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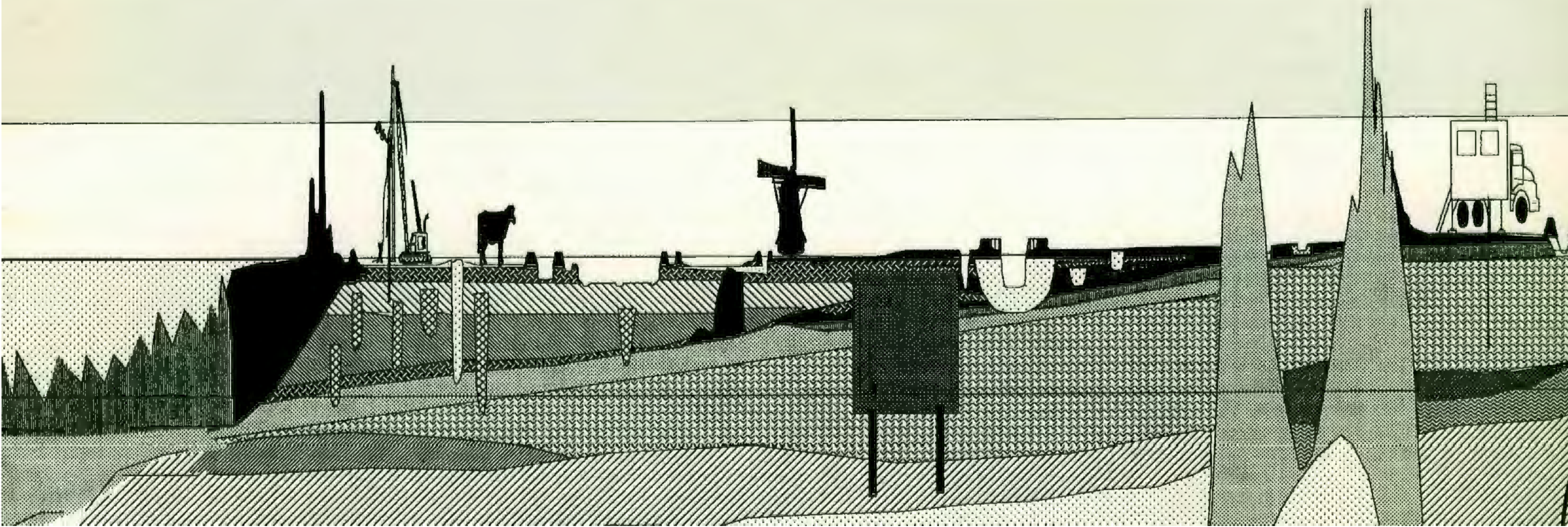
No. 3 Spring 1996



Objective of the Newsletter

The objective of the Newsletter is to inform the members of the Ingeokring, and other interested parties, on topics related to engineering geology and the developments in this field. The Newsletter wants to make engineering geology better known by improving the understanding of the different aspects of engineering geology.

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Notes for the authors

- Authors should send their contributions with their names and addresses, as a WP 5.1 text file to the editorial board.
- Authors are free in choosing the subject of their contribution with the following restraints:
  - The subject is related to engineering geology.
  - The manuscript is not a commercial advertisement (announcements are allowed).
- Layout
  - All figures and tables should be handed in as hard copies of high quality, each printed separately on A4 size. The author should remember that figures will be reduced in size.
  - Drawings can be delivered as a separate Drawperfect file or PCX file.
  - When photographs are used, the originals should be handed in (these will be returned)
  - The article should be delivered as a WP5.1 text, without any formatting or layout-codes, accompanied by a hard copy.
  - Each article must be accompanied by a short abstract (<100 words).

Cover: section through The Netherlands and the North Sea from the Achterhoek to the East coast of England.

From the chairman of the Ingeokring

Dear Ingeokring members,

The past year has seen a flourishing Ingeokring. The number of members is high and the interest in activities is unchanged high too. Two very successful excursions, attended by a large quantity of members, were held to sites which showed engineering geology at the best. The excursion to the sites for the high speed railway line in Belgium - le Train Grande Vitesse - was a success for more than one reason. Technically this excursion was of interest as the site for a high speed railway line is so long stretched that bridges and foundations can be visited which are in all different stages of completeness; from the first groundwork to completed bridges and embankments. It also clearly illustrated the problems involved in a project this size and all participants in the excursion started to understand why high speed railways can be an environmental and social problem. Obviously it was also a good opportunity for intensifying the contacts with our Belgian colleagues. The second excursion brought us to an equally interesting subject of the 'dijk' reinforcement along the rivers in The Netherlands. Although in May 1996 farmers and 'drinkwater' providers complain that there is a shortage of water and that The Netherlands are changing into a desert, it is merely a year ago that the extensive quantities of water in the rivers made the headlines in every paper in the world. (I was in New York at that time and it was quite astonishing to see a flooded Holland on television as the main subject in the American news bulletins. It may be doubted whether this is a positive advertisement of Dutch engineering.) The excursion showed clearly the engineering geological, environmental and social problems of a major engineering project in an environmentally and socially sensitive area. Also a 'dijk' is a long stretched project which made it possible that different stages of 'dijk' reinforcement could be visited and the various problems encountered in the different stages became perceptible.

The large attendance at the annual meeting of this year in May showed that the members are interested in the future of engineering geology in The Netherlands. It can not be stressed enough that the discussion about the contents of engineering geology is of major importance. Certainly in a time of unification of Europe, changes in the positioning of international professional organizations and possible changes in Delft, it is of major importance that engineering geology is clearly positioned in the academic world, but also in industry. The introductions given by the different speakers were the start of an enthusiastic discussion of which a report is included elsewhere in this newsletter.

The interest to be educated in engineering geology and related subjects is unchanged large. The number of students in Delft is the highest ever and also in Amsterdam and Utrecht the education is flourishing. This was clearly illustrated by the quantity and quality of the theses submitted for the annual 'student award in engineering geology - 1996' (qualifying theses for 1997 are expected by the secretary). The interest of students is also shown by a lively DIG - Delft student chapter - which among many other activities resulted in an excursion to Japan.

Ir. Jacco Haasnoot receives the Ingeokring Student Award for the best Master's thesis in the field of Engineering Geology completed in the academic year 94/95.

My PhD study is nearing its completion and since October I have taken over from Niek Rengers as chairman. He handed over a dynamic and healthy organisation that is very well equipped to handle the challenges of the future. This is also illustrated by the changes of the Newsletter you are reading, one of the last initiatives taken by him and his fellow board members. It has become a very professional looking magazine which is an excellent medium for promoting our profession.

Generally it is all very positive and it seems that the future of engineering geology is save, however, we should not sit back and become idle, the already mentioned possible changes in Europe and Delft need our full attention and appropriate action if and when necessary. I wish you all a good summer, for those who can find the time also a good holiday.

Robert Hack

Various views on Engineering Geology

A-M van Noort, chairman of the Student Chapter of Engineering Geology DIG

On Thursday the 9th of May the annual meeting of the Ingeokring took place. After a cup of coffee, the chairman opened the meeting and welcomed all at Grondmechanica Delft. The minutes of the annual meeting are sent along with this Newsletter.

The main topic of the afternoon concerned the future position of the Dutch Engineering Geologist. To facilitate a discussion with the members present 4 presentations were given which addressed different aspects of engineering geology in education, industry, science and government. First Dieter Genske, Professor at the Technical University Delft, highlighted the academical point of view on the subject. René Vreugdenhil of IWACO followed. He pointed out what an Engineering Geologist should and to properly execute environmental studies. Ben Degen from GeoCom pinpointed at the importance of a sound quaternary geological education in Engineering Geology. Last the technical site of Engineering Geology was presented by Sven Plasman working with Fugro.

Dieter Genske: An Engineering Geologist is in-between two disciplines: geology and civil engineering. A comprehensive education should be provided for the Dutch student. The basis is geology and specialization should be directed towards civil engineering. The Engineering Geologist prepares the geotechnical model which then can be applied and utilized by civil engineers. The Engineering Geologist should not be trained for the Dutch market only.

René Vreugdenhil mentioned useful lectures given at the TU Delft, which are geohydrology, groundwatermechanics, foundationengineering, chemistry, geophysics and photo interpretation. The environmental market is in a turmoil. Therefore, whether numerous Engineering Geologists can be employed in this sector in the future may be doubted. He expressed the need for an educational basis for Engineering Geologists with more emphasis on geostatistics and GIS, if necessary at the expense of civil engineering topics. He also stressed that the strength of the Engineering Geologist lies in "being specialized in not being a specialist".

Ben Degen argued that the Engineering Geologist has an advisory kind of job. Advice should be the keyword in the grammar of the Engineer Geologist. Furthermore the Dutch Engineering Geologist should concentrate on the subject at which they are best e.g. Dredging, Environment and Offshore and particularly in soft soil (deltaic) environments. This in combination with a little more education in geophysics for the shallow underground would satisfy the market.

Sven Plasman. The Engineering Geologist can use more background in Civil Engineering subjects. The basis should still be the same as it is presently, but with options to specialize in different fields.

Various members of the Ingeokring reacted to the introductions and gave their opinion on the knowledge and expertise which is most useful for the Dutch Engineering Geologist. In the next section a summary is given of the statements made during the meeting.

First there was a lot of confusion about the new program of the TU Delft in Engineering Geology. Questions were asked about civil engineering subjects; whether these are educated in the first two years as well. In a few words recent changes in the educational program were explained by Peter Verhoef. The additional year in the new 5 year program allows the students to tailor their education to their individual preferences, i.e. every students can choose for a unique package. The student has the opportunity to choose his or her specialization in for example foundation engineering or geophysics for the shallow underground (more information on the new Engineering Geology program can be found elsewhere in this Newsletter, ed.).

It was also stated that not a single educational program can fulfill all the demands of each kind of employer completely. Suggested was that it could be helpful to do a market research and ask employers what they think should be included in the education. Another suggestion was to cut in basic geological education and instead teach only geology-related problems. Another issue was about the necessity of academic education in engineering geology. A more practical training at HBO level in Engineering Geological site investigation could possibly better meet the demands from various employers in particular in industry than a scientific education at university. Prof. Jan Nieuwenhuis, Technical University Delft, Dept. of Civil Engineering, responded with a confirmation about the fact that an Engineering Geologist may have not enough knowledge about civil engineering subjects. On the other hand civil engineers have no knowledge on geology. The Dept. of Civil Engineering intends to strengthen the education in (Engineering) Geology and he hopes that this will improve communication between civil engineers and Engineering Geologists.

Communication was a major topic in the discussion. Because Engineering Geologists are in-between two disciplines we should also be trained in communicative skills. An Engineering Geologist should be able to translate his geological know-how into usable and more concrete information for Civil Engineers. P. van Deursen (Boskalis) underlined this with the remark that an Engineering Geologist should not act as the all knowing leader. There is always insecurity in the Geology. If understanding for each others profession is created then you give birth to perfect and fruitful cooperation.

Niek Rengers was glad that the profession as it is today is widely accepted. The Engineering Geologist is the Geologist which is able to produce a geotechnical model; Site Investigation is his major task. Dieter Genske commented that an Engineer we should also be able to calculate basic Civil Engineering problems.

At the end of the discussion, when once again was emphasized that geotechnical modelling and practical Civil Engineering techniques were said to be important for the Engineering Geologist, every one present at the meeting agreed on one thing: the present educational program in Engineering Geology at the TU Delft is fairly good.

Is it possible to predict the lateral continuity of layers in the Dutch alluvial plain?

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The lateral continuity of lithological units, which you encounter in CPT's and boreholes, is related to the subsurface variability. This variability depends on the genesis of the various units. The article explains the various depositional environments which have existed in the Dutch alluvial plain during the last 2.5 million years, as well as the resulting sediments. During the Pleistocene rivers deposited rather continuous, thick layers of gravel and sand, alternated by more variable layers of finer grained sediments. On top of the Pleistocene sediments Holocene meandering rivers built up a heterogeneous body of peat, clay and sand. Also anastomosing river deposits can be found, showing an even larger spatial variability in their soil distribution.

INTRODUCTION

Predicting lateral continuity of lithological units in quantitative sense, i.e. answering questions like: in which direction and over which distance does a sand or clay layer continue?, is not an easy job. But if you know the amount of variability of a particular part of the subsurface, it is sometimes possible to give a qualitative prediction about the continuity of the various units: large variability implies little continuity of layers.

Subsurface variability is an important aspect for engineering geologists and geotechnical engineers. For example, if you are planning the amount of site investigation for a civil engineering structure, you need to know the subsurface variability: in homogeneous layers it is acceptable to extrapolate geotechnical parameters over a larger distance than in heterogeneous circumstances.

How can the engineering geologist or the civil engineer know how much variability is to be expected in a particular part the alluvial plain subsurface?

This question can be answered once you know which river pattern is responsible for the sediments. Each river pattern has its own characteristic heterogeneity. In the Dutch alluvial plain, figure 1, an alternation of river patterns in time caused a vertical difference in variability. In general more homogeneous, continuous layers occur in the deeper part, with a total thickness of 100 to 300 metres, overlain by more heterogeneous shallow deposits in the upper 5 to 20 metres. Horizontal differences in the sediment bodies in east-west direction result from a longitudinal variation in river deposits.

This article first explains some theory of river patterns. Next, geological history from 2.5 million years ago to the present, and resulting sediments in the Dutch alluvial plain will be treated. Emphasis will be given to the variability of the sediment body and to some engineering geological aspects.

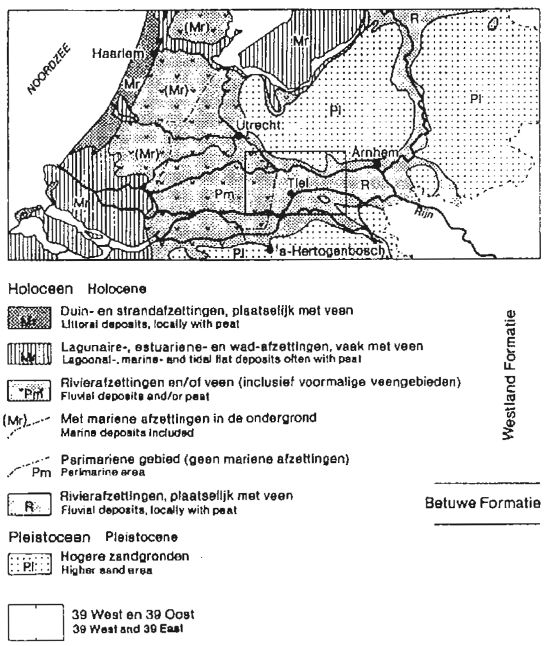

Figure 1 The areas indicated by Pm and R make up the Dutch alluvial plain (After Verbraeck, 1984).

THEORY OF RIVER PATTERNS

Rivers can display four main patterns: braided, straight, meandering and anastomosing, see figure

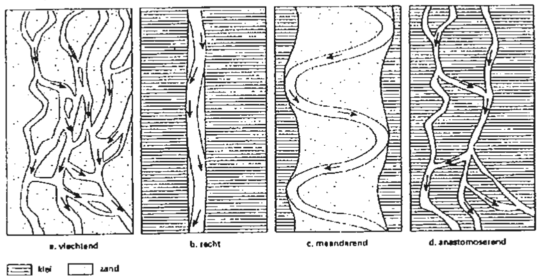

Figure 2 Classification of rivers. a=braided; b=straight; c=meandering; d= anastomosing (Open Universiteit 1992).

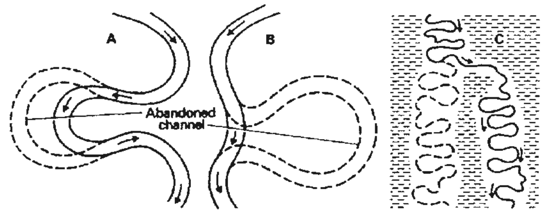

Figure 4 Modes of channel shifting. A=chute cut-off (false channel); B=neck cut-off (oxbow lake); C= avulsion (After Reading, 1978).

2. There are also gradual transitions between the main patterns. The pattern in which water flows, depends on a complex combination of factors like terrain gradient, discharge variations, sediment supply, ground water level rise and subsurface erodibility.

The next paragraphs describe the three river patterns which have existed in The Netherlands, and their characteristic sediments.

Meandering rivers

In general meandering rivers deposit rather heterogeneous sediment bodies. Several processes are responsible for this large spatial variability, they are explained below.

Channel movements

A meandering river is characterised by a single, strongly curved river channel. The curves move both sideways and downstream within the meander belt (*stroomgordel*) by erosion and deposition in the river bed. In the outer bends, where current is strongest, the subsurface is eroded and undercut in the cut side (*stootoever*). The eroded material may consist of older river deposits or any sediment/rock of a different origin. In the inner bends, deposition takes place periodically in times of high floods. The varying deposition rate causes the sediments to form ridges, so called scroll bars (*kronkelwaardruggen*). The depressions in between the ridges are called swales (*kronkelwaardgeulen*). Scroll bars and swales together make up the point bar (*kronkelwaard*), see figure 3.

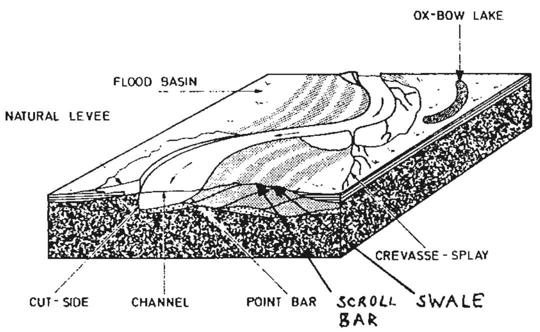

Figure 3 Terminology of a meandering river (After Reineck, 1980).

At flood stages the overflow can deepen pre-existing swales. They will gradually take an increasing proportion of the discharge and slowly the main channel will be abandoned: a chute cut-off (*kronkelwaardgeulafsnijding*), figure 4. The false channel (*dode arm*) will gradually be filled by bedload and, when the ends of the cut-off are plugged with bedload, silts and clays will settle from the lake. Plants may start to grow, building up peat (*veen*) layers. In vertical direction the resulting sediments show a gradual transition from coarser to finer particles. This fining upward sequence can often be recognized in boreholes and cone penetration tests (CPT's, *sondering*).

A neck cut-off (*meanderhalsafsnijding*) occurs when two bends have approached closely and the river suddenly cuts across the next loop, figure 4. The abandoned channel is plugged rapidly at both ends by bed material and an oxbow lake is created. The lake only receives sediment from suspension during high floods and slowly fills with silt, clay and peat: the channel fill deposits (*verlandings- of restgeulafzettingen*). These fine particles lie directly on top of either an erosion surface or the coarser bedload sediments of the former main channel. This vertical sequence differs from the sediments of a chute cut-off in the abruptness of transition in grain size, figure 5.

The meander belt as a whole can also suddenly shift to a new position on the alluvial plain, a process known as avulsion (*stroomgordelverlegging*).

Floodplain and crevassing

In times of high river discharge water level in the river bed rises and can flood the adjacent area, which is called the floodplain (floodbasin,

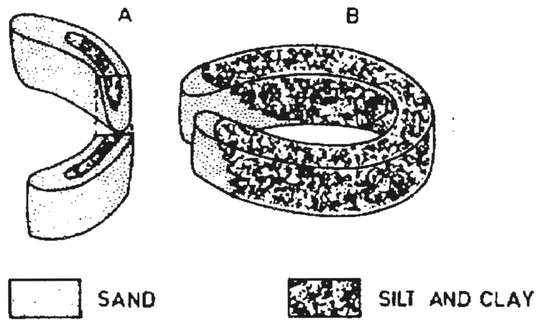

***Figure 5** Channel fill deposits in a chute cut-off (A) and in a neck cut-off (B) (After Reineck, 1980).*

backswamp, *kom*). Once the water flows outside the main channel it quickly looses turbulence and the coarser particles drop near the river bed, thus forming natural levees (river banks, *oeverwal*). The levees can grow as high as the highest flood level and usually exhibit a fining upward sequence. Further in the floodbasin water stops flowing and even the fine clay particles can settle, slowly building up a heavy clay in the floodbasin. In the poor drainage conditions of the floodplain vegetation develops and, when organic production rate is high compared to the sedimentation rate of clastics (depending on frequency of flooding), vegetation horizons (*laklagen*) occasionally develop in the floodplain clays. A vegetation horizon can be recognised as a layer of amorphous organic material in a clay matrix, typical layer thicknesses being 5-20 cm.

Further from the main channel, where natural drainage is lower, the vegetation horizons gradually thicken to peat layers. Peat is defined as a soil in which more than 15% of the soil consist of organic material like leaves, seeds, branches and trunks in various states of decomposition.

By later differential compaction the relief between the natural levees and the channel on the one hand, and the low lying floodplains on the other hand is increased, figure 6.

If, in a high flood stage, the river breaks through the natural levees, a fan of small channels cuts through the floodplain clays. Subsequent sand fill

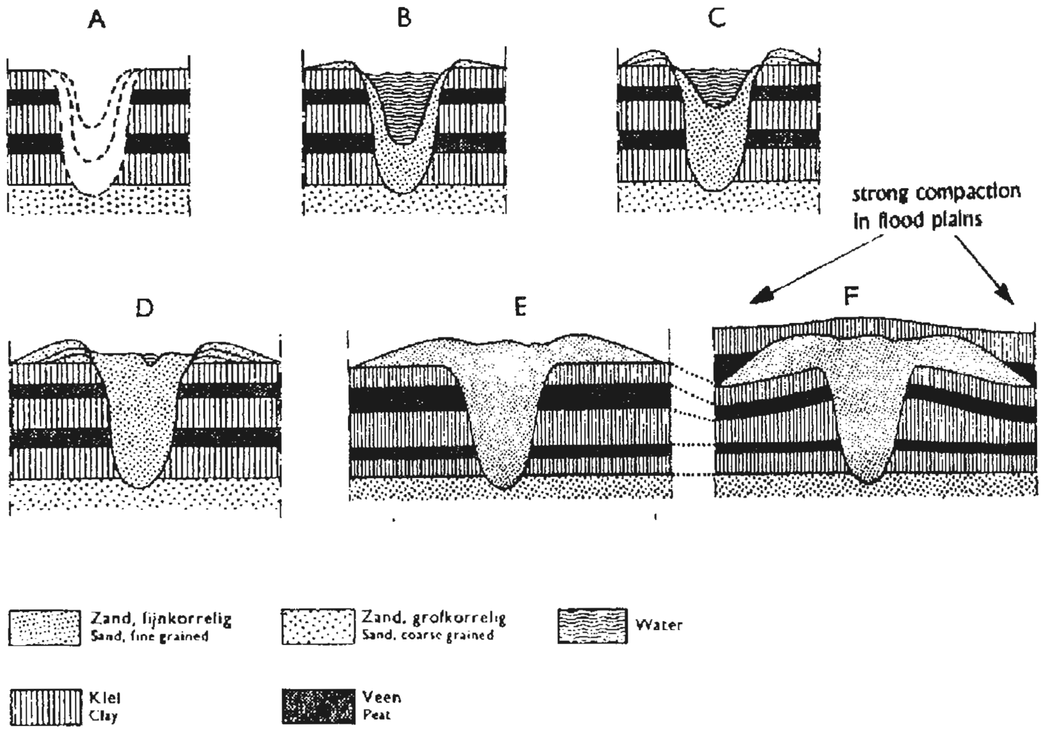

***Figure 6** Successive stages of differential compaction in meandering river deposits, leading to relief inversion.*
A=first stadium of river, incision. The river bed is a depression in the landscape;
B,C,D=build up of natural levees, followed by decreasing river action in a false channel;
E=fossil river with channel deposits and channel fill deposits, slightly elevated in the landscape;
F=further compaction of the floodplains causes an increased relief.
Eventually both the low lying floodplains and the fossil channel are covered by younger deposits (After Vebraeck, 1974).

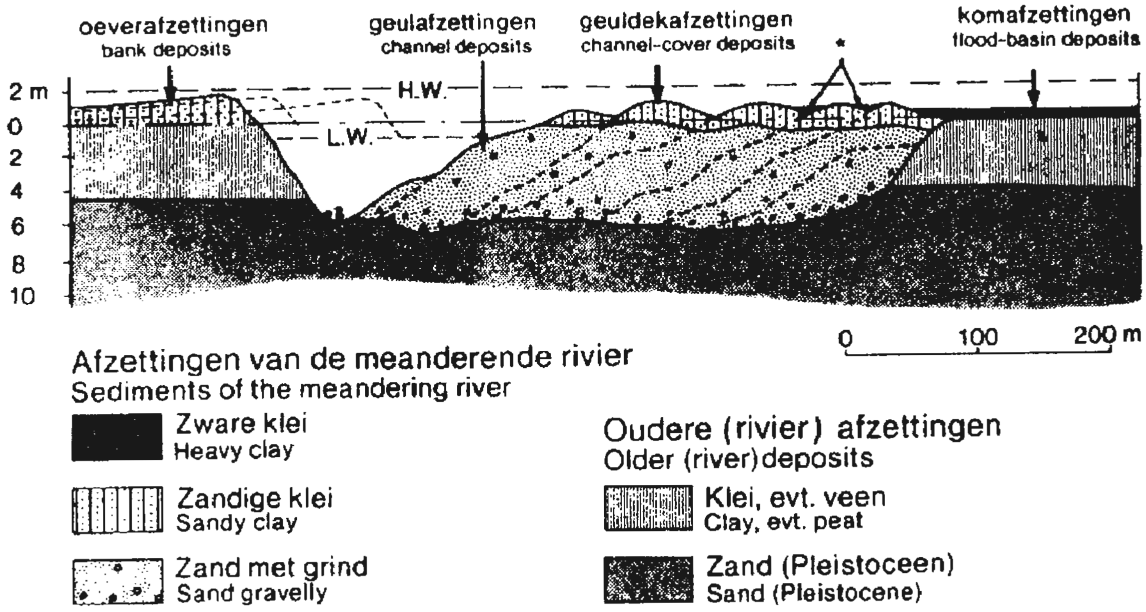

Figure 7 Schematic lithologic cross section through a meandering river, as found in the middle part of The Netherlands (After Verbraeck, 1984).

of the crevasse channels forms the crevasse splay deposits (*oeverwaldoorbraakafzettingen*).

Lithologies and sedimentary structures

Meandering rivers build up all types of soils: gravel, sand, clay and peat. Each depositional environment in a meander system (point bars, abandoned channels, levees, floodplain and crevasses) results in a different lithology. In a borehole or CPT you can recognise these lithologies. Once you have found out the depositional environment of the lithological units, you can predict its lateral continuity, or horizontal extent. But how to assess the depositional environment of an observed lithology? You will have to examine factors like grain size, sorting, sequences and contacts, sedimentary structures etc.

Point bars generally consist of tabular sand units overlying a near-horizontal erosion surface, figure 7. These sands show an upward decrease of grain size and are cross-bedded with upwards reduction of set size. From the cross bedding the former direction of flow can be deduced.

As explained before, cut-off loops fill with either a fining upward sequence from coarse sands to clay and peat, or show a sudden transition from bedload to clay and peat, figure 5.

The natural levee or bank deposits (*oeverafzettingen*) vary in grain size from sandy clay to silt to sand, depending on the longitudinal position, i.e. upstream-downstream, in the river course. The levees are locally interrupted by coarser grained crevasse splay deposits. Common sedimentary structures in levees are ripple cross lamination and parallel lamination. Levee deposits have a low preservation potential because they occur mainly on outer banks and therefore only escape erosion if the channel is cut off.

Floodplain deposits consist of heavy clay (i.e. containing a high percentage of particles $< 2\ \mu$) and peat layers, which wedge out to thin vegetation horizons in the direction to the channel. The areal extent of the floodplain sediments usually is far larger than the meander belt deposits, so these fine grained sediments make up a substantial part of the total Dutch alluvial plain.

Fan shaped coarser sediments in the floodplain result from crevasse splays. Grain sizes in the former crevasse channel vary from silt to sand, channel depth decreases from the levee to the floodplain. Cross lamination directions diverge from those of adjacent channel sands. The sandy and silty crevasse splay deposits form a very irregular pattern in the floodplain clays and peats, in which an individual channel sometimes can be followed for several kilometres.

Summarising it can be said that sediments of meandering rivers are distributed very heterogeneously, due to the processes of channel cut-offs, avulsions and crevassing of the levees. Both in lateral and vertical sense gradual transitions from gravel, sand, silt, clay and peat occur, as well as sudden transitions in grain size. Each lithologic unit belonging to a specific depositional environment (channel deposits and channel fill deposits in chute cut-offs and neck cut-offs, bank deposits, crevasse splay deposits and floodplain deposits) has its characteristic lateral continuity. For most lithogenetic units the horizontal extent in the longitudinal direction differs from that in the direction perpendicular to the river course. Absolute values for the lateral extent of each unit are hard to give because they vary with the size of the corresponding river system and the longitudinal position.

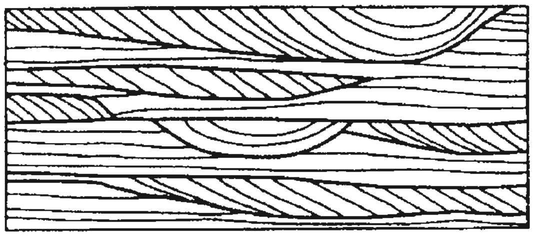

Figure 8 Schematic profile of sedimentary structures in braided river sediments (Open Universiteit 1992).

Braided rivers

In contrast to meandering rivers braided (*vlechtend*) rivers build up a relatively homogeneous body of coarse sands and gravels with large lateral continuity. Braided rivers are characterised by many small, moderately wide and shallow channels, which split and join repeatedly. The islands between the channels are flooded in periods of high water when the river consists of a wide turbulent stream of only a few metres depth. Both the position of the channels and the sediments shift rapidly and continuously in time.

The bars are built up by deposition of sand and gravel at the downstream end and by lateral accretion. On the upstream end of the bars erosion takes place. This process gives the sediments cross bedding structures. When, after a period of high water, the current decreases slowly, parallel bedding structures may form. These two characteristic structures in braided river sediments are shown in figure 8.

The braided river sediment body consists of both a lateral and a vertical alternation of bars of different grain sizes. Gravel bars are poorly sorted, which is inherent to their large grain size. Sand bars can have a more uniform grain size distribution. The difference in grain size and sorting in bars gives braided river sediments a rather irregular cone resistance in CPT's.

Anastomosing

In an aerial view an anastomosing (*anastomoserend*) river shows large similarity to a braided river: several channels which split and join. With respect to sedimentation mechanism though, anastomosing rivers more resemble meandering rivers. The sediments can also be divided into channel-, bank-, crevasse- and floodplain deposits.

In contrast to braided rivers the anastomosing channels are stable and do not shift in time, so no wide stream belt develops, see figure 2. Avulsions do occur regularly though. The anastomosing channels are narrow and deep. In the wet floodbasins between the channels peat may develop. The clay and peat layers in these backswamps are intersected by strongly branched crevasse deposits.

In anastomosing rivers crevassing occurs more frequently than in meandering systems. The crevassing process being a main cause for an extremely variable sediment body, soils originating from anastomosing rivers are even more irregularly distributed than the ones from meandering rivers.

PLEISTOCENE

Now that we have learned something about the various river patterns and their sediments, we will apply this knowledge to the Dutch alluvial plain. We will have a look at the genesis and the geological history of the sediments in the upper 300 metres.

Below the alluvial sediments

The Netherlands form the southern part of the North Sea basin, an area which has been subsiding for a very long time and still continues to do so.

During the Tertiary, the period from 65 to 2.4 million year (Ma) ago, a shallow sea covered The Netherlands in which thick layers of marine clays and fine sands were built up. These Tertiary clays and sands are still present in the Dutch subsurface, but are deeply buried and consolidated in most places. The Tertiary clays generally differ from the Holocene ones in their dark and greenish colour, high stiffness and low water content. The marine origin contributes to the large lateral extent of each of the Tertiary layers.

About 2 Ma ago the sea retreated and rivers started to deposit their sediments on top of the Tertiary surface, which presently lies at about 100 m below surface in the eastern part of the Dutch alluvial plain, and at about 300 m in the western part.

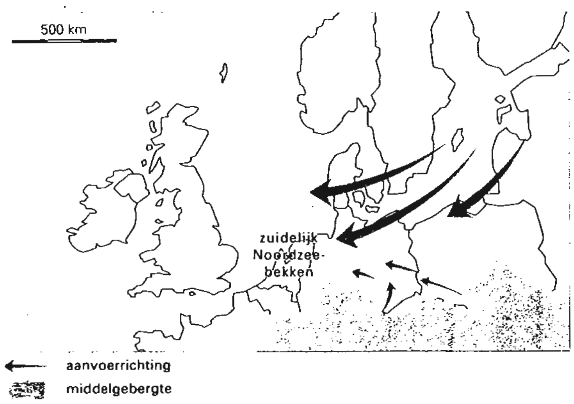

Figure 9 The Baltic river system. Note the immense hinterland, containing Middle and Eastern Europe (Open Universiteit 1992).

Ice ages

The Pleistocene is the epoch of ice ages: climate changes, triggered by variations in solar insolation, led to colder and warmer periods: the glacials and interglacials. Within a colder period temperature could also fluctuate, the warmer periods within a glacial are called interstadials.

The reconstruction of the warmer and colder periods has been done by deepsea core analysis and pollen (*stuifmeel*) analysis. Cores of deepsea sediments are examined on the ratios of oxygen and carbon isotopes in calcite skeletons, which gives information about parameters as temperature of seawater, productivity of organisms and polar ice cap volume. Pollen analysis is based on the fact that each plant flourishes in a specific climate. The pollen of plants are conserved in sediments, and today the paleoclimate of a certain period can be reconstructed from the combination of pollen found in a specific sediment. If the same sample contains organic material, C-14 analysis can provide absolute dating of the reconstructed climate until 30 ka ago (1 ka = 1000 years).

During the ice ages enormous ice sheets covered part of the northern hemisphere. A lot of ocean water was stored in these ice sheets, and the global sea level has been at least 120 m lower than at present. The southern part of the North Sea fell dry and formed a large alluvial plain over which rivers transported meltwater from continental glaciers in the Alps, via The Netherlands, the dry North Sea and The Channel, to the Atlantic ocean.

The typical river pattern during glacials was braided. In the hinterland the cold climate resulted in reduced vegetation and severe mechanical erosion. In winter all precipitation fell as snow, causing little discharge in winter and a large amount of melt water in spring and summer. The

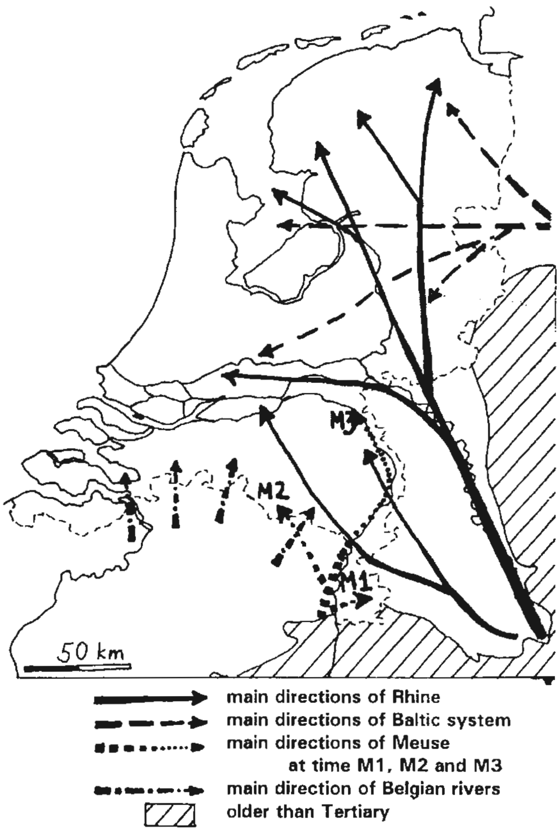

Figure 10 Main supply directions of the river systems transporting Pleistocene sediment to the Southern part of the North Sea basin (Open Universiteit 1992).

seasonal discharge combined with abundant erosion products forced the rivers to be braided.

Pleistocene river systems

In North-West-Europe four river systems were active in the Pleistocene epoch. The Baltic system from Scandinavian and North-German origin, figure 9, ended 500 ka ago in The Netherlands. The other three systems still continue, these are the Rhine system, the Meuse system and some smaller rivers originating in Belgium.

In response to regional tectonics these systems shifted their courses several times. Together they formed a large alluvial fan and their sediments are found in subsurface of the whole of The Netherlands, figure 10.

The boundary between the Baltic sediments on the one hand, and the Rhine/Meuse sediments on the other hand runs in an east-west direction through about the middle of The Netherlands. The Belgian river sediments are encountered in the southern and western part of The Netherlands.

The type of sediments deposited through these

<table>
<tr><th></th><th>EASTERN RIVERS</th><th>RHINE</th><th>MEUSE</th><th>BELGIAN RIVERS</th></tr>
<tr><td>grain size</td><td>medium and coarse sands</td><td>alternation of thick layers of clay and sand</td><td>coarse sands and gravels</td><td>fine sands and clays</td></tr>
<tr><td>colour</td><td>white</td><td>brown</td><td>grey/brown</td><td></td></tr>
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Harderwijk Form.
Enschede Form.
Urk 1 Formation</td><td>Urk 2 Formation</td><td>Veghel Form.</td><td rowspan="2"></td></tr>
<tr><td colspan="2">Sterksel Formation
Kreftenheye Formation
Betuwe/Westland Formation</td></tr>
<tr><td colspan="3">Tegelen Formation
Kedichem Formation
Kiezeloolieten Formation</td></tr>
</table>

Table 1 Overview of characteristics of Pleistocene alluvial sediments.

river systems depends on factors like composition and age of rocks in catchment area, distance of transport, and climatological conditions. Each of the four mentioned river systems has specific characteristics with different engineering geological and geohydrological properties, which will be described below and is summarized in table 1.

Baltic system

In general Scandinavian deposits are thick members of medium to coarse sands and fine gravels, there are hardly any clay layers present. The appearance of the sands and gravels is white, they are sometimes called 'clean' sediments. It is the high fraction of transparent quartz minerals which gives the sands their white colour. In general the Baltic sediments are permeable and form aquifers.

Rhine system

Usually grain size of Rhine sediments is less uniform than that of Baltic sediments. Lithology of Rhine sediments strongly varies in depth: grain sizes depend on climatological conditions during deposition. In the interglacials the meandering Rhine generated thick layers of fine grained sediments like clays and fine sands, while in glacials the braided river deposited coarser particles.

Rhine sands are usually brown coloured because of their mineralogical composition: white, red and grey quartz, red and grey sandstone and black minerals. Rhine sediments form both aquifers and aquicludes.

Meuse system

Meuse sediments consist mostly of coarse sands and gravels in South-Netherlands. The Meuse did deposit fine grained sediments during interglacials but these were washed away during subsequent glacials. The sands contain less red-coloured grains than Rhine sediments and have a more grey appearance. In Limburg changes in climate led to an alternation of erosion and sedimentation and Meuse terraces were built.

Meuse sediments often are aquifers and Limburg is the most important Dutch exploitation area for gravels. They are dredged in pits and mined in quarries from 10 to 20 m thick gravel layers. On the terraces the gravels are overlain by coversands or löss, in the river bed sometimes by Holocene clay.

Belgian system

Belgian rivers eroded the outcropping Tertiary sands of the Brabant Massive, and deposited these in Brabant, southern part of Zuid-Holland and South-Limburg. The river pattern may have been meandering, the sediments consist mainly of fine, well sorted sands and clays. Belgian river sediments are usually considered as aquicludes.

Concludingly it can be said that on top of the Tertiary marine deposits, alluvial sediments of river systems Rhine, Meuse, Baltic stream and Belgian rivers dominate the Pleistocene sediment body, figures 11 and 12. The continuous subsidence of the North Sea basin and the ever changing course of the rivers contributed to the infill of the basin with alluvial gravels, sands and clays of a thickness up to 500 m in North-West-Netherlands, while wind and ice only accounted for minor deposition in the Pleistocene epoch.

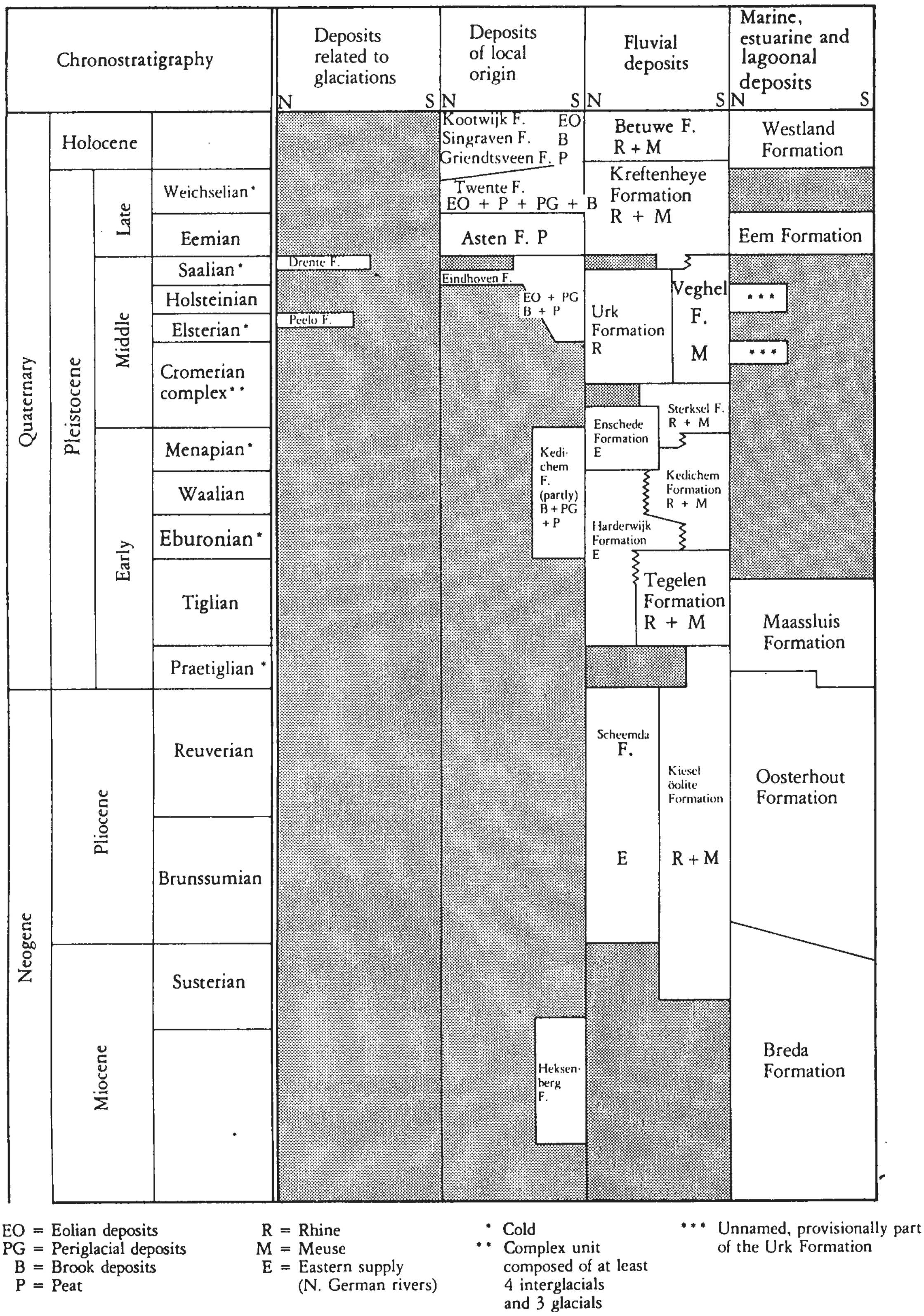

Figure 11 Upper Tertiary and Quaternary formations with reference to chronostratigraphic position and to genesis (After Staalduinen et al., 1979).

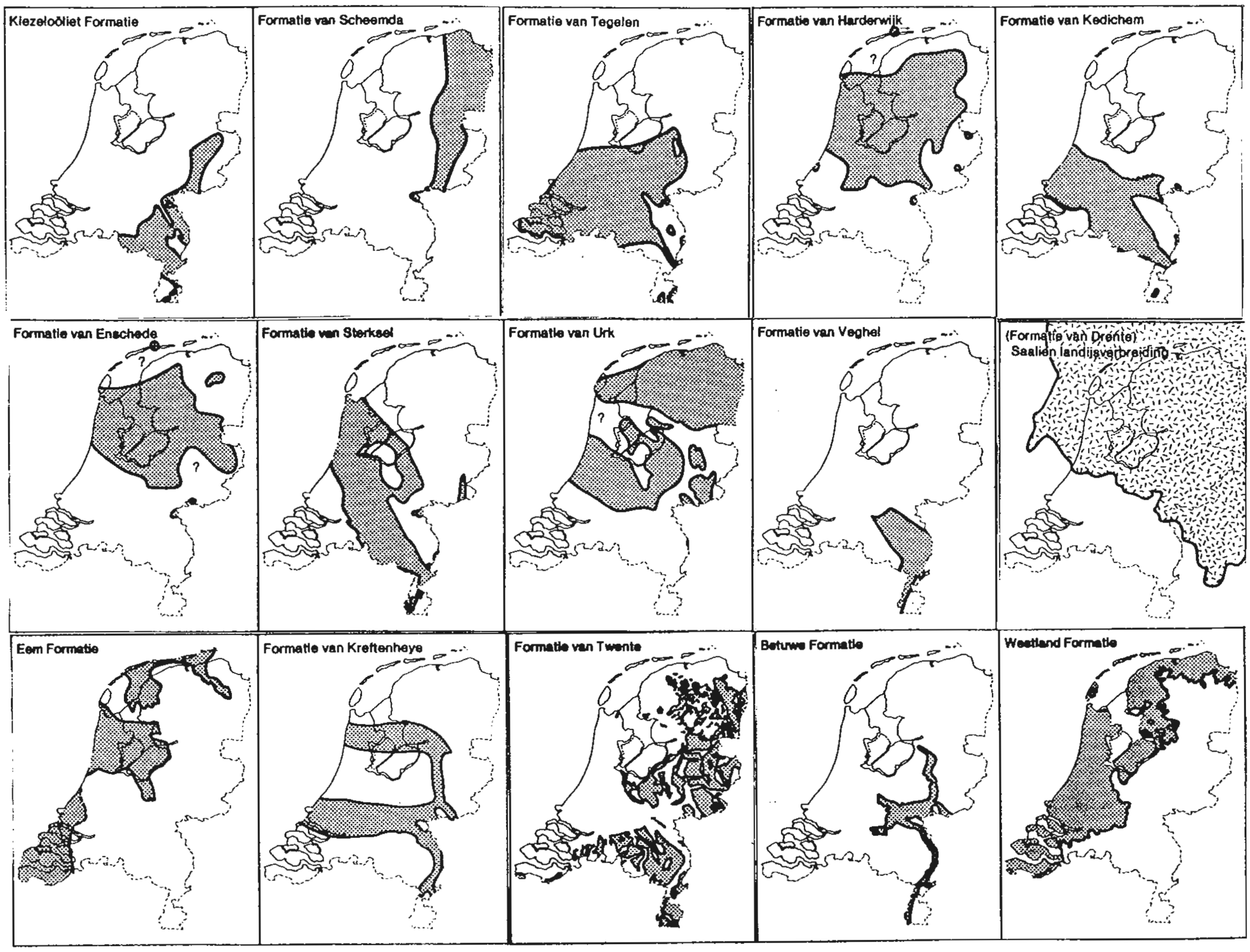

Figure 12 Distribution maps of mentioned Pleistocene and Holocene formations (After Verbraeck, 1984).

Both horizontal and vertical lithological variability is relatively low in the Pleistocene alluvial sediments.

Geological history in the Middle Pleistocene
During the Pleistocene ice sheets covered The Netherlands at least twice: in the two but last and one but last ice ages, the Elsterian and the Saalian. In the Elsterian, characteristic very stiff 'pottery' clay (*potklei*) was formed, but little is known about the detailed processes in this glacial. During the Saalian, which ended 130 ka ago, an ice sheet covered the northern part of The Netherlands, figure 12, banning the rivers and remodelling the landscape north of the alluvial plain. The Saalian was followed by the Eemian interglacial during which the relative sea level rose to about 8 m above the present sea level. The sea intruded into the downstream part of the river channels and deposited a.o. fine grained marine sediments, see figure 12.

Late Pleistocene sediments
Before continuing with the Holocene sediments we will first consider the specific Pleistocene deposits which you can encounter directly below the base of the Holocene sediment body.

In the Dutch alluvial plain the top of Pleistocene sediments dominantly consists of four lithogenetic units: coarse braided river sands, the 'Hochflutlehm' clay layer, river dunes and coversands. They are treated below.

Braided river sands
The Eemian interglacial was followed by the Weichselian glacial which lasted from 120 ka to 10 ka ago. Braided rivers laid down a relatively continuous layer of coarse sands and gravels, they belong to the Kreftenheye Formation. The irregular alternation of coarse sand bars and gravel bars often gives the cone resistance in CPT's a highly variable character. The alternation can usually be recognised in boreholes cores and outcrops as well. Generally the top of the braided river sands dips uniformly to the west, see figure 13.

This Kreftenheye unit is the one on which most buildings are pile-founded in West-Netherlands. For very heavy constructions it is often not suitable as a foundation layer because the underlying fine sediments of the Kedichem Formation (Belgian

Figure 13 Depth of top of Pleistocene sediments in m-NAP (After Zagwijn et al., 1985).

river deposits) can produce unacceptable settlements. In geohydrological terms the Kreften-heye sands compose the first aquifer, but be aware of connections to the phreatic water table! In a next paragraph this warning will be explained in detail.

Hochflutlehm

On top of the Kreftenheye river sands a thin clay layer can be found in most locations. It was deposited at the end of the Weichselian glacial in the Bølling-Allerød interstadial, when climate warmed up for a short period of about 2000 years. The river pattern changed from braided to meandering and cut into the coarse sands and gravels. The river plains flooded regularly and over a large area a clay layer of at most 1 m thickness was sedimented, the so called Hochflutlehm (or *rivierleem*). The deposition of this clay layer did not notably disturb the regular topography of the Pleistocene sand surface.

During the next few thousands of years the rivers flowed in a non-depositional regime, so the Hochflutlehm has been exposed on the surface for a relatively long time before being covered with Holocene sediments. In boreholes the Hochflutlehm sometimes resembles the overlying Holocene clays. Geologically speaking the Hochflutlehm is a different clay though. Due to its far longer exposure it will also have different engineering geological properties from Holocene clays.

River dunes

After the warmer Bølling-Allerød interstadial, climate turned colder again from 11 to 10 ka ago, a period called the Younger Dryas. Braided rivers dominated in a landscape with sparse vegetation and large seasonal variation in river discharge. During low stages the river bed exposed loose material and wind could transport sand from river beds to the river banks and floodplains, thus building river dunes (*donken*). Prevailing winds used to be south-west and dunes formed on the lee-sides of the river beds. Their aeolian origin gives the dune sands a good sorting. River dunes can be up to 20 m high. In the eastern part of the alluvial plain not all dunes are covered with younger sediments and some can still be recognized in the landscape as sandy hills. In the western part only few dunes still reach the surface, figure 14. Most dunes are buried under younger river deposits, e.g. the Hillegersberg in Rotterdam.

The river dunes have a larger bearing capacity and are drier than the surrounding backswamps and the prehistoric engineering geologists advised their people to choose the dunes for their farms and villages, e.g. the village of Wijchen, south-west of Nijmegen.

Just as the braided river sands and the Hochflutlehm, river dunes are included into the Kreftenheye Formation. The correspondence between these three Kreftenheye soils is their river-related genesis and Weichselian age. The occurrence of river dunes gives the braided river sand surface an irregular geometry as can be seen in figure 14.

Mind that, in locations where the Pleistocene Hochflutlehm is present, geological maps displaying the top of Pleistocene do not show the same feature as top-of-Pleistocene-sand maps!

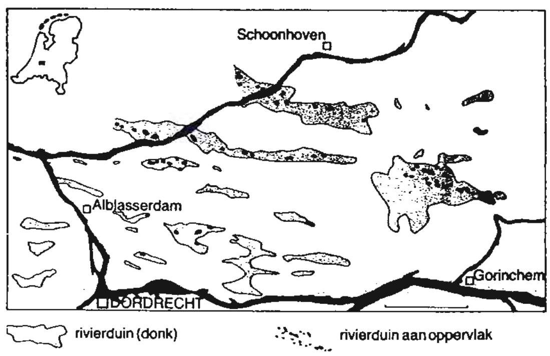

Figure 14 Buried and outcropping river dunes in the Alblasserwaard (After Zagwijn, 1986).

	COVERSAND	RIVER DUNE SAND	CHANNEL SAND
μ-value in μ	150 - 210	210 - 420	210 - 1,000
percentage gravel	0	0	0 - 20
sorting	medium - well sorted	medium - well sorted	medium - poorly sorted
Ca-content	low	low	high
permeability in mm/day	500 - 10,000	1,000 - 20,000	1,000 - 50,000

***Table 2** Typical properties of various sands (After Berendsen et al., 1994).*

Coversands
While in the alluvial plain the three Kreftenheye units formed, coversands (*dekzanden*) spread over large parts of The Netherlands. They covered the landscape like a blanket, thus the name. Coversands are included into the Pleistocene Twente Formation. They are no river deposits but have an aeolian origin. Wind took fine sand grains from the barren land surface, transported and deposited them somewhere else. Coversands are transported further than wind dunes and have a larger lateral extent. Also they have an even better sorting and a smaller grain size: typical μ-values for coversand are 150 to 210 μ, while river dune grains have μ-values of 210 to 420 μ, see table 2.

HOLOCENE

Now that we have discussed the four lithogenetic units composing the top of the Pleistocene surface, we will have a look at the overlying Holocene deposits. First the geological developments during the Holocene will be described briefly, followed by the resulting sediments. Then three differences between the west and the east part of this alluvial sediment body will be pointed out, including some more details about the Holocene geological processes. Next a stratigraphical overview of the various units is given and finally the consequences of the variable Holocene sediments for dike construction and clay mining are treated.

Geological history

After the colder period of the Younger Dryas, climatological conditions changed considerably. The Holocene, the present-day interglacial which hasn't ended yet, started about 10 ka ago. By the raise of temperature ice sheets in Scandinavia and the Alps melted and global sea level rose very quickly during a period of 5000 years. River patterns changed from braided to meandering again for two main reasons.

The first one is that vegetation in the northern half of Europe became denser and prevented severe erosion, so less sediment was available for transport. Secondly the amount of water in glacier-fed rivers became more constant throughout the year: in interglacials discharge fluctuates less with seasons.

During the first 2000 years of the Holocene there was little sedimentation and the meandering rivers cut into the Pleistocene landscape made up of (do you still remember?) the Kreftenheye river deposits, i.e. coarse braided river material, the Hochflutlehm clay layer and the river dunes of fine sand, and the Twente coversands. From 8000 years BP (before present = 1950) on, rivers turned from erosive to accumulative, figure 15. This transition

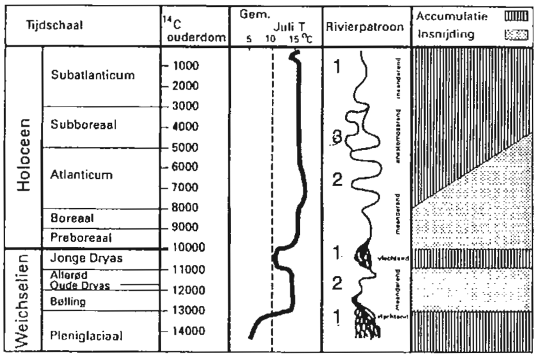

***Figure 15** Changing river pattern in time in Gelderland. Note the difference between west and east (resp. left and right side in col.5). Col. 4: 1= braided, 2= meandering, 3= anastomosing. (Berendsen et al. 1994)*

started in the western part of the alluvial plain and slowly shifted eastward, as will be explained in a next paragraph. Reasons for the transition from erosive to accumulative meandering rivers are deforestation by man in the catchment area on the one hand, and decreasing river gradient due to sea level rise on the other hand.

Alluvial deposits

Meandering rivers

The meandering river systems laid down large amounts of clay in the floodbasins, and vegetation in these backswamps resulted in intercalations of vegetation horizons and peat layers. The floodplain clays were locally eroded by the ever changing course of the meandering- and crevasse channels. These channels were sand and silt filled after abandoning, and often covered by clay and peat of later rivers. A meander belt led to a relatively wide and shallow sand body, figure 2, which often has a width/thickness ratio of over 50. Typical μ-values for channel sands are 210 to 1000 μ. Due to deposition in a lower energy environment these channel sands are in general better sorted than braided river sands and produce a more regular cone resistance in CPT's.

Recapulating: the meandering river system resulted in a fluvial sediment body of very soft and impermeable Holocene clay and peat layers and lenses, irregularly intersected by sand filled channels.

Anastomosing rivers

From 5 to 2 ka ago rivers turned into an anastomosing pattern in the western part of the alluvial plain, figures 15 and 16. Factors as high rate of ground water rise and resistive clay and peat subsurface contributed to the transition to this river pattern. More eastward slower rate of ground water rise and the occurrence of relatively shallow, easily erodible Pleistocene sands continued to provide favourable conditions for meandering rivers.

Anastomosing channels were relatively straight and narrow, and the resulting sand body has a typical width/thickness ratio less than 15. Crevassing occurred more often in the anastomosing system than in the meandering system, leading to an even higher lithological variability in the western part of the alluvial plain.

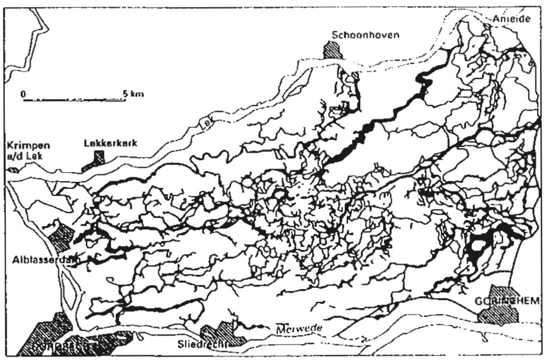

Figure 16 *Anastomosing river pattern in the Alblasserwaard (After Vebraeck, 1970).*

Difference east-west

Additional to differences in lithological variability and in channel width/thickness ratio, the subsurface of the alluvial plain exhibits three more gradual changes going from west to east. These changes will be described below.

1. Peat

The thickness of peat layers in the floodplains decreases from west to east. The western part of the alluvial plain, the so called 'perimarine area', see figure 1, is characterised by alluvial fresh water sediments deposited under influence of the sea level rise. The sea level rise and the consequently high ground water table created favourable conditions for vegetation to grow, and thick, continuous layers of peat developed. Peat layers can reach a thickness of 5 m, which leads to foundation and settlement problems. The total thickness of the soft clay and peat layers is over 15 m in the west part of the alluvial plain, see figure 13.

Further to the east in the alluvial plain, where the ground water table was less influenced by the sea level rise, peat also developed but more lens-shaped and not as thick and continuous as in the perimarine area.

Last centuries lots of Holocene peat has been dredged or dug away to be used as fuel. The peat in the western part of the alluvial plain was not very suitable as fuel. Here the ground water provided abundant nutrients to the vegetation and in the wet floodplains eutrophic peat formed. As a fuel eutrophic peat leaves a lot of ashes. Additionally, it contains much sulphur and smells strongly upon burning. More east in the alluvial plain and in the province of Noord-Holland ground water table was lower and vegetation more depended on rain water. Oligotrophic peat formed, which is more appropriate for fuel purposes. Nearly all of the peat in these areas has been mined. Even nowadays some peat mining still continues in Drenthe. It is used for active coal production because peat has an extremely high absorption capacity.

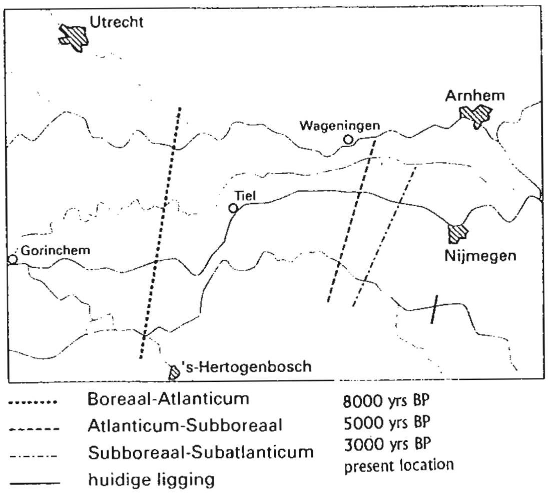

Figure 17 Changing position of terrace intersection in time. (Open Universiteit 1992).

2. Clay

There is a general trend of increasing thickness of the Holocene sedimentary wedge from east to west. As said before, from 8000 to 4000 years ago the meandering rivers Meuse and Rhine turned from erosive to accumulative, a process that began in the west and slowly shifted to the east. In other words: the terrace intersection points (*terrassenkruising*) moved eastward over the alluvial plain, see figure 17. The terrace intersection point is defined as the point in the longitudinal river profile where the river stops eroding and starts depositing. The slow movement of the terrace intersection point implies that in the west accumulative conditions have existed for a far longer time, leading to a thicker Holocene sediment body, than in the eastern part. Nowadays the terrace intersection point for the Rhine lies in Germany and for the Meuse in North-Limburg. This is the reason why the Meuse does not have any river dikes in South-Limburg: it has cut into older sediments.

3. Sand filled channels

Though an accumulative meandering river system as a whole builds up sediments, the meandering channel itself cuts into the underlying soils. Sometimes the channel erodes as deep as to the Pleistocene surface. This happened more often in the east of the alluvial plain than in the western part, schematically shown in figure 18, which can be explained by the wedge-shaped form of the Holocene sediments and the westward dip of the Pleistocene sand surface. Rivers could erode several metres into the Pleistocene sands, in later periods the channels usually were filled with younger Holocene sands. Not all of the Holocene meandering channels reached the Pleistocene sands however, especially in the west older Holocene clay or peat layers can be present in between, see figure 18. Due to tidal effects the channels in the west generally are wider than more eastward.

With respect to sand filled channels two tricky

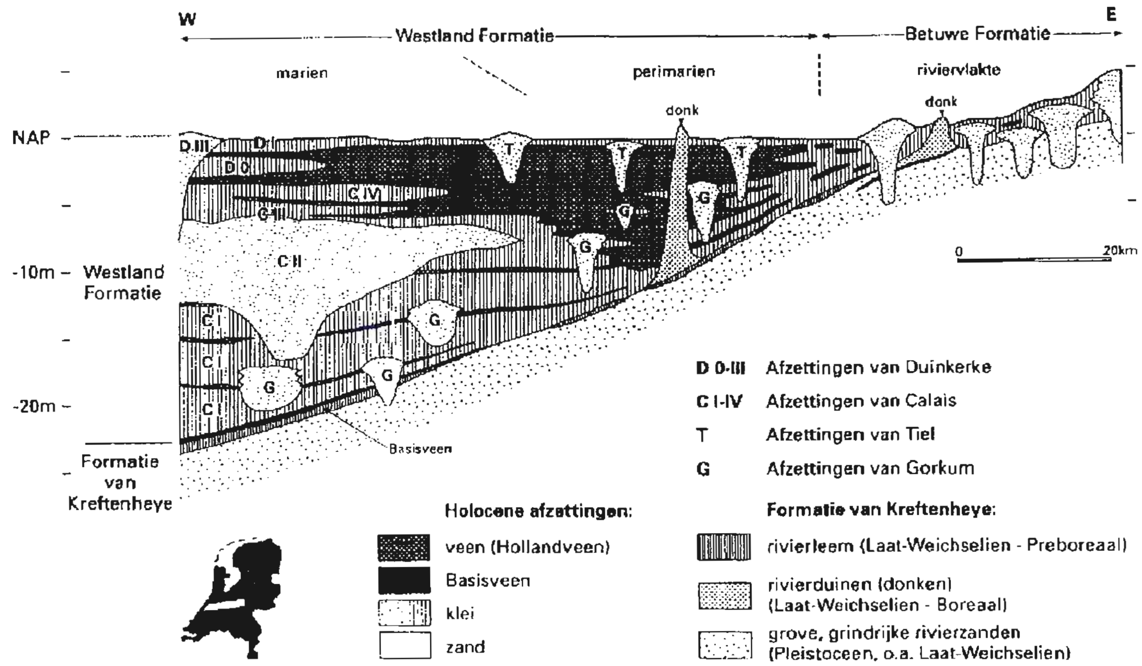

Figure 18 Schematic cross section Voorne - Arnhem. After (Open Universiteit 1992).

engineering geological characteristics are mentioned.

Depth-to-Pleistocene-sand maps are often used to give an indication of foundation depth, but in cases where Holocene rivers eroded into the Pleistocene sands such a map has to be used with caution. In the channel the map shows a greater depth to Kreftenheye sands, but foundation piles might even be shorter than outside the channel, depending on the bearing capacity of the Holocene sand fill.

A second aspect important to the engineering geologist concerns geohydrological aspects. Kreftenheye sands are often considered as a confined aquifer. But on many locations the Holocene channels, either sand filled or still active, connect the Kreftenheye aquifer to the phreatic water table. This implies that the Kreftenheye aquifer is not really confined, especially in the east where many Holocene channels have eroded into the Pleistocene. Additionally the sand deposited in channels in the east is coarser grained than sand deposited further downstream, a fact enlarging the geohydrological connection between the phreatic water and the first aquifer.

Stratigraphy

An overview of some relevant stratigraphical names used by the Geological Survey of The Netherlands (RGD) is given in figure 19. Each unit is characterised by its genesis, lithology and age.

The marine and perimarine Holocene sediments are classified to the Westland Formation. They also include the alluvial sediments in the western part of the alluvial plain, where the fresh water sediments are influenced by the sea level rise. The alluvial sediments further to the east belong to the Betuwe

floodplain deposits (clay)	< 0.1 - 10
floodplain deposits (organic clay, clayey peat, peat)	5 - 100
channel fill deposits (clay, peat)	0.1 - 100
bank deposits (silt)	10 - 100
channel deposits (medium - coarse sand)	1,000 - 50,000
Pleistocene river dune deposits (fine - medium coarse sands)	500 - 20,000
Pleistocene river deposits (sand, gravel)	> 20,000

Table 3 Permeabilities in mm/day for various deposits (After Berendsen et al., 1994).

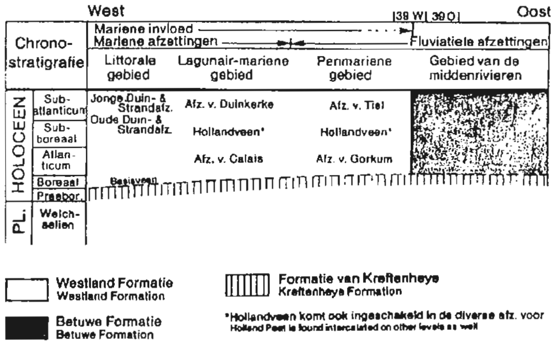

Figure 19 Schematized review of the stratigraphic units recognised in the Holocene succession of the coastal-, peat-, and river-area (After Verbraeck, 1984).

Formation, see also figures 1, 12 and 18.

The Westland Formation is subdivided into peat deposits, salt water clays and fresh water clays. The oldest member is the basal peat (*Basisveen*), a more or less continuous peat layer which can be recognized over larger distances, located directly on top of the Kreftenheye sands, Hochflutlehm and coversands. The shallower, younger peat layers are called Hollandveen. The salt water clays and peat formed along the coast are subdivided into older Calais deposits and younger Duinkerke deposits. The fresh water floodplain clays and other river deposits are subdivided into older Gorkum deposits (*Afzettingen van ..*) and younger Tiel deposits, which are separated by the Hollandveen. Further upstream in the alluvial plain, where floodplains were not influenced by the sea level rise and no thick, continuous peat layers developed, the river deposits are called Betuwe Formation.

Of course there is a gradual decrease of peat thickness from west to east, but on the geological map a gradual boundary between Westland and Betuwe Formation was inconvenient to visualise. A sharp boundary was chosen east of the floodbasins containing thick, continuous peat layers and runs from Wijk bij Duurstede via Geldermalsen to 's Hertogenbosch, see figure 12.

Dike failure

On some locations a dike crosses a Holocene sand filled channel. In the past dike failures often occurred at these intersections. The reason for these failures is that the high river levels generate high water pressures in the permeable channel sands (see table 3) below the dikes, resulting in an increased ground water flow from the river to the low-lying polders behind the dikes. The increased water flow can remove sand from below the dike,

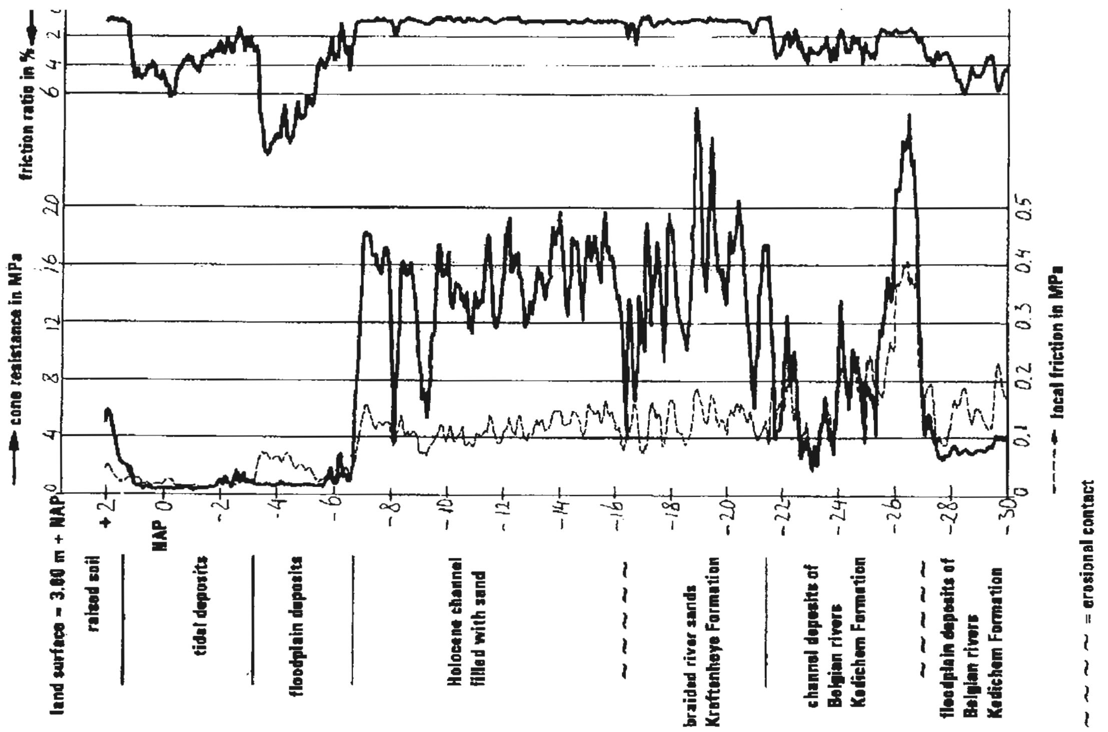

Figure 20 A cone penetration test in the western part of the alluvial plain. The depositional environment and the geological history of the units are analysed, starting at the bottom of the CPT.
The lower 9 metres of fine grained sediments can be divided into two distinct units: a relatively homogeneous clay layer and a more irregular alternation of silty and sandy layers. The layers were deposited in the Early Pleistocene by Belgian rivers in two different regimes: the deeper clay layer was formed in a floodplain, the silt and sand are probably channel deposits. Channel deposits have little horizontal continuity in directions perpendicular to the river course.
The units are overlain by coarse sands with a highly variable cone resistance. In this case it indicates braided river channel bars of the Kreftenheye Formation, deposited during the last two glacials. In general braided river sands and gravels have large lateral extent. Between the Kedichem and the Kreftenheye Formations there is a major time hiatus: during a period of 100,000's of years no deposition of sediments took place. From the geological map of the adjacent area it can be deduced that the braided river sands had been build up to a level of about -13 m-NAP. On top of the Kreftenheye sands the Hochflutlehm clay layer and maybe some fine grained sediments of meandering rivers have probably been deposited. But what we see from -16 to -7 m-NAP is a sand unit with a relatively smooth cone resistance. The regular cone resistance can be explained by deposition in a low energy environment, e.g. in a slowly abandoned Holocene channel. So the Hochflutlehm clay layer and the upper part of the Kreftenheye braided river sands have been washed away by an eroding Holocene channel. On the geological map we can find that the age of the responsible river system is about 4000 years and we know that in this area an anastomosing river pattern dominated at that time. Typical width/thickness ratios of anastomosing river channels are less than 15. The sand which gradually filled the abandoned Holocene channel belongs to the Westland Formation. On top of the channel sand floodplain clays with an increasing organic content are found, friction ratio raises from 1 to 10%. The corresponding environment is a backswamp with a rising ground water table under influence of the sea level rise. The peat is overlain by tidal deposits with grain sizes of fine sand with silt layers and silty clays, belonging to the marine part of the Westland Formation. The upper 2 m consist of raised soil.

this phenomenon is called piping and might eventually lead to dike failure.

When the dike fails, river water erodes a big hole behind the dike, a dike burst pole (*wiel, waal, weel*). Such a hole can reach as deep as to the Pleistocene sands below. Behind the hole the eroded material is redeposited in a fan shape, these dike burst deposits (*dijkdoorbraakafzettingen*) can reach a thickness of 75 cm. One of the larger dike burst poles is the Wiel van Bassa, eroded when the Diefdijk failed in the sixteenth century.

Due to dike construction the sedimentation of clay along the river between the dikes accelerated, and by now it can occur that the *uiterwaarden* lie higher than the surrounding polders. As a consequence the storage capacity in the river decreased, leading to higher risks for dike failures.

Clay mining

Clay is most mined for ceramics production. The suitability of clay for brick or tile manufacturing depends on parameters as silt and clay content, coarse and fine sand percentages, organic content, and amounts of quartz, calcite and iron minerals. An important property of clay for ceramics production is the plasticity, which is determined by the amount and type of clay minerals, usually illite, kaolinite and montmorillonite for Dutch Holocene alluvial clays. A higher clay mineral content and a larger specific surface area (montmorillonite has a higher specific surface area than kaolinite and illite) give the clays a large water absorbing potential and thus a high plasticity index. Each technique of applying the clay into the brick or tile mould requires a specific plasticity of the clay, which is achieved by mixing various clay types.

Colour of the bricks and tiles (yellow, orange, red, purple or black) depends on the presence of the minerals goethite and calcite, and on the oven temperature.

The Holocene clays deposited by the rivers Rhine and Meuse provide most of the resource material for brick and tile manufacturing. Floodplain clays, deposited far from the river channel, are not often used for brick production because of their high clay content (particles $< 2\ \mu$). The clays in the area between the dikes (*uiterwaarden*), abundantly deposited after 1200 AD, are more suitable for ceramics purposes. Meuse clays usually contain somewhat more montmorillonite and less $CaCO_3$ than Rhine clays.

Also clays deposited along the rivers Oude Rijn and Oude IJssel during the Early Holocene, are mined for roof-tile production. In general marine Holocene clays are unsuitable because of their high clay content, Na-Cl content, shells and high montmorillonite percentage.

CONCLUDING REMARKS

It must be said that in general a quantitative prediction of the lateral extent of lithological units is very difficult, even for a geologist. But by assessing the genesis of a particular part of the subsurface, you will have an indication about the variability and about the relative extent of the various units.

The information provided in this article will help to find out the depositional environment of soils encountered in CPT's and boreholes in the alluvial plain. Examples of lithological units belonging to specific depositional environments are: braided river channel bars, or various units formed in a meandering river system: channel deposits and channel fill deposits in chute cut-offs and neck cut-offs, bank deposits, crevasse splay deposits, dike burst deposits and floodplain deposits.

The depositional environment of a lithological unit might be assessed by close examination of the lithology: grain size, sorting, organic content, regularity of cone resistance, colour, fining upward sequences etc. A second clue about the depositional environment can be given by the geological period in which the unit was formed. The geological period might be deduced from the age of the unit, related to its depth, and the stratigraphical name, which is to be found on the geological map.

Figure 20 shows that it is quite well possible to determine the depositional environment of the units encountered in a CPT or borehole. The exercise of examining lithology, using additional geological information, determining the depositional environment and give a quantitative prediction of the lateral continuity of the unit, is worked out for a CPT in the alluvial plain.

ADDITIONAL INFORMATION

Detailed information about the subsurface of the alluvial plain can be found in the published geological maps (e.g. Zagwijn et al., 1985, Bosch et al. 1994 and Verbraeck, 1974), which contain a.o. depth-to-Pleistocene maps at a 1:100.000 scale and locations of the sand filled channels and sand dunes. The sand atlas 'Zand in Banen' (Berendsen et al., 1994) provides maps of thicknesses of permeable and impermeable layers. Also the article 'De ontwikkeling van het Nederlandse rivierengebied' (Berendsen, 1993) supplies some additional information.

An easy to read overview of the Holocene geological processes in the whole of The Netherlands is presented in part 1 of the series 'Geologie van

Nederland', this is the booklet 'Nederland in het Holoceen' (Zagwijn, 1986). Part 2 of this series extensively treats the mineral resources of The Netherlands, both the deep and the shallow ones (Montfrans et al., 1988).

A good overview of the geological history and the stratigraphy from the Palaeozoic on, including a chapter on natural recourses, is given in 'The Geology of The Netherlands' (Reineck, 1980), written in English. Also a geological map of The Netherlands and a mineral resources map, both at 1:600,000 scale, are included. This is a very useful text for the engineering geologist who looks for a better knowledge of the specific Dutch geology.

A special edition of the magazine 'Grond en Hamer' about Gelderland contains interesting articles about the geology of Gelderland (Bruins, 1993) and about the influence of clay properties on the brick and tile production process (Törnqvist, 1993).

An extensive, pleasant to read, treatment of Quaternary processes and consequences for The Netherlands provides the course 'Geologie rondom ijstijden' of the Open Universiteit.

ACKNOWLEDGEMENT

I thank Meindert van den Berg from RGD for his valuable corrections and suggestions to this article. All publications of the Geological Survey of The Netherlands can be ordered at RGD, Postbus 157, 2000 AD Haarlem, ☎ 023-5300300.

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Book review

Coastal Engineering- Waves, Beaches, Wave-structure Interactions

T. Sawaragi, Developments in Geotechnical Engineering:78, 1995, Elsevier, Amsterdam, pp. 469, Price: Hfl.350,=

This book on coastal engineering is part of a series 'Developments in Geotechnical Engineering', published by Elsevier. The series compromises text books on the whole field of geotechnical engineering, forming an interesting library for engineering geologist and civil engineers. To date 78 books have been published, covering geophysics, soil and rock engineering, hydrodynamics, foundation and underground engineering. A new book on waste engineering is presently in preparation.

The original Japanese edition of the book discussed here was published in Japan in 1991, and was well received by a large number of engineers and graduate students in Japan. The English edition is a revised version of the Japanese edition. This book attempts to systematically combine the fields of coastal, ocean, harbour and fishery engineering from an engineering viewpoint based on hydrodynamics. The goal of the book is to give an understanding of the interaction between waves with structures and sediments and the associated responses that underlie almost every problem in coastal and ocean engineering.

The intended target groups are graduate students and senior practising engineers. The book also deals with problems that have not yet been solved to stimulate further developments in this field

The book compromises two parts: Part 1 is entitled 'Fundamentals' and addresses the theoretical and mathematical basis of waves, currents and their interaction with structures. Starting with basic formulation of regular waves part 1 continues with the mathematical description of random waves, wave transformations, numerical wave analysis, nonlinear wave analysis and sediment transport.

Part 2 is called 'Applications' and deals with (1) control methodology such as wave control, sand transport control and motion control of moored structures, (2) harbour tranquillity and (3) fishery structures. Special attention is paid to the recent developments in this field. As in part 1, also in part 2 the subject is treated essentially in a mathematical fashion.

The preface of the book gives the potential reader the feeling he or she has one of the best books available in the field of coastal engineering. However, before buying, it would be a good idea to take a close look at the actual contents of the book. The first thing to notice is the number of equations: 819 in the whole book! Those people that want to make good use of the book should be well educated in higher-order differential analysis and numerical analysis. Otherwise the book will be left on the shelf after the first few pages have been read.

The book seems to be mainly intended for fundamental research in the field of coastal engineering and as a reference when calculations have to be made. The main target group therefore seem to be research institutes and PhD students. For them the book seems a valuable addition to their library, though a rather expensive one. For those that are not working in this field daily or those that have not an active knowledge of advanced mathematics the book may not be very appropriate.

The layout and presentation are, as all books in this series, excellent with high quality figures, plenty of references and an extensive index. Especially with this type of book the index plays a vital role and this seems to have been acknowledged by the editors. The book has a hard cover and will cost about Hfl. 350,-.

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Delft University of Technology
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Section Engineering Geology

In Focus : Robert Berkelaar

Yvette van Velsen & Jeroen Dankelman

Robert Berkelaar (25) graduated at the Technical University in Delft in engineering geology in '94. After joining the army for a year he applied for several jobs. Presently he is working for Gemeentewerken in Rotterdam.

Robert Berkelaar initially started in September 1995 at Gemeentewerken Rotterdam writing reports and getting rid of a backlog they had at Gemeentewerken Rotterdam.

"It was fun for a while, but when you've done one test load you know how it works. You're not learning anything new."

Gemeentewerken Rotterdam has an engineering department with several divisions that are active in the field of e.g. the environment, project management and geotechnics. These divisions usually work for local authorities, but also for provate and semi-state controlled companies.

After a few months he started working for the division of Geotechnics. At present he advises on several projects in the port of Rotterdam.

One of his projects is the Europahaven at the Maasvlakte. At this place there will be a new chemical factory. His job is to investigate the soil conditions, where a quay-wall is planned. "This project involves geotechnical fieldwork, laboratory testing, making an offer, writing a report and then in the last stage give a positive or negative advise. During all this work I will be at the site for only one or two times. That was one of the things I didn't expect. During the study there is a lot of practical work like sampling for instance. The lab-testing and fieldwork are done by two other divisions. I only tell them where I want my cone penetration tests and my boreholes and which samples I want to have tested. An engineer is far too expensive to be working in the field."

The people of the geotechnical department are all of equal merit. So there won't be many possibilities to climb the ladder. Some years ago it was a small group which consisted mostly of civil engineers. Since he is working here three other geological engineers are contracted. He also followed some internal workshops to specialize himself in several subject. Good examples are geophysics at Fugro and foundation technics.

"An advantage a mining engineer has over a civil engineer is that they know more about geophysics. And that is becoming more important nowadays. On the other hand the geological engineer learns for 70% about rocks and he/she knows too little about soil. And one thing we have a lot of in the Netherlands is soil! "

Ir. Robert Berkelaar

He really likes his job at geotechnics, but he might go abroad in the future. "Right after my study I had the chance to get a job in Australia. The company where I had my trainee-ship offered me to work for them. But I didn't get a work permit because I had no working experience at that time. And to get in Australia one needs to get points. I didn't receive any for working experience."

"Another experience abroad was my master thesis in Austria. I was involved in a slope stability problem which was a almost a case right from the study books. "

For this thesis he was nominated for the "Ingeo Award" of the IngeoKring. He was rang up by the chairman of the IngeoKrong who said he had won the prize. Unfortunately they made a mistake. He didn't belong to the academic year September 1994 - August 1995. But the good news is he gets a consolation prize.

NIEUWE & RECENTE A.A.BALKEMA TITELS:

Support of underground excavations in hard rock 90 5410 186 5
1995, 28 cm, 232 pp., Hfl.95 / $45.00 / £35 - Student edn., 90 5410 187 3, Hfl.45 / $19.50 / £16
A comprehensive volume dealing with the design of rockbolts, dowels, cable bolts and shotcrete for underground excavations in hard rock. Many practical examples are given and extensive use is made of user-friendly software developed specifically for this application (available separate). Topics include rock mass classification systems, shear strength of discontinuities, analysis of structurally controlled failures, in situ and included stresses, estimating rock mass strength, support design for overstressed rock and discussions on different types of underground support. Authors: E.Hoek, P.K.Kaiser & W.F.Bawden.

Open pit mine planning and design 90 5410 173 3
1995, 25 cm, 864 pp., 2 vols, Hfl.245 / $125.00 / £90 - Student edn.,90 5410 183 0, 2 vols, Hfl.125 / $65.00 / £46
The book is divided into two parts. Part 1 consists of six chapters in which the basic planning & design principles are presented: Mine planning; Mine revenues & costs; Orebody description; Geometrical considerations; Pit limits; Production planning. Much of the actual calculation involved in the design of an open pit mine is done by computer. Two professional computer programs CSMine & VarioC have been specifically developed with the university undergraduate learning environment in mind. These programs, their related tutorials & user manuals, together with a data set for the CSMine Property, are subject of part 2 of this book. Six chapters involved are: Introduction; CSMine property description; CSMine tutorial; CSMine user's manual; VarioC tutorial & user's guide; VarioC reference manual. Authors: W.Hustrulid & M.Kuchta.

Brittle failure of rock materials – *Tests results and constitutive models* 90 5410 602 6
1995, 25 cm, 456 pp., Hfl.195 / $115.00 / £74
Comprises different basic aspects of brittle failure for rocks. Classical & contemporary models are considered theoretically as well as failure patterns under different loading schemes. Terminology; Strength theories; Contemporary models about brittle fracture; Laborational methods for determining some mechanical properties of rocks; Mohr strength envelopes; Experimental investigation of brittle behaviour; Size effect; Concluding remarks and references. Author: G.E.Andreev.

Fractals in rock mechanics (Geomechanics research series 1) 90 5410 133 4
1993, 25 cm, 464 pp., Hfl.150 / $85.00 / £55
Important developments in the progress of the theory of rock mechanics during recent years are based on fractals and damage mechanics. The book is concerned with these developments, as related to fractal descriptions of fragmentations, damage, and fracture in rocks, rock bursts, joint roughness, rock porosity and permeability, rock grain growth, rock and soil particles, shear slips, fluid flow through jointed rocks, faults, earthquake clustering, etc. A simple account of the basic concepts, methods of fractal geometry & their applications to rock mechanics, geology & seismology. Discussion of damage mechanics of rocks & its application to mining engineering. Author: Heping Xie (M.A.Kwasniewski, Editor-in-Chief).

Rock mechanics in salt mining 90 5410 113 X
1994, 25 cm, 544 pp., Hfl.175 / $99.00 / £65 - Student edn., 90 5410 103 2, Hfl.95 / $55.00 / £6
5 chapters consider general geology, folding & faulting structures compilation of salt & form of salt bodies with the simplifications. 3 chapters deal with the exploration & opening of salt deposits with the aspect of design of safe & stable mine structures, and risk of water inflow into the mine. 3 chapters analyse deformation & failure of the salt due to elasto-plastic, creep & outbursts loading conditions. 5 chapters discuss strata mechanics & control for different mining systems of flat, inclined & massive salt bodies, as well as solution mining & excavation for storage.Last chapter presents the stability analyses to the mine structures in regard to salt mining subsidence. Author: M.L.Jeremic.

Grouting of rock and soil 90 5410 634 4
1996 (May), 25 cm, 288 pp., Hfl.175 / $99.00 / £65
Grouting is a proven but complex method to seal and to stabilize substrata. This book deals – on the present state of the art – with the design and execution of grouting works in all kinds of rock and soil, including jet grouting. The theoretical background is shown so as easy to understand it. Design principles are discussed whereby different approaches, exercised in different parts of the world, are compared to each other and evaluated. The work performance including the necessary machinery and accessories is explained with the aid of many examples from practice. Considerations are made of conventional and advanced methods of tendering and contracting. The book reflects the author's more than 30 year experience in design and execution of grouting work in rock and soil. The readers are invited to participate in prestigeous tasks in many countries of the world and to follow up the approach to solve them. Author: Christian Kutzner.

Al onze boeken zijn verkrijgbaar via de boekhandel of rechtstreeks bij ons.
De complete Balkema catalogus staat op Internet: http://www.jcn.nl/ima/balkema/
Vragen over het uitgeven van boeken en congres verslagen richten aan A.T. Balkema
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A.A. Balkema, Postbus 1675, 3000 BR Rotterdam

Birth of a Deltaplan for the large rivers.

Notes for a november meeting of the engineering geological circle

P.M. Maurenbrecher, Delft University of Technology, Faculty of Mining & Petroleum Engineering, Section Engineering Geology, Delft

The trouble with making notes is that one gets asked to write a report. There are other reasons for writing notes at meetings and excursions; they could be about the people taking part (only to be published in book form as one is liable to be sued; court costs though usually handsomely offset publicity costs and could increase sales), they could be written in large letters so that if a talk is in Dutch the instant English scribbling could be read by the non-Dutch speaking neighbours, they could be to maintain a critical interest (i.e. stay awake!) or they could, as in most instances, for keeping a record and hence be used for report purposes. Constant note taking in this years field work in Spain has aroused the curiosity in colleagues and students. What do I write about? The following are the notes taken with some extra embellishments on a complete day meeting of the IngeoKring

PROGRAMME

The programme for a rather chilly but sunny Thursday November 23rd was as follows (translated from the original):

09.15 to 9.30 Congregate in the auditorium of Delft Geotechnics

09.30 - 11.30 Morning programme: explanation of the problems

-Quaternary geology of the large river areas

-Failing mechanism of the river dykes

-Situation during the period of the "almost disaster"

-Design aspects (zooming in on the demands of the surroundings)

11.30-12.30 Simple lunch and preparations for departure.

12.30-17.00 Visit to the problem areas and works in various stages of progress.

17.30 optional concluding dinner at ITC, Delft

The programme is preliminary

Do not forget to take with you your boots and other field attributes.

WHY THE TITLE (THIS ARTICLE)?

Joost van der Schrier of Delft Geotechnics introduced the day and after which a video show was presented on the near disaster that happened almost a year earlier (And a year before that as well when it was considered still a 1:200 year event calculated by an anonymous statistician and one wonders what is the probability that statisticians get it wrong; 1:200 chance?). The video presentation represents the item in the programme "situation during the period of the almost disaster".

Joost explains that the video is a useful flashback to the situation in January 1995 and that despite the Dutch commentary the images in the video are largely self explanatory. The near disaster was brought on by heavy rains topped up with melting snows occurring simultaneously in northern France, Belgium and Germany. Critical levels were soon realized resulting in permanent guarding of dykes and mobilizing the army and other units to cope with disaster. Birth of a new Delta-type plan?

THE VIDEO

The italic are my notes and are essentially keywords meant to be elaborated into a report. *Dykes strong enough, time, wet socks, no markers left to show water height on water level gauge, water levels same as roofs of houses: 100 000 will flood if dykes give way, factor of safety 1 at several locations, evacuate 250 000 people. No living soul; cows and pigs evacuated. Dykes hold in part due to army, contractors, consultants. Narrow escape at the weak section as extra wind or rain would have caused failure.* The video further explains: *Again an extreme, statistically not possible, feared premonition that nature has other rules, Christmas 1993 and again January 1995, to Limburg, Maas Waal Lek rivers, at Lobith (where the Rhine enters the Netherlands from Germany) the waters rise rapidly; permanent guarding of dykes, disaster mitigation plan brought into action, 10.2 m NAP level reached, a geological looking fence diagram showing water level sections along the major rivers, into a polder, army personnel in rubber boots, wind gusting waves over dyke, trees wading in the flood plain, plastic sand sack. A spring issuing from a dyke along the Waal, (the main* *tributary of the Rhine in the Netherlands, ...Tiel, Coulemborg en Waarder polder district; years of planning and legal procedures has done little to heighten the dykes: mother nature was now speeding things up after this second scare within 13 months, Bollenwaard: evacuation. 16.5 m at Lobith: above the critical level. Ministers Joritsma and de Boer inspect the threatened dykes and walk with other notables along a flooded dyke road. Erosion of dyke slope; more nylon sand sacks and foil. More wind, army. Music, sombre almost funereal.*

EVACUATION AND A HAPPY ENDING.

The notes continue; Mr. Jan Terlouw, Queen's representative in the Province of Drenthe through which these major rivers are causing so much stress looks concerned at a visit to Thielenborg as he announces that evacuation is voluntary the first day and compulsory the second. A waste disposal mound serves as a refuge for farm machinery and construction plant against flooding. Deserted streets patrolled by police. People then return in a festive mood. Minister Dijkstal of Internal Affairs states that only if dykes can be made good can one have a proper restitution for the scare caused by the impending disaster. Disaster was prevented by 90% mans effort and 10% by the more favourable change in weather. Statistics again?

QUATERNARY FLOODS

Bernice Baardman of the Netherlands Geological Survey related the story with slides of the Quaternary on which the present river system is based. Especially much of the Netherlands is underlain by dense sand and gravels brought down by flash flooding resulting from the summer snow melts of the last ice age leaving large continuous fan deposits. These beneficial floods provide not only sands for land fill but also form the main founding levels for piled foundations. Bernice has published her presentation in this issue of the Newsletter. Since her talk one develops a new vision of the landscape: always on the lookout for high ground in a polder landscape indicating differential settlement between high energy and low energy sediments settling differentially or dunes which were formed from sand piled up from dry meanders in the winter periods.

INVESTIGATING DYKES ALONG THE FLOODED RIVERS

Juri van Deen of Delft Geotechnics posed two questions which require geotechnical investigations for their answers:

Why dykes? answer: to prevent floods inundating our homes.

What can go wrong?
- leakage under the dyke such as through buried and filled channels.
- over topping; especially in high settlement areas containing soft clays and peats.
- weakening of dyke: displacements in shear, development of high pore water pressure.

Investigation starts with a geology map followed by cone penetration testing measuring end bearing, sleeve friction and filter water pressures. Many mechanical characteristics can be determined from this test started 60 years ago to simulate a pile. The site investigation is augmented with borings for taking samples often the "Begeman sampler in which the loose sands and soft clays are contained in a nylon stocking which helps preserve much of the original structure of the soil. Much of the "point data" which the CPT and samples represent is augmented by geophysical traverses. Most popular to show variations of the subsurface is the electromagnetic EM-31 survey method so that a transmitter coil induces 5-10 kHz radio signals into the ground. A receiver coil registers the strength of the induction currents; these are proportional to the conductivity of the soil. Further methods are the by resistivity (Werner) configuration and by radar. Seismic methods are used especially for over water surveys.

DYKE DESIGN

Helle Larsen, also working at Delft Geotechnics but graduated from Albörg University in Denmark, responded to the questions posed by Juri van Deen. To design for the long term, information is required on long term subsidence and sea-level rise. There is no shortage of dykes in the Netherlands: 1300 km of dykes to prevent floods from the sea and another 900 km to prevent flooding from the inland water. Much of the sea dyke system has been improved in response to the 1953 floods. The river dykes, however, have many hundreds of kilometres which need improvement. The risk of floods have to be determined using statistical projections in terms of the 1:1250 flood for areas

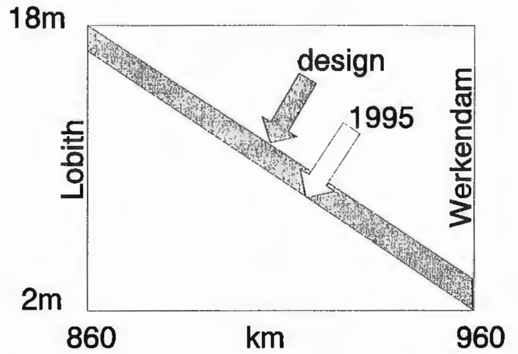

Figure 1 1995 flood level approaches that of the design level along the Waal Rhine tributary.

of lower economic damage potential and a 1:10 000 year flood for areas of high economic damage potential. The 1995 flood was a 1:100 year flood and looked dangerous (see figure 1)

A typical cross-section of a dyke is given in figure 2 with various examples of distress that the dyke could experience during high water levels. Other types of distress a dyke could experience is due to burrowing animals such as muskrats.

The seepage causes, in general, an increase in weight and a decrease in shear strength as a result of increased pore water pressures. To design a proper dyke a test dyke is recommended to determine such criteria as safety margins and boundary conditions (influences of traffic, waves and flood levels).

To improve dykes consideration must be given to heightening to stop over-topping, widening to prevent seepage, improvement of the revetment, extra toe weight berms to prevent slope failure. Piping can be prevented by lengthening the seepage path (see previous considerations) or by building a cut-off. Dykes can also influence buildings close by as the weight of the fill causes both settlement and horizontal displacements. Construction must be relatively slow to allow foundation soil to strengthen under consolidation rather than fail in shear. In conclusion Helle Larsen said that as before landscape and local culture can influence the design.

ENVIRONMENT AND DYKES:

Mr. Rien Viergever of Delft Geotechnics talked about alternative designs for dykes and the role of the Dutch Parliament appointed investigation committee: Commissie Boertien on environmental factors.

The presentation started with slides of buildings near steep sloping dykes in a rather monotonous landscape. Design of the dykes was such that they could contain river discharges of 1800 m^3/s (1:3000 event) in 1956 and changed in 1977 to cope with a discharge of 1650 m^3/s with a return period of 1:1250 years. Despite the second legislation the dykes still needed heightening which resulted in protests by inhabitants. This was because they would either have to have their houses removed or

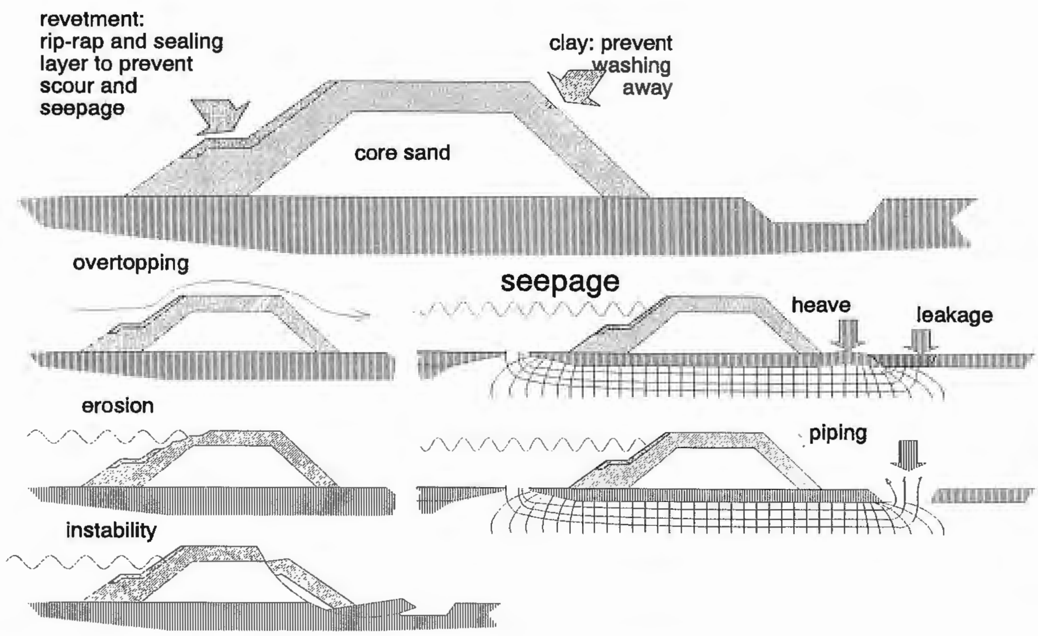

Figure 2 Dyke cross-section and various types of distress that can occur.

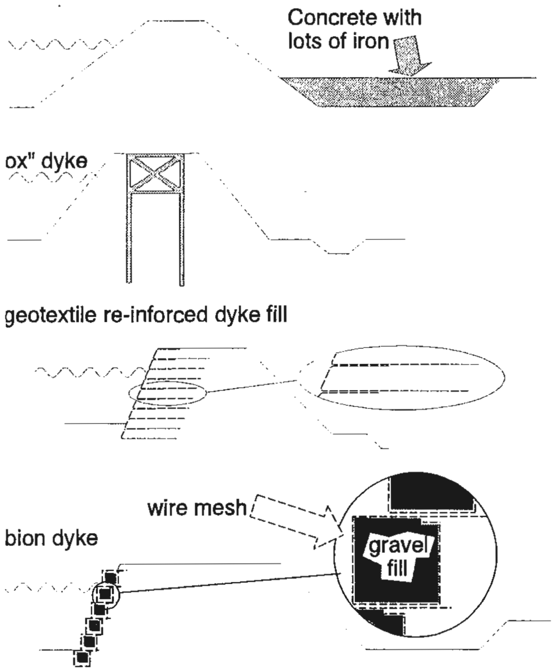

Figure 3 Alternative dykes based on sketches.

that their river views would be impeded. The Commissie Boertien recommended that local people be involved during all stages of the dam heightening. Alternatives were sought to cope with loads, heave, overtopping, erosion, piping, maintenance and non-water retaining structures existing in the dyke body.

The solution was to apply varying solutions to different parts of the dyke. Material in the dyke body: use existing, strength capacity increase to limit ground water flow, install mobile structural elements which can be installed if floods threaten, lower the permeability of sand body by introducing a clay core, use geotextiles to reinforce the dyke fill, maintain steep slopes and as scour protection (instead of rip rap). The toe weight could be increased with concrete containing iron. Strength of fill and foundation can be increased in the short term by drainage using electro-osmosis though it is difficult to control or test its effectiveness. More traditional vertical drains are often effective in increasing foundation strength; more modern variations consist of vacuum consolidation techniques.

Chalk piles can strengthen clays though they may loose their use in a soils having a high organic content. For internal drainage geotextiles are used to connect sandy layer with the dewatering ditch and so prevent piping. Inner slope of dyke can be reinforced with a combination of honeycomb structure revetment-geotextile through which grass can grow. Tests were carried out on a stretch of dyke subjected to a steady over-topping flow. This dyke first bulged, burst and then eroded.

More artificial techniques would be used in urban areas making use of sheet piles, gabions, coffer dams and ground nailing. Sheet piles are often too difficult. Further cut-off can be a cement bentonite screen. A few sketches made from the talks illustrations are shown in figure 3:

WINE FLOOD EXCURSION?

The morning presentations were concluded by the chairman of the IngeoKring, Robert Hack. He thanked the speakers for their excellent presentations and rewarded them with a well earned bottle of wine to help flood a glass or two. A short lunch, courtesy of Delft Geotechnics, was followed by the excursion to visit some of the places where dyke reconstruction was in various stages of progress in the area of the main Rhine Tributaries: the Lek and the Waal. The tour guide was our host for the day Joost van der Schrier and Heller Larsen both of Delft Geotechnics. The visit took us first to Schoonhoven on the Lek, followed by a river crossing by ferry to Nieuwpoort and then south to the north bank of the Waal. (see map figure 4).

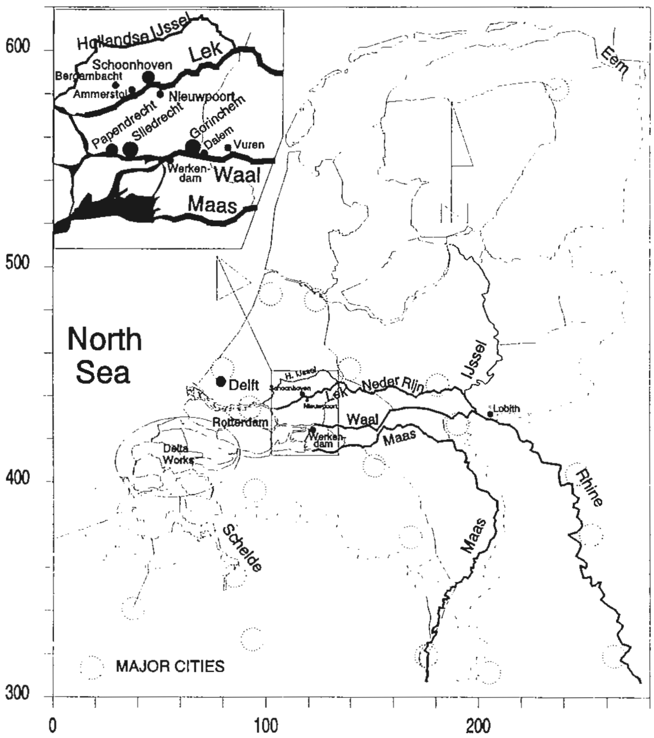

Figure 25 Map of the Netherlands showing locations of rivers and towns on the field trip.

BETWEEN HOLLANDSE IJSSEL & THE LEK

Much of the land near Schoonhoven was the same height as the river some 1500 years ago, but since "*in-poldering*" the process of the construction of dikes followed by drainage of the land through a network of ditches combine with windmills the land has settled, in places up to 6m below sea level. The flooding was not always the enemy: the Dutch often used it for defensive purposes and parts of the old "Water Linie" the bus drove by on the route. An excerpt from W.G. van de Hulst "Water Linie" book (courtesy Wolter Zigterman) quotes in his book a record kept by the at the time on the French army of Louis XIV in the 18th century attempt to invade Holland:

It is a story of purposely flooded polders to keep out the enemy. The description could use the sobre music used in the video: "*lonely isolated farm-houses in this rich farming district poking their roofs above the chilly water, the only sounds is the eerie whine of the wind rustling through branches of the trees. The French in their rapid advance were suddenly forced to pause. Use boats? Not possible as in many places the water was to shallow. Wade? The ditches and canals lurking beneath would cause them to drown. Use the river routes? Sunken boats and specially placed piles backed by purpose built patrol boats would halt this advance.* The Sun King could not subject the Dutch as his paintings in Versailles tried to prophesy.

***Figure 5** Old dyke retaining wall and basalt rip-rap at Schoonhoven.*

***Figure 6** The "coupure" (gate) to Schoonhoven with protective dyke in the background and trees in distance that require removal. Note alignment lamp and sign posts.*

Heller Larsen takes the microphone. She points out that to compensate for a higher level dike a building at Krimpen aan de Lek has been hydraulically jacked up. The term "*tuimel dijken*" refers to a dyke which has been built over an older dyke. A "*wiel*" is a lake or pond that has been left as a result of scour from a dyke burst. The replacement dyke usually curves round to avoid the deepest scoured sections. We pass by Bergambacht which showed much distress as a result of water level decreases resulting in break down of houses. Approaching the village of Ammerstol many leaning buildings can be seen hugging the dykes flanks. A second *wiel* is negotiated along a curved dyke. Up to two years were needed before the land would be drained. Schoonhoven is an old market town on the Lek. It has a leaning church tower its lean being countered by the church nave. A wall protects, now inadequately, the buildings along the river front from flooding. (figure 5)

Its foundations go down to the Pleistocene river braided gravels and sand deposits mentioned by Bernice Baardman. The trees at the Belvedére Hotel, a significant landmark on the Lek have to come down to make way for dyke heightening. (Figure 6)

The main town is protected by its old fortifica-

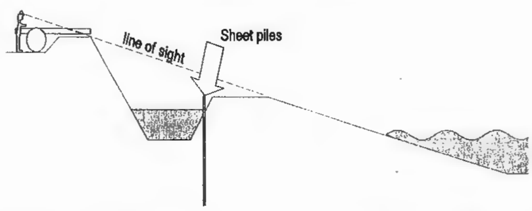

***Figure 7** Cross-section at fortifications near Dalem.*

tions city wall/ embankment. The port through this wall the "*Coupure*" (an opening in the dyke, can be closed off with sturdy beams spanning the entrance. (Figure 6)

BETWEEN THE LEK AND THE WAAL

The bus and excursionists cross over to the Lek to Nieuwpoort. The Dutch fought a battle with the Spanish in 1600 "*Slag van Nieuwpoort*". The dyke goes through the town is hardly noticeable as slopes gently with the road and buildings. The new dyke follows the old city fortifications. The old moat is being returned to water having been filled in and grassed long ago. From Nieuwpoort the road is taken south-southeast across the Alblasserwaard to Vuren. "*Waard*" means either polder or islet (especially islets in rivers. Schoonhoven is situated on the Krimpener*waard*, the islet between the Hollandse IJssel and the Lek. Alblasser*waard* is the islet situated between the Lek and the Waal. These islets are also polders; hence one can choose either definition as islets or as polders.

At Vuren on the north bank of the Rhine's main tributary artery, the Waal, dyke works are in progress: strengthening existing dykes using the box dyke technique (figure 3) and at the fortifications (part of the Water Linie" system the only dyke improvement is sheet piles to reduce seepage flows (see figure 7). The very flat slopes on the river side were such that any enemy approach would be in the firing line of the guns behind the fortification embankments. Opposite the river Castle Loevestein broods over the river in sinister silhouette against the setting November sun; medieval racketeers one expects any moment to emerge to extort money from river users.

An old lime tree (100 years) stands as a lone protester against the works and may win through special more expensive dyke works to preserve its location. (Figure 8) Younger trees planted by a local landowner in the flood plane will not only be removed, but may not be compensated either as the landowner is demanding; the dyke heightening schemes were already known before the planting.

A white-washed house at Dalem has slogans on his house protesting dyke raising. The waters of a canal just west of Gorinchem inland from the river dykes serve as toe weight to prevent landward slip-failure.

The final evidence of dyke works is at Papendrecht where sheet pile are used to strengthen the dyke. Traffic is building up and an awkward stop has to be aborted before the local radio starts adding a traffic jam in Papendrecht to the list being broadcast in the evening rush-hour. Possible idea for mobile flood protection: design cars with skirts and special bumper to bumper interlocks; cause queues to form along dyke roads: almost instant dyke heightening: and there are kilometres of vehicles in the Netherlands to draw upon during the rush hours.

***Figure** 8 100 year old lime tree near Vuren: a challenge for dike reconstruction. Flood plain ("uiterwaarde" i.e. outer-islet or outer-polder) of the Waal.*

Book review

Geochemistry, groundwater and pollution

C.A.J. Appelo & D. Postma (1993). Balkema, Rotterdam, pp.536, paperback Hfl 85,- , computercodes Hfl 75,

During the courses on Hydrochemistry and Groundwater Pollution given by Appelo, the book 'Geochemistry, groundwater and pollution' has been used in support of obtaining knowledge on the interaction between water, minerals and chemicals, that determine the groundwater quality.

The lay-out of the book is very clear, using an easy to read letter type, clear graphs and tables. The book also has a well structurised contents, which supports the relation between subjects well. The theory focussed on in the book is supported by well worked out examples and a series of exercises per subject, to allow for intensive and active study of the theory.

The textbook of eleven chapters can be divided in two parts. The first part (chapter 1-8) deals with the main processes that affect the chemical composition of groundwater. Throughout chapter 1-8 basic chemical subjects like equilibria, complexes, ionexchange, adsorption and redox processes, are discused. More specific subjects, discussed in this part, are carbonate reactions, silicate weathering and salt water influences. Special attention is given to the kinetics of weathering, solid solutions and specific adsorption. Each theoretical part is demonstrated by several examples.

The second part (chapter 9-11) covers mass transport and related chemical reactions in aquifers. The three chapters are respectively 'Solute transport in aquifers', 'Hydrochemical transport modeling' and 'Aspects of flushing and aquifer cleaning-up'.
The calculation of flowlines and the influence of retardation and dispersion on travel times of chemicals are included in chapter 9. Numerical models to solve transport problems in complex groundwater systems are given in Pascal codes.

Chapter 10 gives short guides of the Fortran computer codes of the geochemical model PHREEQE and the hydrogeochemical transport model PHREEQM. PHREEQE can be used to calculate the change in groundwater composition by chemical reactions, mineral equilibria, mixing of solutions, temperature changes, etcetera. PHREEQM calculates the change in groundwater composition during transport in an aquifer, whereby the principles of diffusion and dispersion are used. The programs are demonstrated by examples.

Finally, chapter 11 provides the theory, including desorption isotherms, ionexchange and hysteresis, about the remediation of aquifers by flushing with water or a solution. A subject that is mentioned here is the desorption of heavy metals by ionexchange.

The knowledge that is needed to understand the basic chemical theories in the book is of high-school level. While reading the book, all chemical knowledge is refreshened and facilitated by worked-out examples and problems to be solved, that resemble practical situations. The more specific subjects are written in a clear way, which makes it easier to understand.

M.F. van de Water, student Physical Geography, University Utrecht.

Book review

Drilling and Blasting of Rocks

English version of the Spanish publication of the Geomining Technological Institute of Spain by Carlos Lopez Jimeno, Emilio Lopez Jimeno and Francisco Javier Ayala Carcedo
translated into English by Yvonne Visser de Ramiro
Published by A.A.Balkema / Rotterdam/ Brookfield/ 1995 pp. 391, Price: Hfl 175,- (excl. BTW 6%) (hardcover)

The handbook (391 pages) comprises a comprehensive overview on various aspects related to drilling and blasting of rock. The contents of the book are reflected in the titles of the individual chapters as listed below:

- Rock drilling methods
- Rotary percussive drilling
- Rotary drilling percussive accessories
- Rotary drilling with rolling tricone bits
- Rolling cone rock bits
- Rotary drilling with cutting action
- Special drilling methods and mounting systems
- Compressors
- Thermochemistry of explosives and the detonation process
- Properties of explosives
- Industrial explosives
- Explosive selection criteria
- Blasting accessories
- Initiation and priming systems
- Mechanized systems for charging and dewatering blastholes
- Mechanisms of rock breakage
- Rock and rock mass properties and their influence on the results of blasting
- Characterisation of the rock masses for blast designing
- Controllable parameters of blasting
- Bench blasting
- Blasting in other surface operations
- Blasting for tunnels and drifts
- Shaft sinking and raise driving
- Underground production blasting in mining and civil engineering
- Contour blasting
- Underwater blasting
- Initiation sequence and delay timing
- Evaluation of blast results
- Secondary fragmentation and special blastings
- Planning the work of drilling and blasting
- Structure and building demolition
- Optimizing costs of fragmentation with drilling and blasting
- Land vibrations, air blast and their control
- Flyrocks and their control
- Safety measures for drilling and blasting operations

Carlos and Emilio Lopez Jimeno noted in the preface of the handbook the book is intended to provide basic knowledge of the drilling systems, the types of available explosives and accessories and the parameters that intervene in blast designing, whether controllable or not. The authors claim that the book may be used for both practitioners and students.

The handbook mainly describes the technical and organizational aspects of drilling and blasting projects in their realization phase and does not go deeply into the feasibility studies and engineering geological site investigations for drilling and blasting works.

The book is well written in plain English complemented and illustrated with many graphs, tables, photographs and drawings, which add considerably to the quantitative applicability of this book in practice. The print quality is good and the book has a hard cover.

Dr.ir. H.J.R.Deketh

The position of engineering geology in the Netherlands

Ir. A.N. van de Kolff

Main subject of the autumn-excursion 1995 of the Ingeokring was the dike strengthening programme, one of the most interesting infrastructural works currently undertaken in our country. And a subject, not only topical, but also appealing to our historical struggle against the water.

'Only little geology today' whispered one of the participants while it was explained what type of construction was selected for the improvement of the dike without destroying the absolute magnificent beauty of the (natural?) environment. This remark was not quite true as in the morning hours Bernice Baardman, working for RGD, presented us an overview of the geological history of the main Dutch river systems and its influence on the present subsurface conditions of these areas.

If the lamentation had been 'only little engineering geology today', I would have agreed as I believe that in particular the coupling between the geology and the civil engineering, probably the most essential part of our speciality, deserved more attention.

Not the nature of a cone penetration test, a Begemann sampling method or an electro-magnetic (EM) survey, with which most of the attendants were supposedly familiar, but the application of these techniques in relation to the anticipated geological or geotechnical conditions would have been more interesting. How has the variability of the subsoil, resulting from the depositional environments of the past, affected the nature and volume of the site investigations?

Alternative methods to prevent flooding could have been discussed: in areas with thick gravel strata (old braided river systems) widening and deepening of the river may have to be preferred as it may not be very useful to construct dikes on these very permeable deposits. Areas with rapidly changing subsoil conditions may have initiated other construction methods than areas with uniform and homogeneous geotechnical conditions.

And what about the natural construction materials like sand and clay? Recently a dike-reeve complained on television about the sharp increase of the construction costs suggesting that this was a result of mutual agreements between the contractors. He, however, did not mention the very important influence of the limited availability of suitable construction materials on the construction costs. The shortage of these materials is partly caused by the increased demand, partly by the more strict requirements imposed on the quality of the materials. What are those requirements, how have they been determined and how can we find them using the geological knowledge available?

This criticism is not just incidental, but touches a problem that, to my opinion, reaches further and involves the position of engineering geology in the Netherlands. What is the **current** role of the Dutch engineering geologists and how do **we** define our role? Are engineering geologists in Holland educated to work overseas with foreign companies or to support Dutch civil engineers who are confronted with unfamiliar subsoil conditions like rock or do we have more to add? I believe that we also can have a valuable contribution in the Dutch soft soil situation provided we are properly trained (it may be relevant in that respect to realise that most of the overseas civil engineering work carried out by Dutch consultants and contractors is located in areas where soft soils generally dominate: low lands, deltas, rivers and coasts). Moreover, I am convinced that to secure the university education in engineering geology in the future it will be essential to build up a more permanent position in the Dutch civil engineering world, not only for overseas projects, but also in the Netherlands itself. It is to us to establish such a position by demonstrating and proving our added value. This implies that in the study a more dominant role shall be assigned to subjects like Quartenary geology, sedimentology, clay mineralogy, geomaterials, etc., but also to soil mechanics and foundation engineering to ensure a better coupling between geology and civil engineering. As the chance that the Dutch engineering geologist gets involved in a rock slope stability problem or a tunneling project in rock are very small subjects like rock mechanics, open-cast mining, etc. are believed to be of only secondary importance.

It has never been my intention to suggest that the autumn-excursion was not interesting, but instead I have tried to use it to start a discussion on the position of engineering geology in the Netherlands.

I strongly believe that in the first instance we should serve our home market and therefore must leave our niche of "exotic" specialities. On the long run this shelter will not protect us, nor will it enable us to obtain a fully accepted position. It implies that the engineering geology of unconsolidated sediments must be the nucleus of the training around which other specialities like soil mechanics, coastal engineering, foundation engineering and geostatistics shall be grouped.

Geotechnical aspects in soft soil shield tunnelling

Ir. M.W.P. van Lange, MTI Holland BV, Kinderdijk, The Netherlands

In densely populated areas more and more the underground will be chosen for the location of infrastructural works, storage rooms and parking places. Trenchless technology covers the field of shield tunnelling, pipe jacking and directional drilling; all techniques that have been developed to decrease the hindrance of work under construction for the regular life at the surface. The drilling techniques are highly mechanised and in the design of drilling machines and in tunnelling practice, calculations have to be made regarding torques working on the cutterwheel, friction on the shield, face stability, etc.

INTRODUCTION

At present, many infrastructural works are being built and planned in the west of the Netherlands. Examples are the Piet Hein Tunnel, the Wijkertunnel and the 'Tweede Heinenoordtunnel'. Even larger projects that are planned are the 'Noord/-Zuidlijn' in Amsterdam, the 'Hoge SnelheidsLijn' and the 'Betuwe Lijn' in which the 'Botlek Spoortunnel' is comprised. In the south west of the Netherlands the 'Westerschelde Oever Verbinding' is projected. Going underground seems to be the trend and politics is running warm for it as well.

In many cases trenchless technologies will be applied in order not to disturb activities at the surface or to avoid the necessity of breaking down sites with special historical or environmental value. In this respect the decision has recently been made in politics to drill a tunnel under 'Het Groene Hart' for the 'Hoge SnelheidsLijn'.

Today also for smaller projects such as crossings for pipelines, sewers and cables trenchless technologies are often chosen. Directional drilling and pipe jacking are widely available techniques and for sewers there is an option for relining the system.

Of the projects mentioned above the 'Tweede Heinenoordtunnel' and the 'Botlek Spoortunnel' form two study projects for the Netherlands as these are the first large diameter tunnels built by the shield method; the drilling of the 'Tweede Heinenoordtunnel' will commence by the beginning of 1997 and the drilling of the 'Botlek Spoortunnel' is planned for 1998.

In this article some geotechnical aspects are highlighted that are related to shield tunnelling. Many of them have a parallel to the pipe jacking technique. Both techniques will be briefly explained.

SHIELD TUNNELLING AND PIPE JACKING

Shield tunnelling is the construction of a tunnel in situ, using a machine that excavates the ground ahead of it and that leaves a tunnel tube behind. The shield moves itself forward by pushing against the section already constructed. Machines have been constructed for tunnels with an external diameter of some 5 meters to up to 14 meters.

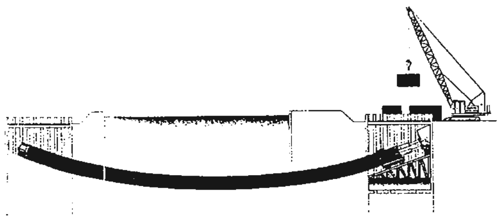

Figure 1 Pipe jacking.

Pipe jacking is generally applied for tunnel diameters ranging from 25 cm to 3.5 m. Here the entire tunnel or pipe, with the machine in front, is pushed forward from the launching shaft. New lengths of pipe are fed into the shaft (figure 1). When the total length of pipe causes a friction that exceeds the thrust force of the jacks in the shaft intermediate jacking stations can be installed that travel along with the tunnel or pipe.

Roughly two types of shields can be distinguished in shield tunneling: the slurry shield and the EPB shield (Earth Pressure Balanced shield). These differ basically in how the stability of the excavation face is secured, which has a consequence for the way of transportation of the excavated soil to the surface.

SLURRY SHIELD

The excavation and mixing chamber of the slurry shield is filled with a bentonite slurry (figure 2).

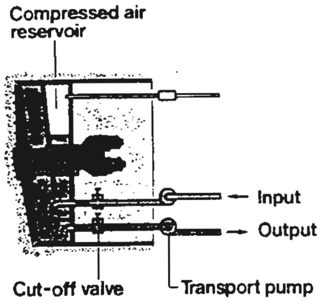

Figure 2 Slurry shield.

Bentonite is a montmorillonite clay mineral. Mixed with water to a slurry with a certain pH it has a stable cart house structure with a typical shear strength ,scosity, depending on the concentration of the slurry. By maintaining a pressure in the chamber that is slightly higher than then the pore water pressure at the face, the bentonite particles will infiltrate and block the pores at the face. Finally a consolidation phase of the bentonite towards the face takes place leaving a so called filter cake behind. The pressure in the chamber acting on this 'closed' face secures the soil stability.ideal medium

The transport of the excavated soil is normally by hydraulic transport: the stable bentonite slurry carries the soil particles and is pumped to the surface. Here the soil particles are separated from the slurry that is subsequently pumped back to the shield for reuse.

The slurry shield has initially been developed to deal with granular soils: pressurised air or water were not suitable to support the face and to control ground water influx in shield tunnelling. With a bentonite slurry it is possible to transfer a fluid pressure to the excavation face.

EPB SHIELD

With an EPB type shield the excavation and mixing chamber is filled by the excavated soil. A screw conveyor that reaches into the chamber extracts the excavated soil from the chamber (figure 3). The pressure of the remoulded soil in the chamber maintains the face stability. Control of the pressure is determined by the revolution speed of the screw conveyor and by a back pressure valve at the outlet of the chamber.

From the outlet the material is dropped on a conveyor belt, which takes care of the transport over the back-up train which houses the auxiliary equipment for the shield. At the end of the back-up train the soil is either dumped into a train for transport to the surface, or the conveyor belt reaches up to the surface. Several alternatives are possible, depending on the length of the tunnel, the advance speed of the shield, the availability of a dump site at the surface.

The soil often has to be conditioned to reach a certain level of plasticity and to decrease the permeability of the excavated soil. The plasticity is needed to improve the flow characteristics while the low permeability is necessary to avoid the influx of water into the tunnel via the screw conveyor. Some soils, such as soft clays, may not require any treatment to reach the desired characteristics. Soil may be treated with bentonite, polymers or foams. The foams that have been developed have the advantage of being biodegradable: the excavated soil can easily be disposed of without any treatment or additional costs.

Regarding the soil conditioning the mixing process in EPB shield tunnelling is much more important than in slurry shield tunnelling. The excavated soil should have a certain homogeneity when leaving the chamber. The mixing is done by the cutterwheel, equipped with possible additional bars at the back, or by extra installed mixers in the chamber.

The EPB shield is of Japanese origin. The application was mainly in clay, which is common in the urbanised areas. The use of foam has widened the range of soil types in which the EPB shield can be applied (figure 3).

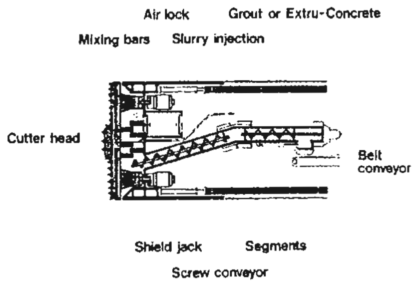

Figure 3 EPB shield.

FACE STABILITY

In shield tunnelling there is a large free excavation surface: the face. When the face is stable no deformation of the ground will occur: there is no settlement or heave at the surface. To maintain face stability ideally the pressure in the chamber is equal to the horizontal ground pressure. Too low a pressure in the chamber will cause active failure of the face while a too high chamber pressure may induce passive failure of the face.

The chamber pressure in the slurry shield is

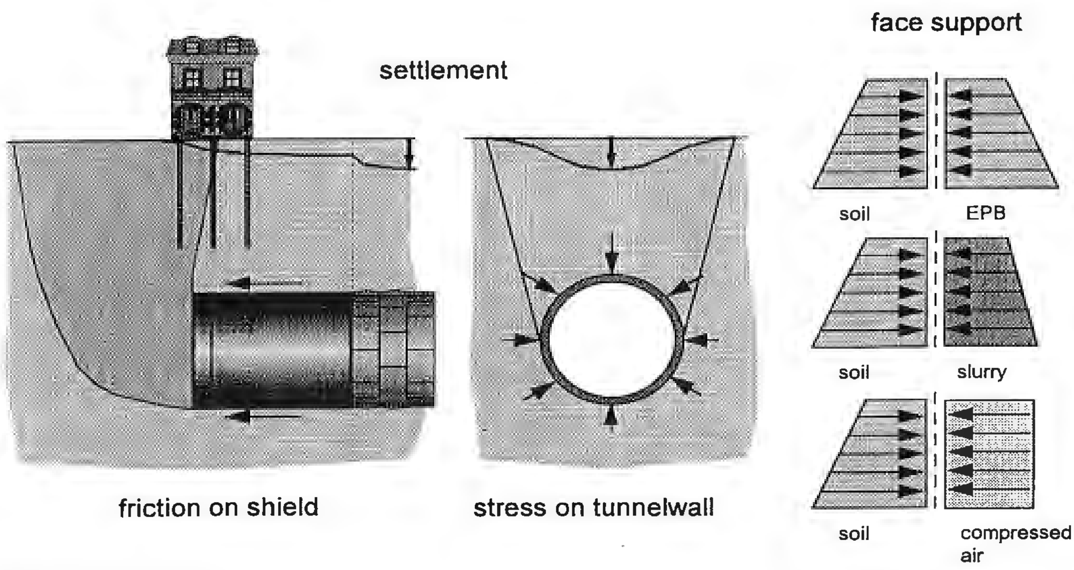

Figure 4 Face stability.

maintained by the pressure of the bentonite slurry. Controlling this pressure by valves and the rotation speed of the slurry pumps is difficult and therefore involves a certain risk. A German patented way of controlling the pressure is by controlling the pressure of an 'air vessel' above the slurry. The slurry shield intrinsically does not offer optimal stability when the density of the slurry is lower than the density which causes a too low pressure gradient along the height of the tunnel is (figure 4).

In the search for optimising the face stability in shield tunnelling and not wanting to apply the German patented way of controlling the pressure of the bentonite slurry in the chamber, the alternative was born to support the face by the excavated soil itself. This has the advantage of a chamber filled with a substance of a density equal to the density at the face. Hence, the pressure gradient is equal as well.

However, to create a natural pressure distribution of the excavated soil in the chamber it should behave as a liquid. This is not to difficault to realize for soft soils. Granular soils, however, will have to be conditioned to reach proper flow characteristics.

SELECTION CRITERIA

As stated above, the slurry shield has been developed for granular soils. The mechanism of infiltra tion of the bentonite slurry into the pores, the blocking of these and the consolidation of the adjacent layer to form the filtercake gives optimum results for these soils. Sofar, granular soils refer to sandy soils (figure 5). Gravels and pebbles induce problems because of their higher permeability and the larger pore size. Additional additives, such as sawdust may be necessary. Leaving some sand in the recycled slurry to block the pores is also mentioned as a solution.

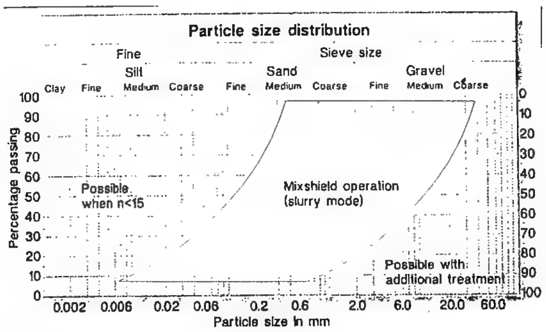

***Figure 5** Grain size distribution of soil suitable for slurry shield tunnelling.*

Soils with a high fines content or cohesive soils give problems at the separation plant: the fines cannot easily be separated from the bentonite particles in the slurry. For an effective separation the plant becomes extensive and expensive and the separation time gets long.

The EPB shield tunnelling method is especially suitable for clayey and silty soils and granular soils with a high content of fines (figure 6). As the excavation and the transportation takes place in a 'dry' environment the flow characteristics of the soil are important. The better the characteristics the less treatment is required and the less important a proper mixing of the excavated soil in the chamber becomes. Recently the range of soils for which the

EPB shield method can be applied is expanding because of the development of new additives, like foams and polymers.

For the selection of the shield type, the costs of the slurry treatment plant in case of a slurry shield is an important aspect. For the EPB method the conditioning of the soil may lead to high operational costs. First of all the applicability of the technique with respect to the soil profile should be determined. In geotechnical terms the parameters are:

- soil type: grain size and grain size distribution
- water content
- ground water pressure

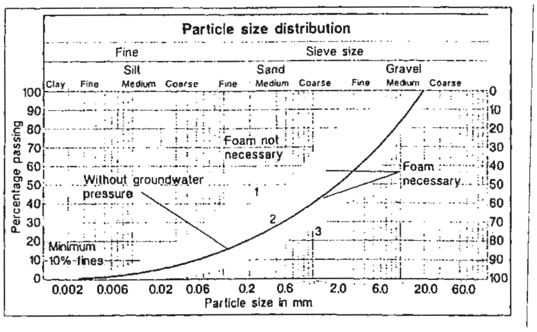

Figure 6 Grain size distribution of soil suitable for EPB shield tunelling.

CUTTING FORCES

The excavation of the ground in shield tunnelling is generally done by a cutterwheel consisting of a hub in the centre from which spokes run radially outward.

In some cases the spokes are surrounded and connected at the circumference by a rim. At the spokes the cutting elements are mounted that excavate the soil face ahead by the rotation of the cutterwheel and the progress of the entire shield. In the design of tunnelling machines it is important to know the maximum torque to occur on the cutterwheel.

One of the torques that play a part is the torque required to move the cutting elements through the face. This torque can be found by calculating the cutting forces for the individual cutting elements on the cutterwheel. The summation of the individual products of the tangential component of the cutting force and the distance to the axis of rotation provides the cutting torque.

Several theories, originally developed for the dredging industry, are available on the cutting of sands and clays. During the cutting process of the cutterhead of a cutter suction dredge the soil is loosened from a fresh soil mass in a watery environment. When cutting sand dilatation takes place in front of the cutting element which causes water underpressures to occur in the cut sand chip. Water can flow into this chip from the uncut sand and from the free surface. The cutting process in a slurry shield takes place in a bentonite environment. Like in the former case dilatation takes place and water underpressures occur, however the resistance for the water (or bentonite) to flow towards the lower pressure is higher. Firstly, bentonite has infiltrated into the face and so into part of the chip or even into the entire chip, depending on the cutting depth. Secondly, the free surfaces are covered by the filtercake of bentonite particles. Consequently, the water underpressures will remain lower. These water underpressures are the cause of higher cutting forces. When the water underpressure reaches vapor pressure cavitation will occur.

Shortly, to apply cutting theories from dredging to the excavation process of a slurry shield new boundary values have to be stated clearly.

The following parameters concerning the ground conditions must be known for calculations on the

MTI Holland BV is the Research and Development department of IHC Holland NV. IHC Holland is the leading builder of dredging vessels and dredging equipment, with shipyards in Sliedrecht and Kinderdijk in the Netherlands. MTI Holland performs studies for both IHC Holland business units and external clients. Fields of expertise are: dredging technology, dredging equipment such as high efficiency dredge pumps, hydraulic transport, alluvial mining, separation plants, comminution, piling and pile driveability, trenchless technology and tunnelling.
MTI Holland has its own test laboratory and soil laboratory. The Measuring Service of MTI Holland performs measurements in the field of pump efficiency, cutter dredge performance, noise and vibrations, pipeline resistance etc.
MTI Holland is partner in the development of the Industrial Tunnelbuilding Method (ITM), together with Wirth Maschinen- und Bohrgeräte-Fabrik GmbH, Fokker Space, Begemann, Fugro Ingenieursburo, Hoogovens, Vereniging Nederlandse Cementindustrie / Mebin and International Systems Development and Support (ISDS).

cutting forces:
- depth below surface and soil profile
- ground water pressure
- density of ground water
- density of the soil
- angle of internal friction
- cohesion
- adhesion
- permeability
- porosity and maximum porosity
- friction angle soil to steel
- characteristics of the bentonite slurry and the bentonite pressure.

Besides the configuration and shape of the cutting elements, the rotation speed of the cutterhead and the progress speed of the machine belong to the input values. Looking to the excavation of the soil in an EPB shield, not only the properties of cut soil have been changed depending on the type of soil conditioning. Also the chip experiences a high friction when travelling along the cutting element because the chamber is not filled by a slurry but by the soil itself.

SHIELD FRICTION

Another important part in the design of a tunnelling machine is the dimensioning of the jacks with which the machine pushes itself forward. Forces involve amongst others the axial component of the cutting forces, the pressure in the chamber and the friction of the surrounding soil along the outer circumference of the shield.

Generally some overcutting of the profile of the machine is done, i.e. the cut diameter is slightly larger than the diameter of the machine. This is done to reduce the friction of the shield in the ground to a certain extent. The friction cannot be reduced too much as in that case the reaction torque resulting from the cutterwheel will cause the shield to rotate itself. After the overcutting relaxation of the soil towards the shield takes place, the result of which upon the resulting stress on the shield is hard to predict. Also will the bentonite fill the space between the soil and the shield, having a lubricating effect. This implies that the regular values for the friction angle between a certain soil type and steel cannot be used.

The overcutting can be done selectively with the position of the cutterwheel. This is to be able to excavate some extra space for initiating and controlling curves in the planned track. Both for friction purposes and for the manoeuvrability of the machine often the diameter of the machine decreases towards the tail. This makes predictions on the shield friction in the ground even more complex.

The geotechnical parameters for calculations on the shield friction are:
- depth below surface and soil profile
- ground water pressure
- density of ground water
- density of the soil
- angle of internal friction and cohesion
- characteristics of the bentonite slurry

TRANSPORT AND TREATMENT

The excavated soil can be transported by hydraulic transport or in a 'dry' state by conveyor belts, train wagons or others.

In hydraulic transport the prevention of settlement of soil in the pipe, i.e. blocking of the pipe, is important. The power depends on the pipeline resistance of the slurry in the pipelines and on the static head. Towards the face the slurry is clean and has a low density. From the face to the surface the slurry is loaded with the excavated soil and has a high density. The pipeline resistance depends on the average grain size of the soil, the roughness of the pipe wall and the slurry velocity.

At the surface the slurry is fed to the separation plant or slurry treatment plant. Here the excavated soil is separated from the bentonite slurry that is used again. For coarse soils this separation is relatively simple. If the soil contains much fines, the separation plant gets more complex because the fines are hard to separate from the bentonite particles. The less the measure of separation the faster the bentonite gets contaminated and the fewer times the bentonite can be recycled. So for the separation it is not only the average grain size that counts but also the grain size distribution that plays a very important part. This way of transport and the slurry treatment are inherent to the slurry shield tunnelling method.

The excavated soil from an EPB machine is often transported dry when leaving the screw conveyor. This means removal to the surface takes place by conveyor belt or by train wagons or others. When foam is used a defoamer may be sprayed on the soil at the beginning of the conveyor belt. No further after treatment is said to be necessary before disposal.

Soil treatment, both separation in the case of a slurry shield and conditioning and defoaming in the case of an EPB shield, is expensive. Estimations on the consumption of foaming and defoaming agents per quantity of soil have to be made. Only little is known about this subject. However parameters that are important in the predictions can be given by:
- density of the soil
- angle of internal friction and cohesion

- moisture content, plasticity index
- shear strength
- grain shape and size distribution
- bulking factor

It is clear that there is an interesting link between engineering geology and mechanical engineering in the field of trenchless technologies. The soil and its properties determine to a large extend the requirements of a tunnelling machine, such as cutterwheel torque, thrust force, transport and mixing phenomena. Many soil parameters are being used in the design phase of a tunnelling machine and during the tunnelling project itself, for extensive calculations. Soil investigation and soil testing is important prior to the design of a tunnelling machine.

A lot of work is still to be done in finding and validating calculation models on the various (geo)-technical aspects of shield tunnelling.

Curriculum Engineering Geology - recent Developments

A. den Outer, D.D. Genske, P.N.W. Verhoef, Delft University of Technology, Faculty of Mining & Petroleum Engineering, Engineering Geology section

During the latest 'IngeoKring - Jaarvergadering'the future developments in Engineering Geology were discussed. One main agenda point was concerned with aspect of engineering geological education. The annual meeting gave the Engineering Geology Group Delft a good opportunity to check whether the existing curriculum is up to date and suits the demands that are posed by contractors, consultancies and other companies in the Netherlands and abroad. During the meeting it became cleat that most of the engineering geologists participating in the discussion referred to the curriculum that was in effect when they studied in Delft. This was a signal that the communication on developments in the curriculum of engineering geology, between the TU Delft and its former students, could be improved. In line with this observation, this article will discuss the recent changes in the curriculum as a result of the extension of the curriculum from four to five years.

THE BASIC COURSE (the first two years)

This first two years have not been changed to much the last years. Throughout these years the focus is on general scientific subjects like mathematics, physics and chemistry, which take up over half of the study load. Selection on capability in the first year has been increased by moving mechanics into the first year. Other than the general scientific subjects the more important specific subject is mainly geology. Geomechanics as well as smaller subjects directed towards the individual specialisations are also available at the faculty. The first-year excursion towards the Ardennes-Eifel is still the main exercise in practising geology in the field. The geological Vesc excursion has been shifted towards the third year to create more room in the first two years for general topics, supporting a better understanding of scientific logic.

THE ENGINEERING GEOLOGICAL COURSE (the final three years)

When composing the new curriculum for the 5-year program engineering geology did try to create a program with a good balance between site investigation/mapping, geology and technology. The curriculum is now organised around key-words, which define study-areas with related subjects (see table 1). The idea was also to reduce the number of individual subjects and combine these into larger subjects, which should improve comprehension of the relation between topics within the curriculum and reduce the number of lectures and exams. Consequently, the student is expected to better prepare the lecture by obtaining the knowledge of a specific topic from the lecture notes, while during the lectures the use and understanding of this knowledge is trained.

Specific changes in the third year of the curriculum are the combination of the courses 'Engineering Geological Mapping' and 'GIS' into the lecture 'Engineering Geological Mapping: Conventional and Computer Methods.' In this way the clear relation between the subjects and the place of these mapping methods within Engineering Geology is better shown. Furthermore, the still popular 'Games' are now a topic themselves, allowing to show the umbrella-function this subject has in the course. Additions in the program are the new lecture in hydrogeology, an extension of environmental geotechnics and the geostatistics lecture. The lecture 'Quarternary Geology' has been renamed into 'Applied Geomorphology' following the changing contents of the lecture. A remarkable change is the room for one or two optional subjects that can be selected individually, either at the university or abroad, in agreement with the department. This is continued more intensively in the fourth and fifth year, allowing for some level of specialisation without loosing to much time on teaching the broad spectrum of topics an engineering geologist is involved in.

The changes in the fourth year are mainly the integration of civil engineering topics as a fixed part of the program, like foundation engineering, groundwater mechanics and numerical soil mechan-

Table 1 Overview of 5-year curriculum topics Engineering Geology

	3rd Year	4th Year	5th Year
Site investigation and analysis			
	Site investigation I	Site investigation II	Excursion: EG site visits
	Mapping: Convent. & comp. Methods	Marine engineering geology	
	Applied geomorphology	Fourier transforms for seismics	
	Engineering geological games	Seismic interpretation	
		Geophysics for EG	
		EG fieldwork SPAIN	
Soil and rock mass performance			
	Soil mechanics I/II	Numerical soil mechanics (CT)	
	Static & dynamic loading	Numerical rock mechanics	
	Slope stability	Subsidence	
	Discontinuous rock mechanics	Foundation engineering (CT)	
Environment			
	Environmental geotechnics I	Environmental geotechnics II	
		Environmental game	
Geohydrology			
	Geohydrology (CT)	Flow & transport in fractured media	
	Hydrogeology	Groundwater mechanics (CT)	
Resources			
	Construction materials		
Statistics			
	Geostatistics	Decision & risk	
Geology			
	Geological fieldwork VESC		
Additional			
	Mathematics: Special topics	Practical work	Colloquium
	Numerical analysis	Seminar: EG today	Thesis
	Seminar: EG today		Seminar: EG today
	Reporting: Written & oral		
Optional			
	2 Topics	3 to 4 Topics	3 to 4 Topics

NOTE: CT = Faculty of Civil Engineering

ics. The reservoir engineering topics have been cancelled from the program. The Spain fieldwork is now done in the fourth year, still in close cooperation with ITC. In the fourth year also the geophysical topics are lectured, both on basic as well as applied level. As mentioned, the number of optional topics is increased in this year to three or four. The site investigation lecture is continued in the fourth year, covering also case studies of recent projects. Furthermore, the environmental studies have become more elaborated by adding a follow-up course with case studies on the initial lecture, followed by a computer interactive game on remediation works. The new topic, 'Flow and transport in fractured media' improves knowledge of contaminant migration through rock. Under the keyword 'Statistics' the course 'Decision and Risk' will cover the theory and practice of taking important decisions based on uncertain data or situations. The practical work of one month is continued.

The fifth year is mainly taken by the graduation work of seven to eight months, an intensive one week excursion to construction sites and three to four additional optional topics. Throughout the year seminars will be organised to discuss recent developments in the field of engineering geology. Running M.Sc.-topics can be included in the presentations.

The Engineering Geology Group Delft believes that the curriculum is up to date with respect to the market demands that were discussed at the annual meeting. A solid knowledge of site investigation methods and applications is included together with sound geological understanding. Lecturing technology has been recognised as an important aspect in the study, as indicated by implementation of important civil engineering subjects. Flexibility in the program has been created by allowing more optional subjects, which consequently gives room for students to do a more in-depth study on topics of interest and allows for a quick response to short-term market demands. By implementing more case studies and the seminar, as well as changing the teaching style, the student is motivated to lift his knowledge of subjects to a level of use and understanding the subjects. A future development will be the addition of a separate course on 'the Regional geology of NW Europe', including the geology of the Netherlands, to replace the successful course by Christiaan Maugenest, which used to be included in the environmental geotechnics lecture. The course will be given by Prof. S. Kroonenberg.

The department also recognises that communication with the market in general is important and that the market can contribute to teaching engineering geology. Possibilities are supplying interesting scenarios for case studies for different topics, guest speakers for seminars and giving feedback on problems to be solved in practice. The Engineering Geology Group sees it as its task to utilise this critique to find possible interrelations and to plan future research to support solutions for such problems.

The Engineering Geology Group hopes that with this article not only the engineering geologists in practice are now better informed on the current curriculum, but that they will also feel invited to give feedback and support to this new program.

Book review

Mechanised Shield Tunnelling

B. Maidl, M. Herrenknecht, L. Anheuser (1996), Ernst & Sohn, Berlin. pp. 428. ISBN 3-433-01292-X. Price: Dfl. 241,50 (translation of "Maschineller Tunnelbau im Schildvortrieb", 1995)

The original version of this book (in German) became in a short period a standard work for professionals involved in shield tunnelling. This is not surprising considering the impressive combination of expertise: Prof. Dr.-Ing. habil. Dr. h.c. B. Maidl (Rühr-Universität Bochum), Dipl.-Ing. M. Herrenknecht (machine manufacturer, Herrenknecht GmbH) and Dr.-Ing. L. Anheuser (managing engineer of contractor Wayss & Freitag AG). The recently published English version and the increased interest in soft ground tunnelling in the Netherlands justifies some attention for this publication.

The general principle of the shield is based on a cylindrical steel assembly pushed forward on the axis of the tunnel while at the same time excavating the soil. The steel shield secures the excavated void from ground pressures and ingress of water until the preliminary or final tunnel lining is built. A brief history of shield tunnelling is given in the introduction. Remarkable is that the principle of shield tunnelling already was invented in 1806 by Brunel. It was first applied in 1825 for a tunnel underneath the Thames river, London.

After the introduction important aspects of shield tunnelling are discussed, e.g. machine design and dimensioning, surface settlement and tunnel lining. Remarks on the wear of cutters are made in the chapter on excavation tools. Much information is given on the different shield systems (slurry, earth pressure balance, open-faced, compressed air and combined shields). Their principles are discussed using clear drawings and photographs. Furthermore, attention is given to microtunneling, health and safety regulations and contractual matters.

A very interesting aspect is that of each shield technique one or two case studies are discussed, among these are the Channel tunnel, the Storebælt tunnel, the Duisburg and Taipei metro. The geological and hydrological situation of all the studies is well described, often illustrated with a geological profile.

One regularly returning sentence of much interest for engineering geologists contains the passage: "depending on geological conditions". Unfortunately, this is not always specified in the text. Although the importance of a good recognisance of the ground conditions is stressed, no specifications are given on this point. The authors confine themselves with a reference of the German standard DIN 4020 (Geotechnische Untersuchungen für bautechnische Zwecke, 1990). This can be from engineering geological viewpoint somewhat disappointing.

This publication contains state of the art information on all aspect of shield tunnelling. The large number of illustrations (319) contributes to the pleasant readability of the book. The extensive reference and index lists make the publication very suitable as a "book of reference" for those interested in shield tunnelling. Therefore, it serves as a good starting point when one requires information about a specific aspect of this process. The publication can be considered somewhat overpriced, Dfl. 240,- is without doubt too much for an interested student.

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Faculty of Mining and Petroleum Engineering
Section Engineering Geology

News and Announcements

GEOINFO '96
Third International workshop Informatics and geosciences
Havana, Cuba, November 21-24, 1996.

Organised by the Institute of Geophysics and Astronomy and the Environmental Agency.
Themes: Geostatistics and spatial analysis, Statistical methods, Data exploratory analysis, Pattern recognition, Spectral analysis, Mathematical modeling (2D & 3D), Automatic mapping, Computer graphics systems, Data base systems, GIS, Image processing and digital analysis, Artificial intelligence and expert systems, hypothesis automation generation, inverse and direct tasks in geophysics. Registration fee: Delegates USD 190 / 220.

Correspondence: Dr. Alberto E. Garcia, General Chairman, GEOINFO'96, Calle 212 No. 2906 e/29 y 31, La Coronela, La lisa. Ciudad de la Habana, Cuba. fax: 537-339497/331325/339117/816798.

DIG ANNOUNCEMENTS
September, Friday the 13th: just to keep up a tradition, November, the 7th.
All members of the Ingeokring, and their partners of course, are invited to come to café 't Noorden.

INTERNATIONAL CONFERENCE ON TRENDS IN THE DEVELOPMENT OF GEOTECHNICS
Belgrade, Yugoslavia, November 18-20, 1996.

Organised by the geotechnical department of the faculty of Mining and Geology - Belgrade University and Sava Centar. Themes: Geology based geotechnics, Interaction of geologic medium and man-made structures, Scale effect in geotechnical investigations, Modeling in geotechnics, Modern methods and equipment for geotechnical investigations, Modern methods and technology of geotechnical works, Geotechnics in land use planning and protection of the engineering environment, Case histories, other problems in geotechnics.

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In Memoriam

Ir. Cyrus Raymond Wassing

On March 16 1996 Ir.Cyrus Raymond Wassing, born at Probolinggo Indonesia on June 26 1922, passed away.

He was one of the founding members of the Ingeokring in 1974. Since then he remained actively engaged in various activities of the Ingeokring. We shall definitely miss him at our meetings, which he attended very faithfully and enthusiastically.

The board and the members of the Ingeokring deeply sympathise with his relatives and wish them all the strength and comfort they may need.

Recently published papers

Most members of the Ingeokring are working in the field of Engineering Geology and related fields of expertise. By virtue of the interdisciplinary character of Engineering Geology the topics of work and study of the members of the Ingeokring range widely, and as a result their work is published in journals and proceedings of different nature. Because of this, not all publications come to the attention of the different members. To ease the access to the publications of different Ingeokring members, the authors of recently published papers are given the opportunity to present a short abstract (15 lines) of their publication, in the Newsletter. In addition the authors should give a name and address, to which persons that are interested can respond to for more information.

New site investigation tools for pre- and post dredging surveys
14th World Dredging Congress 1995

There are many site investigation techniques for dredging surveys available.
Well established techniques include towed geophysical instruments, Standard Penetration Tests, Vibrocoring and Cone Penetration Testing. Recent research and development resulted in novel site investigation techniques especially for dredging surveys. These include seabed based sampling and test techniques, and geophysical and GEOSLEDGE trench test equipment. These developments of light weight seabed operated systems which can be deployed from relatively small vessels are discussed. New geophysical techniques include geoelectrical and airborne radar techniques.

Examples of state-of-the-art site investigation surveys demonstrate the possibilities of geophysical and geotechnical data integration.

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Cone Penetration Testing In Tropical Residual Soils
Ground Engineering No. 1, 1996

Tropical regions include soil conditions not commonly found in the more temperate areas of Europe and North America where CPT apparatus was originally developed. The more complex of these tropical conditions are residual soils and calcareous soils, both of which can be characterised by highly variable and
erratic strength. They offer a harsh environment for CPT apparatus.

The paper presents examples of commercial CPT experience for tropical residual soils. Three sites are considered, covering more than 800 tests including 500 piezocone tests.The sites are situated in Thailand, Malaysia and Singapore. They represent residual soils derived from the weathering of igneous, metamorphic and sedimentary rocks respectively. Comparisons of CPT results with SPT testing and laboratory testing are discussed.

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Engineering geological and legal aspects involving proposals for a large waste disposal facility, the Netherlands
Geological Society Engineering Geology Special Publication No. 11, 1996

In the densely populated area of the Netherlands proposals for a waste disposal tip can involve drawn out legal proceedings before permission is granted. A case history is given in which the author acted as advisor for one of the objectors to the scheme and hence gives insight into both shortcomings in the quite extensive environmental laws concerning, amongst other items, waste disposal facilities. The licensing authorities for such a scheme are the municipal and provincial authorities

who, in this instance, are also supporters for the scheme. Such authorities, hence, do not maintain an unbiased role. High-court arbitration procedures are also outlined and the role of an expert witness. To date the proposers for the scheme have not been successful in being granted a licence, in part, due to the proposer trying to precede new environmental laws before their ratification by Parliament.

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Survey & containment of contaminated underwater sediments

Geological Society Engineering Geology Special Publication No. 11, 1996

The underwater sediments of the waterways, lakes and harbours of the Netherlands are sufficiently contaminated in many areas to necessitate their removal or isolation. The degree and nature of contamination and the general extend can be determined by sampling methods. To determine the thicknesses and distribution of the contaminated layers shallow reflection geophysical surveys can be used in many situations, especially if previous erosion or dredging has created a slightly overconsolidated layer relative to subsequent deposition. The method is also used to aid investigation with respect to quantity control for sand placement to contain contaminated sediments in-situ and to determine the depositional modes of hydraulically transported contaminated spoil in repository basins. Repository design for the Ketelmeer lake allows for a certain amount of contaminant loss to the environment, the principal criteria is to significantly lessen contamination by 50%. Complete isolation would only improve the drop in contamination levels by a further small percentage.

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The functional evaluation of road aggregates

7th International conference on the durability of building materials and components, Stockholm, May 19-23 1996.

The evaluation of road aggregates has traditionally been based on the use of standard tests and standard evaluation procedures. Because of the lack of detailed knowledge of the construction materials and the processes acting in and on the construction, the requirements set in the standards are very high. Furthermore, the durability aspect is often not incorporated in much detail.

The evaluation might be improved by following a more functional approach. Widely accepted in many fields of engineering, this approach is not yet fully appreciated with regard to (road) aggregates. The paper discusses the differences in evaluation procedures as well as the advantages and disadvantages of the traditional and functional evaluation.

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Durability of geological construction materials and the use of petrography

7th International conference on the durability of building materials and components, Stockholm, May 19-23 1996

The terms durability and degradation are widely used in both the field of construction engineering and construction materials. However, one can wonder what exactly is meant with these terms, or how they can be assessed.

The paper discusses these two aspects with regard to geological construction materials. The applicability of petrography as a tool to evaluate the durability of geological construction materials is reviewed.

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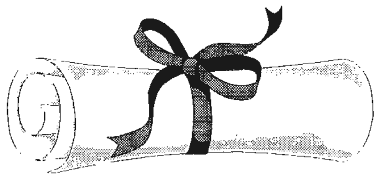
The Netherlands Students Award for Engineering Geology



The Ingenieursgeologische Kring, the Netherlands National Group of the International Association of Engineering Geology (IAEG) has established a prize for the best ir., drs. or MSc thesis in the field of Engineering Geology submitted to a Netherlands institute of higher education. The prize consists of a sum of NLG 1,000 and a certificate, to be handed out at the annual meeting of the Ingeokring in the spring of 1997. The thesis must be a contribution to the application of earth scientific knowledge to the solution of problems in civil engineering, mining engineering or environmental engineering.

We invite the submission of theses produced in the academic year
September 1995 - August 1996

Individuals can send in their own thesis or the thesis of others. Membership of the Ingenieursgeologische Kring is not required. Three complete copies of the thesis (including figures, photographs, annexes) have to be submitted by December 15, 1996 to the secretary of the Ingeokring. The committee which will select the best thesis is composed as follows:

* Drs. H.R.G.K. Hack (chairman Ingeokring)
* Prof. Dr. D.D. Genske (TU Delft, chair Engineering Geology)
* Dr. J. Rupke (University of Amsterdam, Dept. of Physical Geography)
* Ir. A.H. Nooy van der Kolff (Boskalis Westminster BV)
* Ir. C.M. Breukink (IWACO)

Criteria used for the selection will be:

* Relevance for earth sciences and engineering
* Scientific quality
* Originality of approach
* Quality of presentation

The Award is sponsored by:

* Ingenieursgeologische Kring
* Boskalis Westminster BV
* Fugro Engineers BV
* Ballast Nedam Engineers BV
* IWACO
* Rijks Geologische Dienst
* Geocom Consultants

The Netherlands National Group of the International Association of Engineering Geology (IAEG), the "Ingeokring" founded in 1974, is now the largest section of the KNGMG, the Royal Geological and Mining Society of the Netherlands. With more than 200 members working in different organisations, ranging from universities and research institutes to contractors, from consultancy bureaus to various governmental organisations, the Ingeokring is playing a vital role in the communication between engineering geologists in the Netherlands.