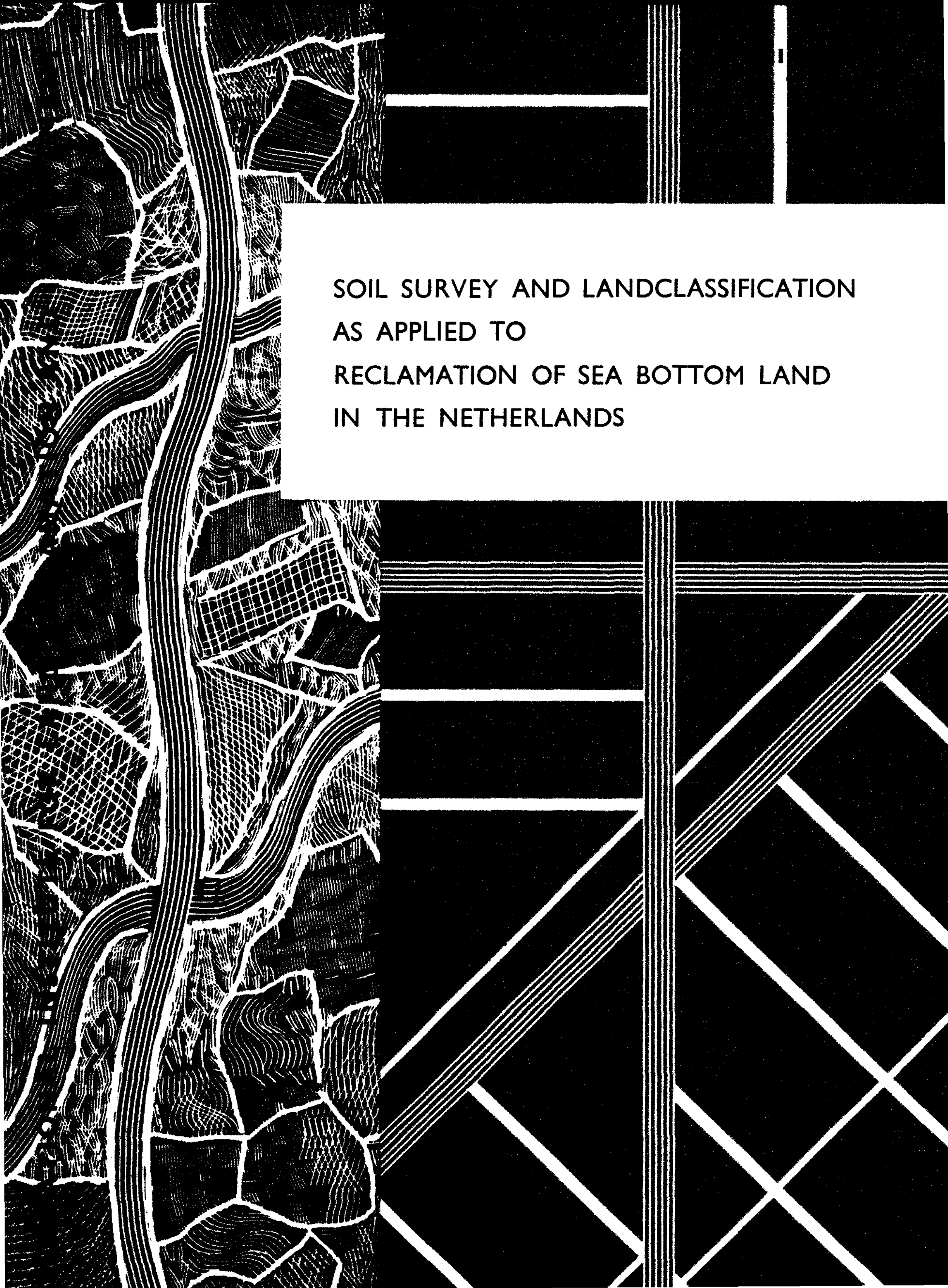

SOIL SURVEY AND LANDCLASSIFICATION AS APPLIED TO RECLAMATION OF SEA BOTTOM LAND IN THE NETHERLANDS

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SOIL SURVEY AND LANDCLASSIFICATION

AS APPLIED TO

RECLAMATION OF SEA BOTTOM LAND IN THE NETHERLANDS

LES ÉTUDES DU SOL ET LA CLASSIFICATION DES TERRES
EN VUE DE L'ASSÈCHEMENT DES SOLS SOUSMARINS
AUX PAYS-BAS

BODENKARTIERUNG UND LANDKLASSIFIZIERUNG
FÜR LANDGEWINNUNG AUF EHEMALIGEM MEERESBODEN
IN HOLLAND

EXAMEN DEL SUELO Y CLASIFICACIÓN DEL TERRENO
PARA LA COLONIZACIÓN DE TERRENOS SUBMARINOS
EN HOLANDA

Ir. H. SMITS

and

Dr. A. J. WIGGERS

Scientific Officers of the Zuiderzeepolders Development and Colonization Authority

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International Institute for Land Reclamation and Improvement
Institut International pour l'Amélioration et la Mise en valeur des Terres
Internationales Institut für Landgewinnung und Kulturtechnik
Instituto Internacional de Rescate y Mejoramiento técnico de Tierras
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- Ministry of Agriculture, Fisheries and Food: fig. 10
- International Institute for Land Reclamation and Improvement: fig. 11, 12

1. RECLAMATION WORKS IN THE NETHERLANDS, PAST AND PRESENT

A population map of the world shows clearly that Holland is one of the most densely populated countries. As regards Western Europe, the Netherlands is at the head of the list, a fact demonstrated by the following figures:

Country	Population in millions 1953	Area in sq. miles	Density per sq. mile
The Netherlands	10.5	12.510	839
Belgium	8.8	11.779	745
Great Britain	50.9	94.209	540
Western Germany	49.0	94.719	517
Switzerland	4.9	15.941	306
Denmark	4.4	16.578	264
France	42.9	212.736	201
Sweden	7.2	173.456	41
Norway	3.4	125.064	27

Holland's dense population results from the continuous and still continuing growth of the native population – 2.6 million in 1829, 5 million in 1899 and 11.1 million in 1957. While in most other countries population increase has slowed down and in some cases is decreasing, the Netherlands has maintained a high rate of increase throughout. Even if the emigration of 30,000 persons per annum is taken into account, the period 1950–1980 will show an increase of about 3 million to some 13 million, while a further rise after 1980 is by no means precluded.
Population density, which has been extremely high since 1900 and which is still increasing now, gave rise to an extensive reclamation of waste land in the period of 1900–1940, which was rendered possible by the application of fertilizers. Reclamation of waste land

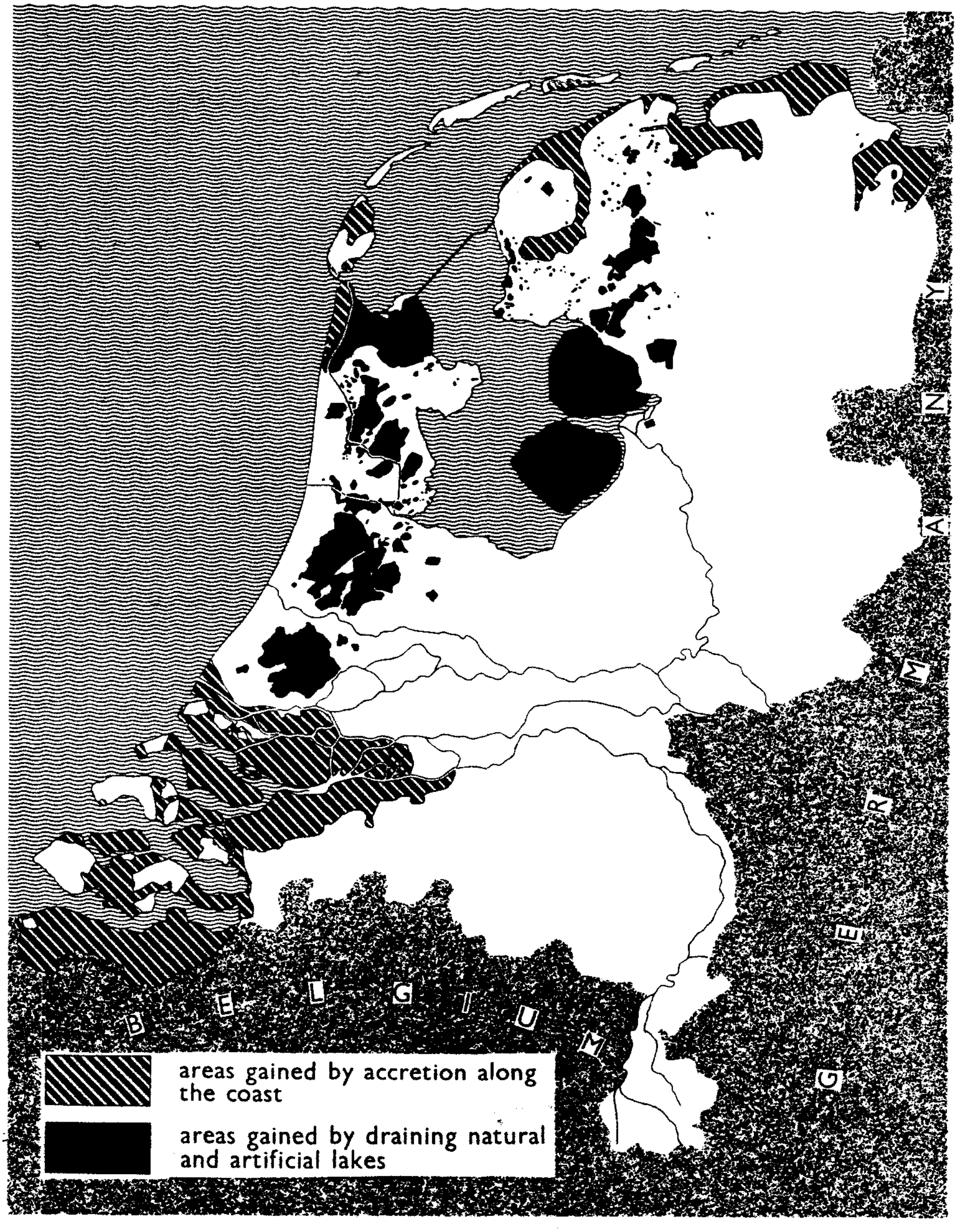


Fig. 1. General view of the land gained in the Netherlands.

for the purpose of enlarging the area of agricultural land has – however – nearly come to an end. Moreover, the remaining waste land (250,000 hectares or 625,000 acres) serves other purposes too, such as protection against the sea (dunes), water catchment, recreation, etc.

Since the 16th century an area of 138,000 hectares (345,000 acres) has been gained by drainage of lakes, especially in the low, peaty areas in the western part of the Netherlands (fig. 1). This drainage became possible with the invention of windmills in the 15th century. During the 19th century, steam engines provided a new stimulus to drainage operations. With their use, the Haarlemmermeer, a lake of 18,000 hectares (45,000 acres) was drained. This marked the virtual completion of lake reclamation.

Since the 13th century flooded territory has been recovered and new areas along the sea were gained, especially in the northern part of the Netherlands, shoreward of the Wadden Islands and in the South, in the area of large estuaries. This method of gaining new land was possible even centuries before the drainage of lakes, because the foreland continues (by sedimentation) to rise to a level somewhat above that of average high tide. Thus the land could be easily drained at low tide by draining excess rain water through sluices.

Dikes along the coast are less spectacular than drainage of large lakes. Since 1200, however, the country has been enlarged progressively by addition of 376,000 hectares (940,000 acres) gained from the sea (fig. 1).

Compared to the reclamation of the large polders in the former Zuiderzee, the diking of marine foreland is of little importance, nowadays. Plans are under consideration to reclaim large parts of the Wadden Sea in the North, while in the south-western part after the enclosure of the large estuaries (Delta-project) some strips of marine foreland along the existing islands and peninsulas will be reclaimed.

Formerly, reclamation schemes were as a rule executed by a group of private individuals, who furnished the necessary capital; after the dike had been built and the enclosed area pumped dry, the land which emerged was generally sold or leased immediately.

But the first farmers had to contend with great difficulties: a shortage of labour and capital, very primitive dwellings and farm buildings, and in the early years frequent crop failures caused by inadequate drainage, excess of salt, very acid soils resulting from oxidization of sulphides, etc.[1])

It should be placed on record that notwithstanding the great difficulties at first, the areas became very prosperous later on, but this result was attained at the cost of great suffering and poverty to the first settlers; a great deal would have been gained if the difficulties could have been eliminated from the start. Consequently, when undertaking the new reclamation schemes in the former Zuiderzee area, the Authorities were faced with the question: should the former procedure be adhered to and the reclaimed land handed over to private users at once, or should another system be adopted, by which the difficulties to the first settlers could be avoided?

Several considerations induced the Government to decide that all operations in connection with enclosure and reclamation should be carried out by the Government. Now-

[1]) See also: Dr. Ch. A. P. Takes, "Physical Planning in connection with Land Reclamation and Improvement". Publication no. I of the International Institute for Land Reclamation and Improvement, Wageningen, 1958, pp. 49–51.

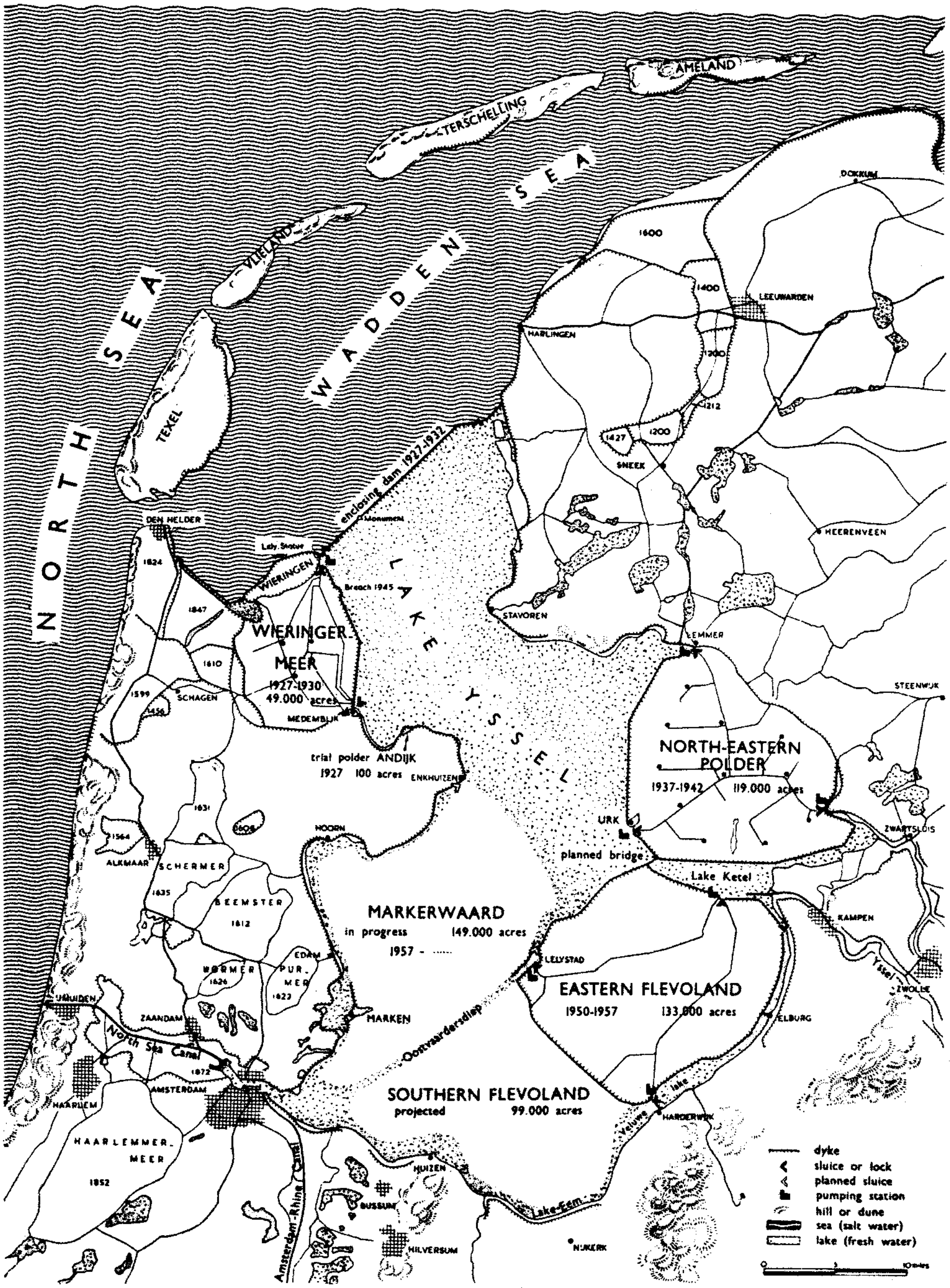


Fig. 2. The Yssel-Lake polders and former reclamations surrounding.

adays, hydraulic works, construction of enclosure dams, pumping stations, locks and sluices, dredging of canals and ditches, construction of bridges and roads are executed by the Board of the Zuiderzee works. All other operations – reclamation, field drainage, initial cultivation of the land, building of farms and villages, letting of the land – are done by the Zuiderzee polders Development and Colonization Authority. Both the Board of the Zuiderzee works and Zuiderzee polders Authority fall under the Ministry of „Verkeer en Waterstaat" (Ministry of Transport and Waterways).

On May 1st, 1919, the initial technical preparations for the construction of the Enclosing Dam between the Provinces of North-Holland and Friesland were started. In 1932, the 20 mile Dam was closed (fig. 2).

The purpose of the Enclosing Dam was to cut off the Zuiderzee from the Wadden Zee and the North Sea, so that a tideless fresh water lake could be formed in the enclosed part, into which the storm-tides could not penetrate. Consequently, the Zuiderzee polders are not situated on the open sea and, therefore, they only required a less heavy type of dike, which meant an important saving in costs and labour.

As a further result the existing dikes along the former Zuiderzee hardly required any maintenance. An additional advantage was, that the new fresh-water lake – called IJssel Lake – could function as a fresh water reservoir for the surrounding country in dry summers.

Lastly it was possible to construct a big road on the Enclosing Dam, which provided a much better connection between the northern provinces of the Netherlands and the western part of the country.

However mighty the Enclosing Dam was, it did not constitute the main object of the work; it only formed one – extremely important – part of it. The aim was the creation of polders and the rèclamation of land.

Before the completion of the Enclosing Dam a small experimental polder of 40 hectares (100 acres) was constructed near the village of Andijk in the Province of North-Holland (fig. 2). Here, several agricultural experiments were carried out, i.e. with the crops, which were to be planted in the large polders later on, and with different methods of detail drainage.

The last opening in the dike enclosing the north-western reclamation area, the Wieringermeer Polder (50,000 acres), was closed in 1929, so that early in 1930 a start could be made with the pumping out of the water contained within the dike.

The cultivation of the land of the Wieringermeer Polder had hardly started, when preparations were on their way to drain the projected Northeastern Polder. The construction of the dike began in 1937 and was completed in December 1940. With the aid of three large pumping stations, a territory of 48,000 hectares (118,000 acres) was added to the cultivated area of the Netherlands (1942).

The third large polder is Eastern Flevoland (54,000 hectares, 135,000 acres). The dike was completed in 1956; the whole polder became dry in June, 1957 and the reclamation proper is in full swing now. Meanwhile the construction of the dike of the next polder,

Markerwaard has started. This polder with an area of 60,000 hectares (150,000 acres) is expected to be drained by 1967 (fig. 2).
Finally, there is the southern Flevoland Polder, with a surface of 45,000 hectares (110,000 acres).
In this report stress will be laid on the soil survey. In chapter 2 some aspects of this soil survey wil be discussed. The third chapter deals with the methods and results of the soil survey as regards hydrological and agricultural operations in the polders of the IJssel Lake, for which purposes various land classification operations have been carried out. In chapter 4 some details will be given with respect to soil survey and its applications to the diking and cultivation of marine forelands.

2. SOIL SURVEY IN THE ZUIDERZEE POLDERS

2.1. INTRODUCTION

The primary object of soil survey in the polders is to obtain results for practical application. In addition to the soil survey being carried out on behalf of agricultural planning and operations, and some hydrological purposes, a great deal of soil research is done with respect to dike construction, waterway digging, road and farm house construction and erection of other buildings, etc. Soil research implementation is not covered in this report.
In soil survey for the purposes of agricultural planning and operations, three stages can be distinguished, each with its own character and purpose. As to the purpose of the different stages of soil survey, the reader is referred to chapter 3.
Before dealing with these three stages, it is necessary to discuss the basis of the soil survey and the principles of soil classification in these very young soils.

2.2. SOIL CLASSIFICATION

The soils in the new polders do not show any development of a soil profile at the time of mapping. Soil survey here means the mapping of the properties of young, unconsolidated sediments. In this regard, clay content is particularly important. There is a close relation between the clay content of the soil and its physical behaviour (water retention, cohesion, adhesion, swelling and shrinkage capacity) and for that reason between the clay content and a great number of important agricultural properties.
The clay content of young Zuiderzee soils is even more important a characteristic than that of many other soil types. In the first place the clay minerals are the same for all sediments, while in the case of types having a higher clay content, the coarseness of the sand-fraction is not so divergent as to result in a variation in agricultural behaviour. Furthermore, no development of a soil profile has so far taken place in these young soils which could have altered the properties. In the third place, the clay content is closely related to a number of properties which are extremely important for the agricultural behaviour of the soil. This fact is made clear by the table subjoined.

TABLE 1. Composition of the soils in the new polders at the moment they emerge from the water

Clay content (< 2 micron, in g per 100 g dry soil)	Organic matter (in g per 100 g dry soil)	Water content (in g per 100 g dry soil)	K_2O [1] (in mg K_2O per 100 g dry soil)	P_2O_5 [2] (in mg P_2O_5 per 100 g dry soil)	Linear shrinkage (in perc.)
2	0.6	26	7	9	–
5	0.8	34	18	13	1.3
8	1.0	43	28	17	2.2
11	1.2	51	39	20	3.0
14	1.4	60	49	24	4.0
18	1.7	71	63	29	5.6
22	2.0	83	77	33	7.2
26	2.3	94	91	38	8.7
30	2.6	106	105	43	10.3
35	3.0	120	123	49	12.2
40	3.3	134	140	55	–

[1]) soluble in 0.1 n HCl.
[2]) soluble in 1 % citric acid.

In point of fact, it may be said of the new Zuiderzee soils that all their properties correlate with their clay content, which is the actual basis of the soil classification.
The natural shape of the former Zuiderzee caused sedimentation in a very regular pattern. The increase in the clay content in the layers, which form the topmost part of the profile, proceeds very gradually in a certain direction. Over a distance of 4 kilometers (2.5 miles) the clay content in samples taken at intervals of 300 meters (1000 ft), amounts to: 8.7 %, 8.9 %, 10.1 %, 10.4 %, 11.6 %, 12.8 %, 14.4 %, 14.6 %, 14.4 %, 15.6 %, 16.4 %, 17.5 %, 18.2 % and 18.4 %. This very regular increase in clay content enables us to group the soils in different texture-classes with small intervals.

TABLE 2. Classification of the young soils in the Zuiderzee polders, according to their clay content and grading of the sand-fraction

Code	Texture class	Clay content in %	U-figure, sand-fraction
0	pure sand	0 – 1½	
1	nearly pure sand	1½ – 3	
2	somewhat loamy sand	3 – 5	
3	loamy sand	5 – 8	
4	sandy loam A	5 – 8	< 120
5	sandy loam B	8 –12	> 120
6	loam A	12 –17	
7	loam B	17 –25	
8	clay loam A	25 –35	
9	clay loam B	35 –50	
10	clay	> 50	

As regards the sandy soils, along with the clay content, the coarseness of the sand-fraction is an important factor as well, because the soil will have a greater field capacity and capillary rise, at the rate at which the sand fraction becomes finer.
The 'grading' of the sand can be represented by one figure, the so-called: U-figure. For the meaning and the determination of the U-figure see Appendix I.
The classification of young marine sandy soils according to the coarseness of the sand is of far more interest than that of the older sandy soils, because the qualities of the latter are primarily determined by their humus content. In the Netherlands the older sandy soils usually have a humus content from 2–10 %; consequently, a classsification of these soils according to the humus content is indicated. Young marine sandy soils, on the contrary, have a very low humus content (0.1–0.5 %); a classification according to the humus content is, therefore, of little importance. The grading of the sand and clay content is of major importance to the agricultural behaviour of the soil. The classification of the marine sandy soils according to sand grading is given in table 3.

TABLE 3. Classification of marine sandy soils according to the coarseness of the sand (particles larger than 16 micron)

Code	Texture class	U-figure
a	coarse sand	< 50
b	moderately fine sand	50– 80
c	medium sand	80–120
d	fine sand	120–180
e	very fine sand	180–270
f	extremely fine sand	270–400

One of the most important properties of the soil – related to the clay content – is the moisture-content at the moment the soils emerge from the water. This moisture content as shown in table 1 is high compared to that of older marine soils. However, as years go by, it will diminish as a result of the soil drying out gradually to its normal field capacity. In the final stage, the maximum field capacity of the topsoil in springtime will be approximately 20–25 g per 100 g dry matter in soils having a low clay content and about 30 to 40 g in soils with a higher clay content. The inference is that soils having a high clay content will liberate much more water than those with a low content.
At the time they emerge from the water soils with a clay content of more than 5 % are virtually impermeable; they consist of a homogeneous paste, resembling boot-polish. As a result of the cracking and crumb-formation, accompanying the drying-out process, the permeability and the drainable pore space of the soil increase. The soil shows ripening, maturation.
One of the results of the loss of water is the shrinkage of the sediment which causes settling. So the thickness and the depth of the different layers change gradually. This

process will continue for many decades. In compiling soil maps one has to reckon with this settling process which sometimes alters the soil profile to a high degree.
All soils are rich in lime: the contents of calcium carbonates mostly vary from 2 to 10 percent.

2.3. THE THREE STAGES OF SOIL SURVEY

Stage 1 – under water survey

The reasons to be summed up in chapter 3 necessitate the making of a survey of the soils in a new polder before it is pumped dry and even before the construction of its dikes has been started.
The carrying out of soil survey in a polder still submerged requires special methods of procedure. Two types of coring apparatus are used, according to the depth to which the sediments have to be mapped. One of these appliances renders it possible to collect an undisturbed core with a length of 1.5 m (5 feet). The implements are operated from a wooden platform rigged up outboard on the starboard side of a fishing-boat (see fig. 3) in

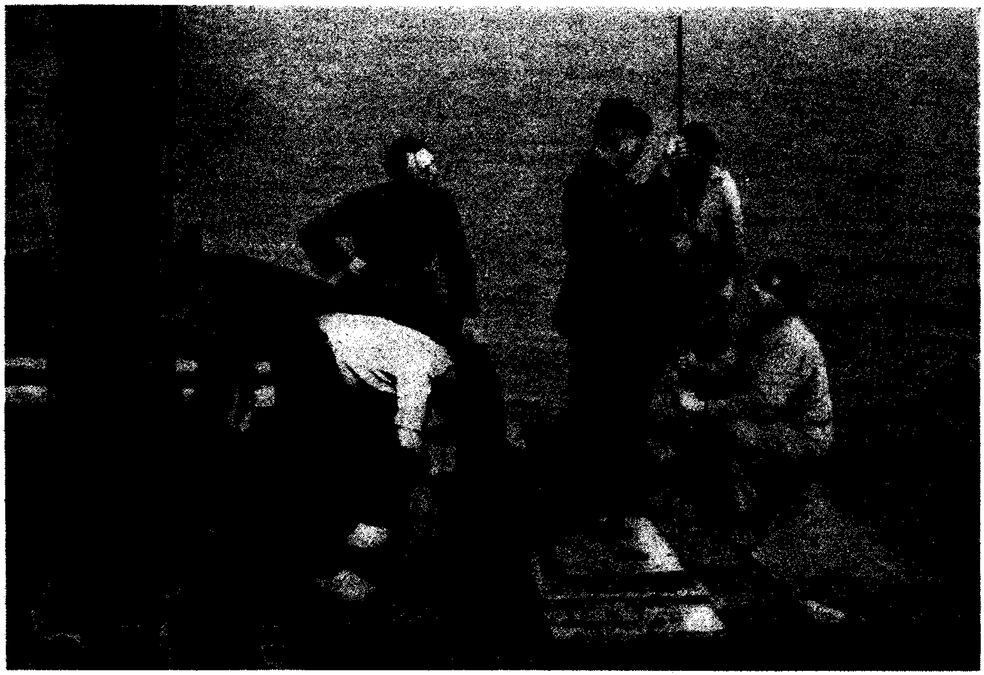
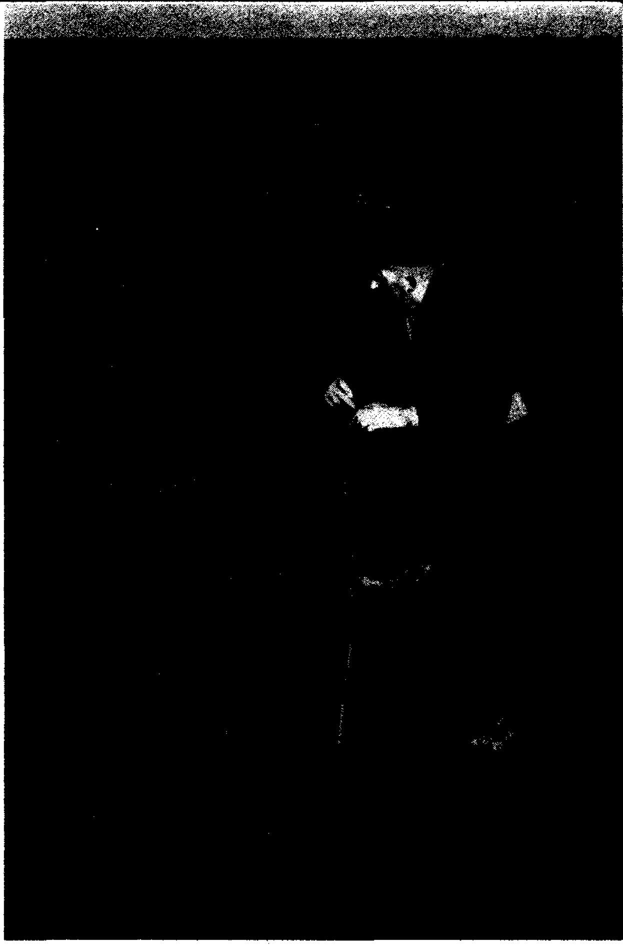


Fig. 3. Under water soil survey.
The man on the left examines an undisturbed core; meanwhile the others are exploring the depth of the sandy (pleistocene) layer by cone sounding.

Fig. 4. Detailed soil survey by examination of a ditch profile. The photo shows clearly the different soil layers.



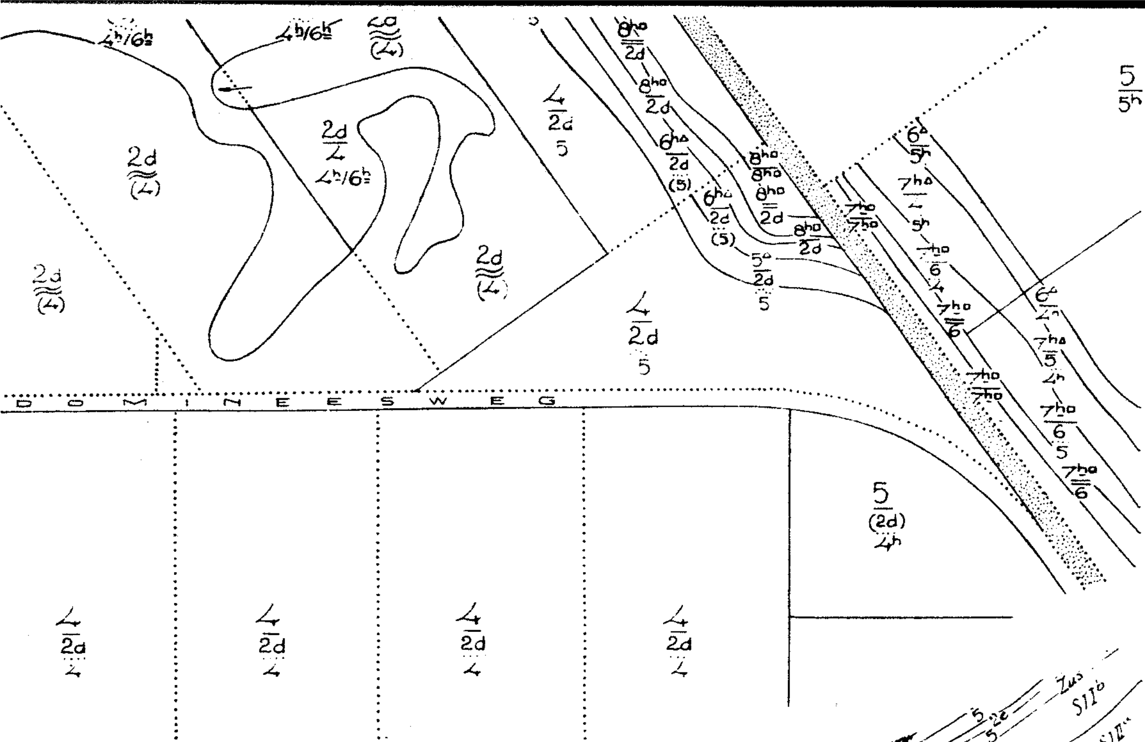
places with sufficiently deep water (approximately 1.4 m). In places along the shore of insufficient depth, the work is done from a flat bottomed vessel or from a rubber boat. This soil survey on the IJssel Lake depends greatly on weather conditions. Because of the expense of this procedure, the intensity of the soil survey is limited to one observation per 50 hectares (125 acres).

Stage 2 – preliminary survey

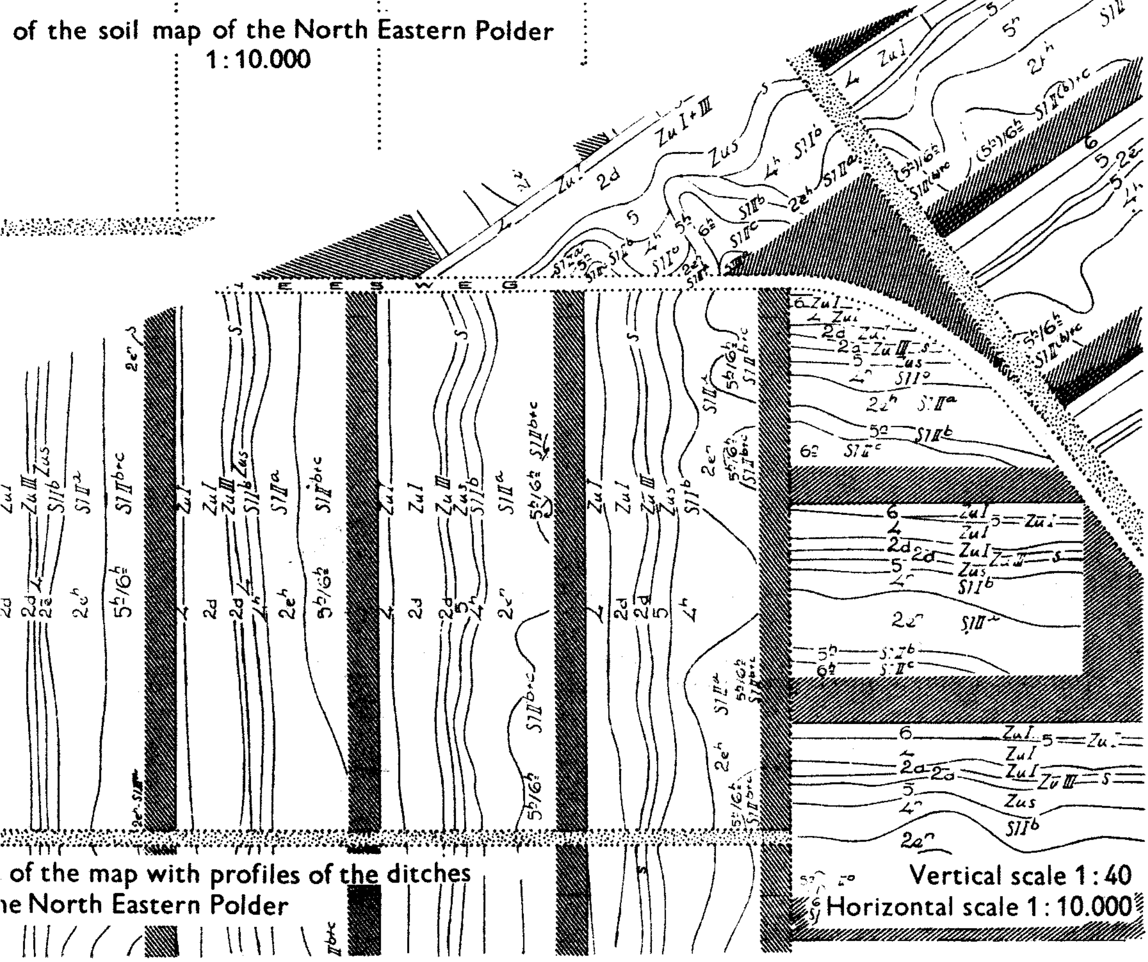
As soon as the polder emerges from the water, but prior to digging of ditches a more intensive soil survey is made. Now the intensity of the survey becomes one boring per hectare.
The soil maps compiled from the data of this survey have far more detail, but are still not detailed enough.
Excavation of the ditches in the polder provides an excellent opportunity for examining the sediments more thoroughly and for making maps with minute detail. So the final survey takes place after construction of ditches.

Stage 3 – detailed survey

The ditches between the lots of a length of 800 to 1,000 metres and a width of 200 to 300 metres, have a total length of nearly 2,000 km in a polder of 50,000 hectares. For the compilation of the detailed polder soil maps, the ditch profiles are described to a depth of 1.4 metres at intervals of 50 metres (fig. 4).
Moreover, the initial trenches – or field ditches – dug at regular distances of 8 to 24 metres (fig. 9) expose to view almost completely the upper 60 cm.
The results of this survey make it possible to compile and publish a finely detailed soil map, scaled 1 : 10,000, of the layers within the uppermost 50 centimetres, and to draw and publish longitudinal sections of all the ditches with a total length of 2,000 km on a scale 1 : 10,000 (see fig. 5).



of the soil map of the North Eastern Polder
1:10.000



of the map with profiles of the ditches
ne North Eastern Polder

Vertical scale 1:40
Horizontal scale 1:10.000

3. APPLICATION OF SOIL SURVEY METHODS IN THE ZUIDERZEE POLDERS

3.1. INTRODUCTION

As it was shown in the preceding chapter, these surveys are made at different stages. This is mainly due to the fact that the successive stages of impoldering present increasingly favourable opportunities to make detailed soil surveys. It is fortunate that the need for detailed data does not yet make itself felt during the early stages of development; however, this need increases later on.
In this chapter the utilization of soil maps will be dealt with, and the stages of survey discussed in the previous chapter will be considered successively.

3.2. UNDER-WATER SURVEY (Stage 1)

Data concerning soil conditions should be available before a dike is constructed, since the proper work is preceded by the making of plans which cannot be designed without a fairly thorough knowledge of the nature of the soil. In what follows, details will be given of the uses of the first soil maps of future polders. A compilation of these first soil maps is presented in fig. 6.

a. Situation and shape of the polder

For various reasons the remaining IJssel Lake will cover an area of 120,000 hectares after all reclamation has been completed. This proviso leaves an area of about 225,000 hectares at the utmost for all polders collectively. Since the former Zuiderzee area shows wide differences as to soil conditions, it is endeavoured wherever possible to reclaim only the good soils and to keep the inferior ones outside the polders.

b. Settling of the soil after impoldering

The sea bottom soils in their original condition are of a very loose structure and have a large pore space. Naturally, all pores are filled with water.
After emerging from the water, the soils lose moisture by evaporation and transpiration.

◁— fig. 5

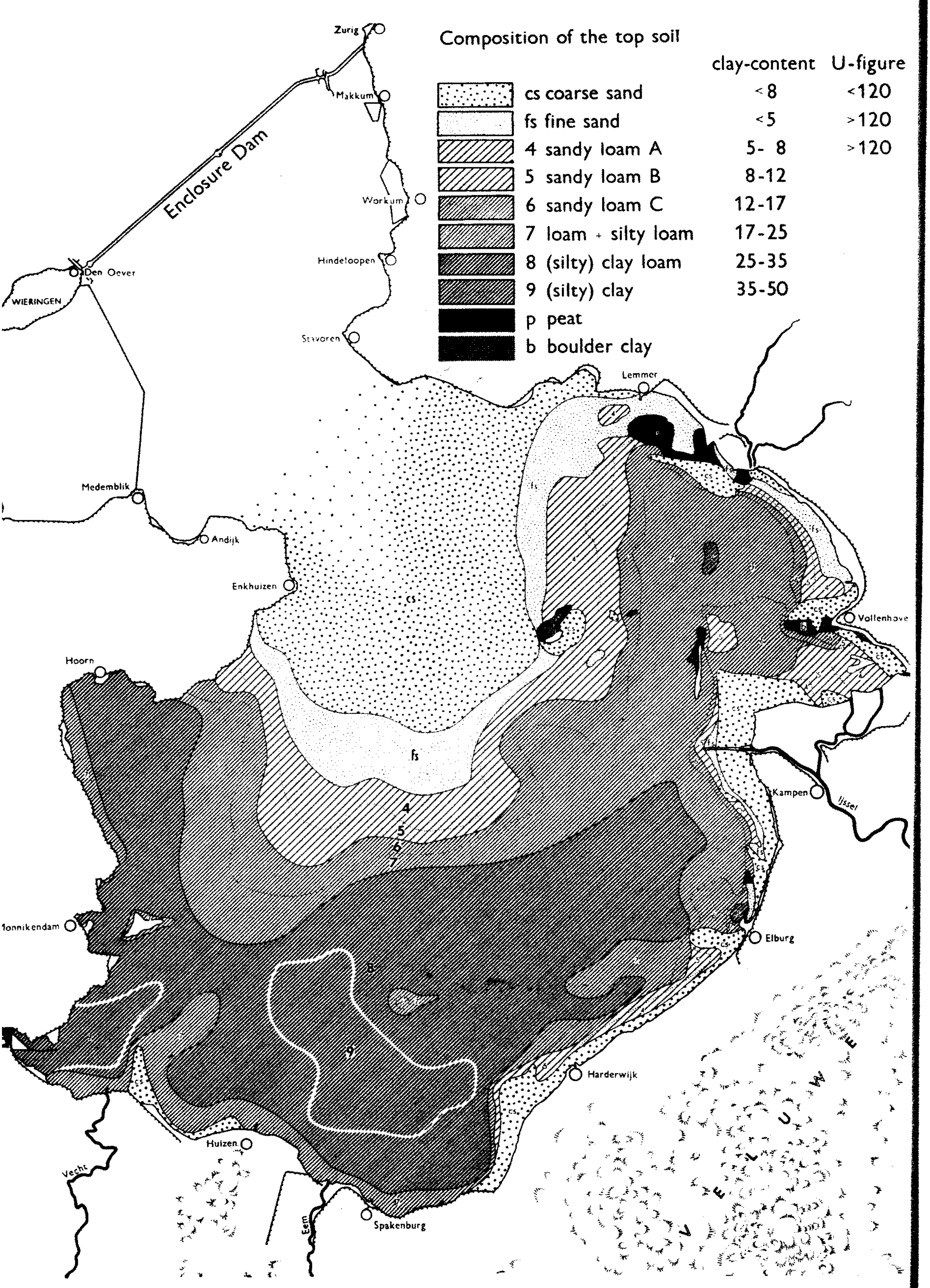


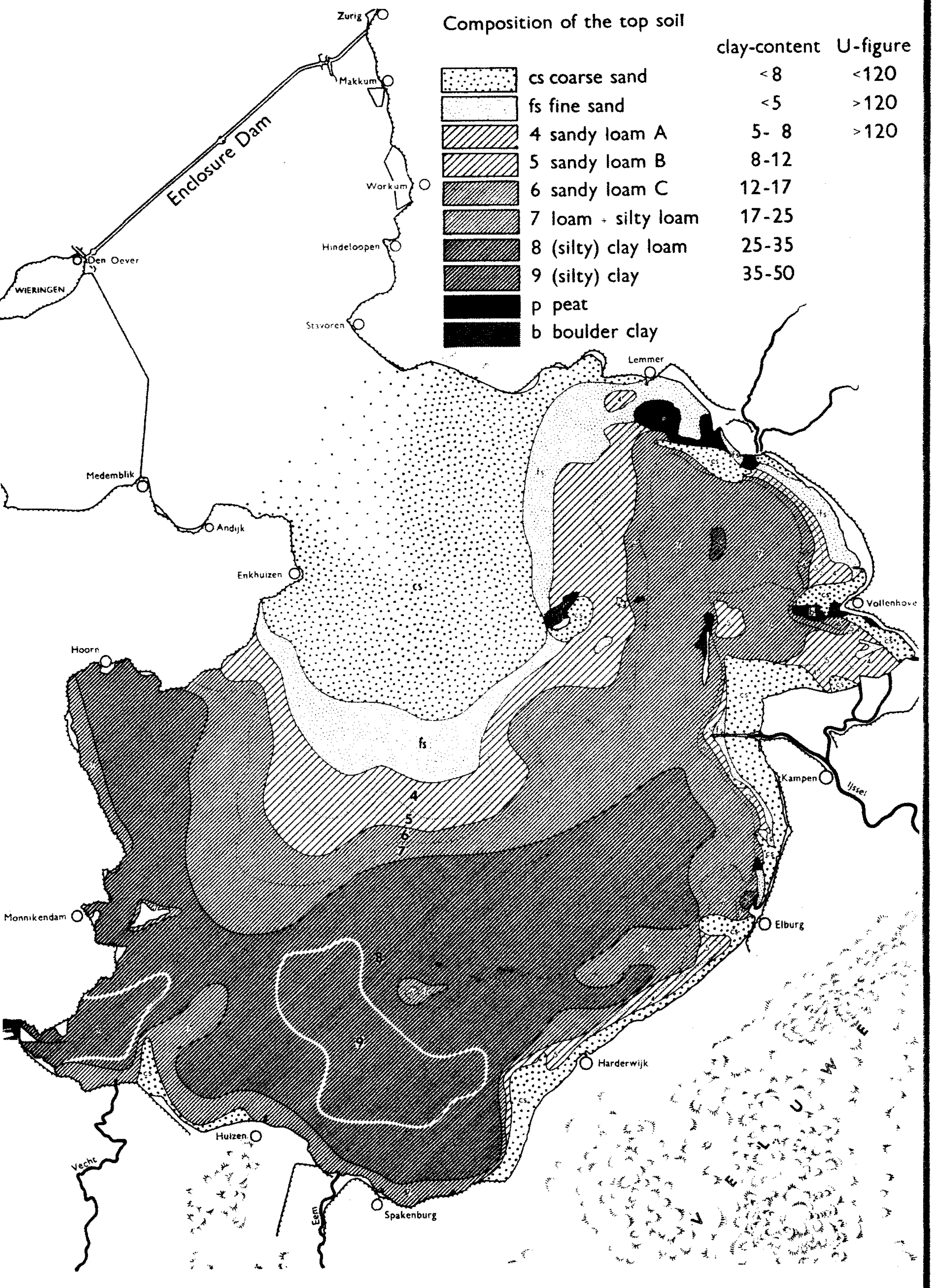
Fig. 6. Soil map of the Yssel-Lake as a result of the under-water survey.

This process of drying out is accompanied by general shrinking of the soil which manifests itself in settling and in vertical crack formation. The horizontal shrinkage is likewise gradually converted into a sinking of the ground level, due to the fact that these cracks are partially filled in; there is a certain amount of 'settling'.
This settling is of great importance, since the drainage system has to be designed for the future ground level, i.e. for the level after settling. The future ground level can be calculated from the level prior to pumping dry and from the extent of settling. With the aid of the under water samples – viz. on the basis of their clay- and water content – a fairly reliable computation can be made as to the extent of the settling.
The future ground level is important first of all with a view to dividing the polder into sections and for the fixing of the "polder water level" in those sections.[1]) The polder water level must be chosen in such a way that the lowest spot in a section is still 1.40 meters above it.
Secondly the settling is (via the polder water level) of importance in connection with the construction of the pumping stations, since the polder water level determines the discharge height of the pumping-plants.
Thirdly, the lock sills depth, the canal bottom depth and the revetment height along canal banks are partly determined by the degree of settling.
The latter depends to a great extent on the condition of the soil. The more clayey and the thicker the layers of soil, the greater the settling. During the first century after reclamation it varies from 0 cm for sandy soils to over 100 cm for soils with thick layers of clay.

c. Seepage forecasts

The Zuiderzee polders are low in relation to their surroundings; the polder water level varies from 4,5 metres to just over 6 metres below mean sea level. Since the permeability of the deeper sub-soil is fairly great on the whole, water shows a tendency of flowing to the low-lying polders, where this phenomenon is manifested in the form of seepage (fig. 7). It is of great importance to be informed of the total amount of seepage water and of its distribution over a polder, primarily for the purpose of determining the capacity of the pumping stations. Experience has shown that in the Netherlands a polder without seepage may be adequately drained, even during wet periods, if the pumping plant can pump out between 10 and 11 mm a day. If, however, seepage in such a polder amounts to a few mm a day, the capacity of the pumping plant has to be increased by that amount. When the pumping stations are designed at a very early stage of reclamation, the amount of potential seepage should be known.
In the second place, a forecast of the seepage and its distribution over the various sections of the polder is required for the drawing up of a reclamation plan. A polder of 50,000 hectares can be brought under cultivation in a period of 10 to 12 years. Since areas with a great deal of seepage continue to be impassible to machines for a long time, they are the last to be developed. Therefore it is necessary to know at an early stage where those areas are situated.

[1]) "Polder water level" is the water level in the *open* canals obtained by means of pumping. The polder water level should be established in such a way, that the ground water table of the land is as favourable as possible for the crops te be grown. The sub-drainage system is utilized to adapt the subterranean water table rapidly to the *open* water level in the canals.



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It is of great importance to be informed of the total amount of seepage water and of its distribution over a polder, primarily for the purpose of determining the capacity of the pumping stations. Experience has shown that in the Netherlands a polder without seepage may be adequately drained, even during wet periods, if the pumping plant can pump out between 10 and 11 mm a day. If, however, seepage in such a polder amounts to a few mm a day, the capacity of the pumping plant has to be increased by that amount. When the pumping stations are designed at a very early stage of reclamation, the amount of potential seepage should be known.
In the second place, a forecast of the seepage and its distribution over the various sections of the polder is required for the drawing up of a reclamation plan. A polder of 50,000 hectares can be brought under cultivation in a period of 10 to 12 years. Since areas with a great deal of seepage continue to be impassible to machines for a long time, they are the last to be developed. Therefore it is necessary to know at an early stage where those areas are situated.

[1]) "Polder water level" is the water level in the *open* canals obtained by means of pumping. The polder water level should be established in such a way, that the ground water table of the land is as favourable as possible for the crops te be grown. The sub-drainage system is utilized to adapt the subterranean water table rapidly to the *open* water level in the canals.

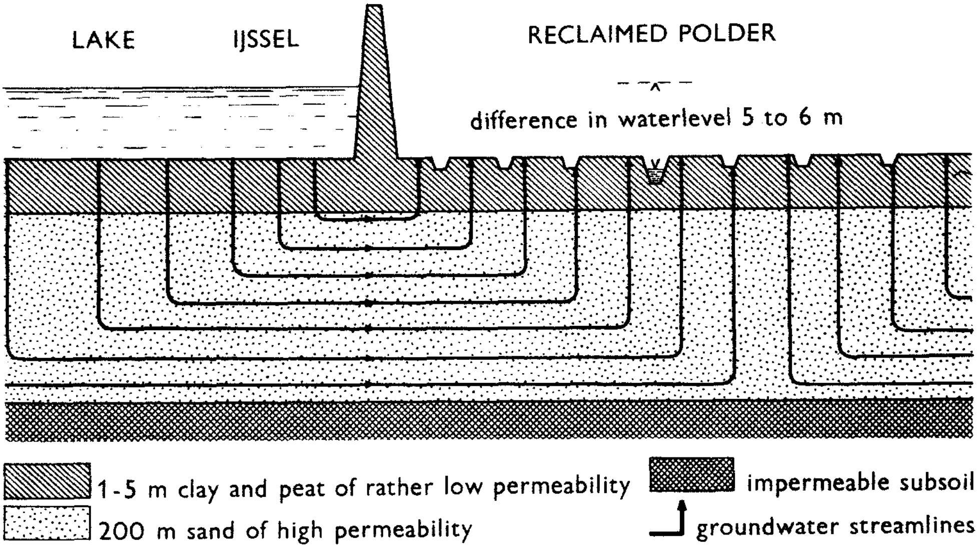


Fig. 7. Seepage into the Yssel-Lake polders (schematically).

The distribution of the seepage is furthermore important to render judgement on the soil suitability. Sometimes it is difficult to give seepage areas sufficient drainage and it is often necessary to establish farms with more grassland than in comparable areas without seepage.

Seepage is also a factor to be reckoned with if a forecast is to be made as to the spacing of field ditches and tile drains. Such a forecast is made at an early date for use in calculation of the number of machines, the materials, and the labour necessary to the reclamation plan. The intervals between field ditches and tile drains are strongly affected by the amount of seepage.

The extent of seepage depends primarily on the difference in level between the water inside and outside the polder, and on the thickness and the permeability of the soil layers down to a considerable depth. The seepage for an entire polder in the Zuiderzee amounts to about 1 mm a day. In specific areas, however, it may be as much as 20 mm a day.

d. Dumping of soil dredged from canals

The principal canals are dredged before the polder has been pumped dry. The matter dredged from them – some 12 million cubic metres (about 16 mill. cubic yards) for a polder of 50,000 hectares – may consist of peat, sand or clay. Since each of these materials is put to a different use, it is necessary to know in advance which of them will be dug from the canals.

The sand is dumped at depots such as future road junctions or in the vicinity of future villages. If possible, peat is dumped outside the polder. Finally, the clay is used to cover sandy soils with a view to improving them.
If the peat cannot be taken outside the polder it is scattered over a large area in the form of a fine layer. Later on it may be worked into the soil by means of deep ploughing.

e. Devising a provisional plan for sub-irrigation

Despite the fact that the Dutch climate shows a yearly rainfall surplus, the crops grown on soils with a small water retention capacity suffer from drought during dry periods. This subject will be dealt with in more detail in paragraph 3.4.
It is sufficient to state here that the drought-susceptible areas, in as far as they are not to be afforested, are given an artificial water supply. The width of the lots in such areas should preferably not exceed 200 m, whereas elsewhere the normal width of the lots is 300 m. For the drawing up of an allocation-scheme it is therefore necessary to know which areas will have to have artificial water supply. These areas are determined by use of the results of under-water survey.

f. Provisional determination of soil suitability and land use

After the soils have been brought under cultivation, they are exploited by the State for a few years. In order to make a plan of crops to be grown during those years, the suitability of the soil has to be investigated. Since this depends entirely on soil conditions, the latter should be known.
The soil suitability indicates the uses to which a soil *may* be put, whereas the land-use denotes the use to which it *will* be put (see paragraph 3.4). When the land-use is to be decided upon, the suitability of a soil does indeed play an important part, but if a choice is to be made between various possibilities, economic and social factors are also involved. For various reasons it is desirable to know the soil suitability at an early stage, so as to be able to use this knowledge in provisional plans for land use.

g. Estimation of the cost of reclamation and building

It is, of course, imperative to estimate the cost of the reclamation of the land and that of the buildings beforehand. This estimate has to be based on many of the items already discussed, all of which, in turn, depend on the condition of the soil.

3.3. PRELIMINARY SOIL SURVEY (Stage 2)

The items discussed under 3.2 all refer to work done before the polder is pumped dry. In the following consideration is given to the work done soon after the land has emerged, in so far as the results of preliminary surveys are applied.

a. Final land division

The first task to be undertaken after a polder has been pumped dry is that of constructing a network of main canals, lateral canals and ditches. This network is, obviously, a highly essential part of the general development scheme, and it can be said that after it has been completed no more changes can be made in so far as the scheme of allocation is concerned. In view of this it will be clear that before the canals and ditches are dug, extremely good care is taken to see whether or not the supplementary data on the soil conditions, as obtained from the preliminary survey, make any changes in the scheme of land-division desirable (fig. 8).

b. Preparing specifications for excavation work

The digging of canals, lateral canals and ditches is awarded to a number of private contractors. In order to enable a cost estimate to be made, the works are described in great detail in the specifications. Such description includes the soil conditions of the areas where the canals and ditches are to be dug. The data required to this end are as a rule taken from the preliminary surveys.

c. Determination of the reclamation plan

As is done in the case of the plan for land division, the preliminary soil map is closely studied to ascertain whether the desirability of amending the reclamation plan is indicated.

d. Determination of the spacing of field ditches (trenches)

After ditches have been dug, the parcels are formed. They have a length of from 800 to 1,000 m and a width of from 200 to 300 m (see fig. 9).

The permeability of the young soils is as yet so poor, that ditches alone do not effect an adequate drainage of lots of this size, so that a detailed drainage system has to be laid down. During the first few years this system consists of field ditches, which are later on replaced by tile drains. The field ditches are 1.15 m wide at the top, 0.25 m at the bottom and have a depth of 0.60 m. The figures 10, 11 and 12 show some pictures of the modern equipment used to this end and its results.

The principal reason why the soil is initially trenched and later tiledrained is the fact that it is almost impracticable to lay drains in the very young, soft soils. Moreover, at the time of trenching the soil has not yet dried out to any considerable depth, and is uncracked and highly impermeable. Therefore, in case of tile drainage the intervals between the tile-rows would have to be very small.

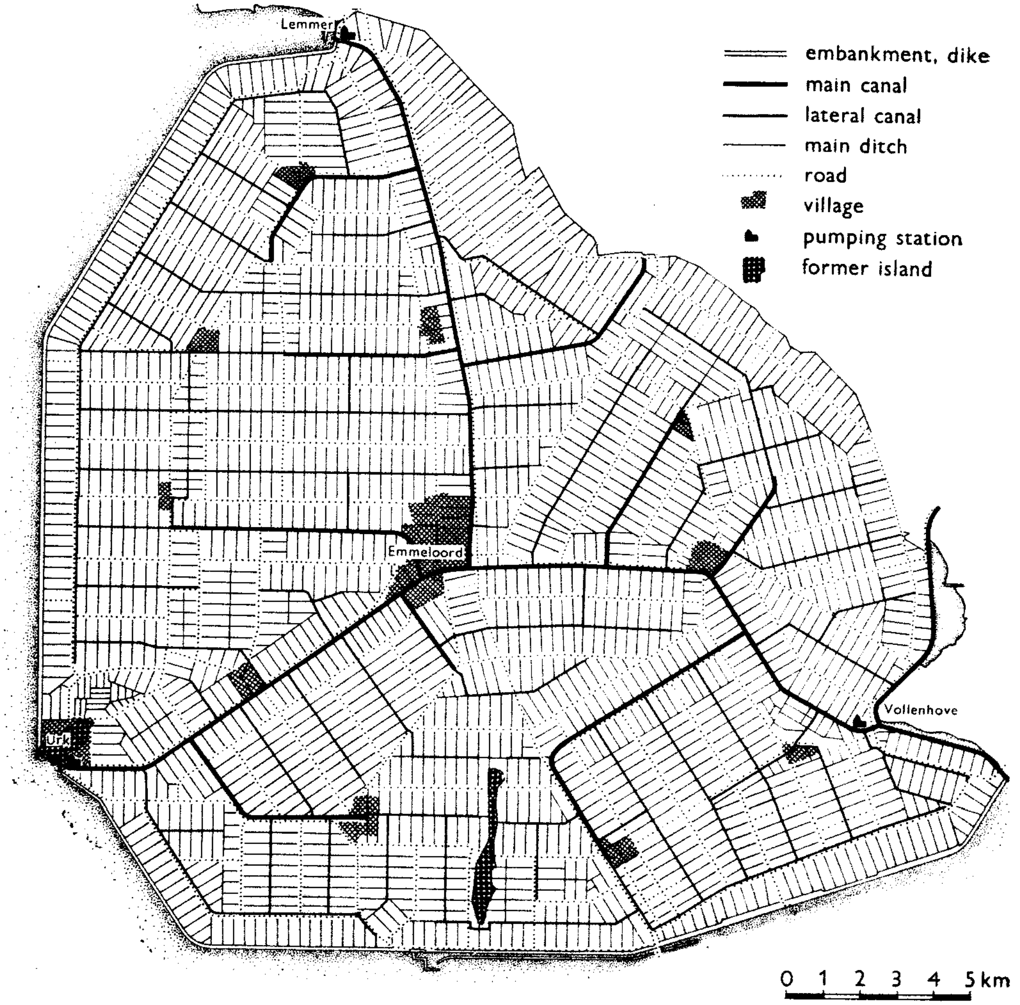


Fig. 8. General lay out of the Northeast-polder.

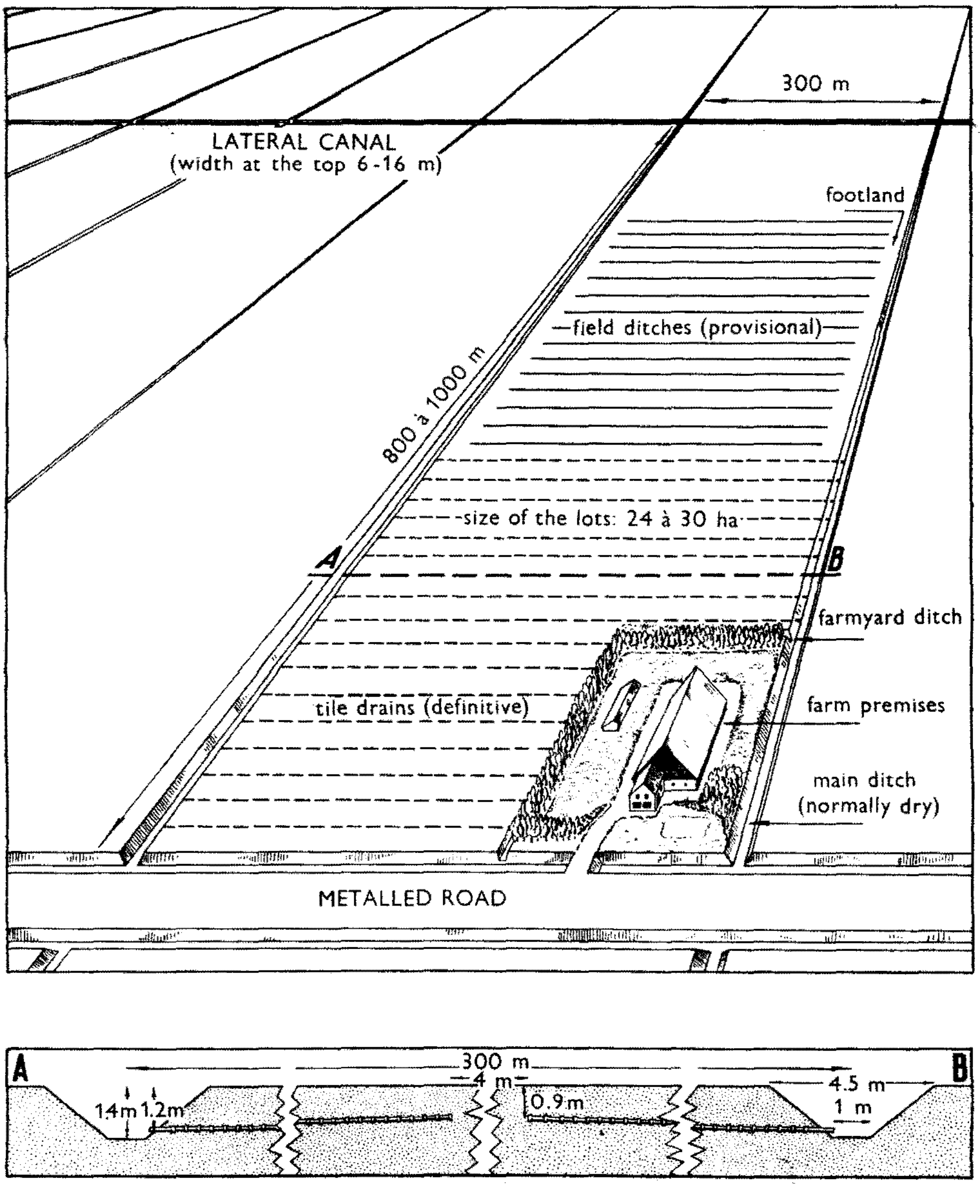
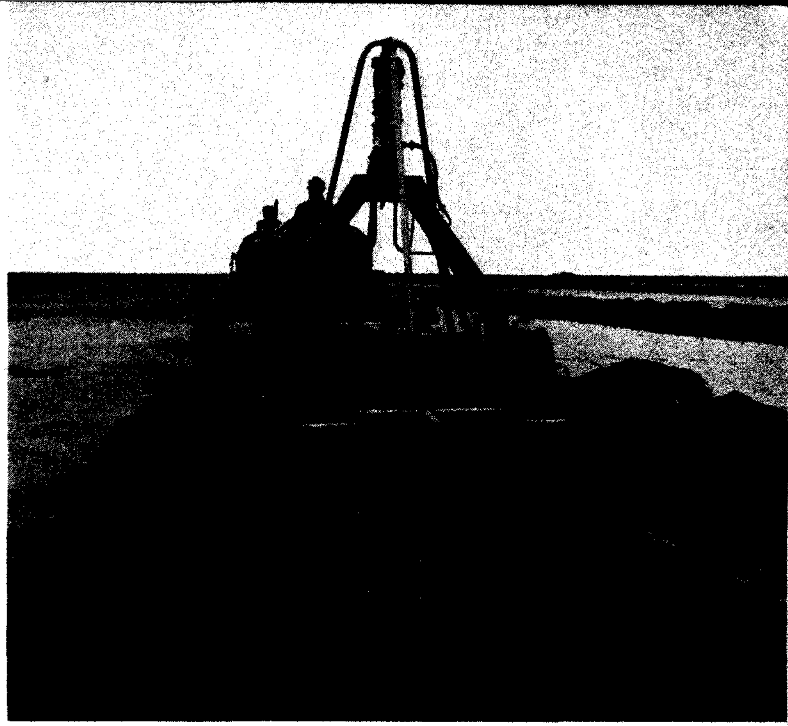


Fig. 9. General lay out of the individual lots.

Fig. 10.
A modern trench-cutting plough with a hydraulic lifting system, pulled by three crawler-tractors.



The distances between the field ditches, which were already estimated for the different areas before the polder was pumped dry are now separately determined for each parcel. Due to the experience gained in the course of the years it has become possible to determine the intervals between the field ditches merely with knowledge of soil condition to a depth of about 60 cm, and the stage of ripening of the soil profile.
Table 4 shows the empirical scheme elaborated for distances between field ditches on heavier soils of the Zuiderzee polders.

TABLE 4. Classification of young marine soils according to field ditch distances

Code	Distance between field ditches shortly after the land emerges	Distance between field ditches after several years' ripening under the influence of spontaneous vegetation
4	8	8
5	8	8–10
6	10	12
7	12	16
8	12	16
9	12	16

e. Choice of crops and manuring during initial State operations

Because additional charges make the labour wages in the polders very high during the period of reclamation, only extensively cultivated crops are suitable during the years of initial State management. These are mainly the following: rape seed, winter wheat, spring wheat, spring barley, lucerne and grass.

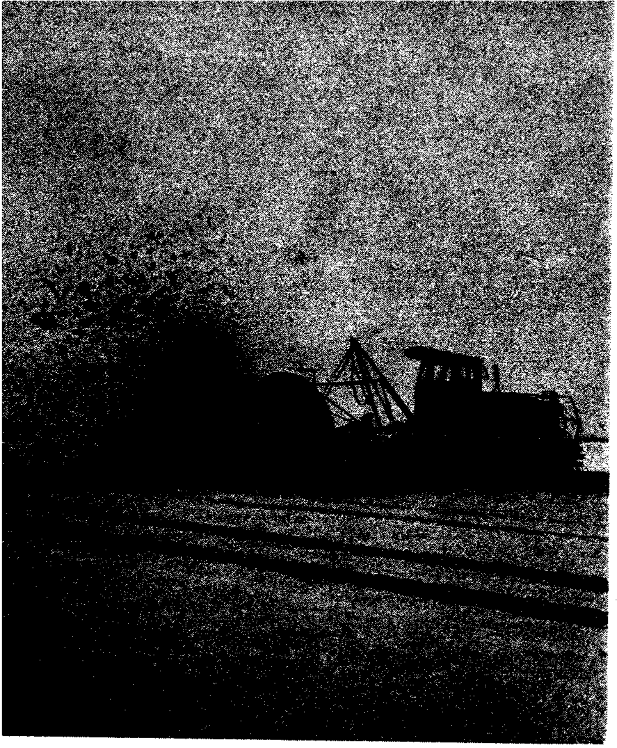
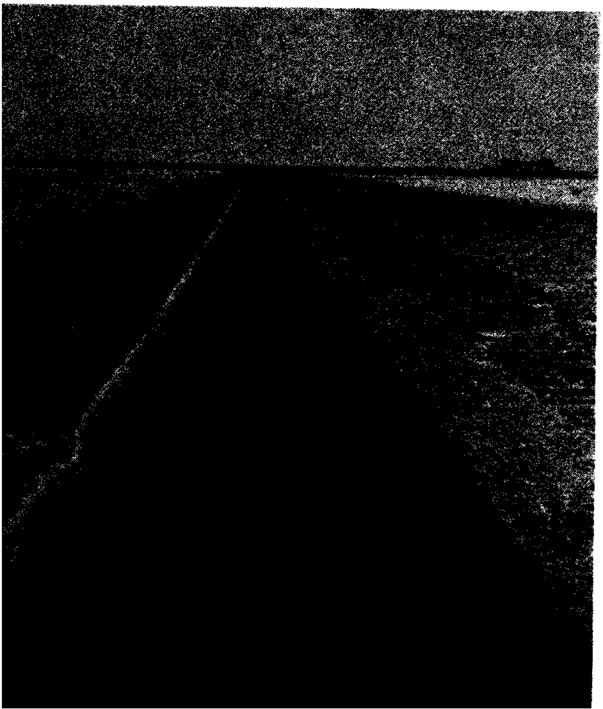


Fig. 11

Rotary-trencher in action in Eastern Flevoland . . .

Fig. 12



. . . and the work it has done.

It should be noted here that the choice of crops at this stage has little to do with soil conditions, but is mainly determined by the possibilities of applying mechanized methods, by the choice of crops requiring intensive labour, by the distribution of tasks, etc. The only thing to be taken into account is that sandy soils should be partly or entirely devoted to grassland to prevent wind erosion.
The amount of fertilizers required, however, depends very much on the condition of the soil. In such virgin soils a close correlation exists between the clay content on one hand and potash and phosphate content on the other. With the aid of standards elaborated on trial plots it is possible to indicate the amount of fertilizers required on the basis of the soil maps.

f. Additional details on soil suitability and land-use

Land-use is also modified in so far as more recent information on the nature of the soil and hence soil suitability call for it.

3.4. DETAILED SOIL SURVEY (Stage 3)

Detailed surveys were used primarily in connection with preparations which have to be made during the initial period of State working for the leasing of the land to private farmers. The provisional detailed drainage system by means of field ditches has to be replaced by a permanent system of tile drains. Wherever necessary, and practicable at a reasonable cost, soil improvements are carried out. Soils susceptible to drought which are not destined for afforestation are given an artificial water supply. The final use of each parcel – as arable land or grassland, or as land devoted to mixed farming, fruit growing, horticulture or afforestation – has to be decided upon, and the size of the farms fixed. After that the houses for tenant farmers and farm labourers have to be built for the farms to be leased out as well as the barns, etc. Finally the rentals have to be fixed.
However, soil conditions make their influence felt not only on the work done during the reclamation and colonization of the polders, but also on the farming by the tenants later on. For this reason not only the items mentioned above will be discussed in the following paragraphs, but also a few additional factors which may be looked upon as tenant uses of the detailed soil maps.

a. Tile drainage

For reasons already stated in the preceding chapter the young soils are at first drained for a number of years by means of field ditches. However, these field ditches have some drawbacks so that they have to be replaced after a few years by series of drain-pipes (see fig. 13).
The sandy soils (codes 0 to 3) will be left out of consideration for the time being, because they are susceptible to drought. In addition to drainage during the winter half year, these soils require an artificial water supply during summer. It is not the drainage during win-

Fig. 13.
A drainage machine replacing the provisional system of field ditches with tile drains.

ter, but the water supply during summer which determines the intervals between the tile drains.

In the heavier textured soils the process of drying out will have made already considerable progress in the subsoil layers at the time that the area is tile drained which takes place about 3 or 4 years after trench draining.

Consequently, these layers have become more or less cracked and permeable according to their clay content. The formation of the soil profile and the structural condition of the layers thus determine the spacing of the tile drains in the heavier textured soils. It has by now become possible to determine the correct distance of the drain rows on the basis of the number and size of the cracks in the soil. (See appendix II.)

It is beyond the scope of this paper to describe in detail the method by which the soil profiles are classified according to their permeability. It should be merely noted here that the stage of ripening of a profile at a certain moment depends on various factors. Some of these are: the number of years that have elapsed since the soil emerged from the water and since it was trenched; weather conditions during those years; the nature and amount of vegetation; the relative level, and last, but not least, the clay content of the various soil layers.

No mention, finally, has yet been made of seepage. In comparison with soils without seepage, soils with some amount of seepage are slower to ripen, and in deeper layers may even fail to acquire any structure altogether. For this reason these soils often require a far more narrowly spaced tile drainage system than do comparable soils without seepage.

b. Subterranean irrigation by means of tiles

Rainfall and evapotranspiration in the Netherlands are such that there is an annual rainfall surplus. During the summer months, however, the evapotranspiration exceeds the rainfall, so that on soils with a low water retention capacity and/or shallow rooting depth crops may suffer from drought.

In so far as the drought-susceptible soils are not afforested, they are provided with an artificial water supply. Since fresh water is easily and cheaply available from the IJssel Lake, and the soils concerned are sufficiently flat, the water supply takes place in the form of sub-irrigation. Subterranean irrigation is considerably cheaper than surface and sprinkler irrigation. There is no danger of salinization of the land since the small quantity of salt accumulated in the top layers during summer is more than adequately washed out during winter.

By this system of subirrigation the water in the boundary ditches is dammed up to a certain level above the rows of tiles. The water is subsequently led through a horizontal series of tiles into the lots, so that the entire area is provided with an artificially maintained water table, and the roots of the plants can absorb water from the capillary zone.

Sandy soils (codes 0 to 3) are susceptible to drought the more, the coarser and the poorer in clay content the soil. Furthermore, shallow soils are susceptible to drought, i.e .soils with a shallow layer of heavier textured soil overlying relatively coarse sand. The more shallow the clayey layer, the more serious the susceptibility to drought. A study of the soil map will reveal which areas stand in need of sub-irrigation.

Since not only susceptibility to drought but also drain row distance and the level to which the water has to be dammed up depend on the soil condition, the soil map may be used for these purposes, too.[1])

c. Designation and execution of soil improvement schemes

Generally speaking the condition of the soil must be accepted as given by nature and it should be considered highly fortunate that the quality of the soil in the Zuiderzee polders is generally very good.

[1]) For further details see: Ir. C. Kalisvaart: "Subirrigation in the Zuiderzee polders", publication no. 2 of the International Institute for Land Reclamation and Improvement, 1958.

However, there are also areas where soil conditions are poorer than might have been wished. As a rule there is nothing to do but to accept the poorer quality of the soil during reclamation, during initial State management as well as later on when it is worked by the tenant farmers.

Locally, however, soil improvements may be carried out. Soil improvement implies all those measures which are executed only once and result in a lasting improvement of the soil profile. Soil improvement measures applied are deep ploughing to reverse soil layers, and deep ploughing to mix soil layers.

In ploughing for the first mentioned purpose, the maximum ploughing depth that should be reached is about 1.90 m. It is done when a sandy layer of not more than 1 m thick lies on top of a heavier subsoil (see fig. 14). In deep ploughing the object is to reverse the profile. It is, however, not possible quantitatively to bring the heavier subsoil to the top. In the greatest ploughing depths losses of at least 20 % have to be reckoned with. A further aim is to make the heavy top layer as thick as possible because – as was previously pointed out – shallow soils have a few less desirable properties. With respect to the thick-

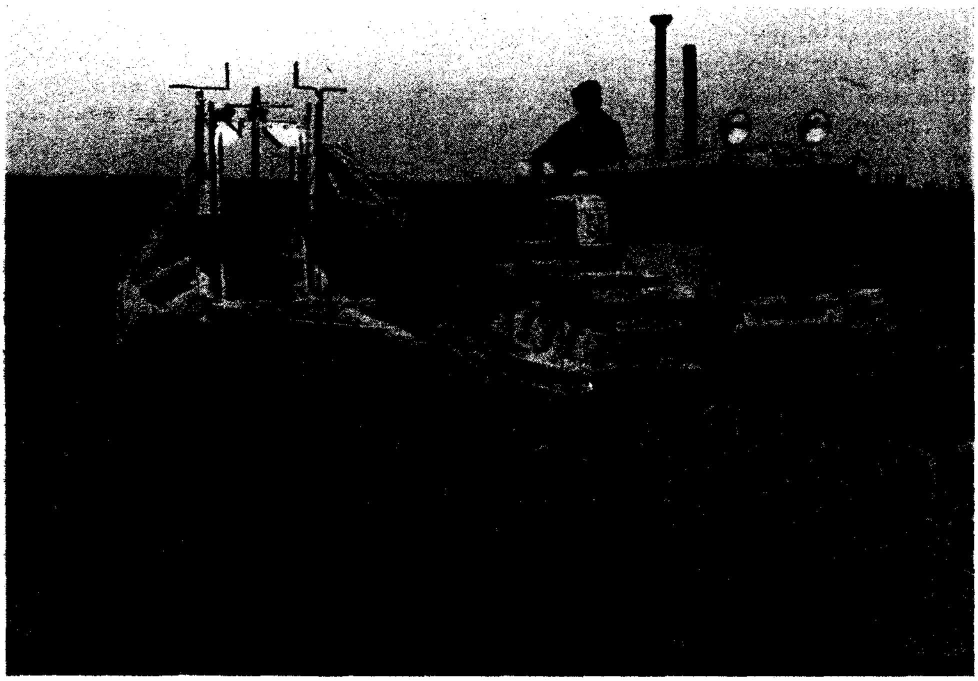


Fig. 14. Deep-ploughing up to 1.30 m (4 feet appr.); the sandy topsoil has to be replaced by clay loam from the subsoil.

ness of the heavy layer brought to the top, it should be noted that it becomes thinner through settling.
The soil maps will show where it is possible to plough with a view to reversing the soil layers.
Deep ploughing with the object of mixing the soil layers is done in order to deepen shallow soils. Investigations have shown that with respect to soils having a shallow layer of heavier textured soil overlying a sandy subsoil, the susceptibility to drought depends almost solely on the thickness of the top layer and not on its clay content. A thicker, light-textured layer is thus more favourable than a shallower, heavy-textured layer.
The above implies that ploughing with the object of adding sand and mixing it as thoroughly as possible with the heavier topsoil represents an essential soil improvement. Consequently, this measure is often applied.
The soil maps show the areas which might benefit from the treatment described here.

d. General pattern of land use

The suitability of the soil has been referred to several times in the preceding chapter. Rough data on this subject are needed at an early stage, since they are required for planning of land utilization.
During the last stage prior to leasing the land, the soil suitability of each separate lot has to be known, in order to decide upon the definitive use of the land and the size of the farm, and so that the buildings required may be designed and built. A detailed soil map is indispensable here.
The concepts of soil suitability and land use overlap only partially. On the one hand the use of land for purely arable farming is possible only if the soil suitability allows it; on the other hand, however, the soil suitability – for instance – may warrant its use as grassland, as arable land or as horticultural land, whereas its use is as a rule restricted to only one of these three possibilities. Soil suitability, therefore, solely concerns the technical aspects of agriculture. In land use, on the other hand, economic considerations and those prescribed by the prevailing agricultural policy are also involved.
This is clearly apparent in the case of loam and clay soils. These soils are suitable for use as arable land, as grassland, for mixed farming, for fruit, and for the cultivation of vegetables of lower economic return. However, extensive areas of fruits and vegetables are not wanted because they are liable to result in overproduction. For this reason only a limited area is to be used for such purposes.
Consequently, utilization as arable land, as grassland, and for mixed farming is left. The choice between these three is not difficult to make: the use as arable land is preferred, both by the owner and by the tenant. For the owner, the buildings for a purely arable farm (without any accommodation for cattle) are cheapest, and for the tenant the profit-earning capacity of arable farming is greater than that of cattle farming.
In its ultimate form a plan for land use consists of a map which indicates not only the

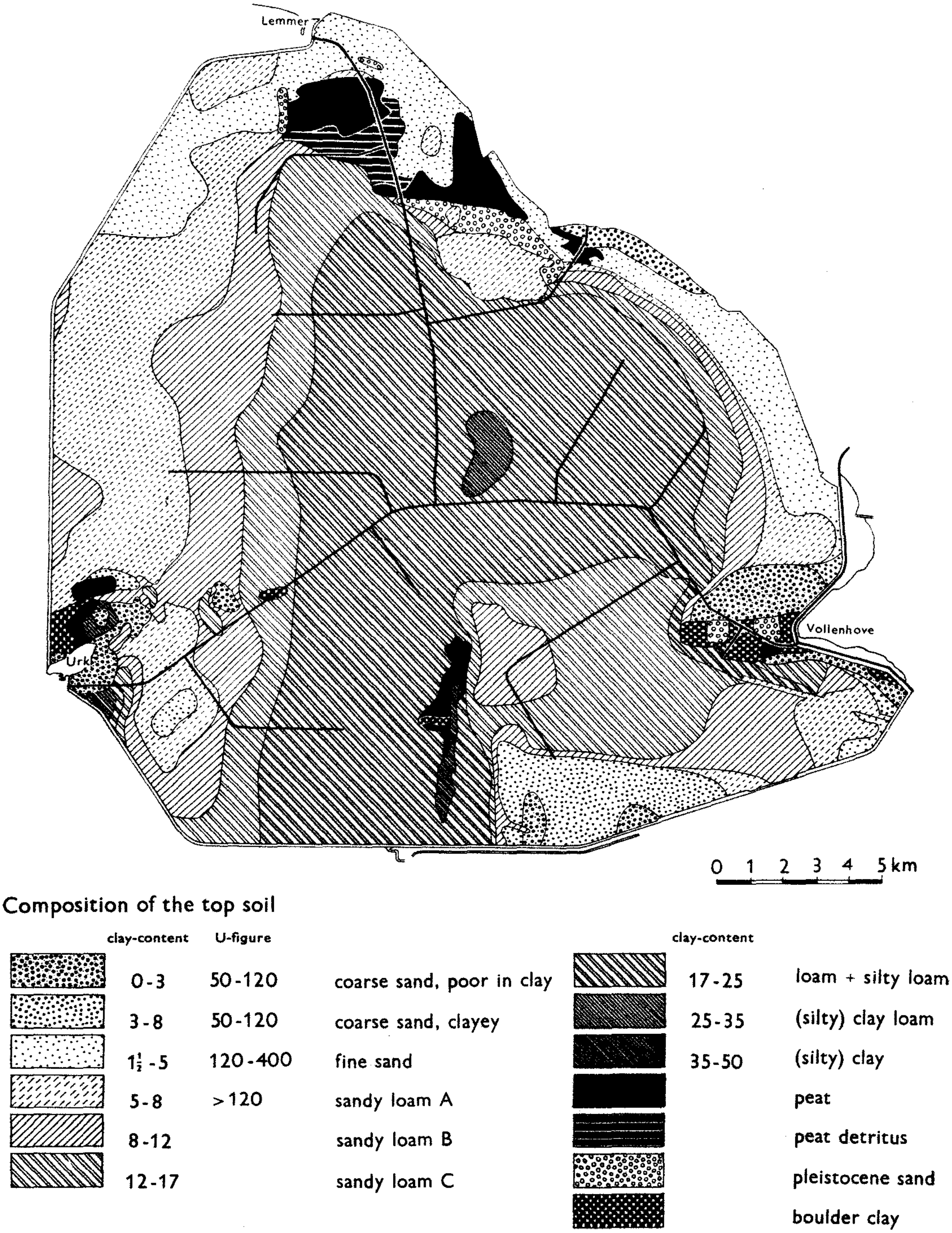


Fig. 15. Simplified soil-map of the Northeast polder.

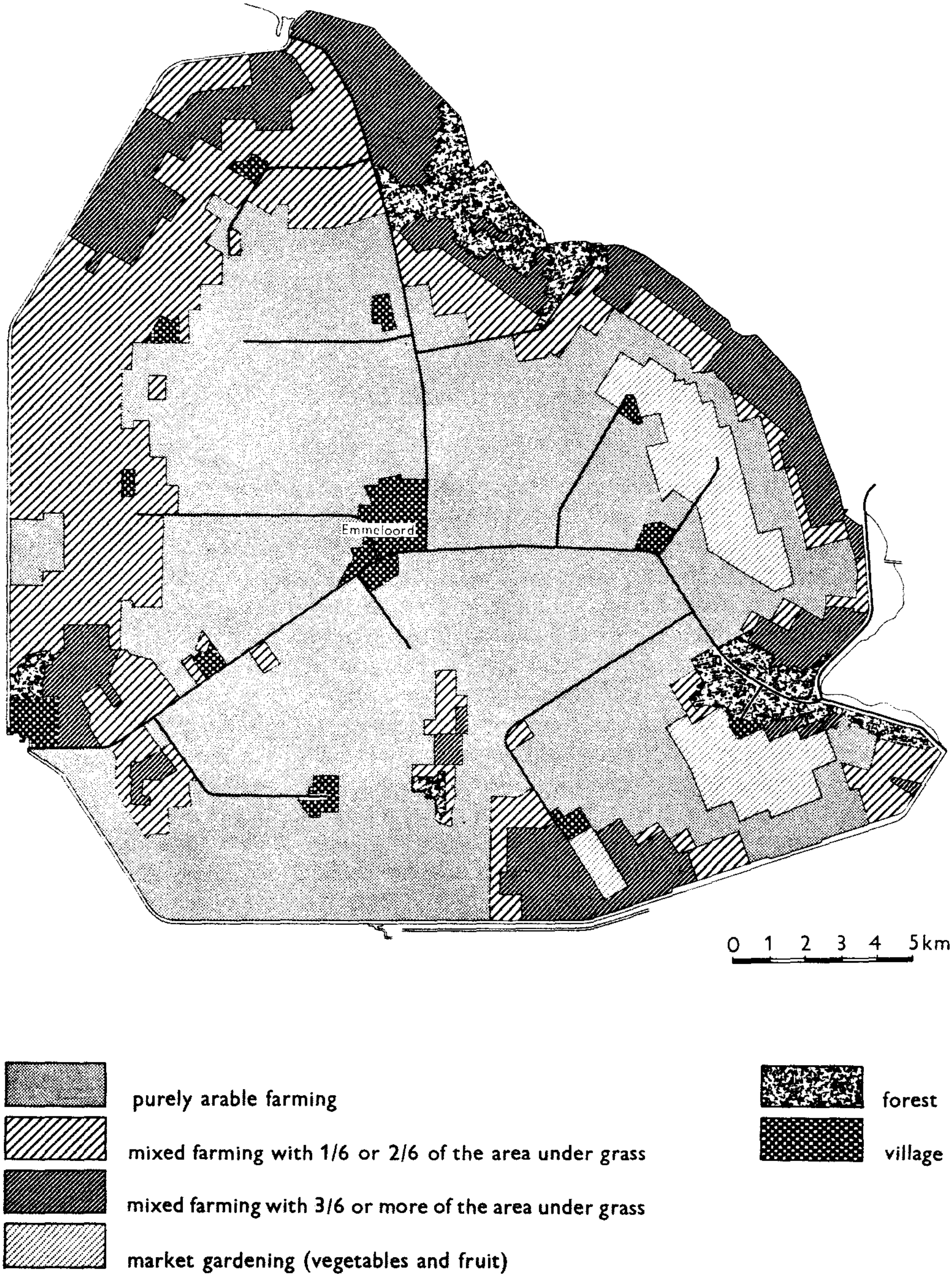


Fig. 16. Simplified map showing the land-use pattern of the Northeast-polder.

farms and their sizes, but also the type of farming (see fig. 16). The following types of land use are found in the young polders:

purely arable farms;
mixed farms with 1/6 of the area allotted to grassland;
„ „ „ 2/6 „ „ „ „ „ „
„ „ „ 3/6 „ „ „ „ „ „
„ „ „ 4/6 „ „ „ „ „ „
„ „ „ 5/6 „ „ „ „ „ „
horticultural holdings (vegetables and fruit);
forests.

With respect to fruit growing and market gardening holdings it has already been stated in passing that only a limited number may be established because of economic considerations. Since these holdings need a lot of capital and/or intensive cultivation, the most suitable soils are allotted to them. As these areas are strictly limited the requirements which soils used to these ends have to meet will not be dealt with in greater detail here.

For afforestation relatively small areas are indicated which are either unsuitable, or relatively so, for agriculture, viz. boulder clay soils, coarse sandy soils or regions where soil conditions show wide differences within a small area.

By far the largest area is used for purely arable farms and for mixed farms with a larger or smaller area of grassland. It has already been pointed out that arable land is chosen wherever possible, and grassland wherever necessary. The necessity of assigning part of the farm land having a certain type of soil to grass is mainly determined by the susceptibility to wind erosion and to deterioration of the structure of the soil surface.

The soils containing less than 7 to 8 % of clay are subject to wind erosion. These are primarily sandy soils, which are more easily eroded by the wind since the soil is coarser and has a lower clay content. According to their properties, sandy soils are used for mixed farming with 3/6, 4/6 or 5/6 of the area taken up by grassland.

In the soils of code 4 the danger of wind erosion is no longer great as a result of the relatively high clay content and the fineness of the sand particles. In these soils it is not on account of the danger of wind erosion that part of them have to be laid down to grass.

The reason is the lack of stability in the soil structure, that shows a tendency to a compact plate structure; if cultivated too much it becomes powdery, after rains a surface seal is developed. This may result in newly sown crops shooting up late or irregularly; occasionally they fail to come up at all.

For this reason it is necessary that the structure be made as stable as possible. This may be done by allowing the soil a period of fallow from time to time by laying it down to grass, and by the application of farmyard manure produced by the cattle on the grassland. A great deal of attention should also be given to green manures.

Only in the case of the soils with code 4 it is considered necessary to remedy the susceptibility to formation of a surface seal by assignation of mixed farms on them, in which 1/6 or 2/6 of the area is allotted to grassland.

On soils with the codes 5 to 9, therefore, purely arable farms may be established. As far as the soils with code 5 are concerned, however, it should be borne in mind that they are susceptible to formation of a surface seal, although to a lesser extent than those with code 4.

e. Size of farms

Table 5 shows that the distribution of farm sizes varies in the different polders.

TABLE 5. Numbers of holdings according to size (with percentage)

Surface	Wieringermeer polder		Northeast polder		Eastern Flevoland polder	
	Number	Per cent	Number	Per cent	Number	Per cent
hectares						
0–10	63	12	–	–	–	–
10–20	101	20	521	33	805	40
20–30	79	16	626	38	465	23
30–40	90	18	270	17	559	28
40–50	115	23	169	11	183	9
More than 50	63	12	16	1	–	–
Total	511	100	1602	100	2012	100
Gross surface approx.	20,000 ha		48,000 ha		54,200 ha	

The data are not entirely comparable one with another since no mention was made of the market gardening and of the fruit growing holdings for the two last mentioned polders These are generally smaller than 10 ha.

The average size of the holdings in the Wieringermeer, the Northeastern polder and Eastern Flevoland is respectively; 32, 25 and 23 ha (80, 62 and 57 acres).

Furthermore financial, political and social considerations lead to a determination of the average size of the holdings and to the number of holdings in the different classes. The most important considerations are the following:

In order to improve the social well-being of the farming population, it is desirable to choose the size of the smallest holdings so that they can provide adequate income for the farming families.

Under the present circumstances this requirement can be amply met if the smallest arable holdings are 12 to 15 ha (30 to 38 acres) provided the soil condition is reasonably good.

Holdings with at least half grassland (code 0, 1, 2 and 3) which are to be established on sandy soil only, must have a size of 20 to 30 ha (50 to 75 acres). Holdings having less than half grass land can be somewhat smaller.
Purely arable holdings may have any current size.
The cost per hectare for the farm buildings increases as the size of the holdings decreases. With a view to the great number of applicants for farms in the new polders, however, it is necessary to choose the average size.
In connection with the wish to attain a harmonious structure of the agrarian population, it is desirable to choose different sizes of holdings. Besides, having such holdings guarantees a place to candidates of varying personal capacities and financial means. The size of the holding is only partly determined by the condition of the soil. The smallest farms (10 to 18 ha or 25 to 45 acres) are not established on soils with codes 8 and 9. These soils require so much tractive power in tilling that it would impose too heavy a burden on the small farms. On the other hand the small farms are not established on sandy soils, (codes 0 to 3) nor on the lightest soils of heavier texture (code 4), since these soils offer too little scope for small holdings. Small farms, therefore, are to be found on good soils that are not difficult to till (codes 5 and 7).
On sandy soils only medium sized farms are established (18 to 30 ha or 45 to 75 acres). The quality of the soil is considered inadequate for small holdings, while large mixed farms are considered less desirable.

f. Fixing of rent

The land is not let to those who are prepared to pay the highest rentals. Land hunger in the Netherlands is so great that many would be willing to pay unjustifiably high rentals if that would enable them to become farmers. The object of the land reclamation, viz. that of enriching the Netherlands with prosperous agricultural areas would decidedly not be achieved in this way.
For this reason the rentals are fixed at such a level that they do not preclude a reasonable subsistence for the tenant farmers. It is, for that matter, not only in the young Zuiderzee polders that a policy of controlled rentals is followed; it holds good for the whole of the Netherlands.
The fixing of the rentals constitutes a problem which as yet is very far from being solved, because here not only the returns, but also the expenditures are involved.
The rentals are fixed per individual farm as fairly as possible on the basis of returns and the experience of State operation during the initial years, and with the aid of soil maps of the farms.
Rentals for the poorest and the best soils now stand in a proportion of about 1 to 4. The poorest soils are the coarse sandy soils, whereas the best soils are those with codes 5 or 6 and higher. The absolute level of the farm rents is in agreement with that of comparable soils in the remainder of the Netherlands.
The rentals may be revised at the end of every three years. This makes it possible to take

into account new ideas as to the relationship of values and possible changes in the economic situation.

g. Farm management: tillage, choice of crops, fertilizer requirements

After the land has been let, the task of the 'Development Board' is finished. The farmer now starts work assisted by various branches of the Agricultural Advisory Service.

On the basis of a detailed soil map (1 : 10,000) agricultural experts assist the farmer to prepare a detailed plan of land use and treatment.

Here a great many factors have to be taken into account such as soil type, size and type of farm (mixed farm or arable farm), personnel and division of labour, mechanical equipment, knowledge of the farmer, conservation of soil fertility, prevention of diseases and pest control, price rates, distribution of risks, etc.

It is beyond the scope of this paper to comment in detail on all these factors and considerations.

Therefore only some effects of the soil conditions with respect to farm management will be indicated here.

The heavier soils (i.e. soils with the codes 5–9) not only require more tractive power than the lighter textured soils, but there is also a difference in time at which certain tillage operations have to be carried out.

This applies particularly to the time of ploughing. The soils with codes 5 or 6 to 9 should be ploughed before winter whereas the lighter soils allow the farmer more freedom in this respect.

The difference in properties between light and heavy soils becomes furthermore apparent in the possibilities they offer for mechanical lifting of potatoes and beets. If wet weather conditions prevail, it appears that very soon it becomes impossible to harvest these crops mechanically from heavy soils, whereas with lighter soils there is no difficulty.

With regard to the choice of crops on the arable land, it can be said that all arable crops customary in the Netherlands may be grown on the arable farms proper (codes 5 to 9). However, this does not imply that there should be complete freedom as to the cropping plans. On the contrary, the normal rules applying to a proper cropping sequence have to be adhered to and moreover, the division of labour is of great importance.

Although the soils referred to above allow a great deal of freedom as to the choice of crops, the cropping plans show differences after some time. The greater risks attached to the harvesting of potatoes and beets on the heaviest soils, for instance, lead to a decrease in the percentage of the area devoted to these crops.

On the soils with code 4 (and to some extent on those with code 5) some crops involve slightly bigger risks than they do on the heavier soils. This fact is reflected in the cropping plan. Owing to the susceptibility to surface seal formation, there is a greater risk of autumn-sown crops dying out during the winter, and there is a greater chance of crops which require a fine seed-bed when sown in spring (flax, sugar-beets) coming up irregularly or failing to appear at all.

On the sandy soils it is particularly the susceptibility to wind-erosion which restricts the choice of crops. Crops which require a fine seed-bed when sown and those which do not produce an adequate ground cover until fairly late, involve a serious danger of wind-erosion. The tendency of a soil on which tillage has to be restricted to the bare minimum falling a prey to weeds also has some influence. Flax (fine seed-bed), peas (weediness) and beets (fine seed-bed, late ground cover) are crops which are not to be recommended here.

As regards the fertilizer requirements, initially a close correlation exists between the clay content of a soil on the one hand, and its contents of potash and phosphate on the other. This correlation is such that the content of the nutrients referred to, increase proportionally to the clay content.
This implies that the fertilizer standards elaborated on trial plots of different clay content may be applied to all soils whose fertilizer requirements may be determined in this way.
The table below indicates – by way of illustration – the relation between the fertilizer requirements and the texture of the Zuiderzee soils.

TABLE 6. Classification of young marine soils according to their requirements of phosphate and potash fertilizers

Code	Phosphate fertilizer in kg P_2O_5/ha	Potash fertilizer in kg K_2O/ha
9	20	–
8	30	–
7	40	–
6	50	–
5	60	–
4	70	80
2b	80	160
1e, 1f	90	180
1b	100	200

Since the tenants have different cropping plans nor do all of them apply the same fertilizers, the correlation between the content of plant nutrients of a soil and its clay content gradually becomes less clear.
It will be clear that after some time, an advice on manuring can no longer be based on the clay content. By then it will become necessary to collect soil samples and to determine their potash and phosphate content.

4. SOIL SURVEY IN COASTAL RECLAMATION WORKS

4.1. INTRODUCTION

The reclamations along the coast during past 30 years are as has already become apparent of far less significance than those of the former Zuiderzee for the simple reason that the possibilities along the coast are more restricted. The accretion of alluvial matter is, however, furthered as much as possible, so that from time to time another tract of land may be reclaimed.

The situation of these coastal reclamations differs very greatly from that found in Lake IJssel. Along the coast there are tidal marshes, which emerge from the sea at low tide. There are often great differences in elevation, and in many cases there are significant differences in soil conditions within a small area. Above a certain level, the ground is covered with vegetation. In Lake IJssel there is no tidal movement; the ground is always under water and all of it without any vegetation. The transition of soil conditions is as a rule very gradual. Moreover, the soils along the coast are saline immediately upon reclamation, whereas those of Lake IJssel are not.

It will be obvious that this great difference in circumstances substantially affects the advisory work done on agricultural and soil matters in connection with the reclamation works.

Owing to the fact that the grounds are dry during low tide, soil surveys can be made in one instead of in three stages as in the case of the Zuiderzee polders. As the landscape before the coast shows a pattern with elevations and hollows, and is traversed by large and small creeks, the places where the borings are made are chosen in conformity with the form of the landscape. Such a landscape obviously also presents other difficulties and possibilities in reclamation, allocation and land use.

It should be borne in mind that small-scale reclamation involves just as many problems as it does on a large-scale. A full description of the uses of the soil surveys made in coastal reclamations would be quite as lengthy as the previous chapter. Repetitions would, however, be unavoidable in this case, and consequently the following will be restricted as far as possible.

4.2. SOIL MAPPING

All grounds suitable for reclamation along the coast emerge during ebbtide. They may for this reason be surveyed without too much trouble at one go. This surveying precedes all other work.

As was already pointed out, the landscape is dotted with many large and small creeks which will have to be tackled later on during reclamation. During surveying the largest possible number of particulars are noted about the size of the creeks, as well as about the dimensions of the levées and the types of soil they consist of. Details are further recorded about the vegetation and about the stage of ripening of the soil.

4.3. PLANNING

In the first place due consideration should be given to whether the execution of a certain reclamation is justified. To this end an estimate is required of the cost involved as well as an evaluation of the new lands. The cost can be estimated only after plans with respect to land division, reclamation, drainage and construction of farm buildings have been made. Just as in the case of the reclamations in Lake IJssel, these plans depend on the soil condition, so that the formation of these plans has to be looked upon as one of the uses of soil surveys.

In many cases an important matter is the polder water level. Along the coast it is only very rarely possible to avoid reclaiming second- or even third-grade soils together with an area of soil of excellent quality. The inferior types of soil are either soils with a shallow layer of heavier textured soil overlying coarse sand, or sandy soils.

The polder water level determines the water tables, and hence the value of these soils susceptible to drought. This polder water level also determines the ratio between the areas of land and water within the polder. With a higher polder water level, the value of the soils susceptible to drought does go up indeed, but the total land area decreases. With respect to the collective value of the soils in a polder, the two factors thus work in opposite directions and the optimum polder water level has to be determined by means of some calculations. Interests other than agricultural or economic may, however, conflict with this optimum polder water level.

4.4. RECLAMATION

In allotting and reclaiming, creeks play an important part. What must be done with the soil dug from the canals and ditches? Which creeks can be filled in and in what way is this best achieved? The answers to these questions require a large number of decisions as to detail. Not only the dimensions of the creeks are important, but also those of the levées, as well as their nature, i.e. whether they are composed of sand, loam or clay.

Advice must be given on the construction of field ditches. The distance between ditches partly depends on soil condition and on the stage of ripening of the soil profile. During

soil mapping, data are also collected about the latter, so that only few supplementary investigations will be needed.
Another point is the risk of wind erosion. During reclamation, this risk has to be eliminated as soon as possible by seeding the soils that are subject to erosion with a grain crop or with grass. The soil map shows where those soils will be located.
Initially the new soils are saline. In order to find out at what stage the sowing of crops is warranted, the degree of desalination has to be investigated. In view of the fact that desalination is partly linked to soil condition and to elevation, the soil map may furnish valuable indications in this respect.
If advice has to be given on the manuring of crops during the first few years after reclamation, or on soil improvement (mainly deep ploughing with a view to mixing soil layers) the soil map proves highly valuable, and it may be further resorted to if the distance between drains has to be determined.

4.5. LANDUSE AND -LEASE

Just as in the Zuiderzee polders, land use is closely linked to the soil condition. As a result of various technical measures such as the filling of creeks with sand, loam or clay, or the mixing of soil layers by deep ploughing, it may differ rather widely from that encountered when the soil surveys were made, so that supplementary investigations may have to be made before the ultimate use of the land is decided.
In planning the farms an attempt is made to allot to each farm a certain minimum area of good soil which will ensure the future farmer a good crop and in addition, an area of soil of lesser quality.
Finally the rentals have to be fixed. They are based upon both the soil map and the general experience gained on comparable soils elsewhere in the country.

5. GENERAL CONCLUSION

It will have become apparent from chapters 3 and 4 that in nearly every part of the hydraulic engineering and agricultural work connected with land reclamation in the Netherlands, soil survey methods are applied. The possibilities of using soil maps are manifold, because by impoldering new regions are created in which it is possible to proceed without being hampered by inherited situations, and further because scientifically tested experience is available for use at every stage of reclamation planning.

APPENDIX I

CLASSIFICATION OF SANDY SOILS ACCORDING TO THE SPECIFIC SURFACE OF THE SAND FRACTIONS

The specific surface (U) is the ratio between the total surface of all particles and the surface of an equal quantity by weight of particles of the same material with a diameter of 1 cm. The particles are assumed to be spherical in shape.
The specific surface of *a given sand fraction* is calculated from Zunker's formula[1]):

$$U = \frac{4.3}{\log \frac{d_2}{d_1}} \left(\frac{1}{d_1} - \frac{1}{d_2}\right).$$

d_1 = diameter of the smallest particle size in mm;
d_2 = diameter of the largest particle size in mm.

EXAMPLE:

for a sand fraction of 0.300–0.420 mm,
$d_1 = 0.30$ mm; $d_2 = 0.42$ mm

$$U = \frac{4.3}{\log 0.42/0.30} \left(\frac{1}{0.30} - \frac{1}{0.42}\right).$$

$$\log \frac{0.42}{0.30} = \log 1.4 = 0.146.$$

$$U = \frac{4.3}{0.146} \times 0.95 = 28.$$

[1]) Blanck, Handbuch der Bodenlehre VI, 1930.

The specific surface (U) of *the total sand fraction in the soil* is calculated as follows:

Calculation based on a practical example. N.B.: The U-values are expressed in whole numbers.

Limits of the sub-fractions in mm	Weight in %	U value per fraction calculated from Zunker's formula	U value of the actual sand fractions
0.016–0.050	5.8	373	22[1]
0.050–0.075	5.2	164	8
0.075–0.105	3.4	113	4
0.105–0.150	6.9	80	6
0.150–0.210	25.6	57	15
0.210–0.300	21.4	40	9
0.300–0.420	9.1	28	3
0.420–0.600	1.8	20	0
0.600–1.0	0.5	12	0
1.0 –2.0	0.3	7	0
Total	82.4	–	67

Specific surface of total sand fraction: $\frac{100}{82.4} \times 67 = 81.$

[1]) $\frac{5.8}{100} \times 373 = 22.$ This is not calculated but ascertained from tables.

APPENDIX II

DETERMINATION OF THE DISTANCE BETWEEN TILE DRAINS ON THE BASIS OF FISSURES OBSERVED IN THE SOIL PROFILE

Experience has shown that the young soils in the Zuiderzee polders show crack formation to a depth not exceeding 1 metre when the tile drains are laid. It is therefore sufficient to know the state of the soil profile down to a depth of 1 metre. However, when coarse sand occurs just below that depth it is important that this fact should be known, since in such cases the drains can be spaced further apart than in similar conditions when there is no sand in the subsoil.

The necessary distance between the drains can now be successfully determined on the basis of the number and dimensions of the cracks in the soil. With the aid of a chart a rating between 1 and 10 representing the degree of fissuring is assigned to each 20 cm layer of soil (0–20, 20–40, 40–60, 60–80 and 80–100 cm). These ratings are then multiplied by 1, 2, 4, 6 and 7 respectively for the 0–20, 20–40, 40–60, 60–80 and 80–100 cm layers and the 'index figures' thus obtained for the various layers are added together. Greater significance is in fact attached to the deeper layers than to the surface layers, since the permeability of the former is particularly important for the drainage. The sum of these 'index figures' can never be more than 200, but it is divided by 2 in order to get a centesimal scale.

The result of this calculation, which provides an index figure for the entire profile down to a depth of 1 metre, now serves to determine the distance between the drains. The relation between this index figure and the drain interval is given in the next table.

Relationship between the index figure of the soilprofil and the distance between the drains on the young marine soils of the Zuiderzee polders

Index figure of the soil profile (centesimal scale)	Distance between drains in metres
< 5	8
5–10	8–10
10–15	10–12
15–20	12–16
20–30	16–24
30–40	24–36
> 40	36–48

Obviously this experimentally ascertained relationship takes account of the requirements regarding the permissible ground water level for a given run-off, while the usual depth at which the tiles are laid is also taken into consideration. With regard to the ground water level and run-off the rule is that at a run-off of 10 mm per day the ground water level between the rows of tiles must not be higher than 30 cm below soil surface. Furthermore, the tiles at the beginning of the rows (i.e. in the centre of a plot 300 metres wide) are laid at a depth of 90 cm below grade. The rows are given a slope of 20 cm per 100 metres, so that they enter the ditches at a depth of 120 cm.

SUMMARY

SOIL SURVEY AND LAND CLASSIFICATION AS APPLIED TO RECLAMATION OF SEA BOTTOM LAND IN THE NETHERLANDS

1. *Reclamation works in the Netherlands past and present*

During the last centuries large areas and various types of land have been reclaimed in the Netherlands to meet the requirements of a continuously and rapidly increasing population (fig. 1).

In some cases this reclamation was rather easy as small areas of good land could gradually be added to the agricultural resources of the country. However, in other cases especially in some older large reclamation schemes carried out with private capital, the first farmers had to contend with great difficulties: a shortage of labour and capital, very primitive dwellings and farm buildings and – in the beginning – frequent crop failures, caused by inadequate drainage, excess of salt, presence of very poor soils, the wrong choice of crops for certain types of soil, etc.

These reclamation works were carried out without any soil investigation or overall planning. Nevertheless these areas became prosperous later on, but this result was attained at the cost of great suffering and poverty to the first settlers, and wasted time, money and energy.

With the reclamation of the Zuiderzee, a large inland sea, a new period started due to the consequent application of new scientific developments (fig. 2). Thorough investigations and planning precede the implementation of all projects and are continued during and after the period of reclamation.

This paper may give the reader some idea about the reclamation of the specific soils which were formerly lying under water. However, the main purpose of this publication is to demonstrate the necessity of detailed soil investigation, land classification and intensive planning, as a means to the best agricultural, economic and social land use.

2. *Soil survey*

Soil survey is carried out in three stages with corresponding differences in intensity and purpose. The need of detailed data is not felt during the early stages of development. This need increases later on.

Stage 1. *Under-water survey*

Undisturbed cores of a length of 1.5 meters (= 5 ft.) are collected at the rate of one per 50 ha (=125 acres). See fig. 3.

Stage 2. *Preliminary survey*
As soon as the polder is dry but prior to the excavation of ditches a more intensive survey is made by means of auger borings. At this stage the intensity of survey amounts to one boring per ha (2.5 acres).

Stage 3. *Detailed survey*
The final survey is carried out after the digging of ditches whose total length is about 2,000 km (1,250 miles) in a polder of 50,000 ha (125,000 acres). See fig. 4. For the compilation of a detailed soil map (1 : 10,000), the profiles of the ditches are described to a depth of 1.4 meters (4 ft. 8 in) at intervals of 50 meters (155ft). See fig. 5.

Soil classification is rather simple here as these young soils do not show any development of a soil profile, due to weathering and leaching. Moreover, they have the same mode of formation, the same clay minerals, etc. Therefore the main criterion for classification here is the texture of the soil. The clay content is closely related to a number of properties which are very important for the agricultural behaviour of the soil. As regards sandy soils the coarseness of the sand fraction is in addition to the clay content likewise an important factor.

3. *Application of soil survey methods*

Under-water survey (Stage I)

Data regarding soil conditions should be available before reclamation work is started, since the work proper is preceded by plans which cannot be designed without a fairly thorough knowledge of the nature of the soils. The first soil maps of a future polder (fig. 6) are used for the following purposes:

a. Situation and boundaries of the polder. As far as possible only the good soils should be reclaimed, leaving the inferior ones outside the polder.

b. Settling of the soil after reclamation. The process of the drying out of the soils which were deposited under water is accompanied by a general shrinking of the soil. The future ground level has to be calculated with a view to the design of the desirable ground water table, the drainage-system, the construction of pumping stations, etc.

c. Forecast of seepage. The Zuiderzee polders are low-lying in regard to their surroundings and the permeability of the subsoil and substrata is – on the whole – fairly good. To determine the capacity of the pumping stations, the quantity of seepage-water has to be known. Furthermore, seepage influences the drainage requirement, soil suitability, etc. (fig. 7)

d. Designing of a provisional plan for sub-irrigation. The location of the soils which need irrigation has to be indicated. The width of the lots needing sub-irrigation should not exceed 200 m (= 660 ft) whereas elsewhere the normal width is 300 meters (= 1,000 ft).

e. Provisional determination of soil suitability and land use. The soil suitability map indicates the potential use to which a soil may be put, whereas the land use map denotes the use to which it actually will be put; for drafting the latter various economic and social factors will have to be taken into consideration, too.

f. Estimating the cost of reclamation and buildings. This necessitates the design of a project, a task which cannot be carried out without knowledge of the soil.

Preliminary soil survey (Stage 2)

The items discussed above refer to work done before the polder is dry. In what follows, consideration is given to the work done after the polder has emerged.

a. Final land division plan. This plan and the general land use plan must be made definite as far as it is connected with the construction of the network of canals, lateral canals, ditches, roads, etc. (fig. 8).

b. Preparing specifications for the digging of canals, etc. Because this work is partly done by private contractors, a complete description has to be made in the specifications.

c. Determination of the final reclamation plan.

d. Determination of the spacing of field ditches. Once the canals and main ditches have been dug, the lots are formed. They have a length of 800 to 1,000 metres (2,500 to 3,350 ft) and a width of 200 to 300 metres (660 to 1,000 ft) (Fig. 9).
Field ditches form a provisional sub-drainage system, as the laying of tiles in the very young and soft soils is almost impracticable (fig. 10,11,12,). Later on they are replaced by a permanent system of tile drains.

e. Choice of crops during the initial management period. During this period only crops suited for extensive and mechanized farming are cultivated.

f. Additional details as to soil suitability and land use.

Detailed soil survey (Stage 3)

The use of the detailed survey primarily concerns the preparations which – during the period of initial operating – have to be made by the government beforeleasing the land to private farmers.

Technical measures:

a. Tile drainage (fig. 13). Detailed investigations are carried out by means of a special method based on the stage of ripeness of the soil and corresponding cracks, so as to classify the soil according to its permeability and the desirable spacing of the drains.

b. Sub-irrigation by means of tiles. The soils are classified according to the needs and desirability of sub-irrigation.

c. The designing and carrying out of soil improvement schemes. Some types of soil can be improved by reversing the profile by deep ploughing (up to about 1.90 metres (6 ft) – see fig. 14 – or by mixing the layers.

Other aspects:

d. General pattern of land use:
In accordance with the prevailing soil conditions including economic and social factors, the final plan of the general land use pattern is made. The following types are found in the polders (see also fig. 16):
- arable land only;
- mixed farming with 1/6 up to 5/6 of the area under grass;
- horticulture (vegetables, fruit);
- forest;
- villages, roads, playgrounds, etc.

e. Size of farms
Once the general pattern of land use is known, the size of the farms can be fixed and the buildings required may be designed and built. Size and number of farms are partly determined by soil type and land use, partly by social, financial and political considerations.

f. Fixing of rent
The rent for each farm is fixed as exactly as possible taking into account the desirable standard of living, type of soil, type and size of farm, etc.

g. Farm management
After the land has been leased, the task of the Development Board has been completed and that of the farmer begins. On the basis of a detailed soil map, agricultural experts assist the farmer to prepare a detailed plan for land use (crop rotation, etc.) and -treatment (fertilizing, etc.).

4. *Soil survey in coastal reclamation works*

The common aspects as well as the differences of this kind of reclamation as compared to the reclamation of an inland sea or lake are briefly discussed.

RÉSUMÉ

LES ÉTUDES DU SOL ET LA CLASSIFICATION DES TERRES EN VUE DE L'ASSÈCHEMENT DES SOLS SOUSMARINS AUX PAYS-BAS

1. *Les travaux d'assèchement aux Pays-Bas dans le passé comme au présent*

Afin de satisfaire aux besoins d'une population dont l'accroissement est à la fois rapide et constant, de vastes régions et des terres de types très divers ont été asséchées depuis quelques siècles aux Pays-Bas (fig. 1).

Dans certains cas cet assèchement fut assez facile, parce qu'on pouvait graduellement ajouter de petites superficies de bonne terre aux domaines agricoles du pays. Dans d'autres cas toutefois, surtout dans quelques-uns des plus anciens projets d'assèchement réalisés au moyen de capital privé, les premiers agriculteurs devaient faire face à grandes difficultés: une pénurie de main d'oeuvre et de capital, des habitations extrêmement primitives, et – au début – souvent des récoltes râtées causées par un drainage insuffisant, une teneur excessive de sel, une très mauvaise qualité du sol, un mauvais choix de cultures sur certains types de sol, etc. Ces travaux d'assèchement furent entrepris sans aucun examen du sol et sans aucune planification d'ensemble. Ces régions devinrent néanmoins prospères plus tard, mais ce résultat ne fut obtenu que grâce aux souffrances pénibles et à une pauvreté extrême des premiers colons, en gaspillant inutilement à la fois le temps, l'argent et l'énergie.

Avec l'assèchement de la Zuiderzee, une vaste mer intérieure, une période nouvelle fut inaugurée par une application systématique des nouveaux développements scientifiques (fig. 2). De nos jours les projets se basent sur des investigations et une planification approfondies, tant avant le début des travaux que, d'une façon suivie, pendant et après la période de l'assèchement.

Cet exposé vous donnera une impression de la mise en valeur de certains sols spécifiques se trouvant anciennement au fond de la mer. Toutefois le but essentiel de cet exposé est de démontrer la nécessité d'un examen détaillé du sol, d'une classification des terres et d'une planification détaillée pour atteindre l'utilisation agricole, économique et sociale la plus adéquate des terres.

2. *L'étude du sol*

L'étude du sol est effectuée en trois étapes, ayant chacune ses différences correspondantes quant à son intensité et à son but. Pendant les premiers stades du développement on ne ressent pas le besoin de données détaillées. C'est plus tard que ce besoin se fait sentir d'une manière toujours croissante.

1er stade: Investigations sous l'eau.
On prélève des échantillons complets et intacts d'une longueur de 1.50 m, au nombre de I par 50 ha (fig. 3).

2ème stade: L'investigation préalable.
Dès que le polder est mis à sec, et avant de creuser les fossés, un levé plus détaillé est fait au moyen de forages, à raison d'un sondage par ha.

3ième stade: L'étude détaillée.
L'examen final est réalisé après que les fossés ont été creusés, ces derniers ayant une longueur d'environ 2.000 km dans un polder de 50.000 ha (fig. 4.) Pour la composition d'un plan détaillé du sol (à 1 : 10,000), les profils des fossés sont enregistrés, jusqu'à une profondeur de 1.4 m, à des intervalles de 50 m (fig. 5).

Dans ces terrains *la classification du sol* se présente d'une façon assez simple, parce que ces jeunes sols n'ont encore développé aucun profil complexe dû aux intempéries ou au lessivage.

En outre leurs modes de formation sont identiques, leurs limons possèdent les mêmes éléments minéraux, etc. Par conséquent le principal critère de classification dans ces terres est la texture du sol. La teneur en particules argileuses se rapporte directement à un certain nombre de qualités toutes très importantes pour le comportement agricole du sol. En ce qui concerne les sols sablonneux, à côté de la teneur en argile c'est la granulation plus ou moins fine du sable qui présente un autre facteur d'importance.

3. *L'application de l'étude du sol*

Étude du sol sous l'eau (1er stade)

On doit disposer de données concernant la condition du sol avant d'entamer les travaux d'endigage, car le travail proprement dit se base nécessairement sur des plans qui ne peuvent être mis au point sans une connaissance assez approfondie de la nature des divers sols. Les premiers plans du sol d'un futur polder (fig. 6) servent aux buts suivants:

a. La situation et la délimitation du polder
Il faut tâcher autant que possible de n'inclure dans le polder que les bons sols, en évitant ceux de qualité inférieure.

b. La consolidation du sol après l'assèchement
Le processus de sèchage des sols anciennement couverts d'eau s'accompagne de leur retrécissement. Le niveau futur du sol doit être évalué afin de pouvoir déterminer le niveau désirable de la nappe phréatique, la structure du système de drainage, la construction des stations de pompage, etc.

c. Les prévisions d'infiltration
Le niveau des polders de la Zuiderzee est bas par rapport à leurs environs et la perméabilité du sous-sol et des autres couches sous-jacentes est en général bonne. Il faut connaître la quantité d'eau d'infiltration afin de pouvoir déterminer la capacité des stations de pompage. L'infiltration d'eau influence en outre l'intensité du système de drainage, et la qualité du sol pour les cultures, etc. (fig. 7)

d. La mise au point d'un projet provisoire d'irrigation souterraine
Il faudra indiquer la situation géographique des sols nécessitant l'irrigation. Ici la largeur des parcelles ayant besoin d'irrigation souterraine ne doit point excéder 200 mètres, tandisque normalement cette largeur est de 300 m.

e. Détermination préliminaire des qualités du sol pour les cultures et de l'emploi futur des terres
La carte d'aptitude du sol indique l'emploi potentiellement possible d'un sol, tandisque la carte d'utilisation présente à quel but la terre sera utilisée effectivement; la dernière carte est établie en tenant compte des divers facteurs économiques et sociaux.

f. L'évaluation du coût des travaux et des constructions
Elle exige absolument qu'on élabore un projet bien déterminé qui à son tour réclame une bonne connaissance du sol.

Étude préliminaire du sol (2ième stade)

Les aspects élaborés ci-dessus se réfèrent aux travaux entrepris avant que le polder soit sec. Les lignes qui suivent traitent des travaux à entreprendre après évacuation des eaux:

a. Plan final de l'aménagement des terres. Ce plan et celui de l'emploi global des terres doivent être décidés définitivement pour autant qu'ils influencent la construction du réseau de canaux, principaux et latéraux, de fossés, de chaussées, etc. (fig. 8).

b. La préparation du cahier des charges pour l'exécution des canaux et fossés. Ce travail, étant en partie exécuté par des entrepreneurs privés, une description complète doit être présentée dans le cahier des charges.

c. Plan final de la mise en valeur des terres

d. La détermination des intervalles entre les rigoles
Une fois que les canaux et principaux fossés ont été creusés la forme des parcelles est déterminée. Elles auront une longueur de 800 à

1000 m avec une largeur de 200 à 300 m (fig. 9). Des rigoles forment un système provisoire de drainage accessoire, étant donné que la pose de tuyaux en poterie dans ce jeune sol très mou est pratiquement impossible (fig. 10, 11, 12). Par la suite ces mêmes rigoles sont remplacées par un système permanent de tuyaux de drainage.

e. *Le choix des cultures pendant la période d'exploitation initiale*
Sont cultivés pendant cette période uniquement les produits se prêtant à l'agriculture extensive et mécanisée.

f. *Des détails supplémentaires concernant les qualités du sol et l'emploi des terres*

Étude détaillée du sol (3ième stade)

L'emploi de l'étude détaillée sert en premier aux travaux préparatoires à entreprendre par le gouvernement – pendant la période d'exploitation initiale – avant de louer la terre aux agriculteurs privés. Il s'agit là de:

Mesures techniques à prendre:

a. *Drainage souterrain* par tuyaux en poterie ou en béton (Fig. 13). On fait des investigations détaillées d'après une méthode spéciale qui se base sur le degré de maturité du sol et des fissures correspondantes, afin de classifier ensuite le sol d'après sa perméabilité et par rapport aux intervalles désirables des tuyaux de drainage.
b. *Irrigation souterraine au moyen de tuyaux.* Le sol est classifié d'après la nécessité et l'utilité d'irrigation souterraine.
c. *L'élaboration et mise en oeuvre de projets d'amélioration du sol.* Certains types de sol peuvent être améliorés en inversant le profil du sol par un labourage profond (jusqu'a environ 1.90 m) – voir fig. 14 – ou en mélangeant les couches du profil.

Autres aspects:

d. *Le mode d'emploi des terres*
On élabore un plan définitif et global pour l'emploi des terres en conformité avec les conditions données du sol, y compris les facteurs économiques et sociaux. Dans les polders on trouve les principaux types suivants (voir également fig. 16):
- Terres arables;
- Agriculture mixte, avec un élément de pâturages qui va de 1/6 à 5/6 de l'ensemble;
- Horticulture (fruits et légumes);
- Sylviculture;
- Villages, chaussées, parcs sportifs et de récréation, etc.

e. *La dimension des exploitations*
Une fois que la structure globale des emplois des terres est connue, on peut fixer les dimensions des exploitations et les constructions nécessaires pourront être conçues et réalisées. La superficie et le nombre d'exploitations sont en partie déterminés par le type du sol etpar l'emploi de la terre, en partie par des con sidérations d'ordre social, financier, et politique.

f. *Fixation du loyer ou fermage*
Le fermage pour chaque exploitation est fixé avec le maximum de précision possible, entenant compte du niveau de vie désiré, du type du sol, du type et de la dimension de l'exploitation, etc.

g. *La gestion de l'entreprise*
Après location des terres la tâche du Bureau d'Aménagement prend fin et celle de l'agriculteur est née. En se basant sur un plan détaillé des sols les experts agricoles assistent l'agriculteur à mettre au point un plan d'assolement (rotation des cultures etc.) comme pour son traitement (fumure, engrais, etc.).

4. *L'étude du sol et son application dans les assèchements réalisés le long de la côte*

On discutera brièvement des analogies ainsi que des divergences que connait cette forme d'assèchement en comparaison avec celle d'une baie ou d'un lac.

ZUSAMMENFASSUNG

Bodenkartierung und Landklassifizierung für Landgewinnung auf dem Meeresboden in den Niederlanden

1. *Landgewinnung in den Niederlanden gestern und heute*

In den Niederlanden sind, in den vergangenen Jahrhunderten, grosse Gebiete und verschiedene Landtypen trockengelegt worden, um den Anforderungen einer ständig und schnell zunehmenden Bevölkerung zu beantworten (Figur 1).

In einigen Fällen war diese Landgewinnung verhältnismässig einfach, weil man allmählich kleinere Gebiete mit gutem Boden den landwirtschaftlichen Hilfsquellen des Landes hinzufügen konnte.

In anderen Fällen jedoch und namentlich in einigen grösseren Landgewinnungsprojekten in der Vergangenheit, die mit Privatmitteln durchgeführt wurden, hatten die ersten Bauern mit grossen Schwierigkeiten zu kämpfen: Mangel an Arbeitskräften und Kapital, sehr primitiven Wohnungen und Betriebsgebäuden sowie – im Anfang – häufigen Fehlernten, verursacht durch unangemessene Entwässerung, Übermass an Salz, sehr ärmlichen Boden, falsche Fruchtwahl für gewisse Bodentypen usw. Die Landgewinnungen wurden ohne vorherige Bodenuntersuchungen oder Planung durchgeführt. Dass diese Gebiete später dennoch zur Blüte kamen, geschah auf Kosten der ersten Siedler, ihres Leides, ihrer Armut, sowie Zeit-, Geld- und Energieverschwendung. Mit der Trockenlegung der Zuiderzee, eines grossen Binnensees, trat man in eine neue Phase, die der konsequenten Anwendung der neuen wissenschaftlichen Erkenntnisse (Figur 2).

Die Projekte fussen auf gründlichen Untersuchungen und auf eingehender Planung bevor mit der Durchführung ein Anfang gemacht wird, und diese werden während und nach der Durchführung des Projektes fortgesetzt.

Wenngleich dieses Referat einige Gedanken bezüglich der Gewinnung spezifischer, früher unter Wasser gelegener Böden vermittelt, so ist doch das Hauptziel dieser Veröffentlichung der Hinweis auf die Notwendigkeit einer eingehenden Bodenuntersuchung, einer Landklassifizierung und einer intensiven Planung, als Mittel zu einer optimalen landwirtschaftlichen, ökonomischen und sozialen Bodennutzung.

2. *Bodenkartierung*

Die Bodenkartierung wird in drei Etappen, mit entsprechenden Unterschieden in Intensität und Ziel, durchgeführt. Das Bedürfnis an genauen Angaben ist in den frühen Phasen der Entwicklung weniger spürbar, steigert sich jedoch im Laufe der Entwicklung.

1. Etappe, Kartierung unter Wasser

Intakte Bohrungen mit einer Länge von 1,5 meter und mit einer Dichte von 1 je 50 ha (Figur 3).

2. Etappe. Einleitende Kartierung

Sobald der Polder trocken ist, jedoch vor der Aushebung der Gräben wird eine intensivere Kartierung mittels offene Handbohrer vorgenommen. In dieser Phase beträgt die Intensität der Bohrungen 1 je ha.

3. Etappe. Eingehende Kartierung

Die endgültige Kartierung wird nach Aushebung der Gräben vorgenommen. Die Gesamtlänge der Gräben beträgt für einen Polder van 50.000 ha 2.000 km (Figur 4). Für die Erstellung einer eingehenden Bodenkarte (1: 10.000) werden die Profile der Gräben bis zu einer Tiefe von 1.40 M. und in Abständen von 50 Metern beschrieben (Figur 5).

Die *Bodenklassifizierung* ist hier verhältnismässig leicht, weil diese jungen Böden noch keine Entwicklung des Bodenprofils, bedingt durch Verwitterung and Auswaschung, zeigen. Sie besitzen ausserdem die gleiche Formationsweise, dieselben Tonminerale usw. Das wichtigste Kriterium für die Klassifizierung ist somit die Textur des Bodens. Der Tongehalt steht in engem Zusammenhang mit einer Reihe von Eigenschaften, die sehr wichtig sind für das landwirtschaftliche Betragen des Bodens. Bei Sandböden ist, neben dem Tongehalt, die Grobheit des Sandes ebenfalls ein wichtiger Faktor.

3. *Verwendung der Bodenkarte*

Kartierung unter Wasser (1. Etappe)

Angaben bezüglich der Bodenbeschaffenheit sollten verfügbar sein bevor die Bedeichungsarbeiten anfangen, weil dieser Arbeit Pläne, die nicht erstellt werden können ohne eine gründliche Kenntnis der Bodenbeschaffenheit, vorangehen. Die ersten Bodenkarten eines zukünftigen Polders (Figur 6) werden zu folgenden Zwecken verwendet:

a. *Lage und Begrenzung des Polders.* Insofern möglich sollten nur gute Böden eingepoldert werden, während die schlechteren Böden ausserhalb des Poldergebietes belassen werden.
b. *Setzen des Bodens nach der Trockenlegung.* Der Prozess des Trocknens von Böden, die unter Wasser gelegen haben, wird begleitet von einem allgemeinen Einschrumpfen des Bodens.
Das zukünftige Grundniveau muss berechnet werden im Hinblick auf die Bestimmung des erwünschten Grundwasserniveaus, des Entwässerungssystems und des Baues der Pumpstationen usw.
c. *Berechnung der Sickerbewegung.* Im Vergleich zu dem umliegenden Festland liegen die Zuiderzeepolder tief, und die Durchlässigkeit des Untergrundes und des Substrats ist – im Grossen und Ganzen – recht gut. Um die Kapazität der Pumpstationen berechnen zu können, muss die Menge Kuverwasser bekannt sein. Ausserdem beeinflusst das Sickern die Entwässerungsfrage, die Bodeneignung usw. (Figur 7)
d. *Entwurf eines vorläufigen Planes für Untergrundbewässerung.* Die Lage solcher Böden, die einer Bewässerung bedürfen, muss angegeben werden. Die Breite der Parzellen, die Untergrundbewässerung bedürfen, sollte 200 Meter nicht übersteigen, während anderswo die normale Breite 300 Meter beträgt.
e. *Vorläufige Bestimmung der Bodenfähigkeit und Landnutzung.* Die Bodenfähigkeitskarte gibt an zu welcher Verwendung der Boden geeignet ist, während die Landnutzungskarte angibt zu welcher Verwendung der Boden gelangen wird, unter Berücksichtigung der verschiedenen wirtschaftlichen und sozialen Faktoren.
f. *Schätzung der Kosten für Trockenlegung und Gebäude.* Diese Schätzung setzt einen Projektentwurf voraus, der jedoch nicht erstellt werden kann, ohne Kenntnis des Bodens.

Einleitende Kartierung (2. Etappe).

Die obenbehandelten Punkte beziehen sich auf die zu leistende Arbeit bevor der Polder trocken ist.
Im Nachfolgenden wird die nach Trockenfallen des Polders anfallende Arbeit behandelt.

a. *Endgültiger Landaufteilungsplan.* Dieser Plan und der allgemeine Landnutzungsplan müssen endgültig aufgestellt werden insofern sie einen Zusammenhang besitzen mit der Anlage des Netzwerkes von Kanälen, Seitenkanälen, Gräben, Strassen usw. (Figur 8).
b. *Aufstellung von Einzelheiten bezgl. Graben der Kanäle usw.* Weil diese Arbeit teilweise von privaten Bauunternehmen durchgeführt werden, muss in der Baubeschreibung eine genaue Beschreibung aufgenommen werden.
c. *Feststellung des endgültigen Landaufteilungsplanes.*
d. *Bestimmung der Abstände zwischen den Feldgräben.* Wenn die Kanäle und die

Hauptabzugsgräben ausgehoben worden sind, bilden sich die Parzellen. Diese haben eine Länge von 800 bis 1000 Meter und eine Breite von 200 bis 300 Meter (Figur 9). Feldgräben bilden ein vorläufiges Untergrund-Entwässerungssystem, weil das Anbringen von Drainröhren in den sehr jungen und weichen Böden nahezu undurchführbar ist (Figur 10/12) Später werden sie ersetzt durch ein permanentes Drainröhrensystem.

e. *Fruchtauswahl für die anfängliche Betriebsperiode.* Während dieser Periode werden nur Gewächse, die sich eignen für extensive und mechanisierte Bearbeitung, angebaut.

f. *Zusätzliche Einzelheiten bezüglich Bodeneignüng und Landnutzung*

Eingehende Bodenkarte (3. Etappe).

Die Verwendung der eingehenden Karte liegt vorwiegend auf dem Gebiet der vorbereitenden Arbeiten, die – während der Periode von einleitender Bearbeitung – von das Staatliche Amt vorgenommen werden müssen, bevor das Land privaten Landwirten verpachtet wird.

Technische Massnahmen:

a. *Röhrenentwässerung* (Figur 13). Um den Boden nach Durchlässigkeit und gewünschtem Abstand der Drainröhren zu klassifizieren, werden eingehende Untersuchungen angestellt, unter Benutzung einer besonderen Methode, basiert auf dem Stadium der Bodenreife und dementsprechenden Rissen.

b. *Untergrundbewässerung mittels Röhren.* Die Böden werden klassifiziert nach Bedarf an Untergrundbewässerung.

c. *Entwurf und Durchführung von Bode meliorationsprojekten.* Einige Bodentypen können aufgebessert werden durch umkehren des Profils mittles Tiefpflügen (bis etwa 1.90 m) – s. Figur 11 – oder durch mischen der Bodenschichten.

Andere Aspekte:

d. *Allgemeines Muster der Landnutzung.* Unter Berücksichtigung der herrschenden Bodenverhältnisse und unter Einschluss der wirtschaftlichen und sozialen Faktoren, wird der endgültige Plan für Landnutzung erstellt. Die nachstehenden Typen sind in den Poldern vertreten (sehe auch Figur 16):

- Ackerland;
- Mischbetriebe mit 1/6 bis 5/6 Grasland;
- Gartenbau (Gemüse, Obst);
- Forstwirtschaft;
- Dörfer, Strassen, Sportgelände und Grünanlagen usw.

e. *Betriebsgrösse.* Nachdem das allgemeine Muster bekannt ist, kann die Betriebsgrösse bestimmt werden und können die erforderlichen Bauten entworfen und erbaut werden. Die Grösse und die Anzahl der Betriebe wird zum Teil bestimmt durch Bodentype und Landnutzung, zum Teil auch durch soziale, finanzielle und politische Erwägungen.

f. *Bestimmung der Pacht* Die Pacht für jeden Betrieb wird so genau wie möglich ermittelt, unter Berücksichtigung des gewünschten Lebensniveaus, der Bodentype, Art und Grösse des Betriebes usw.

g. *Betriebsführung* Nachdem das Land in Pacht ausgegeben worden ist, ist die Aufgabe des Planungsausschusses beendet und fängt die Aufgabe des Landwirtes an. Mit Hilfe einer eingehenden Bodenkarte stehen landwirtschaftliche Experten dem Landwirt zur Seite bei der Aufstellung eines genauen Landnutzungsplanes (Anbauplan, Fruchtwechselplan) und eines Behandlungsplanes (Düngermittel usw.)

4. *Bodenkartierung und ihre Anwendung bei Landgewinnung in Küstengebieten*

Die Punkte der Übereinstimmung und des Unterschiedes zwischen dieser Art der Landgewinnung und Trockenlegung eines Binnensees werden kurz gestreift.

COMPENDIO

EXAMEN DEL SUELO Y CLASIFICACION DEL TERRENO PARA LA COLONIZACION DE TERRENOS SUBMARINOS EN HOLANDA

1. *Introducción*

Durante las últimas centurias grandes extensiones y varios tipos de terreno han sido colonizados en Holanda para atender a las necesidades de un continuo y rápido crecimiento de la población (figura No. 1).

En algunos casos esta colonización es más bien fácil, cuando pequeñas áreas de buen terreno puedan ser gradualmente agregadas a los naturales recursos del país. Sin embargo, en otros casos, especialmente en algunos proyectos de gran envergadura ejecutados por capital privado, los primeros colonos tienen que enfrentarse con grandes dificultades: falta de mano de obra y capital, viviendas y dependencias primitivas, frecuentes fracasos en las cosechas causados por inadecuado drenaje, exceso de sal, suelos muy pobres, la selección equivocada de cultivos para ciertos tipos de suelo, etc.

Estos proyectos fueron ejecutados sin ningún examen previo de suelo, y sin ningún otro examen general.

No obstante, estas zonas llegan más tarde a ser prósperas, pero este resultado se alcanzó a costa de grandes sufrimientos y privaciones de los primeros colonos, y pérdida de tiempo, dinero y trabajo.

Con la colonizacíon del Zuiderzee, un gran mar interno comenzó un nuevo período de modernos y grandes proyectos de colonización, basados en completos estudios previos, así como un proyecto completo, como medio de lograr un mejor uso del terreno desde el punto de vista agrícola, económico y social (figura No. 2).

2. *Examen del suelo*

El examen del suelo se realiza en tres etapas que corresponden a diferencias en la intensidad y propósito. La necesidad de datos detallados no se siente durante los primeros momentos del desarrollo. Esta necesidad aumenta progresivamente.

Primera etapa – Examen bajo el agua

Se toman muestras inalteradas del terreno hasta 1.5 m de profundidad, a razón de una cada 50 ha (figura No. 3).

Segunda etapa – Estudio preliminar

Tan pronto como el pólder está seco, pero antes de la construcción de las zanjas drenes se realiza un estudio más intensivo por medio de barrenos. En esta etapa la intensidad del examen es de un barreno por ha.

Tercera etapa – Examen detallado

Este examen final se verifica después de la excavación de las zanjas drenes, cuya longitud total es de unos 2.000 km en un pólder de 50.000 ha (figura No. 4). Para el mapa detallado del suelo (1 : 10.000) los perfiles de los drenes se describen hasta una profundidad de 1.4 m, y a intervalos de 50 m (figura No. 5).

Clasificación del suelo

Es nuestro caso la clasificación del suelo es más bien sencilla, ya que estos suelos nuevos no muestran desarrollo en el perfil, debido a la meteorización y el lavado. Por otra parte, tienen el mismo origen, los mismos componentes arcillosos, etc. Por consiguiente el principal criterio para su clasificación es la textura. El contenido de arcilla está estrechamente relacionado con gran número de propiedades, que son de gran importancia en el comportamiento del suelo. En lo que se refiere a los suelos arenosos, junto con el contenido en arcilla, la proporción de los diferentes tamaños de partículas es también un factor importante.

3. *Aplicacion del examen del suelo*

Aplicación del examen bajo el agua (Primera etapa)

Los datos referentes a las condiciones del suelo, deben de estar dispuestos antes de comenzar el trabajo en el dique, puesto que este trabajo está precedido por planos que no pueden ser diseñados sin un perfecto conocimiento de la naturaleza de los suelos.
Los primeros mapas del suelo (figura No. 6) se usan por los siguientes propósitos:

a. *Situación y límites del pólder*
Siempre que sea posible solamente los buenos suelos deben incluirse en el pólder, dejando los inferiores fuera del mismo.

b. *Asentamiento del suelo después de la transformación*
El proceso de secado de los suelos que estuvieron bajo el agua es acompañado por una contracción general del suelo. El futuro nivel del suelo debe ser calculado de acuerdo con el nivel deseado para la capa freática, drenaje, construcción de la estación de bombeo, etc.

c. *Pronóstico de subinfiltración.*
Los pólderes del Zuiderzee estan por debajo de las tierras circundantes y la permeabilidad del subsuelo y sub-estratos es, generalmente hablando, muy buena. Para determinar la capacidad de la estación de bombeo es preciso conocer la cantidad de agua procedente de subinfiltración. Además, el agua sub-infiltrada influye en el requerimiento de drenes, posible aplicación del suelo, etc. (figura No. 7).

d. *Diseño de un plan provisional por la subirrigación.*
La anchura de los lotes que necesitan de subirrigación no debe exceder los 200 m, mientras que normalmente la anchura es de de 300 m.

e. *Determinación provisional de la posible utilización del suelo y de la utilización efectiva.*
Una vez analizada la posible utilización de un suelo para determinadas cosechas de acuerdo con las características agronómicas, se determina la utilización efectiva teniendo en cuenta también los diferentes factores económicos y sociales.

f. *Cálculo del coste de la transformación y edificios.*
El proyecto de una transformación no puede hacerse sin el conocimiento de estos conceptos.

Aplicación del examen preliminar del suelo (segunda etapa)

Los conceptos expuestos en el apartado A. se refieren al trabajo que se efectúa antes de que el pólder de seque. Las siguientes consideraciones se refieren al trabajo efectuado después que el pólder ha emergido.

a. *Plan final para la división del terreno.*
Este plan y el plan general para el uso efectivo del terreno deben hacerse definitivos ya que determinan la red de canales, canales laterales, zanjas de drenaje, carreteras, etc. (figura No. 8).

b. *Preparación de las condiciones para la excavación de los canales, etc.*
Como este trabajo es efectuado en parte por contrata, se precisa una descripción completa en el pliego de condiciones (presupuesto).

c. *Determinación del espaciamiento de las zanjas de drenaje.*
Una vez construidos los canales se determinan los lotes, que tienen una longitud de 800 a 1.000 m y una anchura de 200 a 300 m (figura No. 9). Las zanjas de drenaje forman un sistema provisional de drenaje, ya que el drenaje por tubos en estos suelos que

han estado recientemente sumergidos es casi impracticable (figura No. 10/12). Más adelante, las zanjas de drenaje se reemplazan por los tubos porosos.

d. Elección de la cosecha durante el período inicial de administración.
Durante este período sólo se cultivan cosechas propias para el cultivo extensivo y mecanizado.

e. Detalles adicionales.
Como la posible utilización del terreno y su utilización efectiva.

Aplicación del examen detallado del suelo (tercera etapa)

El uso del examen detallado principalmente se refiere a las transformaciones que durante el período inicial de administración deben de ser ejecutadas por el Estado, antes de arrendar el terreno (las tierras) a los colonos.

Medidas técnicas:

a. Drenaje por tubos (figura No. 13)
Se realiza una detallada investigación, usando un método especial, basado en el estado de madurez del terreno y correspondencia de las grietas para clasificar los suelos de acuerdo con la permeabilidad y el especiamiento conveniente para los drenes.

b. Subirrigación por medio de drenes
Los suelos se clasifican de acuerdo con la necesidad de subirrigación.

c. El diseño y ejecución de proyectos para la mejora del suelo. Algunos tipos de suelo se pueden mejorar volteando la capa superficial mediante una labor de profundo arado (de hasta 1.9 m) (figura No. 14) o mediante subsolador.

d. Tipos generales de utilización efectiva del terreno
De acuerdo con la características agronómicas y con los factores económicos y sociales se tdeerminan las distintas clases de utilización. En los pólderes se encuentran los siguientes tipos (véase también figura No. 16):

- terreno laborable;
- cultivo, mixto con 1/6 a 5/6 de superficie con pasto;
- horticultura (vegetales, frutas);
- floresta;
- villas, carreteras, campos de juego, etc.

e. El tamaño de la finca
Después de conocidos los distintos tipos generales de utilización del terreno, el tamaño de la finca puede ser determinado y los edificios necesarios se pueden diseñar y construir. El tamaño y número de fincas se determina en parte por medio del tipo de suelo y uso del mismo, en parte por consideraciones de tipo social, financiero y político.

f. Determinación de la renta
La renta para cada finca se fija con toda la justeza posible, tomando en consideración el conveniente nivel de vida, tipo de suelo, tipo y tamaño de la finca, etc.

g. Administración de la finca
Después del arriendo de las tierras se termina la tarea del Development Board y comienza la de los colonos. Basándose en los mapas detallados del suelo los agronomistas ayudan al colono para preparar un plan detallado de utilización del terreno (alternativa, etc.) y tratamientos (fertilizantes, etc.).

4. *Examen del suelo y su explicación en la colonización a lo largo de la costa*

Los aspectos comunes, tanto como las diferencias de esta clase de colonizacíon con la de un mar interior o lago se discuten brevemente.

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No. 1: BEERS, Ir. W. F. J. van, The auger hole method, 1958. (32 p.p., 7 fig. and 4 graphs). $ 0.60