil thin A1 (bog peat in lowest sections of stream valleys)

<table>
<tr><td rowspan="4"></td><td rowspan="4">Raw peat soils, overburden scarcely mouldered</td><td>Initial raw peat soils unripened</td><td>Shoal peat soil (weak low-level peat soil)</td></tr>
<tr><td>Podzol raw peat soils peaty B (glide) ripened</td><td>Mouth peat soil with sand cover and glide (peat colonial soil)</td></tr>
<tr><td rowspan="2">Ordinary raw peat soil Ripened</td><td>Weideveen (Moor marsh) and waardeveen (Nevermore) soil with clay cover clay-on-peat soil)</td></tr>
<tr><td>Lake peat soil with sand cover (peat colonial soil)</td></tr>
</table>

Fig. 635 Peat soils

N.B.: M o u l d e r i n g : drainage enabled soil life, influencing the peat. Plants that were still recognisable at this point disappeared, creating a darkly coloured humus-type peat.

4.4 Millimetres

4.4.1 Soil structure

S o i l s t r u c t u r e is determined by the spatial arrangement and bond of soil particles, i.e. the mutual arrangement of soil particles and the corresponding voids, and the bond between the particles, i.e. composition.
The significance of soil structure lies in the presence of pores and voids, into which air, water, roots and contamination can penetrate. Coarser pores are responsible for discharging excess water.

Structure types

There is a range of structure types, which must be taken into account when preparing a terrain for development. We can identify the following structures:
- crumb
- clod
- prismatic structure
- platy structure
- grain structure
- (pumiceous structure / concrete structure)

Agricultural use

Crumb and clod structures play a particularly important role in agriculture, while prismatic and platy structures are often responsible for causing floods, as these structures do not allow for water penetration. These layers are found on the earth's surface as well as deeper down in the ground. Grain structures are found mainly in sand soils; they can easily become wind-borne, provided they are located on the earth's surface and are bereft of vegetation (this in turn has implications for the surrounding area). In addition, these grounds easily silt up or slam shut during heavy rainfall, leaving large pools of water.

Mechanical impacts

Grounds that are frequently subjected to (agricultural) traffic tend to have poorer structures. On-site material storage, for example during building work, can also result in poorer soil structures.
As mentioned above, water behaviour in the soil is heavily dependent on the soil structure. Platy structures are not conducive to water discharge, while other structures are characterised by more stable water runoff.

Soil profile

Individual soil particles present in the soil are influenced by water and vegetation, creating various processes contributing to soil formation and the formation of a soil profile. These processes occur under the downward influence of gravity. The following processes can be identified:
- water inflow and drainage (illuviation and eluviation); heterogenisation
- inflow and conversion of organic material
- homogenisation by man, plant and animal
- oxidation and reduction (primarily conversion of iron)
- maturing (withdrawal of e.g. water of recently raised ground)

Layers

These processes are responsible for stratification, which was originally lacking. The layers, known as s o i l h o r i z o n s , differ in terms of composition and properties, and together form the soil profile. Soil scientists classify profile horizons using the letters indicated in 30.
W e a t h e r i n g of soil particles and solid parent material continues during soil genesis or soil formation, slowly releasing fertilizing substances and minerals.

4.4.2 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 classification of ground water.

Soil water and ground water in geology

In Geology, subterranean water is divided into two groups; water in unsaturated upper zone – soil water - and water in the underlying saturated zone – groundwater.
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 groundwater table.

Fresh water and sea water

In general, the term groundwater refers to fresh water, responsible for all manner of 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[a]. The deep polders of these provinces (4 to 6m below ground level) contain salt seepage water[b] due to the absence of, or excessively thin layer of, fresh groundwater due to (surface) water removal.

Quantity

The following table indicates the estimated quantity of water on earth. A distinction is made between fresh water and salt water.

	Quantity $km^3 \times 10^3$	% of total
Surface Water		
Fresh water lakes	125	0,009
Salt and brackish lakes and in land seas	104	0,008
Main quantity of rivers and canals	1,25	0,0001
Subsoil water		
Water in un saturated zone of the soil	67	0,005
Un deep groundwater (till depth of 800 m.)	4168	0,31
Deep groundwater (till depth of 5000 m.)	4168*	0,31
Remaining occurrences of water		
Ice caps and glaciers	29200	2,15
Atmosphere (on sea level)	13	0,001
Seas and oceans	1320000	97,2
Totals (in round figures)	1359000	100

U.S.-Geological-Survey (1969)

Fig. 636 Water on earth

[a] Freshwater has a lower specific gravity than salt water, and as such “floats “ on the salt water.
[b] Seepage is a vertical groundwater flow; upward movement from the ground water table to the surface under influence of water pressure.

	volume (in km³ × 10³)	percentage van totale volume
Oppervlaktewater		
zoetwatermeren	125	0,009
zoute en brakke meren en binnenzeeën	104	0,008
gemiddelde inhoud van waterlopen	1,25	0,0001
Ondergronds water		
water in de onverzadigde zone	67	0,005
ondiep grondwater, tot een diepte van ± 800 m	4 168	0,31
diep grondwater, tot een diepte van ± 5000 m	4 168*	0,31
Overige voorkomens van water		
ijskappen en gletsjers	29 200	2,15
atmosfeer (op zeeniveau)	13	0,001
zeeën en oceanen	1 320 000	97,2
Totalen (afgerond)	1 359 000	100

Table pag. 316 Pannekoek

Fig. 637 Estimated amounts of water (see also Fig. 339*)*

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 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.

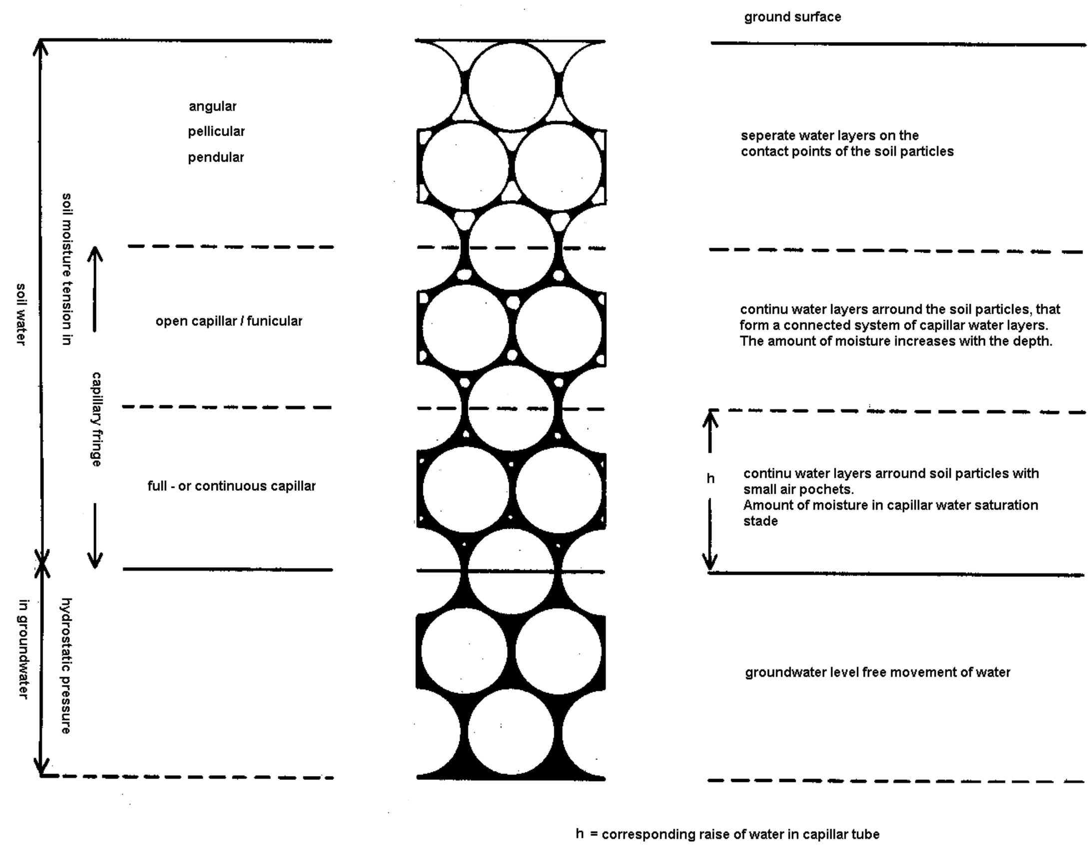
Capillary zone

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 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. 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 (a d h e s i v e forces). Water that is 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.



A.J. Pannekoek (1973) Table p.316

Fig. 638 Capillary action of the soil

Capillary levels

Based on laboratory tests and field observations using dipsticks, the following values for c a p i l l a r y p i e z o m e t r i c l e v e l s above the ground-water table have been determined in accordance with Bogomolov (1958):

– 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.

Water-table classes.

G r o u n d w a t e r t a b l e s are divided into w a t e r - t a b l e c l a s s e s , where the highest mean groundwater level (H M G L) and lowest mean groundwater level (L M G L) is processed. The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative. 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. 639 Main subdivision of water-table classes (groundwater level in cms below ground level)

Horizontal groundwater flow

Downward g r o u n d w a t e r f l o w s 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.
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 (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

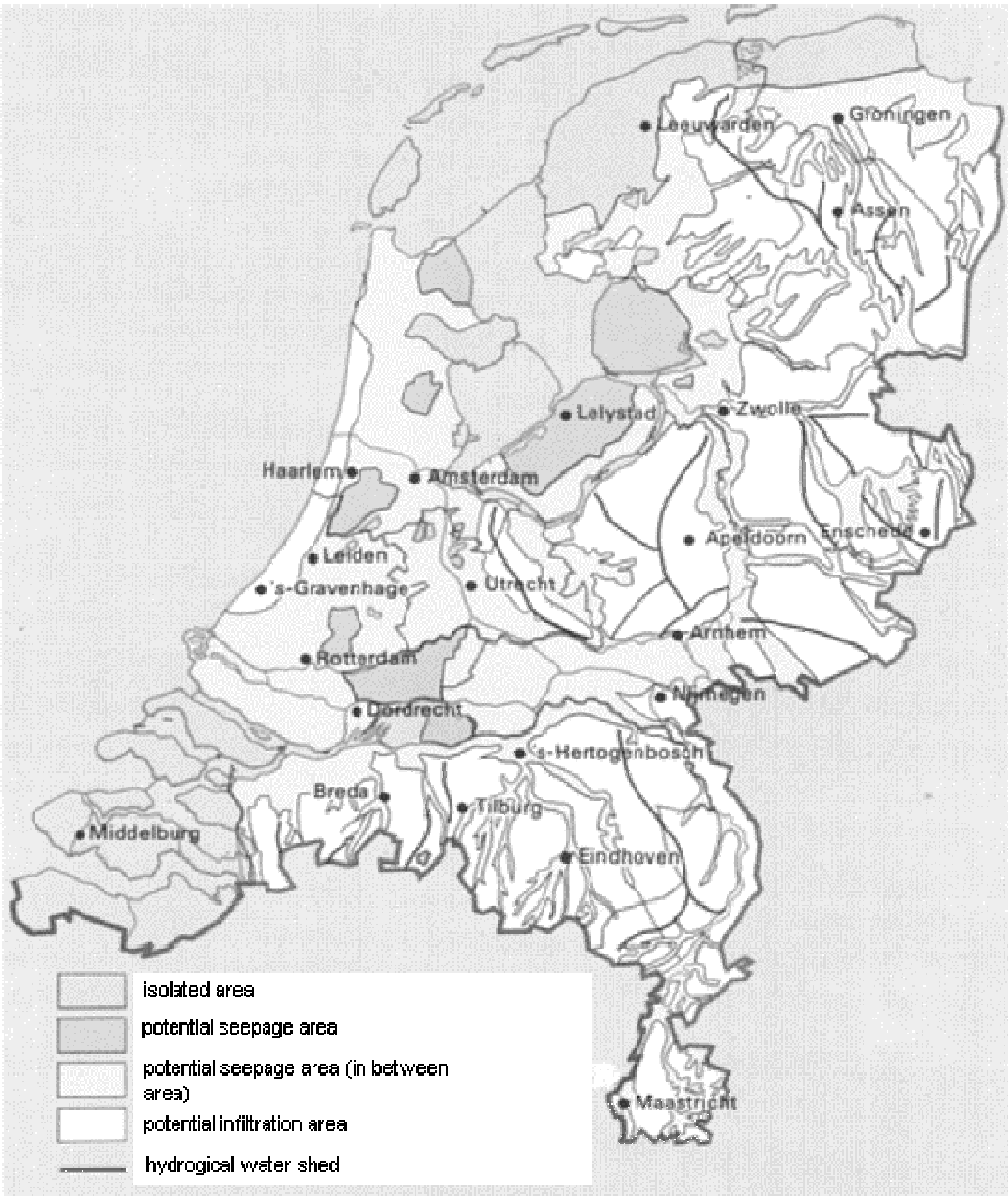
E f f l u e n t s e e p a g e is caused by water pressure from an elevated area to a low-lying area. Effluent seepage can occur along h i l l r i d g e s , when the groundwater level on the hill ridge is higher than the adjoining areas. This causes a subterranean flow in the direction of the lower-lying area. Springs are created in areas where the water issues to the earth’s surface.

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 s e e p a g e w a t e r 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.



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

Fig. 640 Potential seepage areas

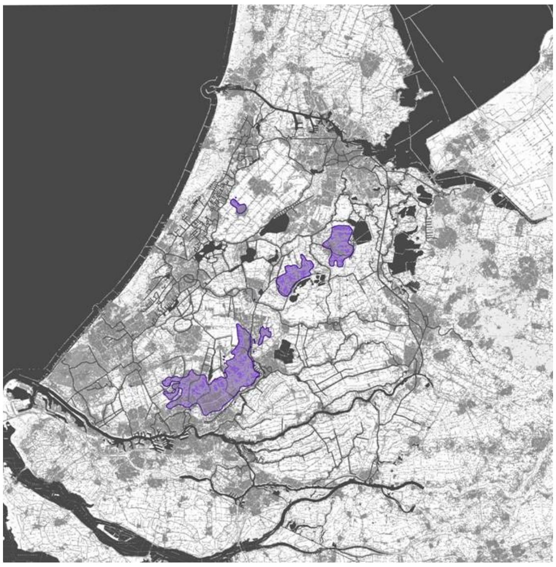


Fig. 641 Deep polders in the Randstad <5m-NAP

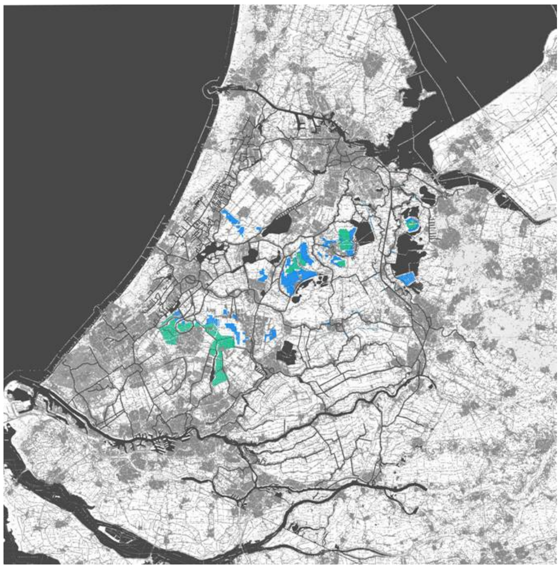
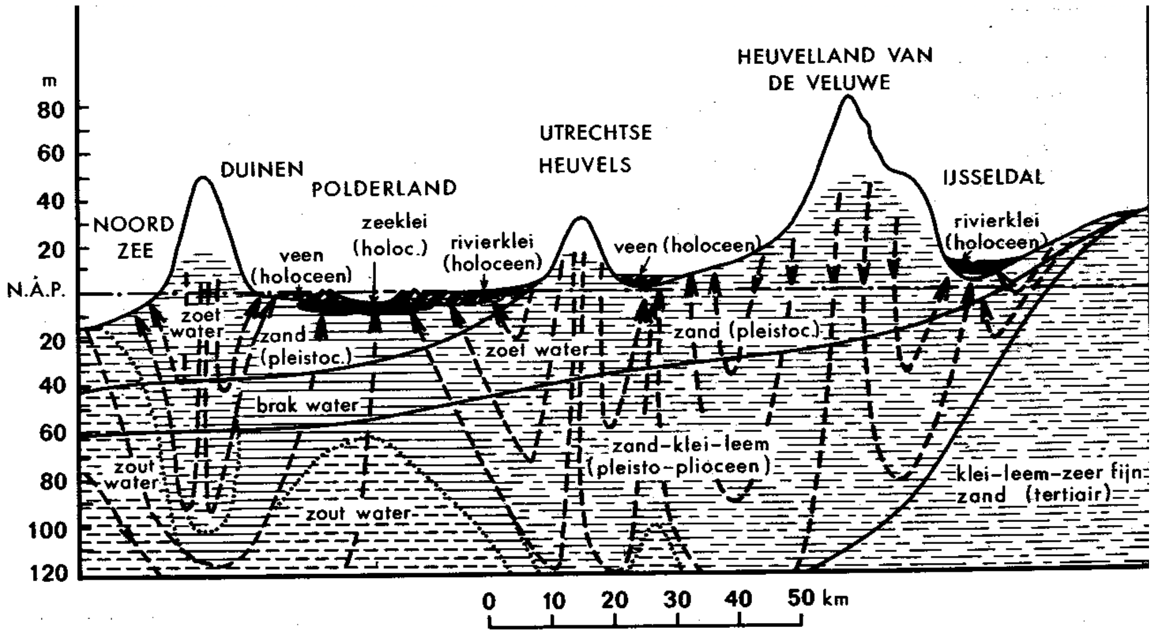


Fig. 642 Seepage areas in The Randstad



A.J. Pannekoek (1973) p. 323

Fig. 643 Water in the dunes

Schematic hydrogeological cross-section of the Netherlands (from: Commissie-Drinkwatervoorziening-Westen-des-lands (1940))

Supplemeted with a schematic not quantitave image of the pattern of groundwater flowlines for the deeper groundwater flow. The precipitation 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 4.6.1, page 370.

4.4.3 Soil horizon differentiation

The potential outcome of all these soil forming processes is that soils that originally “looked the same”, will start to differ from each other in the course of the centuries (soil horizon differentiation). Soil profiles develop due to a range of factors, including:

- climate (temperature and precipitation)
- parent material
- slope of the terrain
- groundwater level
- period of weathering.

4.5 Micrometres

4.5.1 Chemical composition of the earth's crust

Cooling magma

The composition of the residual liquid is changed as a result of crystallisation of the cooling magma. The first minerals 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 form. This explains the complete absence of beautiful, big crystals in plutonic rock. Rock composition is analysed with the aid of a microscope.

Main minerals

Out of the huge number of known minerals, only a minority are formed as igneous rock. Igneous rock primarily contains the following minerals:

- 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 SiO2, Al2O3, Ca, Na, K, CaO, Na2O, K2O.
- Amphiboles include hornblende, olivine, peridotite; they consist of the elements Mg, Fe, Ca, AlO4, SiO4, 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 SiO4-, AlO4- and FeO4 tetrahedrons.

To a significant extent, this composition also determines the chemical composition of the soil.

4.5.2 Weathering

Sedimentation of weathering products

Weathering occurs when rock on the surface is eroded by water and oxygen. Under the influence of gravitational force and, primarily, water, this material from elevated planes is transported to low-lying basins, where it is subjected to sedimentation into kilometre-thick layers. The Netherlands lies in such a sedimentation basin.

Classification of weathering

We can distinguish three types of weathering:

- physical weathering
- chemical weathering
- biogenic weathering

- Physical weathering mechanically reduces solid rock lying at the earth's surface. No change in chemical composition occurs! The resultant loose material is layered across the original rock. Physical weathering takes place under the influence of temperature, water and/or wind, and is characterised by the processes of expanding and contracting, dissolving, swelling and contracting, and abrasion.
- Once the rock has shattered into smaller fragments - causing the overall surface to expand - chemical weathering starts to play a major part. Under the influence of water, oxygen and acids such as carbon and organic soil acids, numerous minerals are manipulated and converted into new minerals.
- Biogenic weathering can be of a physical or a chemical nature. Rock is split as a result of root growth. Under the influence of fungi and bacteria, organic material releases substances such as acids and CO_2, causing the soil to react in a variety of ways.

4.5.3 Sediments

As mentioned previously, weathered material from elevated areas is transported by ice, flowing water or air (wind) to low-lying areas.

The Netherlands

In the Netherlands, loose material is deposited in different ways and in different periods.

- by rivers from surrounding countries
- by coastal currents
- wind-borne from areas with a lot of loose material such as the dried up North Sea and the elongated river plains during dry periods of the Ice Age (virtually bereft of vegetation)
- by ice from Scandinavia during the penultimate Ice Age.

Material sorting and stratification

In general, sediments are characterised by stratification and material sorting due to the manner of deposition.

- Water deposits are generally stratified, while the layers themselves have a relatively homogenous particle size composition.
- Wind-borne deposits have a uniform composition, provided material is transported across a big distance. Loess has a particle size of 0.05-0.075 mm and cover sand 0.075-0.15 mm. These deposits do not form any stratification within the parcel. Material transported across a relatively short distance, as is the case during dune formation and in sand drift areas, creates areas characterised by cross stratification and relatively little particle size uniformity due to fluctuations in wind velocity.
- Ice deposits, such as boulder clay or t i l l in the north and east of the Netherlands show no signs of stratification and are not sorted (large boulders in loam)

Upward and downward processes

The earth's surface is subjected to two distinct processes. In addition to the upwards weathering processes, soil formation processes occur in weathered loose material. This is a downwards process, and occurs under the influence of water and plant growth.

4.5.4 Soil

Initially, s o i l t y p e s are classified according to particle size:

(large rock block	
small rock block	
large stone	
small stone)	
coarse gravel	
fine gravel	
coarse sand	2000 - 210 □
fine sand	210 - 50
loam / silt	50 - 2
clay	< 2

Fig. 644 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 m2 for sand, 100 m2 for silt and 1000 m2 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.

S a n d f r a c t i o n s retain hardly any water or nutrients. S i l t f r a c t i o n s retain water reasonably well (but not nutrients) and c l a y f r a c t i o n s retain both water and nutrients, and are responsible for soil contamination.

4.5.5 Identifying soil fractions

S o i l f r a c t i o n identification is carried out on the basis of vegetation. C o l t s f o o t for example indicates a high content of soil consisting of particles smaller than 0.016 mm. 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.

4.5.6 Naming of ground types

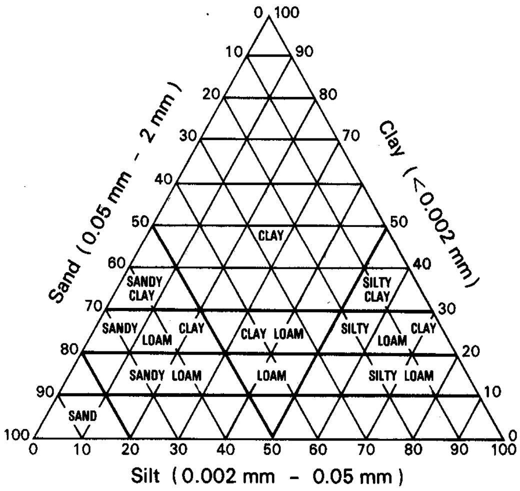
Clay and sand

Naming ground types is one of the most complicated processes in pedology. A distinction is made between clay grounds and sand grounds. These names alone encompass a broad range of particle sizes, as naming is dependent on the distribution of particle sizes in the ground. Based on the present classification, clay grounds comprise a minimum of 8% clay or clay fraction and over 10% of soil containing particles smaller than 0.016 mm (=clay + loam/silt); the rest of the clay soil is made up of sand. Note the difference between clay and clay ground! Clay can be the soil fraction or a mineral, while clay ground is a ground type. Sand ground is mostly made up of particles bigger than 50 mu.

Subdivision clay grounds			Subdivision sand grounds	
% clay	% particles smaller than 0.016 mm	name	% loam	name
0-5	0-6,5	sand with a negligible clay content	0-10	sand with a negligible loam content
5-8	6,5-10	Clay-like sand	10-17.5	sand with a medium loam content
8-12	10-16	extremely light sandy clay	17,5-32,5	sand with a high loam content
12-17,5	16-23	moderately light sandy clay	32,5-50	sand with an extremely high loam content
17,5-25	23-33	heavy sandy clay	50-85	sandy loam
25-35	33-45	light clay	85-100	silty loam
>35	>45	heavy clay		

Fig. 645 Fig. 33 *Subdivision clay and sand soils*

Particle size



Class	% sand	% silt	% clay
sand	80 - 100	0 - 20	0 - 20
sandy loam	50 - 80	0 - 50	0 - 20
loam	30 - 50	30 - 50	0 - 20
silty loam	0 - 50	50 - 100	0 - 20
sandy clay loam	50 - 80	0 - 30	20 - 30
clay loam	20 - 50	20 - 50	20 - 30
silty clay loam	0 - 30	50 - 80	20 - 30
sandy clay	50 - 70	0 - 20	30 - 50
clay	0 - 50	0 - 50	30 - 100
silty clay	0 - 20	50 - 70	30 - 50

(...)

Fig. 646 Soil fraction diagram

4.6 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.

4.6.1 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.

4.6.2 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

[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. 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. 647 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.

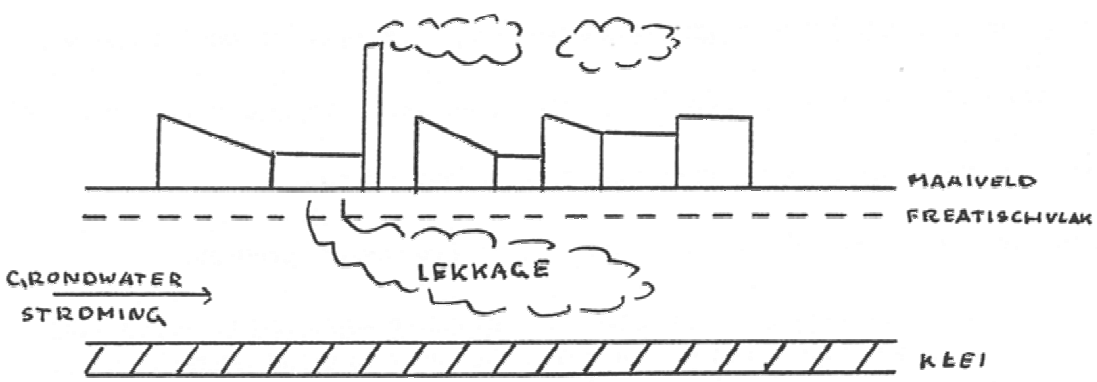


Fig. 648 Horizontal groundwater flow

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.

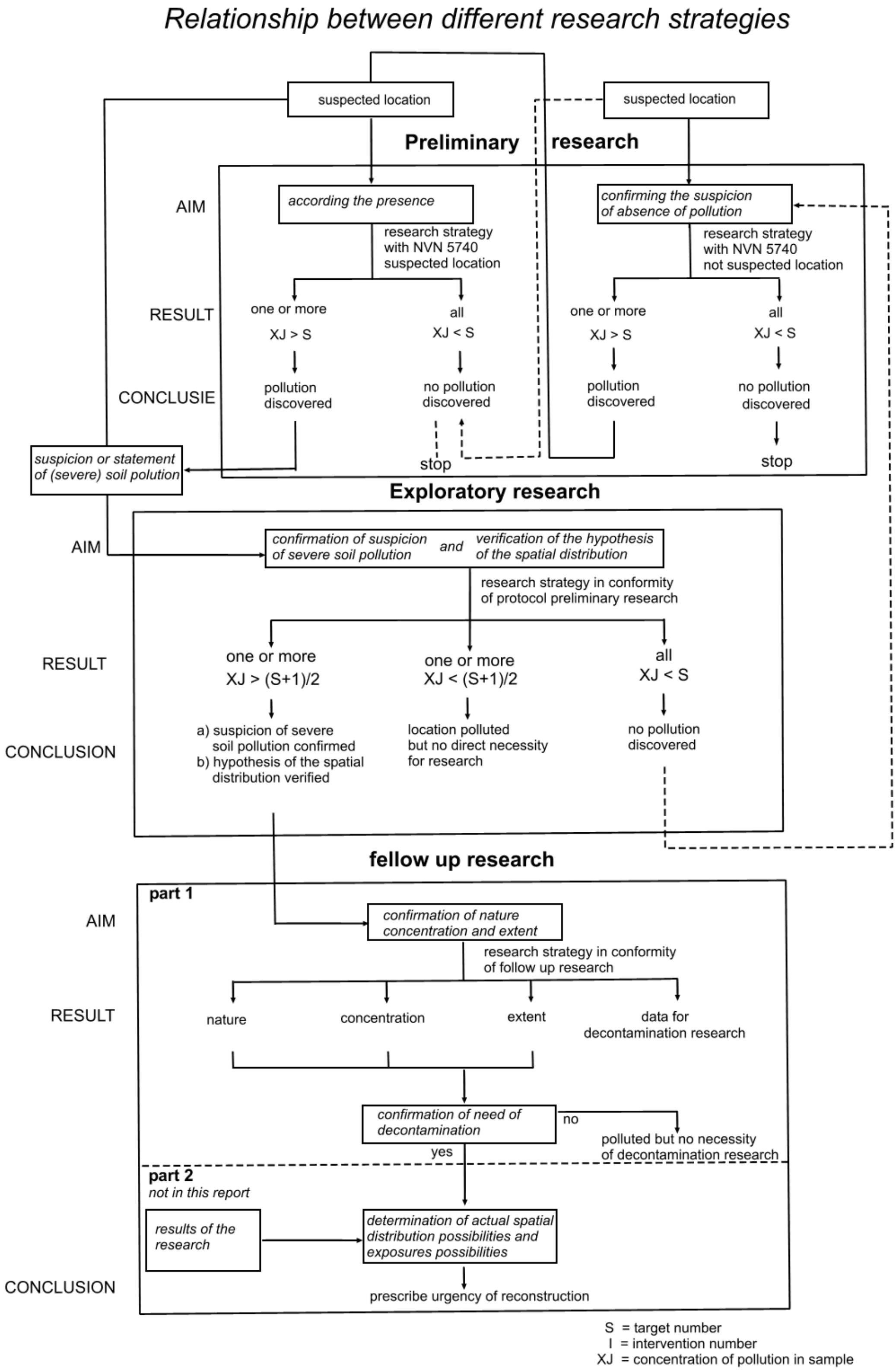
4.6.3 Soil pollution and building activities

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.

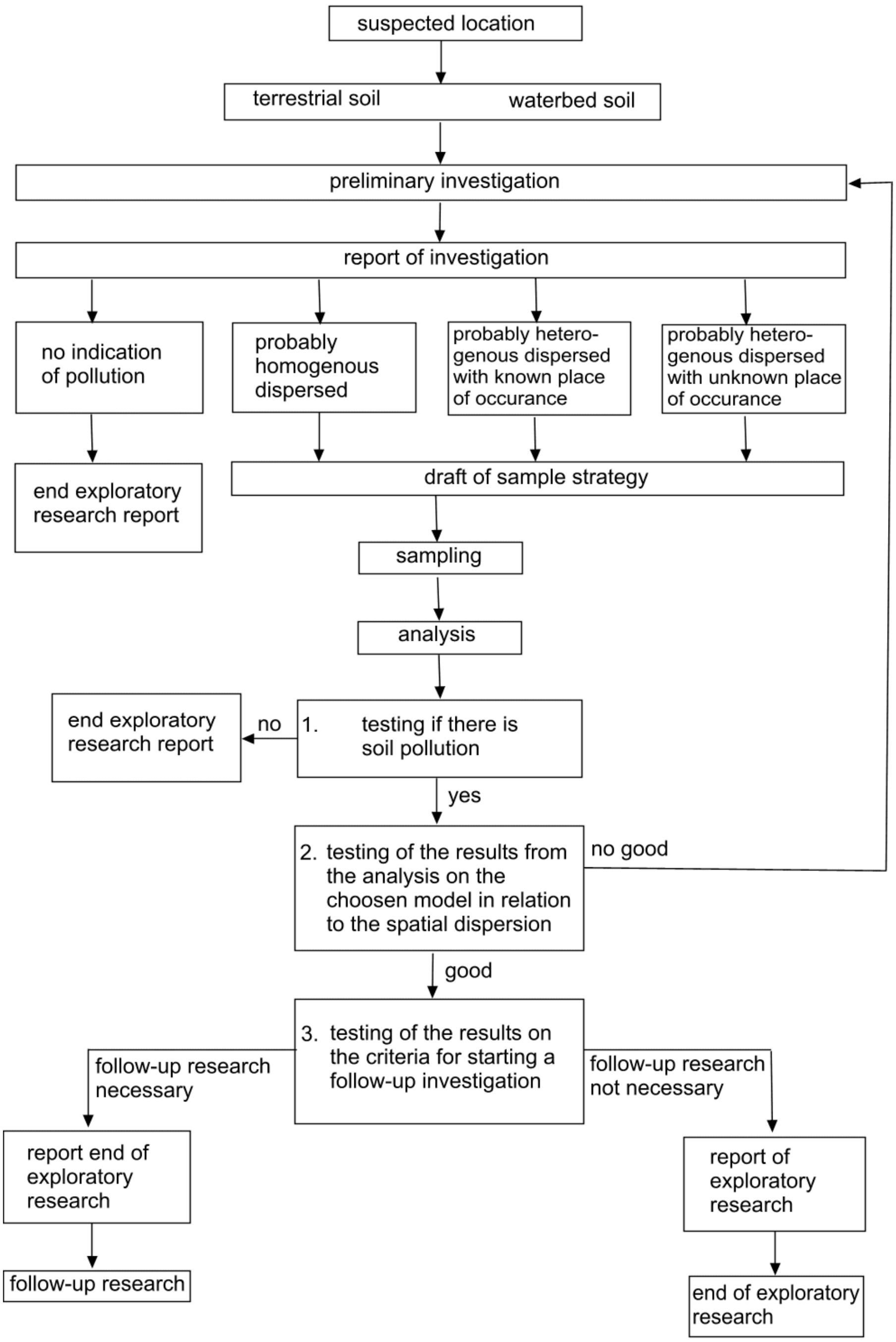


The exploratory research in confirmity of NVN 5740 refer only to the research of a land soil.

F.P.J. Lame and R. Bosman (1994)

Fig. 649 Research strategies in protocols

4.6.4 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. 650 Exploratory survey protocol[a]

[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.

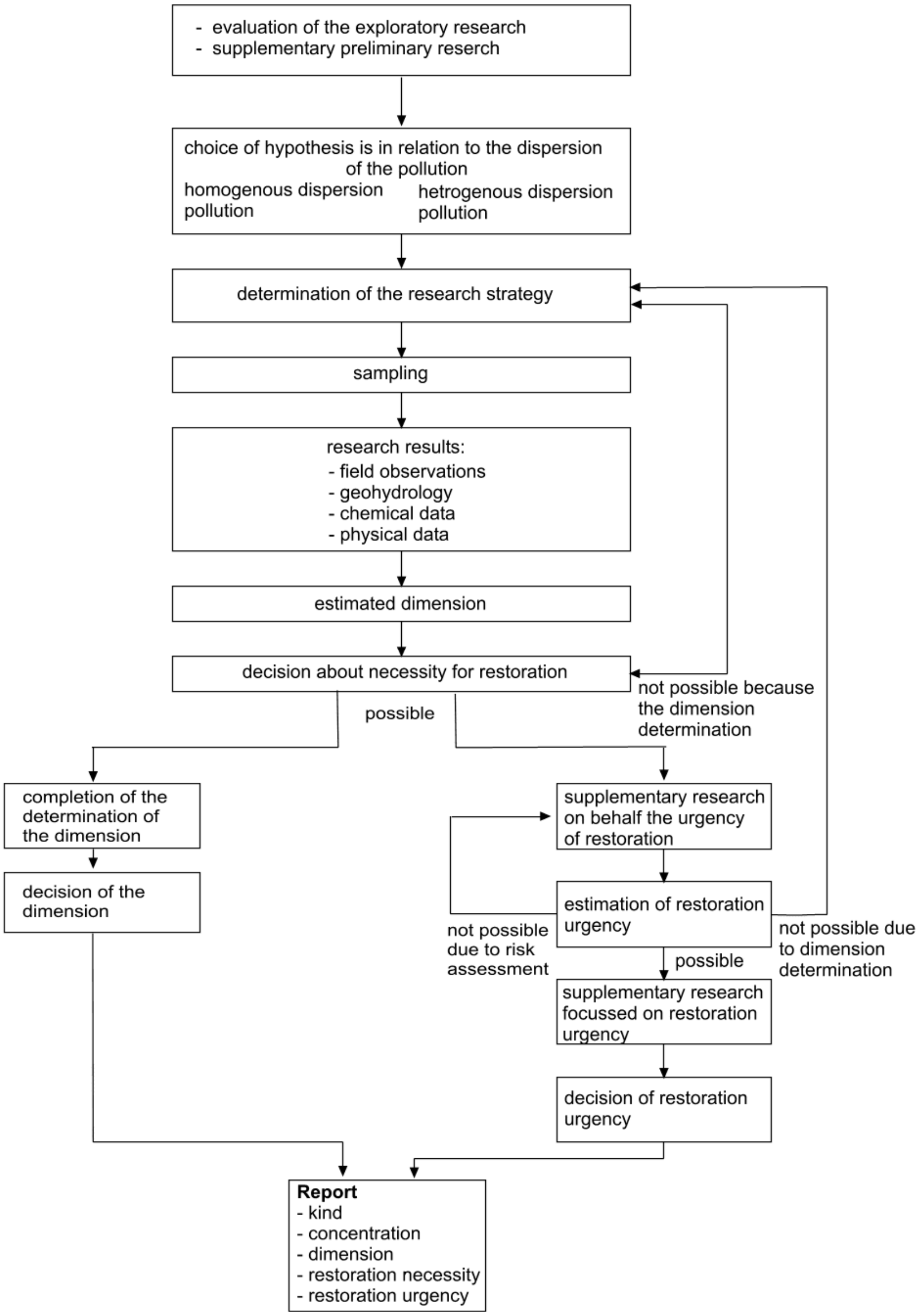
Carrying out the investigation
In principle, anyone can carry out the survey, provided the details on past and present use have been incorporated in the final report. The same applies to information on soil composition and the geohydrolic setting. Soil samples that require analysis can be carried out 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.

Afvoer En Verwerking Van Afvalstoffen Bv	0181-262088
Amitec Bv	0413-269091
Argo Consult	0183-626156
Arnicon Bv	0180-320600
Arns Milieutechniek Bv	0481-377165
Ascor Analyse Bv	076-5415960
Aveco Bv	030-2957977
Bedrijfslaboratorium Voor Ground- En Gewasonderzoek	026-3346346
Bkh Adviesbureau	015-2625299
De Bondt Rijssen Bv	0548-515200
Adviesbureau Brouwers Bv	0475-334651
Adviesbureau Voor Milieutechniek Colsen Bv	0114-311548
Conex	0318-649444
Cso Adviesbureau Voor Milieuonderzoek	030-6594321
Depot Milieubeheer Bv	0181-619788
Dhv Argus	050-3142777
Dhv Milieu & Infrastructuur Bv	033-4682700
Van Dijk Milieutechniek	030-6661745
Dvl Milieu & Techniek	0495-535884
Envicon Bv	045-4041359
Fugro-Ecolyse	030-6050466
Geofox Bv	0541-512501
Geo & Hydro Milieu	0313-450111
Geurts International Bv	0412-624980
Grondmechanica Delft	015-2693500
Grontmij Advies & Techniek Bv	030-2207287

Groundwater Technology	010-4424242
Haskoning Koninklijk Ingenieurs- En Architectenbureau	024-3284284
Heidemij Advies	026-3778609
Heidemij Realisatie	0416-344044
Heijmans Milieutechniek	073-5289358
Ign Bv, Geotechnisch En Milieukundig Onderzoeks- En Adviesbureau	0184-620700
Imd Micon	0342-429711
Milieu Adviesburo Interprojekt	070-3500377
Iwaco Bv, Adviesbureau Voor Water En Milieu	010-2865432
Kejako Recycling Beheer Bv	0487-573025
Landview Bv	0229-246787
Ingenieursbureau Van Limborgh West Bv	0182-571760
Loran Engeneering Bv	0495-531275
Lyons Business Support	0475-481811
Milfac Bv, Milieu-Advisering	058-2157143
M+P Raadgevende Ingenieurs	0297-320651
Nbm Bodemsanering	0183-646744
De Nooij Bennekom Bv	0318-314227
Omegam	020-5976666
Ingenieursbureau Oranjewoud Bv	0513-634567
Pro Analyse Milieulaboratorium	0342-421800
Promeco Bv	0492-463903
De Ruiter Milieutechnologie Bv	020-4978011
Sgs Ecocare	0113-319000
Tauw Milieu Bv	0570-699666
Tebodin Consultants & Engineers Bv	070-3480911
Techmil Management & Technologie Bv	078-6315665
Milieu-Adviesbureau Tjaden Bv	023-5339006
Tno Milieu- En Energietechnologie	055-5493493
Laboratorium Tritium Bv	040-2454647
Handelslaboratorium V/H Dr. A Verwey Bv	010-4761055
Milieutechniek De Vries & Van De Wiel Bv	0224-217900
Wareco Amsterdam Bv	020-6954398

Fig. 651 List of agencies specialised in soil analyses and research into soil pollution

4.6.5 Follow-up investigation



F.P.J. Lame and R. Bosman (1993)

Fig. 652 Protocol for follow-up investigation[a]

[a] Lamé en Bosman, Protocol voor het nader onderzoek, SDU, Den Haag 1994

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).
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[17]:

- 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.

4.6.6 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[18]:

- 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 contamination19. 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[20] (new A value) and soil remediation intervention values[21] (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] [22].

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 carpentry and wood preserizing	all kind of heavy metals, pak's and chlorophenol
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.

J. Verschuren (1993)

Fig. 653 Overview of prominent forms of soil pollution per operation

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.

[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.

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:
- 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

4.6.7 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[23].
- 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[24] 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[25]. Temporary storage is considered if the purification plant has a limited capacity[26].
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[27]. 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[28]:

- 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[29].

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.

4.6.8 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[30]. 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.

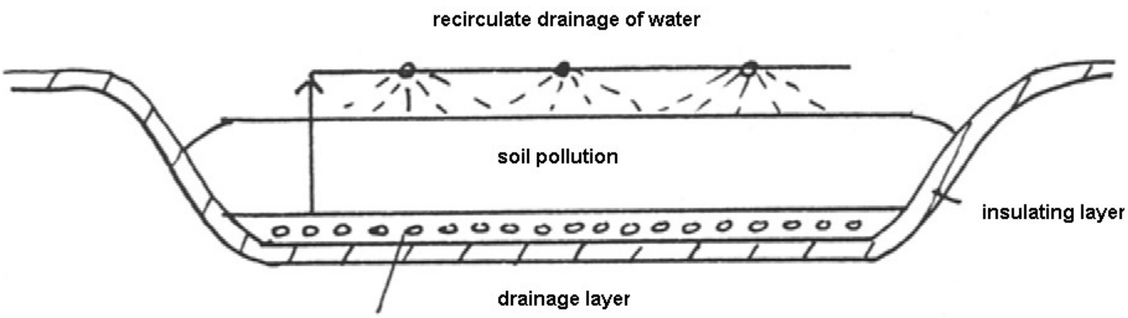


Fig. 654 Landfarming diagram

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.

4.6.9 Appendix saneringsregeling wet bodembescherming P.M. (remediation regulations under the Soil Protection Act)

4.6.10 References soil pollution

Koolenbrander, J.G.M. (1995) Urgentie van bodemsanering: de handleiding ('s Gravenhage) SDU

Lame, F.P.J., R. Bosman (1994) Protocol voor het oriënterend onderzoek: naar de aard en concentratie van verontreinigende stoffen en de plaats van voorkomen van bodemverontreiniging ('s Gravenhage) SDU

Lame, F.P.J., R. Bosman(1993) Protocol voor het nader onderzoek deel 1: naar de aard en concentratie van verontreinigende stoffen en de omvang van de bodemverontreiniging ('s-Gravenhage) SDU

Schut, E (1994) In-situ reinigingstechnieken voor vervuilde grond (Delft) Wetenschapswinkel TU

SDU (updated to 1994) Handboek bodemsaneringstechnieken, Leidraad bodemsanering, leidraad bodembescherming[a] ('s Gravenhage) SDU

Verschuren, J. 1993) Bodemsanering van bedrijfsterreinen; praktijkboek voor bedrijf en beroep (P.O. Box 6038, 4900 HA Oosterhout) Verschuren

[a] Soil Remediation/Protection Guidelines

4.7 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.

This chapter is divided into six parts:
- 4.7.1 Site analyses, including determining the suitability of a site for certain purposes.
- 4.7.2 Preparing a site for development
- 0
- Methods for preparing a site for development
- 4.7.4 Detailed elaboration for urban functions
- 4.7.5 Check lists
- **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.**

4.7.1 Site analyses

Information required for a desired activity
Site analyses can be carried out in a number of different ways. The preferred method of analysis depends on the information required for a certain activity. The analysis focuses on the built-up and undeveloped parts of the area. Furthermore, the analysis must not be confined to the area covered by the plan itself; it must exceed the boundaries of that area, as any manipulation may have an impact on the wider surroundings. All analyses concern the existing forms and condition of the site.

Classification of analyses

We can distinguish the following analyses:

- topographic analyses
- pedologic analyses
- water analyses
- cultural-historical analyses
- land use analyses
- analyses of existing landscape and development forms of the area
- visual analyses
- vegetation analyses

The majority of these analysis types are self-explanatory. The methods deployed are dependent on the researcher and the available material. The methodology is further dependent on the anticipated depth of research and analysis.

Topographic analyses

Topographic analysis involves accurately determining the boundaries of different topographical elements pertaining to urban development such as buildings, road and rail network, waters (in the form of rivers, channels, ditches and lakes), as well as altitude of the area. The position and spread of the different elements are also incorporated in this analysis.

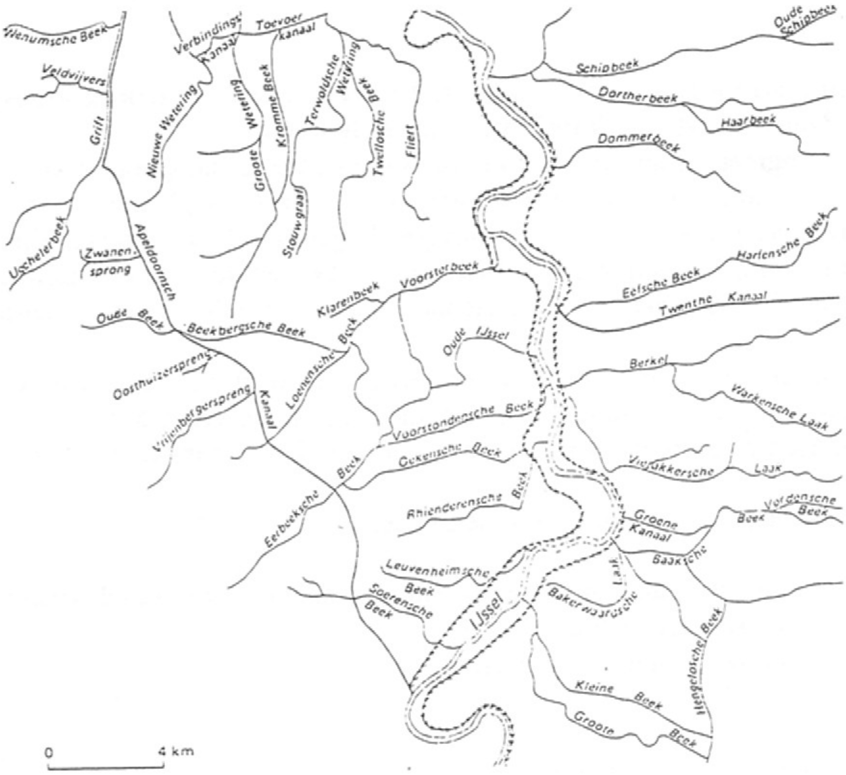
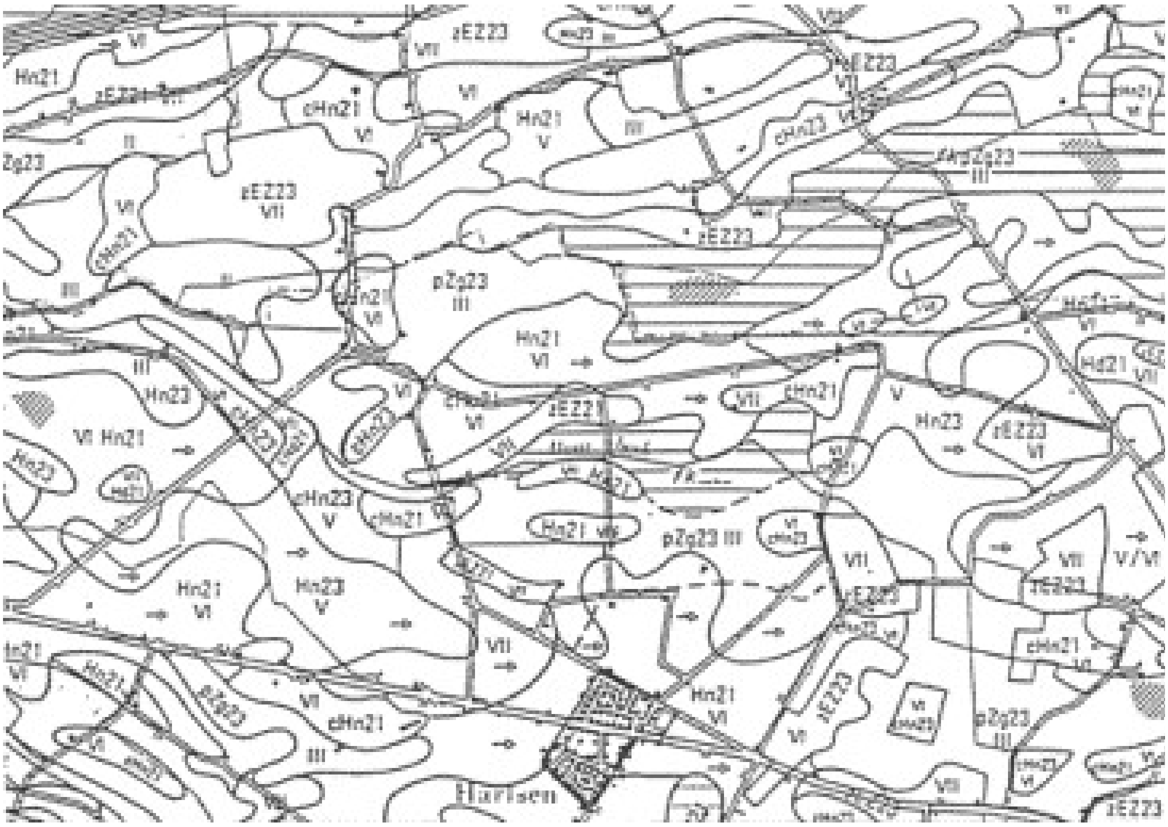


Fig. 655 Drainage pattern east of the Veluwe

It goes without saying that this analysis is best served by topographic maps with corresponding legends, while aerial photographs provide additional information, as they reveal all elements and forms found on the earth's surface.

Pedologic analyses



HUMUS PODZOL SOIL	ENKEERD SOILS	EERD SOILS
Hn: field podzol soil	zEZ: large black enkeerd soil	pZg: brook eerd soil
cHn: Laar podsol soil		

Fig. 656 Soil map

This survey analyses the different soil types present in the designated area. Groundwater data can also be collected, focusing on groundwater quality, depth of the groundwater level, annual fluctuations of the level and groundwater flow.

Potential uses

Potential uses can be determined by analysing the properties of the soil types.
The following soil characteristics are easiest to determine: particle size, particle form, quantity of mineral or organic components, ratio mineral components to organic components, water retainability of the ground, depth of ground-water table, stratification and distribution of the different soil types.

Groundwater levels
The groundwater level of a terrain or building pit is easily determined, and is outlined in the appendix.

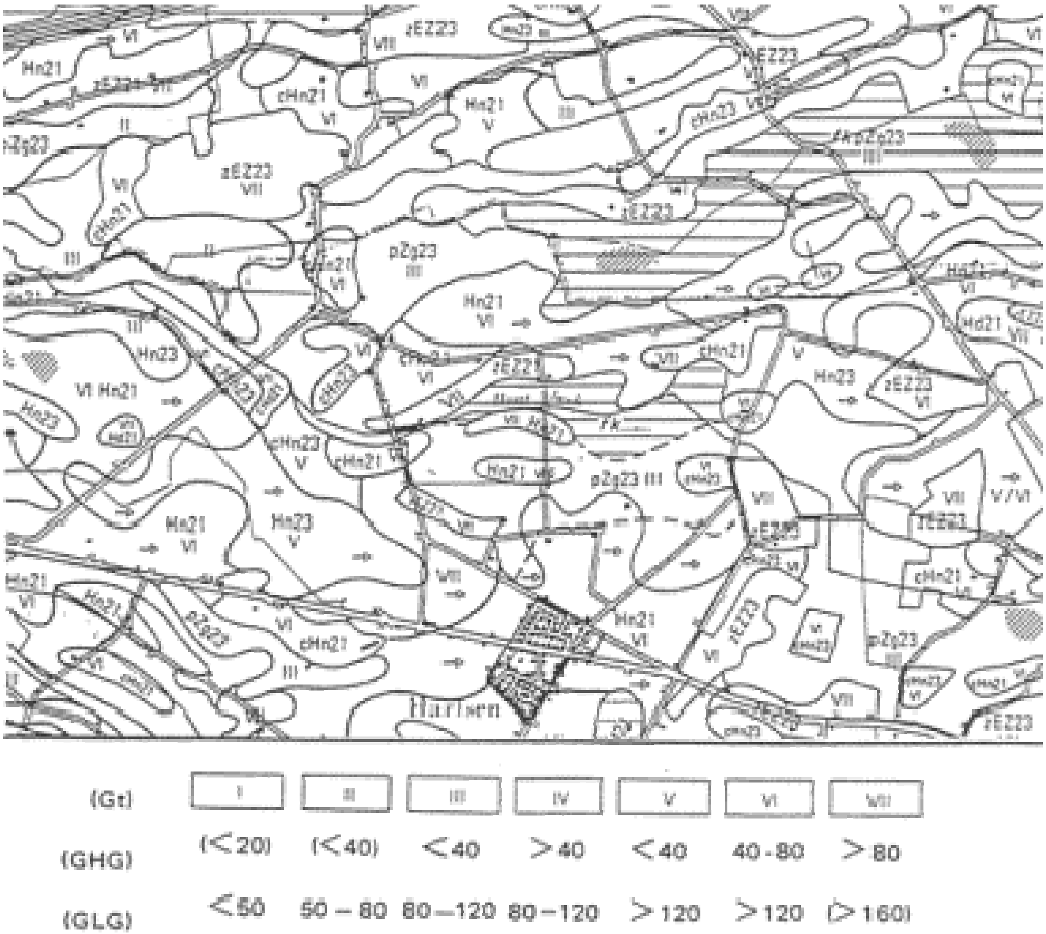


Fig. 657 Ground water class map

Ground-water tables are divided into water-table classes, where the highest mean groundwater level (H M G L) and lowest mean groundwater level (L M G L) is processed (see *Fig. 657*). The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative.

Recognising annual fluctuation
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 due to the presence of iron in the soil.

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.
Areas adjacent to the waterways are characterised by groundwater flows towards these waterways.
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.
For further information on soil pollution and soil remediation, see 4.6.
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.

Soil vapour

Soil vapour occurs in all areas where the pores of the soil are not saturated by water. This vapour plays a part in all biogenic activities in the ground (soil animals, decomposition of plant remains). In addition, the presence of oxygen in the soil produces a number of different chemical processes.
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 pedologic processes and soil pollution, the composition can differ significantly from the atmosphere, and even be toxic.

Processing data

In line with most analyses, use is made of data already contained on maps. Available maps include soil maps and ground-water maps, as well as geological maps and geomorphologic maps. Topographic maps are not only used as a basis for the analyses, but also contain relevant information on waterways. All government-produced maps have a scale of 1:50,000. More detailed, large-scale maps are also available; these usually serve a specific purpose. They are available from the Soil Survey service or the local council.

The maps that are used to carry out analyses are known as suitability maps or potential maps.
In general, pedologic data is only provided at a depth of 1 metre. As a result, geological maps will need to be consulted for areas deeper underground (i.e. information on load bearing capacity).
When processing the data, remember to use the descriptions provided in the accompanying booklet. This offers extremely valuable information on soil and landscape, and additionally promotes a better understanding of the area.

Lastly, all analyses depend on the expertise and proficiency of the researcher, and knowledge of the area.

Water quality

These analyses can effectively be divided into two parts, namely groundwater analysis and surface water analysis. The analyses share common ground in terms of food gradings and/or water contamination. This analysis also focuses heavily on the issue of public health. The direction of flow of both ground water and surface water must also be taken into consideration when making design choices, as this indicates changes in water quality. The quality of water improves the further upstream we move.
Data on water quality can be obtained from the water quality manager, usually the water board, provincial authorities or the RIZA (Institute for Inland Water Management and Wastewater Treatment - Rijks Instituut voor Zoetwaterbeheer en Zuivering van Afvalwater).
The surface water of flat areas always flows in the direction of the pumping station, which discharges water from the area. In principle therefore, the 'cleanest' water is found furthest away from the pumping station.

Hydrographic maps

Ground-water maps contain information on ground-water depths. They are delivered as standard with soil maps. The appendix contains information on ground-water levels and ground water types.

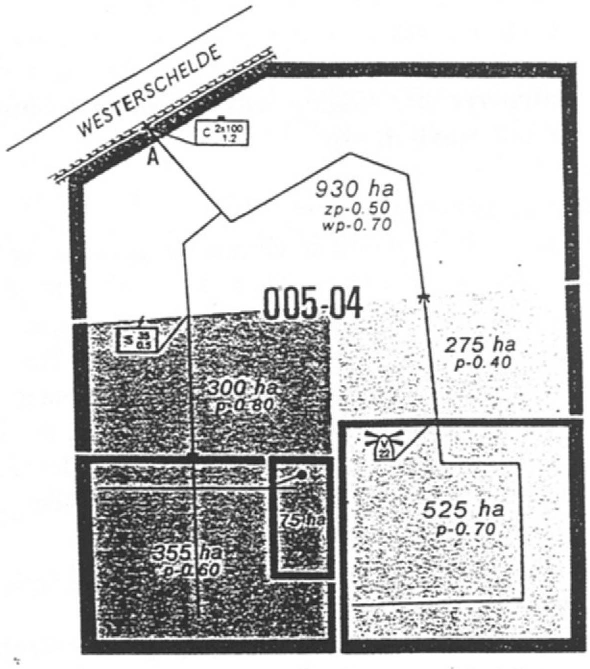


Fig. 658 Hydrographical chart, section (see also Fig. 475)

Hydrographic charts contain data on surface water, polder levels, drainage basins, pumping-stations etc (artificially managed water). These charts are produced under the supervision of water boards in the Netherlands. As is the case with geological, geomorphologic and Pedologic maps, hydrographic charts in the Netherlands are produced at a standard scale of 1:50,000.

Separated and fluctuating water levels

Hydrographic charts highlight units with identical ground-water tables, individually managed as polders. Water level fluctuations in a polder do not pose a problem as such; in the worst case scenario, the water level of the bordering polders may fluctuate slightly in the direction of the fluctuation. Matters become a little more complicated, when the water level of a *section* of the polder needs to be changed. This can be achieved through fill, and by reducing the water level by dividing the polder into two new polders with separate water levels.

Altitude variations

Hilly sites have a set of completely different problems in regulating the surface water and ground water. In general, the lowest sections of these sites tend to be the wettest. In these areas, drainage would cause the elevated grounds to dry up. Interventions of this nature must therefore be carefully considered and used sparingly. In these areas, it would be more advisable to raise the level of the lowest sections (especially if building is to commence anyway). This would render the influence of the elevated sections virtually negligible. One disadvantage of this approach is that the interesting design features, created by the altitude variations, are virtually completely levelled out.
The above provides information on the 'behaviour' of water. This information is used to carry out water analyses for planning purposes.

Cultural-historical analyses

This analysis is based on a variety of perspective, including agricultural exploitation types, historical towns and urban boundaries, historical villages, historical farms, etc.

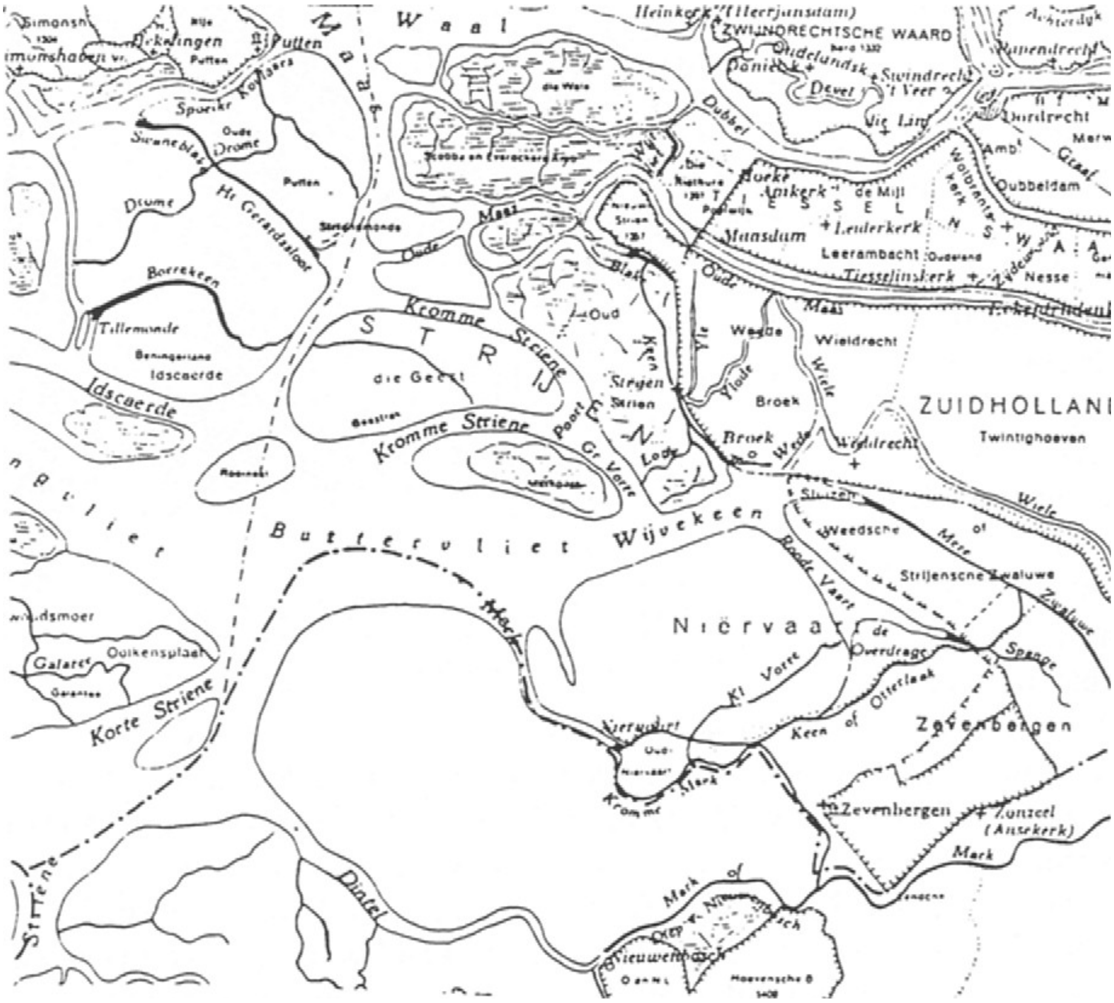


Fig. 659 Historical map

With regard to the countryside, land divisions are assessed, alongside historical village types, in particular the 'originality' or the historic value of the divisions. The subdivisions typify the technological capabilities of man in the given time and circumstances.
This type of analysis embraces concepts such as *esdorpen* landscape, *slagen* landscape, *veenontginningslandschap* (peat excavation), *veenkoloniaal gebied* (former fen communities), (Hollandse) and *veenweidegebied* (peat pasture).

This analysis is carried out with the aid of historic maps and topographic maps. These differ in scale, requiring a certain degree of improvisation.

Land use analyses

In general, this analysis is denoted by the American term 'land use', while the term 'landcover' is reserved for 'unused' and uncultivated land, for example nature reserves and uncultivated territories. A function can thus be assigned to any area.

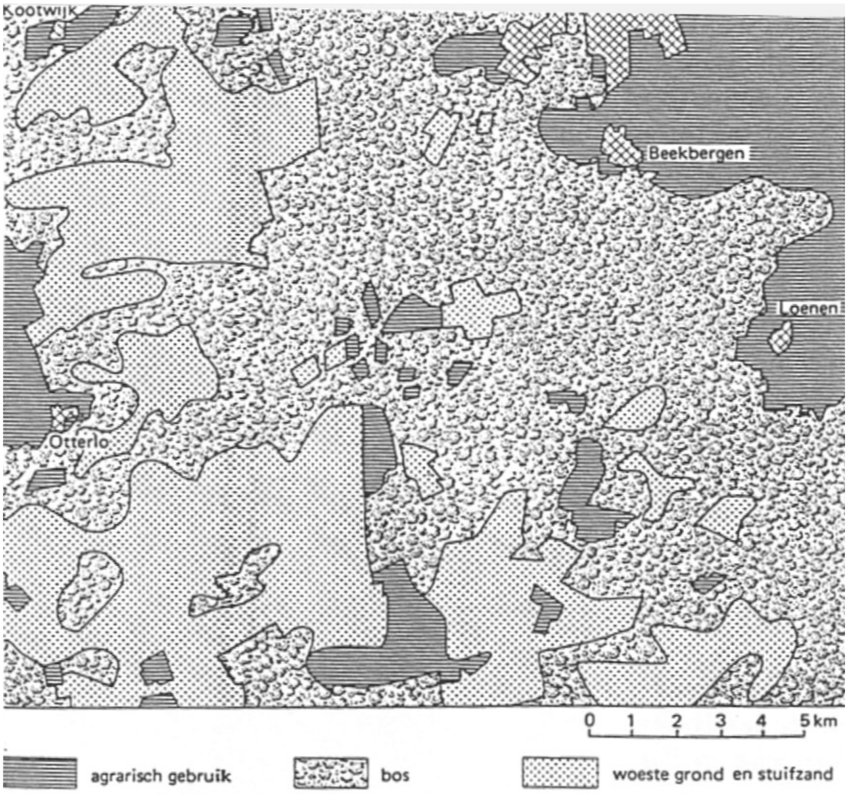


Fig. 660 Land use map

This analysis is carried out using the most recent topographic maps or, better still, up-to-date aerial photographs, as these highlight the current situation rather than categories introduced by the "cartographer". This allows the researcher to draw up his own divisions.
Generally speaking, recent aerial photographs are more up-to-date than maps.
Like topographical maps, aerial photographs can be ordered from the topographical service in Emmen and the NLR (National Aerospace Laboratory - Nederlands Lucht- en Ruimtevaartcentrum) in Emmeloord. Special maps are available from local municipalities or provinces.
Aerial photographs vary greatly in scale. Stereoscopes can be deployed to identify more details on an aerial photograph. If need be, satellite images can also be used, although their scale is generally a hindrance (1997 images have a maximum scale of 1:40,000).
Further information on aerial photography and satellite imaging is contained in monograph no. 69: Remote Sensing (art.nr.382).

Visual analyses

More so than any other analysis, these analyses are keenly dependent on the subjective opinions of the user. We can distinguish a range of visual analysis methods, and they are highlighted in the literature list.
Visual analyses are primarily concerned with visually perceptible external phenomenon of an area. Man is continually interacting with his environment. As humans deploy all their senses to perceive their surroundings; sensory observations are characterised by a high degree of subjectivity. Observations are also influenced by the reference frameworks of the observer and the purpose of the observation.

Concrete features

The perceived (landscape) image is described using conceptualised features.
In general, the following concepts are deployed:

- size
- form
- boundaries
- vista
- volume

Abstract features
Certain features are more characteristic, more influential than others.
We can distinguish the following features:
- completeness
- degree and density of use of space (intensity)
- age of the area
- technical qualities
- use and possibilities of use
- unevenness
- pattern of lines, elements and planes
- degree of care and maintenance
- spatial effect
- atmosphere
- degree of diversity (amount and type of information)
- seasonal aspects
- front and/or back of designing elements (building, line of dunes, direction of land division)
- colour

No hierarchy or level of preference should be derived from the above list.

The image of an area
When surveying the spatial image of an area, the following elements must be mapped out to create as complete an image as possible of the observation:
- the spatial factors, determining the space such as size, boundaries, form, vista etc.
- the global spatial units, divided into sub-categories if required
- dominant features of the visual observation

The perception of the analysed area is highly personal. A distinction can be made however between perceptions based on aesthetical considerations, and observations based on potential uses of an area.

Sources of visual analysis
The analysis is carried out using maps, aerial photographs and "field" observations. In most cases, maps do not provide sufficient information on boundary areas. Furthermore, all maps give an interpretation and (standardised) perception of reality. As such, maps do not always satisfy analysis criteria. Own interpretations can be made using (large-scale) aerial photographs. These interpretations can be supplemented with direct "field information".

Vegetation analyses
In this analysis, a distinction can be made between the presence of ‘green’ elements, such as planting avenues, trees, parks, woodland areas etc, the type of vegetation, such as flowers, hedges, shrubs, trees etc, and the types of plants.
The presence of green elements and ground use can be detected with the aid of topographic maps and aerial photographs. Vegetation types can only be identified using aerial photographs or ‘field’ observations, while plant types can only be determined ‘in the field’.
Soil maps are used to determine which plants will grow naturally in a certain soil type. The most obvious method is to select those plants that will grow naturally in a certain area.
Vegetation analyses are effectively an extension of a specific component of either visual analyses or land use analyses.

Maps for vegetation analysis
The following maps are used in landscape surveys to assist the planning and building process:

- geological maps (representation of the deeper underground, including mineral stocks if necessary)*
- geomorphologic maps (representation of the pattern and genesis of landscape forms)*
- geo-hydrologic maps (representation of groundwater deeper underground with ground-water flows)
- soil maps (representation of soil types, that occur on the earth's surface – up to a depth of 1 m)*
- ground-water maps (representation of groundwater depth and fluctuations)*
- groundwater quality maps
- hydrographic charts (representation of the water boards and their management)*
- soil suitability maps for different activities
- vulnerability maps for different activities
- subsidence maps (reaction of the ground when extracting water or gas, or during raising)
- foundation depth maps
- industrial sand maps
- terrestrial heat maps
- maps highlighting deep layers of clay for heat storage
- vegetation maps, potential vegetation maps or natural vegetation maps
- cultural-historical maps

N.B. soil maps and ground-water maps are published together.

The availability of maps

These maps are not always in stock, and many will have to be produced manually by combining existing maps. The choice of maps required during the planning and design phase depend on the planner/designer and the design principles. Maps marked with an asterisk can generally be obtained from the structural map archive.
The Stichting voor Bodemkartering (STIBOKA, Wageningen), the Rijks Geologische Dienst (RGD, Geological Survey of the Netherlands, Haarlem), Rijkswaterstaat (RWS, Directorate-General for Public Works and Water Management, The Hague) and the Dienst Grondwaterverkenningen TNO (Netherlands Organisation for Applied Scientific Research, Delft) produce several of these maps at a standard scale of 1:50,000. As this scale is unsuitable for executing plans, further research is required. The maps are however sufficiently detailed to reveal which areas are ideally suited for a certain purpose, and which are wholly unsuitable. These maps can therefore be used during the planning phase to compare destinations on an objective scientific basis. Alternative sites can be assessed in a similar fashion.

Geotechnical or soil mechanic surveys

Separate geotechnical or soil mechanic surveys must also be carried out for fixed destinations and in particular for building projects, to determine the load bearing capacity of the foundation stratum.
In addition to this soil mechanic survey, soil pollution surveys are essential to obtain a "suitability certificate" for the planned function. (for soil pollution, see 4.6)

The different map analyses and theme analyses serve a monitoring role with regard to the consequences of human activity on the surrounding area – such as development and planting – and on the supply of natural minerals, such as water, sand, gravel, gas etc.

4.7.2 Preparing a site for development

Development and habitation

A commonly held misconception is that the preparation of a development site is primarily concerned with creating a solid sub-base for buildings.
The term ‘preparing a site for development’, in its narrower sense, generally involves cleaning up sites, creating space for bigger engineering structures, installing drainage systems, sewerage systems, open water systems, engineering structures, and the building of new streets.
The processes of applying road surfacing , cleaning up building sites, installing green areas and recreational facilities as well as cables and wires, placing street lighting etc are denoted by the phrase ‘preparing a site for habitation’.

In the Netherlands, we have two main pedologic concerns:

- foundation stratum, load bearing layer
- drainage

Location, plan and technique

When developing a site for complete development, the following aspects are distinguished:

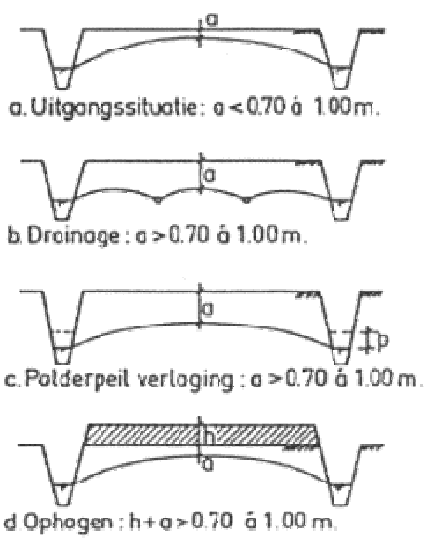
- identifying a suitable location for urban planning based on soil conditions and soil hydrology (determining location),
- urban design plan and
- selecting construction and foundation methodology.

In other words, potential sites are assessed in terms of their suitability for:

- constructing buildings,
- laying and maintaining roads, cables and wires,
- vegetation growth and
- if required, keeping crawl spaces under residential areas dry.

Principle drainage solutions

In general, a minimal drainage of 0.9 m is required with regard to all these functions.



a. original situation a 70 cm
b. drainage: a > 70 cm
c. lowering groundwater level (of the polder) a > 70 cm
d. raising the ground level h + a > 70 cm

Fig. 661 Principle drainage solutions

Impact of drainage on vegetation

With regard to green space, a drainage requirement of 0.9 m is excessive. Willow, alder, as well as poplar, ash and elm are also capable of growing in conditions with periodically high ground-water tables. In addition, planners could decide to plant greenery capable of adapting to the surrounding area, thus eliminating the need for embankment and/or lowering groundwater levels for planting. This is an ecologically sound way of selecting suitable vegetation, which in turn greatly reduces the need for maintenance.

4.7.3 Methods for preparing a site for development

There are two opposing approaches to preparing a site for development.

- 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.

P.M.

Fig. 662 Fig. 50 *Assessment for preparing a site for development*

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 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.

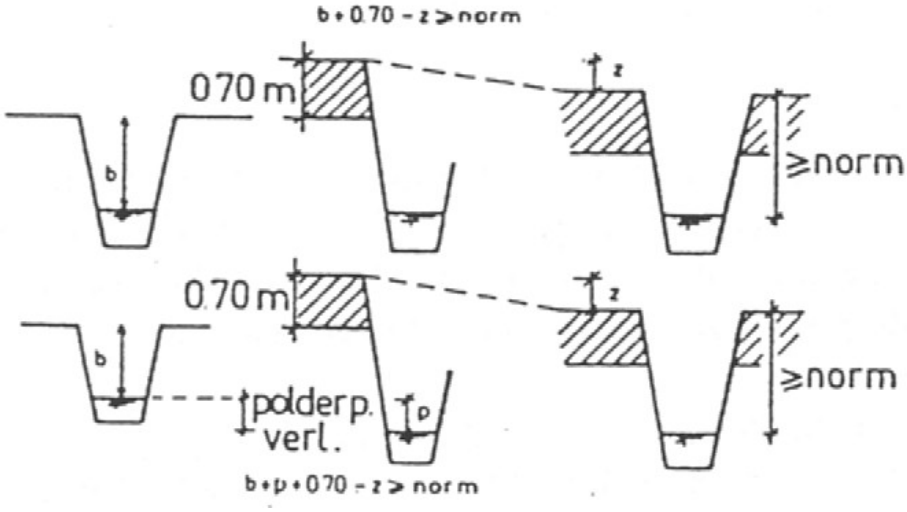


Fig. 663 Raising with sand and lowering polder level

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.

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.

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.

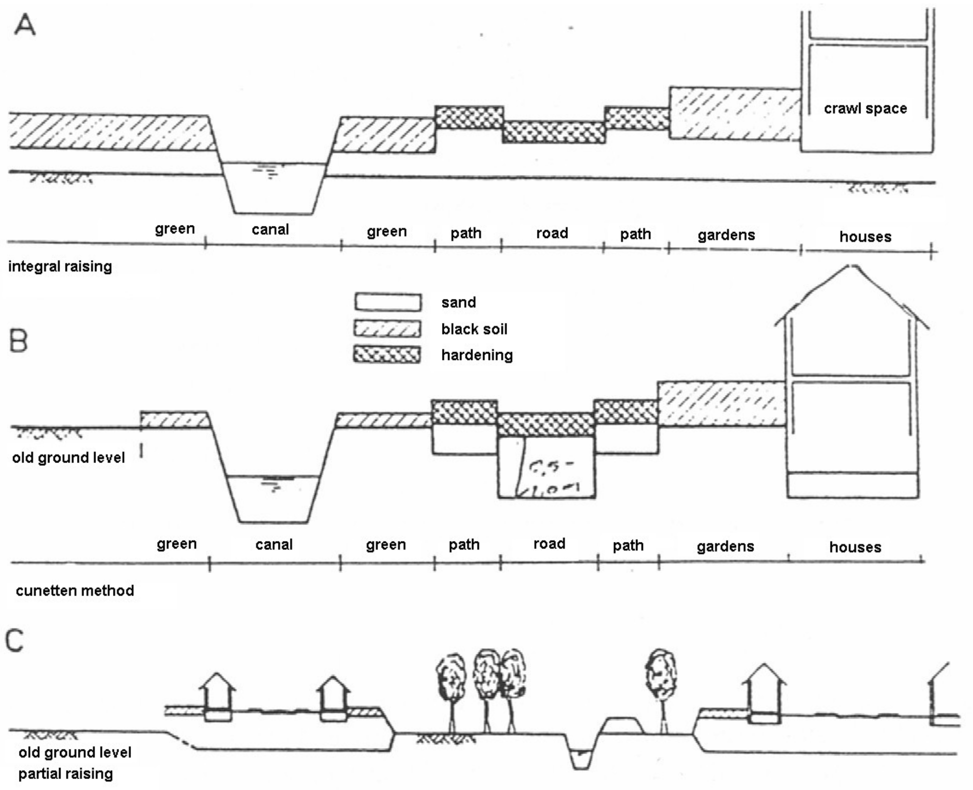


Fig. 664 Raising with sand

Sand delivery per 'axle"

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.

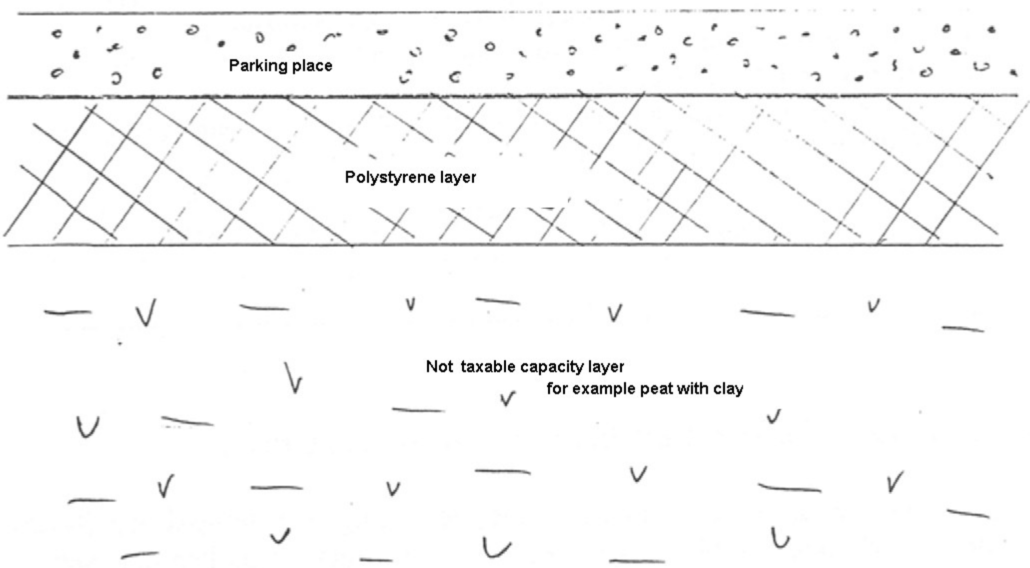


Fig. 665 Lightweight fill-material

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.

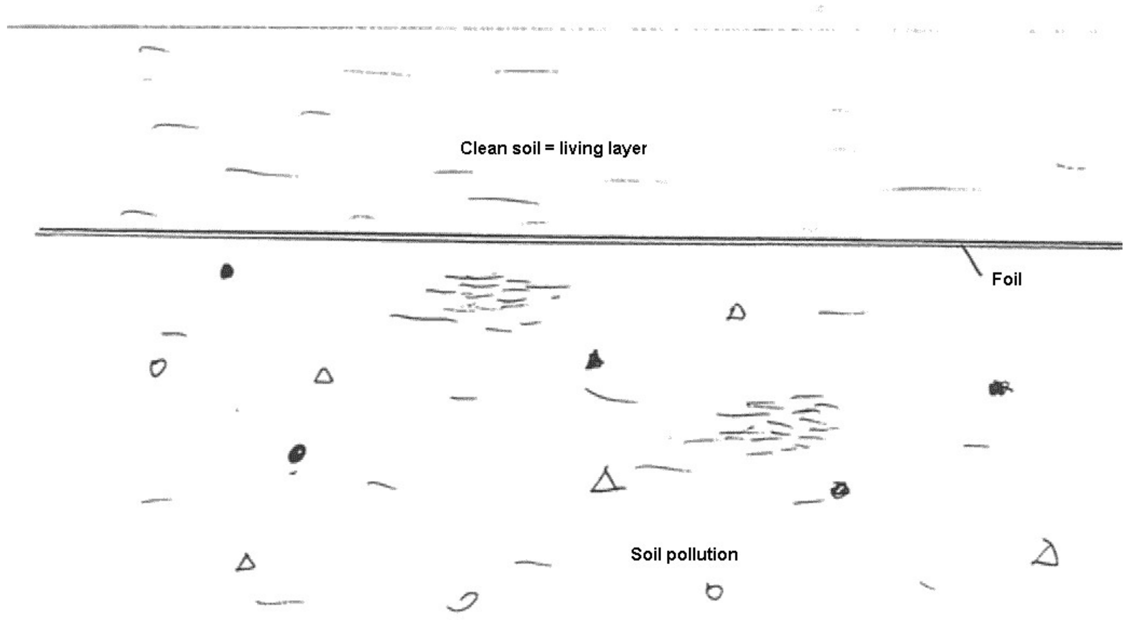


Fig. 666 Living layer

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. 667 Bijhouwer, soil map of Kethel and surroundings

Fig. 668 Bijhouwer, development plan of Kethel and surroundings

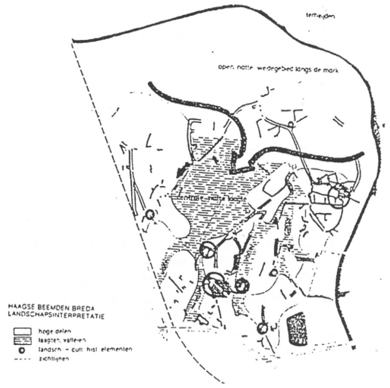


Fig. 669 Maas and Tummers Haagse Beemden

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 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.

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.

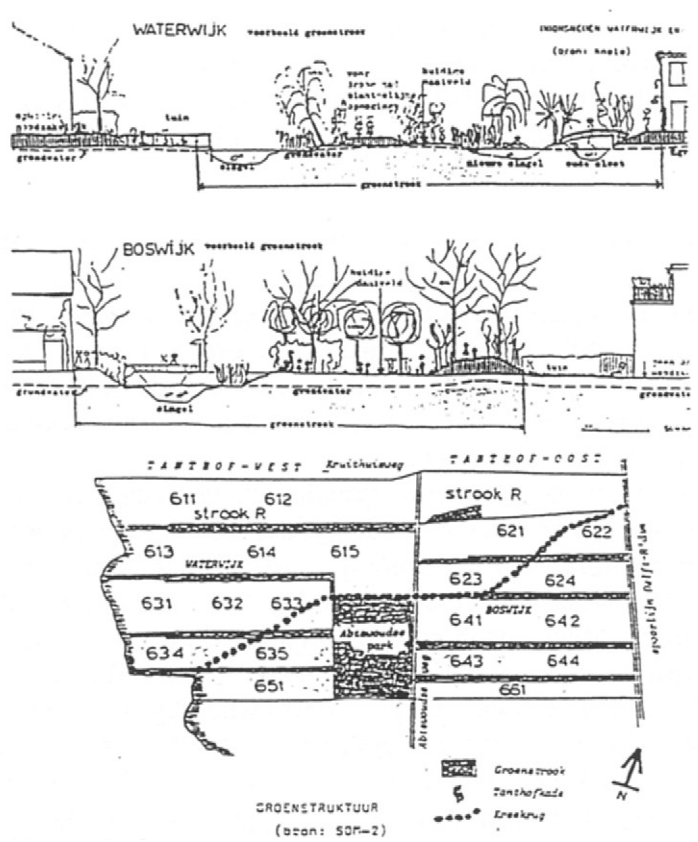


Fig. 670 Tanthof, Delft

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 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.

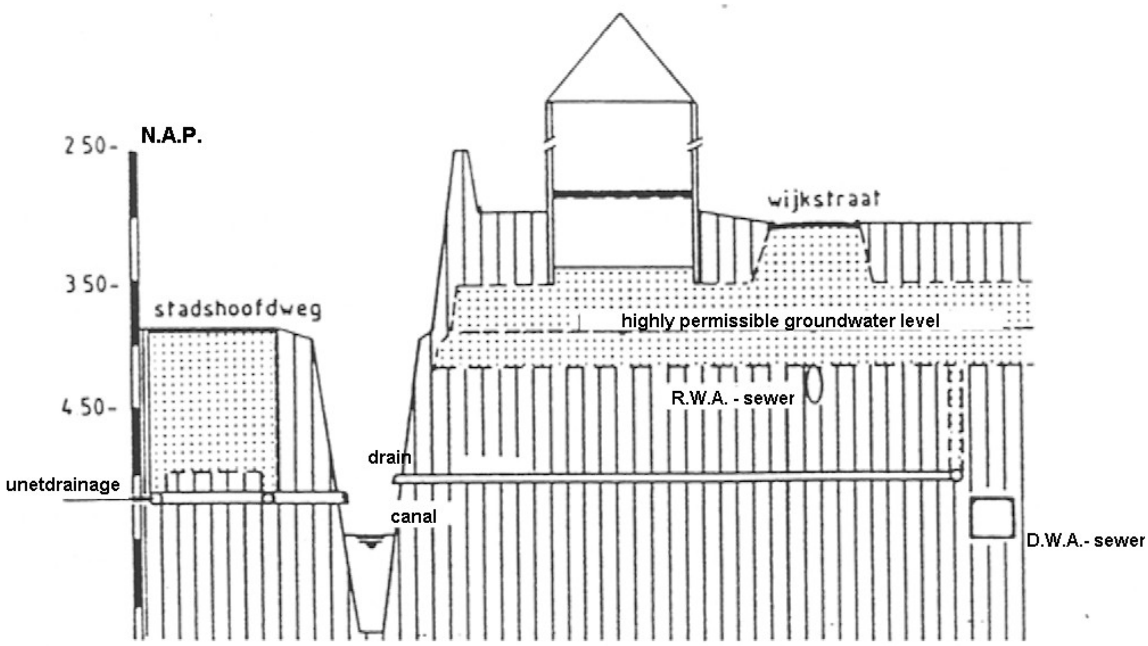


Fig. 671 Water control in urban areas

4.7.4 Detailed elaboration for 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.

4.7.5 Check lists

Criteria set by all destinations.
- bearing capacity
- passableness
- relief
- drainage depth
- dewatering
- water retainability
- infiltration ability
- closed water storage
- open water storage
- discharge

Condition of soil and water management

Soil condition can be defined on the basis of the following basic details:

- soil type (part of the below basic details are derived from soil type),
- soil composition (stratification),
- depth load-bearing layer,
- compressibility of the higher layers,
- bearing capacity of the upper layers,
- altitude,
- relief,
- ground-water table,
- permeability,
- water retainability,
- capillary elevation,
- piezometric level of deep groundwater and
- open water.

Measures to improve soil and water management

The following are eligible for improvement:

- drainage depth and dewatering: raising (depending on compressibility, raising with sand results in settlement, necessitating raising the level to a greater height than is required for increasing the drainage depth), lowering of the level (depending on the soil type, the lowering of water levels may create settlement, necessitating lowering the level to a greater depth than is required for increasing the drainage depth), draining, profile improvement, changing distance of open water, combinations of the above;
- water retainability: ground consolidation by reducing or bringing in top soil, ground consolidation through deep ploughing;
- closed water storage: raising with sand, lowering the polder level,

Improving drainage;

- open water storage: increasing surface area of open water, lowering the polder level (and maintaining maximum permissible ditch level);
- dewatering: adjusting pumping station capacity, adjusting wetted area;
- passableness: raising or excavating and filling with sand or cinder bed, installing steel (temporary) sheets, constructing roads with temporary paving;
- bearing capacity: adjusting foundation to building methods, for low-rise buildings: possibly shall foundation or sand fill;
- relief: accentuating or levelling; and
- infiltration ability: improve by deep ploughing, improve by sand fill.

Drainage, dewatering, drainage depth and water storage must be carefully tuned to each other. There is no point in improving dewatering ability without good drainage; likewise, increasing open water storage capability without good drainage is also pointless.

The dewatering processes are interconnected as follows:

DRAINAGE DEPTH	DRAINAGE
	open water storage
	dewatering
drainage	drainage depth
	open water storage
	dewatering
water retainability	infiltration ability
closed water storage	infiltration ability
open water storage	drainage
	dewatering
dewatering	drainage depth
	drainage
	open water storage
infiltration ability	water retainability
	closed water storage