POLDERS OF THE WORLD

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THEME A.   POLDER PROJECTS

SUB-THEME: VARIOUS ASPECTS OF POLDERS IN A CERTAIN AREA

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Abstract

What is the essential feature of a polder?
We hear ten answers to this question. All are quite different, but all are equally valid.
From the Netherlands we have two answers: it is reclamation of the sea bed for agricultural, urban and recreational use; it is also the protection of dense populations from accidental inundation.
In West Germany it is the avoidance of false political and sociological goals.
In Hungary it is the attainment of the optimum balance between minerals, water and air in a soil.
In Romania it is the protection of a part of the flood plain of a great river from too-frequent inundation.
In Spain, Thailand and Vietnam, the correct management of water to combat toxic ions in the soil is the central feature of reclamation.
In Guinea Bissau, it is the adaption of modern techniques of reclamation to methods appropriate for an African social structure.
In Suriname, supplies direct from tropical rivers must be combined with water collected from the swamps themselves to give the best management of reclaimed lands.
The papers are fascinating in their variety; impressive in the unity of resolve the authors show in overcoming the problems with which they are confronted.

Introduction

Answers to the question 'What is the essential feature of a polder? come to us from different parts of the world, and, although the answers are so different, all are good and correct answers, because the authors have started from the same fundamental unspoken assumption. It is that the earth, which often appears so hostile, can be transformed into a home in which men and women should live in peace, and free from drudgery and want. From this common assumption, the contributors have provided a set of highly individual answers. They are not easy to summarize together for each goes to the heart of the local problem which has to be solved for that area. A sketch of the main features of each paper there fore follows. Finally a table lists and reclamations and compares important elements in their design.

THE NETHERLANDS -- The Ysselmeer Polders -- Constandse, de Jong and Pinkers.

The former Zuyder Zee became the Ysselmeer or Yssel lake after 1932 when a barrier dam separated it from the North Sea. Four polders have been reclaimed in the lake. A fifth is under discussion. Total reclaimed area will be 200 000 ha. In winter, rainfall exceeds evaporation but in summer this is reversed. A large part of the Netherlands (40%) depends on artificial drainage. Soil types vary over the area, but a large proportion are very fertile loams.
Reclamation of the polders is only part of a plan made in 1890 and approved in 1918, which had the following objectives:-

a) Shortening of the coastline to give more effective safety against storm surges in the North Sea.

b) Reclamation of high quality agricultural land.

c) Improved water management with better control of level and salinity.

d) Improved road systems.

As construction has been under way for 60 years, new objectives have been set in the field of urban development, forestry, nature conservation and recreation.

Three state organisations supervise the development:-

a) Zuyder Zee Works Agency designs and constructs large scale civil engineering works e.g. dikes, pumping stations, bridges, canals, roads

b) The Public Body of the Yssel Lake Polders is in charge of local government

c) The Ysselmeer Polders Development Authority prepares the newly reclaimed land for its final use, including social and economic development.

Reclamation works proceed through the following stages:-

1. Construction of enclosing dike, pumping stations and drainage canals following by pumping dry of the polder
2. Mud surface is sown with reed seeds from aircraft
3. Smaller drains are dug, land is sub divided into fields and roads are built over a 10 year period
4. Cultivation starts with burning-off of reed beds and preparation of land for cropping.
5. Land is farmed for 5 years by Government
6. Subsurface drain-pipes are installed and farm buildings constructed. Water, electricity and telephone services are installed. Villages are built.
7. Land is allocated in holdings needing 1-4 workers. The occupiers of the land live on their farms.
8. Landscaping, forestry and recreational areas are given attention.
9. Finally, when all works are complete, maintenance is handed over to a Polder Board, and local government takes over the administration.

The land is divided into rectangular fields about 500 m x 1200 m, each with road access and boundary canal. A labour force of about 700 men cultivate an area of about 20,000 ha. during the first five years. Thereafter, the land is let out to farmers. There are many more applicants than farms so a selection procedure is necessary. The average size of farm is 40 ha, varying between 20 and 90 ha.

In the first two polders, agricultural development was of prime importance and only the poorest soils were reserved for other use. In the course of time, urban development has become more important along with associated recreational facilities. In the recent polders, even good agricultural soils are being allocated for these purposes. Two large

new towns are under construction - Lelystad in Eastern Flevoland for 100,000 inhabitants and Almere in Southern Flevoland for 125,000.
In the early polders is was assumed that each farm should be within cycling distance of a village (max. 7 Km) so that shops, schools and churches should be within easy reach. Consequently, a relatively large number of small villages (500-2000 inhabitants) was built. In present circumstances, with greatly increased productivity, the number of farm workers has diminished, and with greater motorization the distance between farms and village is no longer a problem. A village is now considered to require 3000 inhabitants to farm a viable unit and therefore the number of villages planned for Eastern Flevoland has been reduced from the original fourteen, to only three. In Southern Flevoland, there will be the large polynuclear town of Almere for 125000 to 250000 inhabitants, plus only one local service centre called Zeewolde.
Recreational facilities have been provided on the lakes bordering the polders and in the areas set aside for forestry. Nature reserves have been established to preserve and extend habitats for plant and bird life.

THE NETHERLANDS - Protecting the North Holland Polder Area against Flooding -- Vernimmen and Heyligers.

The province of North Holland occupies the flat coastal area north of Amsterdam. In the Middle Ages there were a number of lakes in the area in open connection with the Zuyder Zee. In the 16th Century the major estuaries were closed and in the 17th Century nearly all the lakes were drained. The method was to surround the lake by an embankment called the 'boezem' embankment in such a way as to leave a strip of water known as the ring canal between the embankment and the border of the lake. The water of the lake was pumped into the ring canal. The ring canals were connected with each other and with other canals in the area to form a maze of water courses all at the same level, called a 'boezem' system.
On either side of the canals, several metres lower are the polders.

These are tracts of land surrounded by dikes with artifical water level control, very fertile soil and numerous towns and villages with some millions of inhabitants.

Sea walls must be capable of standing up to extreme gale-swept floods, but these boezem embankments need only rise a small amount above normal water level because the range of variation in boezem water level is only a few decimetres. On the other hand, the embankment must be capable of withstanding the difference in level between boezem water and polder water (up to 5m.) Investigations have recently shown that many of the embankments do not have a sufficient degree of stability to meet present-day standards.

Although the same banks can be reinforced by placing sand on the polder side, it is still possible for bursts to occur due to undetected weak spots, pipeline fractures, burrowing animals or acts of war.

If a boezem dike bursts, the damage is often very severe. Usually it will not be possible to close the breach until the water levels have equalised. There is the danger of loss of life, damage to buildings and services, disruption of industry. etc. A rapid fall in boezem water level can also cause considerable damage to banks.

A dike burst occurred in 1960 in North Holland in the embankment of a small polder lying on a large boezem and 2600 homes were flooded and 1100 inhabitants had to be evacuated.

The consequences of dike bursts may be restricted in two ways:-

- by reducing the area that can be inundated
- by reducing the quality of water that can flow from the boezem into the polder.

The first method would imply the construction of a great many additional embankments within the polders, and therefore the second method has been used very widely.

It was decided to create a facility for dividing the boezem into sections by means of sluice gates. The project comprised the construction of 37 new sluices and 23 are now complete. Emphasis has been placed on isolating major bodies of water , such as lakes, from the remainder of the boezem network.

Various types of sluice have been considered, depending on the circumstances at each site. For use in the wider watercourses, an inflatable weir has been developed. This weir consists of a flat steel box lying on the bed of the canal, containing a folded envelope made of nylon-reinforced rubber. The weir is operated by pumping water into the folded envelope. It then emerges from the box and retains the boezem water as a solid rubber dam. The system incorporates an automatic monitoring and warning system. At important locations, flow meters have been installed whereby the rate of flow and direction can be scanned electronically If for a certain period, the velocity exceeds a certain preset value, an alarm is activated. In this way, a high degree of protection against flooding is preserved for the densely populated and low-lying polder land in the western Netherlands

WEST GERMANY - The Origin and Early Stages of the Hermann Goring Polder (Tumlauer Koog) in Schleswig Holstein. -- J.C. Smit.

In 1931 a plan was drawn up to shorten the coastline on the west coast of Schleswig-Holstein, reclaim the mudflats behind the dikes and establish new villages in the area. By 1945 most of the plan had been realised: 7 polders on former mud flats had been reclaimed, varying in size from 500 to 1300 ha.

The best known polders were originally called the Adolf Hitler Koog and the Hermann Goring Koog, named after the two men who initiated them in 1935. They are now known as Dieksander Koog and Tumlauer Koog.

When the National Socialists took power in 1933, they decided that reclamation could serve some of the main objectives of their policies eg. increasing home food production in Germany, strengthening of agricultural communities, selection of settlers with supposed favourable racial characteristics.

Throughout the course of development of the Tumlauer Koog, each stage was marked by differences of opinion between the parties involved. A settlement company was formed to carry out the development and select the new settlers, but its views were often at variance with government agencies. For example, the Company wanted dispersed settlement throughout the polders, but the Government wanted concentrated settlements. Farm buildings were constructed in the traditional style of farms in the neighbouring old land, with thatched roofs because there was a lot of propaganda for this style in the time of National Socialism. Initially

34 settlers came to live in the Tumlauer Koog (500 ha.) Many were selected because of party affiliations.
Soils were much heavier than the settlers had expected and cultivation was very laborious, harvests were disappointing and the government had to provide subsidies to preserve the propaganda- value of the project. After the war, a new generation gradually took over. Farms have merged and the average farm size has grown from 14 ha. to 31 ha. The initial ideological aims of the reclamation have now disappeared and farming has adapted itself to the pattern in the rest of the surrounding land.

HUNGARY - Hydroamelioration of Agricultural Lands in Hungary -- M. Szinay

Hydroamelioration is defined as the branch of science and technology which deals with improvement of the natural condition of soil for plant growth, by controlling the soil moisture budget. The aim of hydroamelioration is to manage the soil moisture in such a manner as to allow plants to grow at their optimal rate. The key factor which will ultimately control agricultural development in Hungary, and in most of the rest of the world, is water supply. Agriculture can progress in two ways:- 1) 'extensive' - ie, bringing into cultivation new tracts of land for example in semi-arid zones. 2) 'intensive' ie gaining better crops from existing cultivated land, by providing optimal moisture conditions at each stage of plant growth. In either case, hydroamelioration is expected to perform two basic functions, namely the removal of excess water by drainage and the supply of water to cover shortages by irrigation.
In Hungary there is an area of 5 million ha. in which soil fertility is impaired and which can be corrected by proper water management in the soil. In applying the principles of water control it is important to remember that the soil is a 3 phase system of minerals, water and air, and when any one element in the system is changed, the others are also affected. For example, saline soils exist over 1 million ha. in Hungary, most of which could be improved by leaching with irrigation water

ROMANIA - Some of the Danube Floodplain Polder Project Criteria - I. Mihnea and M. Clarian

In Romania, the area below river flood levels is about 3.5 million ha. and of this 2.2 million ha. is agricultural land. There is therefore a long history of embankment schemes alongside the Danube and other major rivers, which aim at the protection of polder areas in the flood plain. At first most of the land was protected only by low submersible dikes, some 3m. above land level, with a crest width of 5 m. These gave a standard of protection up to about the once-in-ten-year flood. More recently, new polders have been reclaimed by constructing dikes up to the once-in-a-hundred year flood level plus a 1m. safety margin. In 1962 a decision was taken to reclaim 450,000 ha. in the Danube floodplain in this way. An area of 290,000 ha divided into 17 polders is included in the first stage of this scheme. The dikes are built about 200m. from the outer limit of the river bed with a crest width of 5m. Drainage channels and pumping stations are provided to evacuate excess water in the polders themselves. Field drainage is provided by means of open ditches with a minimum spacing of 400m. The capacity is calculated to give a rate of discharge of 5 to 6 mm/day. In some places lakes for fish farming were integrated into the reclamation plan. The need for irrigation is also incorporated in the design of the drainage works. In the reclaimed areas it has been found that groundwater levels have declined to a level 4-5 m. below ground and this has had a beneficial effect on soil aeration. The cost of the reclamation works have been fully justified by the increased crop production which has been obtained.

SPAIN -- Basic Information about the Marshes at the Lower Guadalquivir River -- R. Bellas Rivera

At the mouth of the Guadalquivir River in South West Spain there is a large area of marshland covering 136,000 ha. at about the level of high tide, 3.6 m above mean sea level. In summer, evaporation far exceeds rainfall and irrigation is required to sustain crop growth. Moreover, groundwater is saline and slightly alkaline and these salts must be kept out of the rooting zone. Reclamation work is therefore seen as having four aims:-

1) Prevent inundation by impoldering.

2) Provide a drainage network which allows rain or irrigation water to pass through the soil, washing out injurious salts

3) Maintain a water table which allows roots to develop and does not allow capillary rise to the surface.

4) Loosen the soil by cultivation to increase permeability.

Success has been achieved in decreasing salinity and increasing agricultural yields up to levels obtained in the surrounding districts which do not have salinity problems.

GUINEA-BISSAU - Natural and Social Constraints to Polder Development in Guinea Bissau -- R.J. Oosterbaan.

Guinea-Bissau is a coastal state in the extreme west of Africa with an area of 36,000 Km^2. There are coastal mudflats extending to 400,000 ha, and 100,000 ha. have beem empoldered. The remaining area is covered by mangrove forest, but as there is a need to increase rice production, the Government is considering extension of the reclaimed area.

The traditional method of reclamation is to construct dikes 1.5 to 2m. high alongside the tidal creeks, although more recently dams have been built across the creeks and this reduces the length of dike required. By custom the men construct and maintain the polders whilst the women cultivate the rice.

Water supply in the polders is entirely dependent on incident rainfall and no irrigation water from outside is used. A system of cultivation in ridges is followed and this seems to be very beneficial in controlling the presence of noxious elements in the acid-sulphate soils, and in using the available moisture to the best advantage. Drainage of the area is by means of surface drains and these are also used to retain water.

There has been a failure to bring some of the newly reclaimed land into cultivation, and it is thought that emphasis should now be placed on improvement of existing polders rather than on reclamation of new areas.

THAILAND - Land Reclamation in Thailand - Ruanglek, Chaveesuk and Poolsup

The Klongdarn Drainage Project was carried out between 1921 and 1931 as an irrigation scheme covering 200,000 ha. close to Bangkok. Now it is intended to reclaim 24,000 ha. of marine clay as part of the same project. In 60% of this area, soils are saline, and the aim is to make these soils suitable for cultivation of rice. The methods used is to provide surface drainage and allow irrigation by flooding during the dry season to flush the salts down beyond the rooting depth of the rice (20 - 30 cm.) Evaporation and upward movement of salts from saline groundwater must be kept to a minimum by double cropping. It is hoped to produce 2.5 tonnes/ha. in the dry season.
A sea dike has been constructed along the southern edge of the area to keep out sea water. In the dike there are associated discharge sluices and bridges. Irrigation water is conveyed to the area from the north along the Raphiphat Canal. Drainage channels are designed to discharge at a rate of 46 mm/day, and irrigation canals are provided with a capacity of 7 mm/day.

VIETNAM - The Experimental Polder for Research on Acid Sulphate Soils in the Mekong Delta -- E. Stamhuis.

In the delta of the Mekong River in Vietnam there is a very flat area of 4 million ha. Half of this area has acid sulphate soils and a method is being sought of managing these soils in such a way as to give increased production of rice.
Land is not embanked, and when rivers overflow in the wet season, fields are inundated to a depth of 1.5 - 2m. This is of value to the soil moisture budget. Higher yields of rice have been attempted by using shallow drainage systems to give improved leaching of topsoil, by planting acid-tolerant varieties of rice and by the use of fertil-

isers, but usually these methods are too expensive and large areas remain with low yields.
An experimental polder has therefore been set up by the University at Can Tho, with assistance from the Dutch University of Wageningen. The area, 8 ha. in extent, has been surrounded by a clay dike. It has been provided with drainage and irrigation channels and sub divided into small plots. Within each plot, drainage and inundation depth can be controlled. The pH value of the irrigation water can also be varied as required. Tillage depth and rate of fertiliser application are further variables to be investigated. From these trials it is expected that improved techniques can be devised for the management of polders in the Mekong Delta, and that agricultural yield of the area can be increased.

SURINAME - Present state of Water Resources Development in N.W. Suriname -- A. Spier

The extent of reclaimed swampland in N.W. Suriname has grown rapidly since 1950 to an area of about 40,000 ha. mainly used for the cultivation of rice. A much greater area (180,000 ha.) of very fertile soil is potentially available. Much technical data has been collected, but the most difficult problems are concerned with land ownership and its legal and social implications.
Water for irrigation can be made available by means of low banks to build up the level of water seeping across the land towards the coast. This traditional method is still used but more efficient ways of water resource management are now being sought.
The most promising method of development seems to lie in an integrated system of river water intakes and canals to cut off seepage from swamps. On the Corentyne River work has started on a multi-purpose project. Some water must be left to prevent saline intrusion, but 50cu.m./sec can be withdrawn by a pumping station and conveyed along a canal 67 Km in length. This will allow reclamation of 12,500 ha. of new polders and provide irrigation water for 33,000 ha. The yield could be increased by:-
a) Installation of extra pumping capacity to operate only at low tide.
b) Flow regulation by means of a dam to be constructed upstream for

hydropower.

c) Collecting water which seeps from the Nanni and Coronie swamps. The latter option is most promising. Care must be taken not to lower the water level in the swamps by too much because only the top most layers of soil (mainly peat) are permeable. By combining the yield of the river with the yield of the swamp, an integrated resource can be developed, which has a combined yield greater than the sum of the component parts. In this way the total polder area can be increased to 57,000 ha.

VARIOUS ASPECTS OF POLDERS IN CERTAIN AREAS.

LIST OF AREAS DESCRIBED, AND MAIN DESIGN FEATURES

Region	Authors	Subject & Main Theme	Design Parameters*
Netherlands, Ysselmeer	Constandse de Jong Pinkers	Comprehensive agricultural and urban development	R=750 E=680 A1=166 A2=41 A3=207
Netherlands, N. Holland	Vernimmen Heyligers	Flood protection: Safety from accidental inundation	
W. Germany, Schleswig-Holstein	Smit	Effects of social policy on origin of polders	A1=0.5 (Typical polder)
Hungary	Szinay	Hydroamelioration: optimisation of soil moisture budget	R=580 A3=5000
Romania, Danube	Mihnea Clarian	Planning polders in floodplain of large river	D=5 to 6 A1=29 A2=426 A3=455
Spain, Guadalquivir Marshes	Bellas-Rivera	Improvement of saline alkaline soils	R=570 E=430 A3=136
Guinea-Bissau	Oosterbaan	Constraints on development: finding appropriate technology	R=2300 A1=100 A2=300 A3=400
Thailand	S.Ruanglek S.Chaveesuk M.Poolsup	Regulation of quantity and quality of soil moisture	R=1200 E=712 D=46 I=7 A1=184 A2=24 A3=208
Vietnam, Mekong Delta	Stamhuis	Experimental polder: control of acid sulphate soils	D=86 I=20 to 35 A3=4000
Suriname	Spier	Water from swamps integrated with river abstraction	A1=40 A2=12 A3=57

*R=Annual rainfall in mm. E=Evaporation

D=Design rate for drainage mm/day I=Design rate for irrigation

A=Areas in 1000's ha. A1=Complete. A2=Proceeding. A3-Ultimate.

SUB-THEME: VARIOUS ASPECTS OF POLDERS IN A CERTAIN AREA (CONTINUED)

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Abstract

This General Report deals with ten papers, nine of which describe aspects of the construction, amelioration and management of polders while the remaining one pictures the disposal of dredged sediments in deep polders.

Four papers discuss the large (13.500 km^2) delta development and reclamation projects in the densely populated and naturally hazardous coastal provinces of Bangladesh. Smaller, but pursueing similar purposes, is the amelioration scheme of the Lezíria Grande in Portugal.
Designs of new polders are the subject of papers on the Tana River Project in Kenya and the Hadejia Vally Project in Nigeria; both situated in a semi-arid climate.
A Dutch paper surveys the four types of polders that have developed during the past ten centuries above and below sea level in the low and slowly subsiding coastal Netherlands. The works required to combat the effects of subsidence caused by excessive use of ground water are the subject of a paper from Taiwan.
A paper from Rotterdam describes the methods of disposal of the large quantities of (partly heavily polluted) dredged material from the harbours in polders and the environmental aspects of this use of polders.

The wide range of natural, economic and social conditions encountered in the project areas lead to interesting comparisons of ways polders are laid out and operated. Dutch consultants were involved in most of the projects.

1 General observations

Definitions of polders all contain the elements of land and water and their joint management in a well defined area. This separation from the surroundings is a direct consequence of the control of processes within the polder and the exclusion of external influences.

The element "land" leads to various aspects such as location, geology, soils and land use while water leads to associations with climate, hydrology and water control. The joint management presupposes a goal which must be feasible and which leads to a technical design and an organisational structure for the operation and maintenance. These aspects of polders are the subjects of the ten papers to be reviewed in this Report.

The location not only points to a place on our globe but even more to the vertical position of the polder with respect to the surrounding water level. Differences of a few decimetres in altitude can have far reaching consequences for the technical realisation of the supply and evacuation of water. The development of hydraulic machinery with increasing head and capacity multiplied the range of lands suitable for reclamation as a polder. In the Netherlands, with drainage as the main problem, the successive steps in the conquest of the water were (see de Bakker and Kooistra).

- construction of dwelling mounds (2000-1000 BP);
- embankment of the surrounding high grounds (1000-1500 AD);
- embankment of naturally accreted areas (1200-present);
- drainage of lakes up to 6 m below sea level (1450-present), and
- reclamation of large areas of sea bottom (since 1930).

The first three could still do with gravity flow but the latter two types required the power of wind, steam, combustion engines and electricity. Notwithstanding the availability of this range of technical means, there is an understandable (economy, reliability) tendency to solutions with the sole use of gravity (see Brouwer).

2 The papers; location and climate

The ten papers, which are the subject of this General Report, can be classified, according to their location and the climate, into five categories.

1) Bangladesh.
   - Delta development in Bangladesh by Shafiqul Haq
   - Polder development in Bangladesh
     I Past and present by Md. Mohsin Uddin and S. Islam
     II The land reclamation project by A.T. Chowdhury
     III The delta development project by Md. Abu Quassem

   all pertaining to 13.500 km^2 along the estuaries and the coast of the delta of the rivers Ganges and Brahmaputra with a tropical monsoon climate: precipitation 1500-3000 mm; evaporation 1200 mm.

2) Taiwan.
   - Problems in stratum settlement due to ground water exhanstion by Sih Mong-Hsiung.

   About an area of 40 km^2 in the south of the island of Taiwan in a sub-tropical humid climate: P = 1300-3000 mm from July to October.

3) The Netherlands.
   - Marine polders in the Netherlands by H. de Bakker and M.J. Kooistra.
   - Polders as a disposal site for dredged material from Rotterdam by H.J. Groenewegen.

   Pertinent to about 10.000 km^2 (one third of the country) in the coastal part of the Netherlands in a temperate marine climate: P = 760 mm; E = 690 mm.

4) Portugal.
   - Land reclamation and agricultural development of the Lezíria Grande (Portugal) by L. Santos Pereira and M.G. Bos.

   130 km^2 in the estuary of the Tagus River and in a dry sub-tropical climate P = 400-1100 mm; E = 1200 mm.

All these polders are situated in tidal areas. In most cases, the land surface is above the mean sea level or even above mean high water but below the highest floods caused by the tides, the spates of a river or storms. The polders in Taiwan are gradually subsiding and some of the Dutch polders are dry lake bottoms up to 6 m below sea level.

5) Africa.

- Irrigated rice polders in the delta of the Tana River, Kenya by H.W. Appel and M.M. Vierhout.
- Hadejia valley irrigation and drainage project, Nigeria by R. Brouwer.

Areas of 100 and 200 km^2 respectively near the Indian Ocean in Kenya and in the North of Nigeria in a semi-arid tropical climate: P = 600-700 mm; E = 2000-2500 mm.

Both project areas are situated in the flood plains of rivers some tens of metres above the ocean and Lake Chad. They are subject to seasonal flooding.

3 Objectives

In all cases, the construction of a polder means protection of the land against inundation:

- by embankments (bunds) against intrusion from the outside by floods of fresh river water and tides, and surges of saline sea water, and
- by a drainage system against an excess of local precipitation and seepage.

Contrary, an often temporary shortage of water is met by irrigation in Africa, Portugal and Bangladesh. An excess of salt, which mainly occurs in coastal areas (Bangladesh, Portugal, Netherlands) is fought by the prevention of inundation by salt water and by flushing with fresh (irrigation) water.

In most cases, the empoldering of an area is an offensive act: land is withdrawn from "Nature" and made to (a better) use. Along the Dutch coast and on Taiwan also defensive aspects are important because subsidence of the area increases the natural dangers.

Generally, the protection of inhabitants, property and crops against the various catastrophes is expected to increase the usability of the land or of the bottom of a lake or sea.

Most of the reclaimed or improved land is used for agriculture. An increase of the production of (better) food is the main objective of the projects in Bangladesh, Portugal and Africa. Other expected benifits are: better living conditions (safety, economy) for the local people, more room in a densely populated contry (Bangladesh, the Netherlands), a better infra-structure of the area, changes of the social structure (land tenure, co-operatives) as in Bangladesh and Portugal.

Pilot areas, such as being developed in Bangladesh, are expected to yield experience with certain techniques to be used in the future development of the whole project and they are meant to be examples for a larger area.

An exception are the deep polders around Rotterdam to be filled in order to dispose of the great quantities of (partly polluted) dredged material from the harbours.

4 Geology and soils

Because land improvement is a main objective of the construction of a polder, the geology of the area and the properties of the soils are of great interest. The latter should be "suitable or highly suitable" in order to make projects, as designed in Bangladesh, Africa and Portugal, feasible.
Control of water level requires a relatively flat area and the availability of water. These requirements point to recent coastal plains and alluvial plains along rivers and lead away from mountains and deserts. From the discussed areas the ones in Bangladesh, Taiwan, Portugal and the Netherlands are situated along coasts and estuaries while the polders in Nigeria and Kenya are projected in flood plains of rivers.
Also in view of the water control, the vertical movements of the soil surface are of mayor importance. The relative rise of the sea level along the coast of the Netherlands, caused by a eustatic rise of the mean sea level (1 mm/year), a tectonic subsidence and compaction of the subsoil (1 mm/year), compaction of (local) recent sediments and various types of erosion of the surface, has mounted up to almost half the tidal range since the Dutch started building embankments. Probably the same occurs

in Bangladesh. Artificial subsidence, caused by the mining of natural gas and ground water add to the problems in the Netherlands and are the main subject of the paper about Taiwan.

The complex process of deposition and the subsequent soil formation generally lead to a very complicated soil map. The one of the Lezíria Grande in Portugal is a good example.

The soils of the coastal, lagoonal and estuarine areas of Bangladesh, Taiwan, Portugal and the Netherlands are generally described as clays, sands and some peat. The salinity of the soils is one of the problems to be solved by their empoldering. The soils are more or less calcareous depending on their formation. Older marine non-calcareous soils tend to develop into acid sulphate soils (cat clay).

The soils in the projects in Nigeria and Kenya are alluvial and aeolian deposits of clays and sands. Some of the terrace soils in Kenya are saline.

5 Land use

In all cases agriculture is the main use of the land. Details depend on location, climate and soil conditions, a brief review shows the great variety.

- Bangladesh: 60% is under cultivation with crops as rice, betelnut, jute, fruit, vegetables, condiments, pulses, sugarcane, oil seeds, tobacco and sesame; the rest is waste land, forestry, shrimps and salt production.
- Taiwan: not specified except fish farming.
- Kenya: mechanised rice production.
- Nigeria: sorghum, millet, cow peas, maize, ground nuts, wheat, cotton, vegetables and rice.
- Portugal: presently 50% fodder and pasture; the rest wheat, other cereals, tomatos, melon, etc.; the production of irrigated rice will be promoted.
- The Netherlands: pasture land, arable land, horticulture and fruit.

Generally some of the land is used for the infra-structure such as roads, canals, towns, industry, etc. Specially mentioned are recreation, natural reserves and the dumping of dredge spoil.

6 Hydrology and water management

The purpose of water management in a polder is to influence the local hydrologic phenomena in a favourable way. Briefly, the following means are available (or not):

- precipitation, evaporation and seepage within the polder can hardly be influenced;
- supply from outside can be controlled within the limits of the source (rivers, ground water);
- drainage to the outside depends on external conditions, and
- the storage in the polder (soil and open water) is given with the design.

Irrigation and drainage can be aided by technical means. They are the main instruments of the management. Irrigation is needed when the storage is insufficient to fill the gap between evaporation and precipitation (and seepage) during a dry period and drainage should remove an excess; both within a reasonable time. Such measures are meant to safeguard a crop or even to allow for an extra crop.

With these observations in mind, and in vieuw of the great variety in climate and land use, it is no wonder that the polders described in the papers show great differences in the water management. From the three elements - flood protection, drainage and irrigation - the first two appear in all areas under consideration.

River floods occur in the project areas in Nigeria (once a year) and Kenya (twice a year). High tides and storm surges are the main problem in Taiwan and the Netherlands. Both are met with in Bangladesh and Portugal. In all cases embankments are expected to protect the polders against floods of which the recurrence period varies between 20 years (Bangladesh) and 10.000 years (the Netherlands).

Most of the described polder areas are drained by gravity flow into the river or (at low tide) into tidal water. In the Nigerian case a special buffer, in the lower part of the polder provides storage capacity to facilitate a proper drainage to the river and to a lower flood plain; avoiding a pumping station. Such stations are indispensable in the very deep polders in the Netherlands and in the subsided area on Taiwan. They are considered in the amelioration scheme for the Lezíria Grande in Portugal.

Irrigation is not very common in the Netherlands with an evenly distributed precipitation, relatively little evaporation and a large storage capacity of most soils. In Bangladesh, where 90% of the annual rain falls in the monsoon from mid May to mid October irrigation is applied in some areas for the flushing of salt. In all other schemes, irrigation is an important aspect.

- On Taiwan, especially the fish ponds need vast quantities of water; also outside the rainy season which lasts from July to October only. The use of ground water for this purpose caused a shortage and severe subsidence of the area.
- In Kenya, the two wet seasons around April and December are too weak and need assistance by irrigation to facilitate the growth of two crops. Water can be taken from the Tana River.
- In Nigeria, the precipitation of 700 mm in concentrated squalls from August to October must be supplemented by irrigation from the Hadejia River in which water is retained by a series of reservoirs upstream from the project.
- In Portugal, the period of low precipitation and high evaporation during the summer will be bridged by irrigation from the Tagus river. This will facilitate the growth of rice. Pumping stations will bring the water into and through the northern half of the polder.

Salt, which poses problems in Bangladesh, Taiwan, Kenya (only locally), Portugal and the Netherlands, is generally expected to be combated via the drainage of excess rain water during the wet seasons.

A special feature of the Land Reclamation Project in Bangladesh are large ponds to be used for the storage of drinking water for villages. They will be filled by wind mills.

7 Environmental aspects

The reclamation of land, by its nature, changes the hydrology (surface and underground), the flora and the fauna within and probably also outside the area. Relatively little attention is paid to this aspect in the papers.

An exception is the paper of Groenewegen which, however, deals more with the environmental problems of the disposal of heavily polluted dredged material than with the effects of a polder. It discusses the paths and the effects of a multitude of contaminants in the soil and in the ground water within and outside the dumps. Various effects on water quality, flora, fauna and structures were studied.

8 Feasibility; economic and social

The economic feasibility is briefly discussed by a few of the authors. The very large (14,000 km^2, 86 polders) project in Bangladesh caps everything with an estimated cost of about US $ 0.25 billion. Benefit cost ratios of 2.35/1 and 3.88/1 are mentioned for specific parts of the the project. For the Tana River project (100 km^2, 3 polders) the cost per net ha is estimated at US $ 6,670 with running costs at US $ 970 per annum. Various alternatives lead to internal rates of return of 10.5% to 13.8%. The final evaluation (on farm level and on the national level) of the Lezíria Grande project in Portugal encompassed four reclamation alternatives and three farm structure alternatives. The adopted plan is expected to have an internal rate of return of 8%.

The social aspects of the projects appear in some more papers. Structures and objectives vary greatly.

- In Bangladesh the system of (absentee) landlords is proposed to shift to small land-ownership with an organisation of farmers in co-operatives. Also other changes in the social structure of villages and of the whole area are expected to result from the scheme.
- In Portugal the ownership of the project area is in the hand of the "Companhia das Lezírias" which also is a large agricultural company.

It is proposed to maintain the present structure but to promote the settlement of small farmers on plots of 12 to 100 ha. depending on the type of crop.

- In the Netherlands much of the old land was empoldered and managed by associations of landowners. The empolderings of lake bottoms were private enterprises under charter from the Government. The Zuiderzee-polders were constructed and reclained by the Government and for the greater part rented in parcels of 12 to 60 ha to farmers.
- In Kenya the three polders in the Tana River project will be owned and run as a state enterprise.

9 Design, areal planning and details

The areal planning is a well considered composition of all elements constituting a polder such as the drainage system, the farm plots, the irrigation system, roads, villages, etc.; all taking into account the natural conditions. Technical skills have greatly improved in the course of history; just to mention the Archimedean screw, the wind mill, various pumps, modern power sources, automotive transport, fertilizers and modern farming equipment. These developments are reflected in the areal planning of the successive polders in the Netherlands (de Bakker and Kooistra) as well as in the amelioration schemes for the polders in Bangladesh and Portugal. For the latter case, the author gives some details of the alternative drainage and irrigation schemes. Tertiary units of 30-40 ha. with 25 to 30 farming families, living in a typical circular village, are contemplated in a pilot polder in Bangladesh.

The technical design of the projects is sparsely mentioned in the papers. The most important aspect is the flood protection. The project in Bangladesh provides for 4050 km of bunds of three types viz. sea dikes, river dikes and marginal dikes. Each has its own design based upon the hydraulic conditions on the coast, in the estuaries and along lesser canals, and to be constructed from locally available materials. In the Tana River project (Kenya), the flood embankments are combined with a main drain; detials (also of a main canal) are given in the paper.

Drainage sluices of a special type were designed in Bangladesh; the number of vents (1,5 x 1,8 m^2 each) to be adapted to the local conditions. The use of bamboo field drains is mentioned.

A special case is the description of the construction of dredged material dumps around Rotterdam: The deposition in settling basins, the stimulation of the ripening process and the drainage of the water from the transportation of the sediments, from the compaction process and from normal precipitation.

10 Management and operation

Some aspects of the general management have already been mentioned as points of social development. The management and operation of the drainage and irrigation systems are often in the hands of public bodies in which the farmers have a say. In Bangladesh a polder committee (consisting of representatives of the project, the co-operatives and the agricultural department) will oversee the main system assisted by sub committees for the sluices and local canals as well as for the water control in the tertiary units. In Kenya the estate management authority will be responsible for everything. On Taiwan, a Provincial Water Conservancy Bureau maintains the drainage and irrigation systems as well as the sea-wall. The same aspects are looked after by the "Associação de Defesa" in the Lezíria Grande in Portugal. In the Netherlands, the water management and the flood protection is in the hands of water boards in which the committee is chosen by the landowners and which operate under supervision and co-ordination of provincial authorities.

SUB-THEME: GENERAL DESCRIPTION OF POLDER PROJECTS

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1 Introduction

The eleven papers describe general features of polders in areas as widely separated as Canada and Indonesia, for objectives as diverse as the development of prime agricultural land (U.K.) to the flood protection of densely populated urban areas in South East Asia.
In essence, polders aim to isolate areas of land hydrologically from their surroundings whilst controlling the hydrological processes within, to enable the desired human activity to proceed. They are usually situated on low lying lands adjacent to a major element of the regional open water system, i.e. the sea and/or a river estuary where the construction of dykes lessens the incidence of flooding.
Soils in lands bordering such areas are often highly fertile, comprising the products of erosion carried down from higher lands. Their evenness, fertility and ease of access make them highly attractive for development either for agriculture or urban development, the two competing uses not always in harmony.
In estuaries, progressive raising of marsh levels by deposition creates conditions well suited to small step by step impoldering and their continued successful development is usually assured by the presence of a firm existing agricultural foundation. Elsewhere, large new polders are developed mainly by the state either to extend existing agricultural strengths as in Spain or to create new strengths as in Egypt.
The papers reveal that urban and agricultural polder developments

create conflicts concerning the desirable degree of control to be exerted on the external and internal hydrology. Cities near or within polders provide a ready market for produce whilst creating problems of pollution and waste disposal. They also tend to draw people away from the land to the urban environment. The papers also reveal that impoldering involves major changes in the natural ecology of areas and increasing concern about the preservation of natural habitats is making it increasingly difficult to continue to create further polders in Europe purely for agricultural development.

The papers cover a number of interesting problems and for reporting, have been grouped around linking themes. The first group is a very general description of four polders. The second group describes polders within peat lands whilst the third group concerns polders mainly within developing countries. A further challenging paper (Kafue Flats) questions the philosophy behind the large scale introduction of what are seen to be fairly sophisticated polder systems into developing countries.

The final group of papers deal with a polder specifically established to assist in a population relocation programme whilst two deal with most unusual and interesting technical problems. The first of these deals with the problems occurring in a polder subject to large scale differential subsidence and lying within an earthquake prone area (Venezuela). The second and final paper explains how the problems of a densely populated polder area in Jakarta involving water management and waste disposal were overcome.

2 Papers describing general details of polders

2.1 Reclamation of land on the Eastern Coast of England

by P.D. Cook

The paper describes the reclamation of prime agricultural land from the marshes bordering the shores of the Wash, a broad and shallow estuary in Eastern England. The level of the seaward marsh progressively rises due to the deposition of sediments accelerated by the marshes vegetative cover. The area is reclaimed by constructing a dyke as far out into the marsh as possible. Later, the prime silt soils are under-drained by pipe drains.

The reclamation is privately financed by the farmers bordering the reclamation and for this reason the minimum width of 'economic' reclamation tends to be about 400 m. The dyke is constructed from the locally available silty material and is protected from wave action firstly by preserving sufficient protective marsh to seaward and secondly, by covering the dyke by a thick grass sward. On a recent reclamation the failure to establish a sward rapidly and unusually high tide levels (1978), resulted in damage to the dyke costing approximately 50% of its construction cost in 1977. In recent years, pressures to maintain the marshes in their natural state as a sanctuary for wildlife are making it increasingly difficult to consider future reclamation.

2.2 Dykelands (Polders) along the Bay of Fundy, Canada
by C. Desplanque

In the maritime provinces of Canada, large areas of grassland, in particular bordering the Bay of Fundy, were endiked by French settlers in the sixteenth century. Today, much of this area lies below the existing seaward marsh which has, like the Wash areas of U.K., continued to rise due to deposition of sediments. This suggests that the endiked areas could be progressively extended as in the Wash. The land is surface drained by a system of cambered beds leading to shallow drainage channels, this method being chosen because of the high rainfall intensity in autumn (20 $cm.day^{-1}$) and because of ice formation which blocks open channels preventing groundwater drainage by pipes discharging into open collectors. Since the 1950's, dykes have been raised in certain areas whilst tidal sluices have been installed in others to restrict the flow of water and hence control the rise in tide level thus reducing the need to raise the dykes. It would be of interest to learn how the decision to opt for the sluice or the raising of the dykes was made and to know whether the installation of tidal sluices has increased problems due to deposition elsewhere in the Bay.

2.3 Polders of the Vistula River
by P.J. Kowalik

Large areas of land bordering the Vistula River have been reclaimed over the centuries by impoldering. In recent years, the tendancy has been to amalgamate areas and even to install intermediate pumping stations thus creating polders within polders. The close proximity of urban areas (Gdansk) has provided a ready market for produce, though this advantage has been countered by the drift of population from the land to the town and by the environmental impact of the town causing water and air pollution and problems of waste disposal.
In Figure 2, a detailed graph is presented relating predicted grassland yield to water table depth and nitrogen fertilizer. It would be helpful to learn whether these predictions have been tested in the field and how the information is used in practise.

2.4 The soils and water table properties of the polder area "Castillo De Doña Blanca"
by V. Gomez-Miguel et al

The fourth paper describes soils and climatological data for a polder development bordering the Guadalete River near Cadiz in Spain. The area is to be irrigated using low to moderately saline river water. Two minor points require elaboration.
Firstly, Figure 2 depicts an annual water balance showing periods of excess and water deficit. The excess which it is stated gives occasional efficient leaching of the soil, presumably depends upon the deficit being made good by irrigation. The reporter would like this to be confirmed, to know whether a parallel salt balance has been developed, and how salinity is to be controlled within the polder.
Secondly, the significance of the comment "the level of the river bed is more than two metres in the dam called La Corta, 5 Km upstream from the E limit of the polder" is not clear.

3 Paper involving the reclamation of peat soils

3.1 Peatland polders of North-West Germany
by R. Eggelsmann

This paper is broadly a restatement of the considerable body of knowledge gained in the development of peat lands in Lower Saxony. The restatement of existing knowledge on the shrinkage and oxidation of peat is justified and timely in view of the potential developments in such soils in the tropics where these processes are accelerated.

3.2 Drainage of peat soils in the polder of Pega-Olivar Alicante, Spain
by I.G. Sánchez and J. Martínez Beltrán

This paper is a good example of the extent to which sound hydrophysical survey (Figures 2, 3, 4 and 5) combined with a stepwise approach to reclamation and drainage can lead to sound drainage measures. The soil in the area is characterised by a clay layer 0.5 m deep underlain by layers of peat (up to 3.0 m thickness) sand and clay. Trials with subsurface drains have indicated a preference for drain depths up to 1.8 m deep.

In view of the first paper, it seems that the peat will shrink and oxidise and so some elaboration on this possibility and its effects on the project would be relevant.

In 1976, a socio-economic survey was undertaken. This indicated that benefits were virtually double the costs. The reporter would like this evaluation to be elaborated, particularly bearing the following factors in mind. Does this evaluation include all the costs or just some and to which group of participants in the polder development do the figures relate, the farmers, the development authority, etc.? Also, to what extent have cost evaluations and changes since 1976 altered this projection?

3.3 Reclaiming Muturajawela, Sri Lanka
by S.H.C. de Silva

This paper deals with the possibilities for reclaiming Muturajawela swamp temptingly close to Colombo, the capital of Sri Lanka.
This 2400 ha swamp runs parallel to the coast for 10 Km immediately North of Colombo. The swamp consists of aquatic vegetation overlying substantial depths of peat (3-10 m) overlying sand. The swamps surface lies below mean sea level whilst its perimeter is ringed by canals and roads. Up to the present day, the sheer costs have prevented reclamation. The possibilities investigated are:

1) sand pumping to raise the land above mean sea level
2) replacement of peat by sand
3) impoldering and lowering of the water table

The high development cost mitigates against its sole use for agriculture and so urban development seems to be the most likely justification for any real developments. It would be of interest to know what uses the mined peat, obtained as part of the second proposal would have been put to and whether a time scale for shrinkage and oxidation had been included in the third proposal. Also, it would be helpful if the authors could elaborate on the strength of the arguments in favour of keeping the swamp in its present form.

4 Kafue Flats, Zambia : Flood plain planning on a crossroads
by W.T. de Groot and M. Marchand

This stimulating paper concerns an environmental study of developments in the Kafue River flood plain near Lusaka, capital of Zambia. In the natural state, the plain is shallowly flooded for several months annually. The flooded area supports a rare Antelope, the Lek, whose ability to graze in the flooded lands makes it uniquely able to exploit their grazing potential whilst the reduction of herbage that would otherwise decay, enhances and supports the inundated areas abundant fishlife. The area also supports a traditional human society dependent upon cattle grazing the drylands, fishing and small scale dryland

agriculture.
In recent years, the Kafue River has been regulated by means of dams for hydro-power generation resulting in considerably reduced areas of annual flooding and an increase in the permanently inundated areas. Cattle now have access to grasslands throughout the year, whilst the areas suitable for Lek have been severly curtailed.
Within Kafue Flats up to 70,000 ha of land could be impoldered and developed. However, the main contention of the paper is that it is in the nature of polders to strengthen the arm of the central organising body, in this case the State, and at least in a developing country, weaken the existing pattern of life. This phenomenon is ambiguously described as the centre-periphery complex.
The paper argues that polders should develop organically, that is to say, in small units based upon existing agricultural strengths as happened traditionally in the Netherlands and still occurs in the Wash area of the U.K.
The paper also points out that economic analysis can be targeted to produce answers ranging from the optimistic highly profitable to a pessimistic annual loss. It is in the nature of development to feel persuaded to the most optimistic forecasts although in the reporter's view, realistic ends to the economic spectrum should be identified before final decisions are made. Furthermore, in viewing Kafue Flats, one might question the value of traditional accounting to such a complex situation. How is the cost of the existing situation and social order to be deduced and can accounting allow for the reality that many large projects in developing countries fail to realise the aspirations of Northern hemisphere planners? Perhaps the time has come to invest finance wisely though not necessarily economically in developments that will build strengths without disrupting the status quo; that will succeed albeit on a small scale where larger schems would fail.

5

The final three papers deal with impoldering as part of a transmigration programme (Egypt), with a polder on land that is differentially subsiding (Venezuela) and land which is subsiding rather less but entails impoldering a densely populated urban area (Jakarta)

5.1 Polder areas of Northern localities of the Nile Delta, Egypt
by M. Sh Diab

This large polder lies right at the Northern base of the Nile Delta in an area of predominantly heavy clay soils of low hydraulic conductivity. The elevation of the land is at approximately -0.6 m below mean sea level, the groundwateris at shallow depth, 1-1.5 m below ground level and it and the overlying soil are highly saline. Though not stated, it would seem that these levels are indicative of inseepage via the deep sandy aquifer. The area which is required for resettlement of peoples from densely populated Southern areas is to be irrigated and drained. The planned drainage relies on parallel open ditches some 25 m apart at 1 m depth.
The reporter would like further elaboration on the potential for reclaiming and controlling salinity in these soils. Also, what incentives and plans have been made to attract the migrants to stay and work what are evidently difficult soils in what to them, must be an alien environment.

5.2 Polders and Dykes of the Bolivar Coast, Venezuela
by J. Abi-Saab Soto et al

In Venezuela oil extraction from beneath Lake Maracaibo and its surrounding low lying polder areas has caused progressive subsidence, up to 4.5 m in certain areas.
The subsidence decreases with distance from the extraction zones and creates severe cracking of the land at the points of greatest curvature, i.e. the edges of the areas of subsidence. The cracking clearly poses hazards of piping and failure in the impoldering dykes whilst the settlement causes problems for any rigid structure, i.e pipelines, passing through the dyke. In addition, the area lies within

an earthquake zone so that the accelerations and consequent stresses resulting from earthquakes pose major stability hazards.
The dykes have been progressively increased in height as the land level, though not the lake, has subsided. The increasing depth of water on the lake side of the dyke has sharpened the risks of wave attack whilst the original use of rigid concrete revetments against wave attack has been discontinued in favour of flexible rip-rap which is more able to adjust to differential settlements. Nowadays, pipelines and jetties have to pass freely over the dykes to avoid settlement problems within the dyke. An additional problem is that the drainage within the polder continues to change as levels change differentially. A finite element analysis has been developed to identify the probable sequence of stress patterns in the dykes during a design earthquake. Consideration of the effect of these cyclic stresses on undrained samples in a triaxial test apparatus has suggested that the dyke is prone to liquefaction in the sand layers at the upstream and downstream toes of the dykes.
Further elaboration of studies underway into the 'field significance' of these findings would be of interest. Also, it would be of interest to find out how and by whom, the costs of the remedial works for the polders are met. One point of detail requiring further explanation concerns the comment that the soil is unlikely to crack, i.e. in the dykes, if the capillary zone is less than 3 m thick. The reporter was unsure whether this referred to the depth of the water table within the dykes in general, or the depth of that part of the dyke above lake level.

5.3 The "Pluit" urban polder
by J.H. Kop _et al_

The final paper deals in a most comprehensive way with the design and operation of the "Pluit Urban Polder" in Jakarta, 2760 ha of low lying land containing a population of 1.5 million people. The acute problems posed by the area include high rainfall, a largely impervious surface area, the need to also use open channels to dispose of foul water containing large quantities of garbage and debris.

The main outfall drain leading to a pump station is now refrehsed daily. Automatic screens at the station remove the worst debris whilst storms and floods are handled by a combination of external diversion canals and, within, pumps assisted by temporary retention reservoirs. The system depends upon sophisticated operation and maintenance and it would be of general interest for the authors to elaborate on the organisational framework established to implement these measures. Also, it would be of interest to know what provision has been made for stand-by pump or generator capacity.

THEME B 1. LAND AND WATER MANAGEMENT

SUB-THEME: WATER MANAGEMENT SYSTEMS AND DESIGN CRITERIA

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Abstract

The water management of polder areas is essentially a multidisciplinary activity, involving among others elements of civil engineering, hydrology, agriculture and economics. Systems analysis provides a convenient framework within which to consider alternative strategies for providing drainage and irrigation systems that are optimal according to a specified design criterion. Such criteria may be expressed in terms of the costs and benefits of the scheme, but invariably the economic factors are implicit rather than explicit owing to the use of objective functions such as the maximisation of crop yields or the minimisation of irrigation water supplies. The economic performance of the scheme must also be considered at farm level as well as project level. As the power of small micro-computer systems continues to increase, the use of management techniques based upon systems analysis is likely to become more prevalent.

1 Introduction

In what is perhaps the most general definition of the term, a polder may be considered as a well-delineated areal unit whose resources of land and water may be managed independently of other adjacent units. The size and complexity of a polder may vary widely, from the simplicity of a small, bunded rice paddy to the sophistication and areal extent of the Ijsselmeer polders. Yet despite this diversity, their management invokes common principles. As with many facets of water resources analysis, polder management has benefited from, and could take further advantage of, the flexibility and potential afforded by the digital computer in its various forms. The majority of the papers which form the subject of this Report provide confirmation of this trend, with their reliance on mathematical modelling and their emphasis, implicitly or explicitly, on the search for some optimal solution to a design problem.

An important consequence of the well-defined physical nature of a polder is the extent to which the hydrological inputs and outputs can be either measured, controlled or estimated to an acceptable degree of accuracy. However, in terms of land and water management, the hydrology of the polder is only one pertinent aspect of its behaviour. The response of a given crop to soil moisture levels (or standing water levels in the case of lowland rice), particularly with regard to the reductions in yield that accrue from failure to meet the optimum requirements at different stages of growth, is equally if not more important in economic terms. The subsequent analysis of costs and benefits is another essential ingredient of resource management and serves to emphasise the interdisciplinary nature of the exercise.

As with many similar resource allocation problems, polder management is amenable to a systems analysis approach. This theme is developed in Section 2, along with a generalised representation of a polder water management system. The latter provides a framework within which to review the eleven papers that form the subject of this Report in Section 3. The Report concludes in Section 4 with some general observations on the role of computers in the water management of polder areas

2 Systems approach to polder water management

In its broadest sense, a system is a set of components that collectively transform an input into an output. The system may vary in its complexity, and both inputs and outputs may assume a wide variety of forms, depending upon the problem under study. In practical terms, the components of the system and their inter-relationships are described by a series of mathematical and logical statements which are readily translated into a computer-compatible form. The analysis of a system is generally carried out either by simulation or optimisation. The former approach is particularly relevant where a high level of detail on system behaviour is required. A simulation model provides the time series of outputs produced by the system operating on a given series of inputs according to a predetermined strategy. This approach tends to place large demands on computer core storage, and the location of an optimum operating policy has to be undertaken on a trial-and-error basis, which can prove both expensive and time-consuming and carries no guarantee of absolute success. In contrast, optimisation is highly appropriate for determining a strategy that is the "best" according to some specified criterion. This approach may also be demanding on core storage, but less so than simulation. In addition, care must be taken in defining the system in order to ensure that the problem is amenable to treatment by a standard solution procedure. For example, where all relationships describing the system are linear, the technique of linear programming may be employed.

A schematic representation of a polder water management system is presented in Figure 1. The core of the system may be seen to consist of two mathematical models, one of which describes the hydrological and hydraulic component and the other the economic component. In its simplest form, the hydrological model may consist of a single equation which accounts for all inputs and outputs during successive time increments. This water balance may be described in compatible units by an equation of the form:

$$H(n+1) = H(n) + (RF+IRR) - (ET+INF+DR) \qquad (1)$$

where

- H (n) = soil moisture (or water) level at the end of the nth time increment
- RF = precipitation
- IRR = amount of irrigation
- ET = evaporation

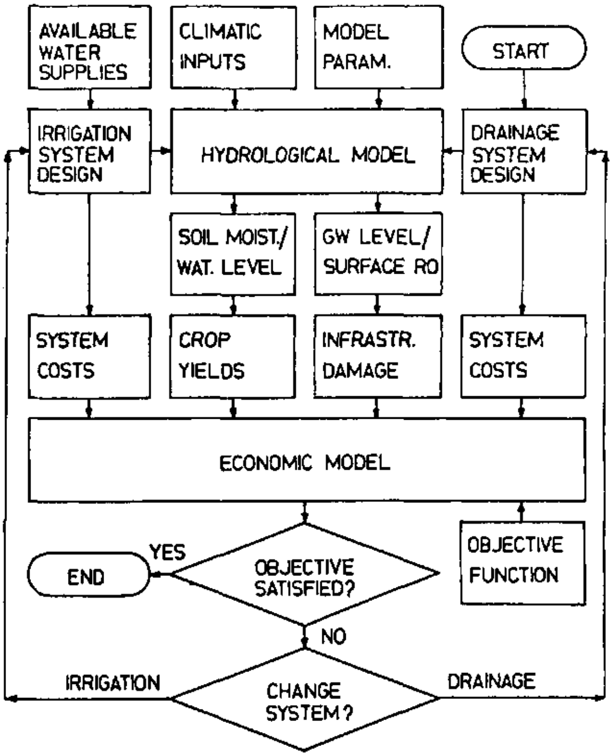

Figure 1. Schematic representation of a polder water management system

INF = seepage loss

DR = amount of drainage

Of these variables, RF and ET may be derived from climatological observations, but IRR and DR are design variables and INF must either be chosen on the basis of experience or determined by experiment.

Whereas equation (1) may be adequate to describe the water balance of a precisely delineated cropped area, such as a rice paddy, this model is obviously inadequate to deal with more complex problems. For example, in order to describe the behaviour of the drainage system serving several such land parcels, account must be taken of both saturated and unsaturated groundwater flow as well as free surface flows in the major arteries of the channel network. A distributed, layered conceptual catchment model would then provide a more appropriate representation of this system component.
Having produced a time series of soil moisture or water levels corres-

ponding to a given drainage modulus or configuration of drainage system, these data become the inputs to the economic model forming the second major system component. The moisture status throughout the growing season is a principal determinant of crop yield. Similarly, if supplementary information is available on groundwater and surface water levels, estimates can also be made of any infrastructure damage resulting from periods of excessive flows. These benefits and costs may be combined with the installation and maintenance costs of the drainage system and (if provided) the irrigation system, and discounted to a common economic basis.

The adequacy of the outcome of these computations is dependent upon the form of the criterion of optimality, or objective function, under which the study is being performed. The possible forms of objective function are many and various, but the most commonly applied would appear to be minimum annual costs or maximum difference between benefits and costs. Frequently, these criteria are implicit rather than explicit. The design variables may be continually updated until the objective function is satisfied.

Having met the criterion of optimality, a further, but equally important, phase of the computation is entered in which the sensitivity of the outcome to the basic assumptions and design variables can be tested. In its simplest form, such sensitivity tests may consist of repeated application of the systems model with individual design variables set to different values with all other variables held constant. Such an exercise may often provide insight into the level of detail to which each system component needs to be represented. For example, the relative importance of the individual terms in equation (1) in relation to the magnitude of the crop yield may be evaluated in this manner. By drawing attention to such issues, the systems approach is able to isolate those aspects of a problem where additional information will yield the maximum dividend. In particular, crop water/ yield relationships, which form an important linkage between the hydrological and economic components of the system model, would appear to be a fruitful area for further investigation.

3 Review of papers

The group of papers under review deal with a range of diverse problems, but all are concerned with some aspect of design criteria for polder water management systems. The contributions may be broadly divided into two groups, the first of which addresses problems of rice cultivation and the second the design of polder drainage systems.
Three of the authors treat the problem of rice paddy drainage on the basis of the model described by equation (1). Whereas both Buijs and Dahmen rely on a computer-aided recursive solution procedure, Garzon has opted for a statistical approach in which the change in surface storage (equivalent to a combined term H(n+1)-H(n)+INF) is used as the independent variable in a series of linear regression analyses for groundwater table elevation and groundwater flow. The comparatively poor explained variances obtained for these equations, particularly in comparison with those for groundwater table elevation in terms of lagged rainfalls and numbers of days since the opening or closing of the irrigation system, raises the question as to whether a more physically-based approach, taking into account the water movement in the upper soil horizons, would not have produced a more reliable model.

According to Buijs, the cultivation of rice in Suriname is based upon a strict water management schedule that apparently takes little account of growing season rainfall and therefore results in a large drainage requirement. The return flows are large compared with the discharges in the rivers to which they drain, but can be reused, subject to certain water quality considerations. This "recycling" assists in maximising the use of the available water supplies and bringing the largest possible area into cultivation.
The paper by Dahmen, in treating the more general problem of determining the drainage modulus which minimises the variations in crop yields, is notable for its emphasis on the importance of economic considerations, both at the farm level as well as project and sub-project levels. The procedure which the author outlines is readily identifiable in the general framework of Figure 1. In addition, a timely warning is sounded on the need to assess the reliability of the available climatological information prior to undertaking any analysis.

Rice production is also the topic discussed by Wiersinga and Sudibjo, who describe the reclamation of a tidal swamp area in Indonesia for the cultivation of rainfed crops. This project gave rise to a series of design objectives, including the drainage of excess water and noxious compounds; the maintenance of adequate water and soil moisture levels in the croplands; protection against saline flooding; and the provision of access and effective transportation within the developed area. Those authors describe the structural measures that were devised to meet these objectives and outline the management practices that are to be followed within the developed area. The latter are heavily reliant on the operation of structures with flap gates and stoplogs, which are notoriously subject to human error.

The second group of papers, which deal with various aspects of polder drainage, is notable for the wide spectrum of design problems that is discussed. In some cases, the design criteria are largely qualitative. For example, Hebbink provides a detailed discussion of the different types of subsurface drainage systems that have been installed in the Flevoland polders, and elaborates on their advantages and disadvantages. Current advice on preferred systems would appear to place greater emphasis on avoidance of disruption than on minimising installation and maintenance costs.

A more quantitative approach to polder drainage design is provided by Dorai. Again, the crop is rice, and the design criterion for the drainage system is the minimisation of periods of inundation. This objective is achieved by varying the dimensions of the main outfall sluice, subject to downstream tidal variations. In minimising the duration of submergence of the rice plants, the economic component of the systems model (Figure 1) is implicit rather than explicit.

A similar implicit criterion is evident in the work of Kuroda and Cho. Those authors describe the management problems of an irrigation scheme in a low-lying delta area in which creeks are used as buffer storages which even out the irrigation water demands placed on the main canal system. Dynamic programming is employed to optimise the time series of canal water supplies and creek water levels in order to minimise the irrigation water intake.

An automatic optimisation procedure is also used by Schultz to determine the values of five design variables that together characterise a polder drainage system. This contribution provides a clear example of the application of the systems approach. The hydrological and economic components are comprehensively described, and the objective function, which involves the minimisation of annual costs is explicit. Furthermore, the author presents in his Figure 4 the results of a sensitivity analysis which reveals the importance of avoiding the underestimation of subsurface drain depth and water level.

Each of the above-mentioned contributions relates to polder areas having a single agricultural land use. The reminder provided by van de Ven and Ven of the contrasts in storm runoff response that exist between rural and urban areas is therefore apposite. The effects of the enhanced peak discharges from the urban areas are mitigated by the effective use of the associated urban canal systems as detention storages. Determination of the dimensions of the latter, including the crest width of the outfall weir and the surface area of the canal, also constitutes an optimisation problem in which the objective function involves the limitation of the magnitude of the flood lift to that associated with a specified frequency of occurrence.
By virtue of their physical characteristics, polder areas are invariably located in low-lying areas adjacent to a coastline. In these circumstances, the wind fetch from certain points of the compass may be considerable. The elongated open water bodies that comprise the polder drainage system may therefore be subjected to wind set-up. This problem is treated comprehensively by Bouwknegt and Kroon. Whereas the latter authors employ a computational hydraulic model based upon the Saint Venant equations, Tanaka and Shikasho treat the problem of fore-casting the depth of unsteady open channel flow by an approximate method involving the extended Kalman filter.

4 Concluding remarks

Several of the papers reviewed in Section 3 above have described analytical approaches to the solution of a water management problem.

These contributions have demonstrated a variety of techniques, ranging from sequential solutions to the water balance equation to automatic optimisation techniques and numerical solutions to the Saint Venant equations. While much can be accomplished with hand-held programmable calculators, as aptly illustrated by Dahmen, the demands on core storage made by the more sophisticated modelling procedures inevitably involve the use of a larger computer. Unfortunately, access to the larger mini and mainframe computers is far more restricted in the developing countries than in the developed parts of the world. In these circumstances, more consideration should perhaps be given to the transferability of techniques. The authors may care to reflect on how dependent their approaches were on the availability of a particular type and size of computer.

In terms of an appropriate level of computing at which to disseminate analytical techniques to advantage, the different types of micro-computer that have become available within the last 3-5 years would appear to have much to offer. Many makes are now capable of handling mathematical programming problems with 40-50 variables and as many constraints (see Annesley et al, 1982), and several of the problems considered in the papers under discussion would fall within their scope. As their capital cost continues to decrease as their size in terms of random access memory increases, micro-computers would appear to provide a highly versatile tool for future water managers.

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SUB-THEME: WATER MANAGEMENT SYSTEMS AND DESIGN CRITERIA (CONTINUED)

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Abstract

The paper summarizes 11 submitted articles dealing with traditional and new approaches in the design and watermanagement procedures of polders and pumped catchments. The review goes from the classical agrohydrological experiments, resulting into drainage criteria and watermanagement concepts, through the definition of design levels and pumping capacities based on the statistical processing of hydrological data collected over a long period of years. Both approaches assume in their design steady flow conditions. Often the criteria as the design procedure are modified to engineer's experience and/or to the failure of existing systems. According to the increasing need of reducing the investment and operation costs of water control works for the agricultural improvement of low-lying parts of river basins in deltaic and coastal areas, new techniques have been introduced for the refinement of design and management. To those belongs the technique of modelling which allows to simulate the water level in existing or designed arterial drain networks of pumped catchments in function of a rain event with given characteristics. This powerful approach, based on the modelling of the unsteady flow conditions in polders permits to examine alternative design concepts, management and maintenace schedules in terms of level control, quality control of the boezem waters and cost estimates. According to some of the reviewed papers, the general application of simulation models offer consi-

derable scope for the refinement of the design and maintenance policies of pumped and free drainage networks, reflecting into an optimization of the economic accounting of the engineering works needed.

1 Considerations of existing design procedures for in-field drainage systems

Low-lying parts of river basins, in deltaic and coastal areas are continuously or frequently subjected to waterlogging conditions, either by seepage, flooding or through the discharge of water from the surrounding uplands, limiting agricultural development of this areas. In addition salinized soils may be formed if the seepage or flood water is brackish in composition. Lowering of the groundwatertable may also be necessarily in irrigated agriculture in order to control the salt balance of the rootzone.

As generally accepted in engineering works the benefits of the engineering measures should be balanced against the costs of the water control works. Drainage and water control (dikes, canals, pumping stations, etc.) measures require rather high investment costs per ha, of which a relatively exact estimate can be made. However details of the benefits to be anticipated from flood control and drainage works are not that clear. The adverse effect of poor drainage, temporarily inundations, salinity, etc., on crop growth is complex, depending on the timing and the duration of the crop stress. Additionally, waterlogging may hamper soil tillage, transport of machines, leading to the detoriation of the structural conditions of the soil.

Rather few data are available of crop response on waterlogging. Increasing efforts have been made recently to express the benefit of drainage in increased land workability. From irrigation studies a large number of criteria have been forwarded of crop tolerance levels for salinity. Among the papers to review one paper (DONKOR) dealt with the experimental determination of the salinity-yield relationship of rice. The experiments were run in the coastal area of Suriname on clayey soils of marine origin, with very little percolation especially when in an unripened state. Leaching on these soils seems to be only adchieved through intensive drainage together with sprinkling irrigation. Peak yields

occured at salinity levels around 0.4 mmho (EC-values were measured on 1:5 soil water extracts, and converted to standard EC-values), a relatively decrease in rice yield occured over the EC range 0.4 - 1.15 mmhos, and at EC-values more than 1.15 mmhos, rice yield fell sharply. According to the author the salinity-yield relationship is influenced by other factors as type of land preparation and pH-level of the soil.
Until recently most of the field drainage experiments were run to establish field drainage criteria. A classical example of such a study is given by VIEIRA et al. The agrohydrological experiments were run on some experimental plots situated in Leziria Grande, an island of 13074 ha in the lower Tejo Valley, 25 km upstream from Lisbon. The soils of the area are mostly heavy, saline and alkali. Based on the results of a detailed investigation of the potential drainage area three experimental plots were installed in the Southern part of the Leziria Grande. The plots differing in composition, permeability and groundwater regime were surface drained with 60 cm deep ditches installed every 20 m; subsurface drained with corrugated PVC pipes, 5 cm in diameter, installed at an average depth of 1.20 m at a varying drain spacing of 10, 15 and 20 m. In addition half of the plots received a gypsum treatment in quantities varying from 10 to 40 ton per ha depending from the ESP-value. Gypsum was applied to verify its effect on the alkali condition, and indirectly on the internal drainage capacity of the soil. From rainfall, drain discharge, EC-values of drainage water and watertable level measurements following drainage criteria and design recommendations for the agricultural exploitation of the area were derived by the authors:

- Subsurface drainage controls the watertable better than surface drainage. Narrow drain spacings are more effective and gypsum applications favourises watertable control by improving soil structure through sodium replacement by calcium.
- The leaching of salts in surface drained plots was remarkable inferior to tile drained plots. Salt leaching seems not to be influenced by drain spacing and as could be expected gypsum effects positively on desalinization.
- A drain spacing of 20 m and drain depth of 1.20 m is recommended for the marine soils of Leziria Grande. The heavy and poorly drained fluvial soils needs a drain spacing of 30 m. For the fluvial soils with intermediate conditions a drain spacing of 60 m is recommended, while

the sandy and loamy soils with high elevation do not need drainage.

- The drain discharges derived are 2.5 $l.s^{-1}.ha^{-1}$ for the marine soils with surface drainage, 2.0 $l.s^{-1}.ha^{-1}$ for the marine soils with subsurface drainage and 1.0 $l.s^{-1}.ha^{-1}$ for the fluvial soils with subsurface drainage.

For the improvement of the drainage and salinity problems in the Leziria Grande future drainage works should consist of subsurface PVC drain pipes (which does not or slightly interfer with the existing irrigation network), concrete collectors and open secondary and main canals, served by pumping stations. Drain pipes should be installed at an average depth of 1.20 m, while the water level in open ditches and canals must be 1.50 m below ground level. The field drainage system should be complemented by land levelling and by gypsum application.
An analogous agrohydrological experiment was run in Jarikaba (Suriname) from 1966 to 1972 in order to derive the drainage criteria for banana plantations in the coastal plain. The conclusions of this research as reported by SOE AGNIE's paper are: a positive correlation between rooting and drainage depth; a greater effect in yield decrease with age with decreasing drainage depth, and an increase in optimum lifetime of the plantation with increasing drainage depth. The optimal field lay-out for heavy clay soils with a permeability between 1.5 and 2.0 $m.day^{-1}$ is a cambered bed system with six meter wide depths, with a groundwatertable level at 80 to 90 cm below surface in combination with a discharge capacity of 2.3 $l.s^{-1}.ha^{-1}$. Farm management treatments on the agrohydrological plots revealed that no soil tillage is allowed on those low-permeability, low-stability, young clayey, marine soils. Use of machinery is not permitted for the same reason of risk of unreversible compactation and physical degradation even for clearing the forest after empoldering, for the maintenance of the drainage system, as well as for the transport of fruits at harvest.
Having defined for a given region the drainage discharge criteria, the design watertable level, a variety of equations for predicting drain spacings, based on the soil hydraulic conductivity and geometry of the flow domain have been developed. The most widely used drain spacing equations are of the steady state type assuming equilibrium between drain discharge and design rainfall. However, even for circumstances, where drains are installed primarly to cope with winter rainfall, which

often is rarely uniform long enough to establish a steady state, drainage design is mostly based on the use of the steady state equations. The alternative use of transient equations has been explored by ARMSTRONG. But still the unsteady approach has not yet been developed to a procedure that can be used routinely. The limited application of transient equations is due to the costs of the investigatory work needed for scientific drainage design, the spatial variation in soil properties and cropping practices. Because of this, ARMSTRONG and others developed a rational drainage design procedure suited for the drainage of the English fenlands. Their approach is based on a design rainfall rate (taking into consideration climate, cropping and drainage type), on soil profile examination and experience. According to them the experience of advisors and contractors is not to be despised. In some cases the dogmatic insistence of close spacings could be wipped out through the application of the rational drainage design concept. For a field varying in soil composition they advice to make the design for the dominant soil type, and to modify it in relation to any included soil variation. As for example a dominantly peat soil would normally be drained at fairly wide spacings (in excess of 20 m), which may be decreased to say 15 or 10 m in the presence of clay layers.

The drainage design of the peat soils, as present in the fenlands of Eastern-England, should take into consideration specific problems as the lowering of the surface by shrinkage and oxidation of the organic matter when drained. As a consequence the drains tends to become shallower and risk to loose their grading. If the outfall cannot be deepened the soils have to be redrained periodically at successively greater depths, the pumping requirements to be increased and if after some time the underlaying clay will become exposed the drainage characteristics have to be adapted.

Beside peat wastage blocking of field drains by iron deposits and siltation can cause total failure of drainage schemes. In the U.K. siltation of drainage pipes seems according to ARMSTRONG not of national significance and can be circumvented by the use of pipe filters, while iron deposition seems to be a common fact in peat soils. Once it occurs, remedial works are paricularly difficult, and the only solution according to ARMSTRONG's paper seems to be a programme of repeated drainage until the store of iron is exhausted. In addition, the use of drain

lines to supply water to the plant in the summer months has recently been investigated. Technically it seems to be possible to maintain the watertable in the fenlands at a specified level by reversed drainage, but to be effective for agriculture the land should be levelled, which is not only expensive, but may also expose unripened subsoil material. Most of the problems encountered in draining the fenlands, however have not yet resulted into a firm set of recommended procedures. As for other areas, it is rather impossible to base the design to a large extent upon equations, either of steady or non-steady state. Local knowledge and skill, suggests ARMSTRONG, will always be essential for a proper dealing of the particular set of problems encountered locally.
Due to the traditional approach of poldering, rendering optimal conditions for habitation and agriculture, polder development often results into high technical requirements; high investment costs, high organizational requirements, low rate of implementation, social and environmental repercussions, incompatible with local economic, social and environmental conditions of the developing countries. HORST in his contribution advocates strongly that other development concepts generating a greater participation of peasants, resulting into a lower investment cost per ha, corresponding better with the traditional farming systems, causing less disturbance to the ecological equilibrium should be explored. Some possible alternatives that are worthwile to be considered are improved drainage only, improved drainage plus submersible dikes, complete diking without pumping and/or with low pumping capacity, the practice of horse shoe dikes, the introduction of floating rice or deep water rice in the flood period, etc. The effect of those alternatives on the possible length of the growing season is been illustrated graphically by HORST in his paper. It is self evident that the applicability of those alternative forms of water control will depend on land use, on the local topographical and hydrological situation.

2 Design considerations of pumping plants

Traditionally it is accepted that 6 to 13 $mm.day^{-1}$ should be discharged from polders. For the IJsellakepolders a general accepted starting point for the estimation of the pumping capacity was the demand that 40 mm of

rainfall during five consecutive days within the same period should be discharged. If the land is used for the production of high valued crops discharge rates are taken in some cases even equal to 18 $mm.day^{-1}$ (BERAN).
It would be preferable if the design of pumping stations could be based on the runoff behaviour of polders or pumped catchments similar in size, composition and land use. Slightly the collection of hydrological data becomes a matter of routine. In his paper DIJKSTRA is analysing the yearly total runoff volumes of the Wieringermeer and northeast-polder, collected during a large number of years. The pump capacities of the different polder sections analysed ranges from 8.4 to 17 $mm.day^{-1}$. The mean pumping capacity of the IJsellakepolders is close to 12 $mm.day^{-1}$. From the mean value of the total runoff during a year it could be concluded that the entire installed capacity of approximately 12 $mm.day^{-1}$ is operating appears to be 1440 hours during a year. From the analysis of long time series of recorded water levels it could be verified if the pumping capacity of 12 $mm.day^{-1}$ be on average sufficient to maintain the water level in the ditches within permissible limits. According to DIJKSTRA following conclusions could be drawn from the frequency of occurence of extreme water levels: the design assumption of the pumping station is or is not in accordance with the statistical distribution of the water rise; the effect of increase in pumping capacity on the diminish of extreme levels can be estimated, as well as the effect of increase of open water storage on the return period of certain levels.
While DIJKSTRA's study was devoted to large polder areas, BERAN tried to formulate flood frequency curves for smaller areas, 100 to 15000 ha large, situated in the fenlands of the U.K. His findings are based on the processing of daily discharge data collected on 15 pumped areas for at minimum 5 years. From the flood frequency curves, i.e. the relationship between a certain magnitude of runoff and its return period, the degree of utilization of the installed pumping capacities could be derived. As a result a 10 mm pump capacity seems to have a 20 year return period protection in the East Anglian fens but no more than a 5 year return period protection elsewhere. The current design standard of 12.5 mm, as imposed by pump technology, will provide even a 30 year protection at the East Anglian stations.
One of the pumped areas have been studied more intensively by BERAN in

order to establish the catchmant response to storm rainfall. Therefore water levels, rainfall and soil moisture status have been recorded simultaneously at several locations. The most notable feature of this research was the tendency for all points in the catchment a long the arterial drain to march together suggesting that the lag-time of the field drain response may be equated with the lag-time of the basin as a whole. The runoff coefficients from rainfall events so far studied range from 5 to 40 % and the variations seem to be related to the soil type of the catchment, the catchmant wetness, and the storm precipitation. The author suggests further that research should be continued to identify the factors controlling the runoff coefficient. Confirmatory studies are also needed on the slope of flood frequency relationships, including the aspect of seasonal dependency. Those results will help in defining more precisely pump size.

3 Modelling as a design and management aid

Up to now most of the design criteria being used are based on the result of agrohydrological studies of polder and/or pumped catchment areas. In addition these criteria were modified to the engineer's experience and adapted to the failure of existing systems. Recently hydrological studies have tried through a statistical treatment of existing level and pumping data to establish the frequency with which different extreme levels and volumes of pumping within different periods of time have been experienced. However, the existing design procedure for pumped catchments with its assumptions of steady flow and an extreme arbitrary frequency of exceedance of water levels seems to be inadequate for refined economic design. As a result complementary studies have been aimed at modelling the whole of a pumped drainage system deterministically.
The hydrodynamic model approach permits to assess how a given drainage network together with its pumping station performs during an unsteady event occuring with a given frequency. Modelling permits to simulate the effect of small changes to the basic design of the arterial drains and of changes in the maintenance schedules on the frequency and duration of water level exceedance in the network. This fine tuning, done with deterministic models has proven to reduce significantly savings in construction, operation and maintenance costs of drainage networks.

Of the papers in the subtheme B 1.2, I had to review 4 papers that were dealing with the development of model concepts for the computation of total water demands for level control and control of chloride concentration, for the hydrodynamic simulation of flows and salt distribution in boezem systems in pumped catchment areas and in tide-driven drainage networks. In most of these papers various design alternatives were compared in terms of specific impacts on water and salinity level, flow conditions in the canals, pumping performance, costs of construction, operation and maintenace.

VAN BOHEEMEN describes in his contribution a numerical model to calculate the water supply needed for level control during the growing season, April 1 to October 1. The water requirements are calculated per timestep of 10 days and per bloc of 25 ha. To each of the distinguished blocs, in which the polder districts have been subdivided a representative land use, soil type, and various hydrological characteristics have been given. For each timestep data have been collected on precipitation, global radiation, and potential evapotranspiration. Then the water requirement of each bloc of 25 ha is calculated. For five different types of land use a separate method has been developed to compute the water requirement. In a next step the water requirements of the blocs are added to obtain the water supply of the entire area.

A validation has been made for two polder districts, the polder district of Rijnland: 106,300 ha large and Delfland: 35,875 ha in size. As validation criteria the simulated water supply was compared to the actual one. The comparison has been made for the summer periods 1975 through 1978. In general the model results are slightly higher than the actual values. According to VAN BOHEEMEN the differences are due to following model assumptions: shortages and surplusses are replenished, respectively discharged immediately so that no fluctuations in open water level occur; an optimal water supply sytem and a full-grown crop being present during the entire summer.

Due to the presence of large scale glass house horticulture in the polder districts in the Netherlands and to the water supply for level control, an additional water supply for water quality control became of growing importance, with special emphasis on the chloride content of the polder and boezem water. GRIJSEN et al. carried out a study to assess the additional water needs for flushing the internal and external salt load

of polders. In addition they analysed various technical alternatives of water supply systems to Delfland. Among the alternatives compared, comprised such possibilities as the construction of a new canal, reconstruction of existing canals, construction of pipelines and syphons, construction of a reservoir and use of purified waste water.
With a hydrological model, comparible to the one described in VAN BOHEEMEN's paper, the water demands for level control were computed for each decade of the summer half years in the period 1911 to 1978, both for the present land use pattern in the region as well as for the one anticipated for the year 2000. In a next step the water demands for flushing were computed for each decade. Hereto the hydrodynamic model, ABOPOL (Analyzing a BOezem POLdersystem) was used. This model calculates the chloride distribution in the boezems and the additional water demand for keeping the salt level of the boezem water below the standard for salt concentration.
In a following step the yearly extreme water demand figures were subjected to a frequency analysis using the Gumbel distribution. Water demands with a return period of 35 years were taken as design flow for the water supply systems. The present study resulted to a total water demand of the region for level and chloride control of only 73 % of earlier made estimates. Previous improvement in the estimate of total water demand was possible since in a dynamic approach the same quantities of water serve various purposes at the same time and since the numerical description of the polder regime became far more detailed and comprehensive as before.
Since in the model ABOPOL the schematization of the project area, of the canals and the boezems has to be imputed, it was possible to check the effect of alternative water supply systems in terms of the chloride level. The cost estimates of the alternative projects ranged from 54 to 224 million dutch guilders compared to the estimated 137 million guilders for the original planned water supply canal. Which of the studied alternatives should be realised depends however from many other non-technical aspects, which cannot be considered with ABOPOL.
From the concern that any investment in improved drainage should be made properly, PRICE et al. of the U.K., argue in their contribution that we should get rid of the semi-empirical design procedure for pumps (= are based on runoff of 0.34 $m^3.s^{-1}.km^{-2}$) and ditches (= a fall of 10 cm per

km and water velocities up to 0.3 m.s^{-1}), with its assumption of steady flow and an extreme arbitrary frequency of exceedance of water levels. As a result, a comprehensive procedure for the design and analysis of pumped drainage systems have been worked out and presented in PRICE et al's paper. The procedure is based on the simultaneous use of two models: the first to design the dimensions of the arterial drains, which is regarded as a dentritic network and the second model aims to simulate the performance of the complete system, the operation of the pumping station included.

The hydraulic design of the arterial drains is optimised in such a way that the costs of excavating and of the land lost for agricultural purposes be minimal. A discrete differential dynamic programming method is used to obtain a minimum value of the cost function. From a test of the model on the Newborough catchment was found that : the optimal design corresponded with the critical slope that is, the smallest gradient defined by the maximum permitted water level at the upstream end of any drain and the water level at the downstream end of the branch; the maximum velocity constraint is a critical factor in determining the geometry of the drains.

A simulation model was developed for the description of the unsteady flow in a pumped drainage network. The model is applicable on a designed or existing system and permits to experiment with various alternative changes in terms of the capacity of the arterial drains to store runoff, pump capacities, settings of the pumps, etc. The simulation model is being used to simulate the performance of these alternative changes in design, operation and maintenance schedules on the water level at several locations of the drainage network for any arbitrary rainfall storm, which might be characterised by a given duration, intensity and return period.

In a last paper YANES et al. presented a simulation model for the improvement of the watermanagement of tide-driven drainage networks, with application on the Guara island, situated in the delta of the Orinoco river. Guara like all other islands in the delta, have their lowest land levels towards the center and embankments towards the periphery. The main drains were designed to discharge into the river channels surrounding the island, driven by the water slope produced during low tide in the river channels.

The simulation model, described in YANES et al. 's paper, for the optimization of the management policies has been based on the application of the Saint-Venant type equations. Via the combination of the conservation of mass and momentum equation, using Manning's expression to define the frictional slope, a system of non-linear equations is formed, where the unknowns are the stages (water levels) at the discretization points and the knowns are formed according to the boundary conditions imposed. The system of equations is solved using the Newton-Raphson algorithm. The simulation is simplified by fixing the upstream boundary condition as a slowly varying hydrograph given by the stage of a reservoir. At the downstream boundary a varying tidal stage hydrograph of 12 hours periodicity is taken. A stage-discharge function has been used to describe the downstream discharge through the one way tide control gate.
The rapid growth of aquatic macrophytes was taken into consideration in the hydraulic model by increasing the roughness coefficient in a way which depends on density and plant structure. It has been observed namely that three of the most abundant species display very striking differences in increasing the roughness coefficient. The paper shows the discharge of the island Guara versus time as obtained by computer for a complete tidel period. Besides that the authors claim that the model can serve to analyse alternative management strategies and to optimize water levels.

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SUB-THEME: WATER QUALITY, GEOHYDROLOGY AND SOILS

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Abstract

This report discusses papers on water quality and changes in soil properties and their influence on water management. A total of seven papers from Australia, Egypt, Iraq, Japan (2x), the Netherlands and from FAO (Rome) was received.
The latter paper deals with planning programs for irrigated areas with emphasis on the effects on water quality of drainage water from irrigated areas.
The Australian paper describes the water management problems in relation to river water quality of the Murray river in South Australia.
The Egyptian paper discusses the problems encountered by reclaiming and irrigating a strip of desert land of some 17,500 ha.
The Iraqi and Dutch paper treat changes in soil physical properties as a consequence of reclaiming saline land and polders respectively. The latter paper gives a model to simulate the soil ripening to be expected in future.
The two Japanese papers deal with desalinization of newly reclaimed land along Tokyo Bay and the design of fresh water lakes along the sea respectively.

1 Introduction

The papers falling under the congress theme B1 (land and water management) that included the topics water quality, geohydrology, soil ripening, - subsidence, - physics and - improvement could be divided into three groups namely:

- papers dealing with seepage problems in polder areas;
- papers discussing water quality aspects in irrigated areas;
- papers on changes in soil physical properties during and after reclamation of polders and saline soils in irrigated areas.

The report on papers falling in the first category is given by Romijn, the papers falling in the latter two categories are discussed in this report.

Although irrigated areas are not always polders in the original sense of the word, they have many things in common with polders, the main point being the autonomous water management system. Both reclamation of polders and saline soils in irrigated areas have in common that they form the cause of changes in soil properties that are necessary to make the soil suitable for cultivation and the growth of agricultural crops. These changes are of utmost importance for the water management systems to be applied.

Water management problems in irrigated areas

Introduction of irrigation in arid regions inevitably brings about a rise of the groundwater, an increased salt load in the groundwater and a deterioration of the downstream surface water, due to the disposal of drainage water from the irrigated areas themselves.

Because of the ever increasing demand for food there is a world wide tendency to enlarge the productive agricultural area by introducing irrigation. In many areas good quality of irrigation water is scarce. Moreover, agriculture has often to compete with domestic and industrial water demands in the distribution of the scarce resource.

Control of water quality leads to cleaner water and an increase in agricultural production. It may provide extra water to meet additional demands by agriculture, industry and population and it can reduce energy consumption. Improving water management practices can diminish the salt load from agricultural areas, leaving a better water quality for the downstream sections of the river and saving water for use in these areas. A better water quality itself can increase crop production considerably and reduce the hazard of soil salinization. Prevention of soil salinization in turn can save large amounts of water otherwise needed for reclamation of soils once salinized.

Kadry (1) in his paper warns that too often reclamation and irrigation projects in arid and semi-arid regions are designed without considering the effects of implementation of these projects on other regions. He advocates a careful analysis of water quality problems in all the areas of a river system. Such an analysis should start with an inflow-outflow analysis of surface water and groundwater for all the subareas. On the basis of this analysis water and salt balances should be set up to detect the magnitude and sources of salinity. Next one should consider on-farm water use systems to obtain appropriate solutions for minimum salinization of soil and water. From these possibilities acceptable practical solutions should be chosen on which a cost-effectiveness analysis has to be applied to arrive at the best management practice for salinity control in a river basin.

The paper gives planning frameworks for developing best management practices in subbasins and in river basins, but does not go into detail as far as it concerns necessary data or research to obtain them, that are needed for implementation. In that respect the paper leaves a number of questions to be answered. To mention some:

- For implementation of plans and application of technologies participation of the farmers is necessary. The author chooses for the solution of this problem training and field demonstrations. Could cooperation of the farmers not better be sought in participation of them in irrigation districts?
- The author points several times to the necessity of systematic monitoring of flows and water quality parameters, but does not indicate who must organize this and take responsibility for. Moreover, monitoring alone is not sufficient. Who takes action when results indicate problems?
- The author states that remote sensing techniques can be useful to guide the selection of measuring points, the carrying out of soil surveys and land evaluation activities, but does not indicate how this should be done.

- How far wants the author to go with respect to costs of design and accompanied research, say expressed as a percentage of the total investment costs of a project?
- What organizational framework is necessary to realize the planning frameworks included in the paper?

An example of the many problems that appear in water management and the control of salinity is given in the paper of Schrale and Desmier (2). They discuss the problems of the water management of the Murray river in South Australia. This river delivers 90% of the irrigation water in South Australia and is used as a source for drinking water for Adelaide.

Due to return flow of irrigation water and underground seepage of groundwater the salinity of the river water is increasing. Annual costs for urban water users increase with $A 79 200 for each additional EC-unit while irrigation farmers loose $A 18 100 for each additional mg salt per litre. Polders along the river are used as pasture land with a potential production of 27.5 tonnes dry matter pro ha. The actual production is less than 50% and is decreasing due to salinization and water logging of the soil causing changes in composition of the grassland.
Analyses of return flow volumes revealed that irrigation efficiency is only about 50%, but also that the amounts of salts removed are 2 to 5 times as high as the inlet amounts. This leads the authors to the conclusion that the main reason for the increasing salinity of the river is groundwater seepage. Measurements of groundwater seepage during the nonirrigation season showed that seepage intensities are between 0.1 and 14.2 mm per day with an electrical conductivity up to 34.2 mS per cm. Further research on improved drainage and irrigation combined with resowing of the grass should lead to the solution of the problem in the polders themselves while alternative methods of drainage water disposal have to be considered after reduction of its volume as a solution for eliminating the effect of the drainage water on the river water salinity.

The paper gives interesting data on the effect of salinity for both drinking water and agriculture. An actual production of grassland of about 13 tonnes per ha dry matter is very reasonable. A potential production of 27.5 tonnes in a nine month growing season is comparable with Dutch data of about 16 tonnes for a five to six month season. Taking a transpiration ratio of 30 kg DM per mm of water would demand roughly 900 mm of water. Subtracting the underground seepage from this demand, it becomes clear that the irrigation method must be the main source of the trouble as far as it concerns waterlogging and the accompanying salinization of the soils in the polders. Drainage may solve this problem, but is not a remedy for the underground seepage. Peculiarly the authors do not mention further research on this subject as a possibility to find a solution for the increasing salinity of the river water.

A second example of water management and salinity problems is given by Korany and Hussein (3). It pertains to a 17 500 ha area of desert land west of the river Nile in Egypt.

The authors give a description of the geohydrological and climatological conditions in the area. There is a 67 to 100 metres thick aquifer of Holocene material underlain by impermeable Tertiary formations from Pliocene, Miocene and Eocene origin. Rainfall is restricted to 22 to 45 mm per annum and high temperatures are accompanied by relatively strong winds. Potential evaporation in the area is estimated to be 1450 to 1840 mm per year.

Water brought into the area and originating from the river Nile is of excellent quality. After reclamation of the area in 1965 groundwater levels rose to 19.6 metres and in some spots even to 0.1 m below surface. The groundwater is somewhat brackish but mixed with surface water it gives 25% of the total amount of irrigation water applied in the area. The authors report on results of pumping tests and groundwater maps indicating the direction of groundwater flow.

Unfortunately they do not go into further detail on the results of their findings. Some remarks on this paper could be:

- The authors report that the k-value in the aquifer ranges from 15.4 to 32 m per day. Taking an average of 25 m per day, a gradient of 0.2 m per km (data mentioned are 0.15-0.26 m per km) and a thickness of the aquifer of 75 m, one arrives at an underground loss of 0.38 m^2 per day. For a boundary length of 80 km this comes to 30 400 m^3 per day or 0.5 m^3 per second.

- A potential evaporation of 1650 mm a year as an average leads to a water requirement of 9.14 m^3 per sec. while the authors mention 10,273 + 10,846 = 21,119 m^3 per sec. Therefore seepage losses from conveyance canals must be of utmost importance in determining the water need unless the underground seepage out of the area is highly underestimated.
- The mentioned water requirement means a total irrigation of 3850 mm per annum. From this roughly 40% evaporates. Since the concentration of the surface water is given as 555 ppm this would give a salt content in the groundwater of 2½ x 555 ≃ 1400 ppm. The authors give values between 1467 and 4789 ppm. Apparently fossile salts in the profile play an important role and the question is what will happen with both the groundwater table and the salt content of the groundwater in the future under prolongued irrigation. So what do the authors expect that will happen with the future salinization of the soil and the possible seepage losses from the area?

Changes in soil physical properties

As mentioned earlier both reclamation of saline soils and reclamation of polders imply changes in soil properties that are of utmost importance for both water management and water quality.
Okazaki (4) reports on the land reclamation in the eastern part of Tokyo Bay. Here land is reclaimed from the sea by heightening the soil with the aid of sand pumping from the sea.
The soil in the land obtained is saline due to the seawater from the dredging activities. When the material is sandy, leaching by natural rain is rapid enough to allow after some time tree planting and construction works. Many areas reclaimed with finer material had a too poor drainage to be used. In addition, unequal shrinkage of the land leads to depressions that are very saline.
Shrinkage was found to be highly dependent on soil material and started with crack-formation upon drying, the largest cracks occurring at high clay contents. In places with fine-textured subsoil and lighter topsoils, no cracks occurred. Due to the low permeability of the subsoil layers leaching of salts did not occur. Salts accumulated then on the edge of

the depressions due to evaporation.
Movement of chloride was found to be easier than that of sodium, causing differences in pH. This was one of the reasons for differences in the halophytic vegetation found on the land.

From the standpoint of soil formation and the relation between salinity and vegetation type the conditions prevailing in the reclaimed land are very interesting. Technically it is well-known that sand pumping leads to very heterogeneous soil profiles, the heterogeneity depending on the speed of pumping, type of sediment, drainage etc. A solution for the problem that soils are not leached therefore has to be found at least partly in developing better techniques for depositing the soil material during the sand pumping.
Al-ani et al. (5) report on experiments concerning the effect of sodium salts on the permeability of soils.
Salts in water do not only change their physical and chemical properties, but bring into contact with soils such solutions that are liable to exchange of chemicals with the adsorption complex of the soil. Therefore changes may occur in soil properties and water movement in the soil.
The authors saturated undisturbed soil samples of a nonsaline silty clay soil with solutions of sodium chloride, sodium sulphate, sodium carbonate and calcium chloride. Next permeability tests were carried out with the same solutions until constant values were obtained. As a next step the experiments were proceeded using tap water to see which changes took place. The ratio of the values found was used as an indication for the changes in hydraulic conductivity that may occur during leaching of saline soils.
Authors found that especially high concentrations of sodium salts in the soil will reduce the hydraulic conductivity upon leaching. On the other hand the presence of calcium and magnesium salts does not show this effect.
The authors point out that although the results of the experiments cannot be used for direct application in leaching procedures, they give an idea about what can be expected upon the time of leaching of saline soils.

A complete different problem of soil formation, namely the ripening of newly reclaimed polders in the Netherlands is reported by Rijniersce (6). Soil ripening is necessary to obtain enough bearing strength and to make growth of plants possible. In the Dutch practice of reclamation of polders reed is seeded as a pioneer crop to obtain moisture extraction from the soil as a start for the ripening. After some years, when the soil is dried sufficiently to allow the construction of a furrow drainage system, this vegetation is removed and replaced by agricultural crops. The soil ripening is important for the design of the required drainage and to predict the rate of subsidence of the land that has to be taken into account for construction of canals, ditches, roads, buildings, etc.
The author gives the principles of a numerical simulation model for physical soil ripening. The soil profile is divided into a number of layers ranging from 0.5 cm in the topsoil to 5 cm in the subsoil. The water movement in the soil is then simulated to obtain soil water contents and accompanying shrinkage and cracking.
Open water evaporation (Penman) corrected for soil cover is used as evaporative demand. Transport of water through the profile (both upward and downward) is then computed for every period of ten days. Computed soil water suctions are next transferred into a moisture profile with the aid of relations between organic matter content and bulk density on one side and water contents at given soil water suctions on the other hand.
A modified Terzaghi formula is used to find the compaction due to the load excerted by the drying soil layers. This gives the increase in bulk density upon drying. The increased bulk density results into subsidence and crack formation. By means of a distribution factor changes in bulk density are distributed over subsidence and cracking. The model finally predicts the subsidence, the depth of the cracks and the amount of water stored in the soil profile. Examples of comparisons between computed and measured data show that the model gives a reasonable prediction.
The model offers the possibility to obtain data on soil ripening in a relatively simple way. It uses a number of relations between parameters derived for conditions in the Dutch IJsselmeerpolders. This implies that the available model cannot be used for other conditions without proper adaptions as the author points out in his paper.

Water quality in reservoirs

A paper that is somewhat beyond the topics of this report is that of Tohara (7). It describes the water quality in a reservoir that is separated from the sea by an enclosure dam provided with a drainage syphon to let water out. Due to seepage through the enclosure dam salt water accumulates in the reservoir below the level of the outlet while the top layer has fresh water. Under the influence of wind the diffusion of salt from the bottom layer into the top layer is accellerated. The author gives a mathematical description of this phenomenon and discusses the various parameters included.

On the basis of this theory he developes a simulation model for the case that the horizontal distribution of salt in the reservoir is homogeneous. By dividing the depth into a number of layers and applying the finite difference method, both vertical velocity and salinity changes caused by it, can be found numerically. In order to maintain the water quality in the reservoir the amount of water causing the salt movement has to be counterbalanced by an equal amount of fresh water.

From experiments and simulations the author finds that in order to keep the chloride content in a reservoir with surface area A (ha) below 500 ppm, the amount of water Q required is $Q/A = 123H^{-1.8}$ ($m^3.ha^{-1}.d^{-1}$). Under wind velocities $u > 5$ $m.s^{-1}$ the critical depth of the reservoir to prevent mixing of salts is $H_c = 0.74u - 2.6$. Under practical conditions in Japan one generally uses $H_c = 5 \log u - 1.0$.

This paper is interesting for problems where fresh water reservoirs close to the sea are used for water intake by for instance agriculture or for the production of drinking water.

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SUB-THEME: WATER QUALITY,GEOHYDROLOGY AND SOILS

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Abstract

Seepage problems in polder areas have been a major hydrological research item for many years, especially in The Netherlands. They stimulated the development of geohydrology of semi-confined aquifers.

The papers of Kochev & Yovkov and of Diankov deal with the problems of river polders along the Danube in Bulgaria. Both analytical and numerical model techniques are used for drainage design.

In order to design the most economic and effective drainage system, the fluctuations of the river level and the seasonal precipitation excess must be taken into account.

Barends calculates with an analytical formula the response of a step function in the river level outside the polder, with steady state as a starting point. The leakage factor λ has become time dependent, increasing with time to the limit $\sqrt{KDc}$ after several years.

On the other side the total seepage into the polder increases with time until the maximum value at steady state is reached.

Wesseling's paper deals with an extensive study in the province North-Holland. As a result of the hydrological computations the contribution of various sources to the surface water quality could be calculated namely from the saline underground (deep) seepage, effluents of industry and households, artificial gas-wells, inlet water, agriculture and rain water and salt used in winter against ice on roads.

The paper of Kirkham falls somewhat beyond the subject of this report.

The writer has developed a potential theory for the shape of the cone of depression for the classical problem of an unconfined well centered in a circular island.

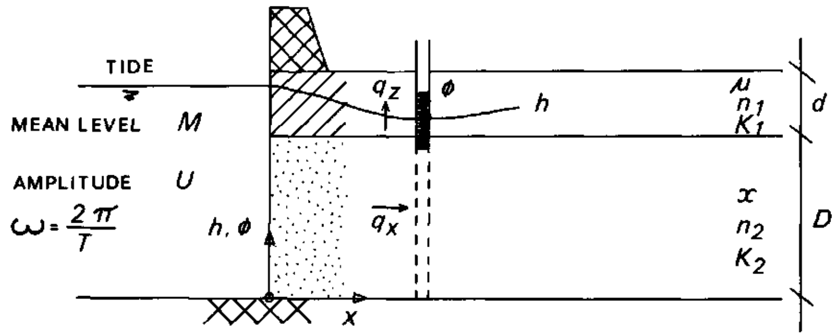
Introduction

Seepage problems in polder areas have been a major hydrological research item for many years, especially in the Netherlands. They stimulated the development of geohydrology of semi-confined aquifers. The hydrogeological scheme, consisting of a sandy aquifer above an "impervious" clay layer and covered by a "semi-pervious" claypeat complex (the aquitard) is often called the Dutch Polder Profile. Because of the refraction of the streamlines of the ground water flow at the boundary of the aquitard and the aquifer, for simplicity the flow is assumed to be vertical in the aquitard and horizontal in the aquifer. Further basic assumptions are:

- Darcy's law
- the law of conservation of mass
- a specific set of equations of state with respect to density and viscosity of the system as a function of pressure, temperature and chemical composition

In all the papers presented, temperature effects are neglected, the water is incompressible, the pressure only effects the soil and the permeability of the soil is time independent.

As an example let us examine the transmission of tidal waves in an extensive Dutch Profile. Case studies of this type were in the Netherlands already described by e.g. Steggewentz in 1933, Bosch in 1951 and Wesseling in 1959. Taking into account the compressibility of the aquifer, and using symbols as in next Figure, the following equations hold



- Darcy's law

$$q_x = -K_2\ \partial\phi/\partial x \qquad q_z = (\phi-h)/c$$

- Mass balance

$$D \text{ div } q_x + q_z = -D\partial n_2/\partial t = -S\partial\phi/\partial t - Z\partial L/\partial t$$

$$q_z = \mu\partial h/\partial t$$

with $c = d/K_1$ (hydraulic resistance), $S = \rho g D\alpha$ (storage coefficient), $Z = \rho g D n_1\alpha$, α as compressibility coefficient of the soil matrix, μ the drainable pore space, n the porosity, K the hydraulic conductivity.

The flow equations become

$$(\phi-h)/c = \mu\partial h/\partial t,\ KD\partial^2\phi/\partial x^2 = S\partial\phi/\partial t + (\mu-Z)\partial h/\partial t$$

with boundary conditions

$$x = 0 \qquad \phi = h = M + U \sin \omega t;\ x = \infty \qquad \partial\phi/\partial t = 0$$

The formula for the piezometric head is

$$\phi = M + U \exp(-Px) \sin(\omega t - Qx)$$

$$P^2-Q^2 = \frac{\mu c(\mu-Z)\omega^2}{(1+\mu^2c^2\omega^2)KD} \quad , \quad 2PQ = \frac{\omega(\mu+S-Z+\mu^2c^2S\omega^2)}{(1+\mu^2c^2\omega^2)KD}$$

which illustrates that at distance x the piezometric head Φ shows a reduction of amplitude exp (-Px) and a phase shift Qx.

Discussion on the papers presented

The papers of Kochev & Yovkov and of Diankov deal with the problems of river polders along the Danube in Bulgaria. Both analytical and numerical model techniques are used for drainage design.
In order to design the most economic and effective drainage system, the fluctuations of the river level and the seasonal precipitation excess must be taken into account.
Kochev & Yovkov define a critical drain spacing such that the phreatic level mid between the drains is just at the level of the piezometric surface of the underlaying aquifer. Their drainage formula for steady flow takes into account the radial flow near the drains, a horizontal flow component and a vertical one due to the piezometric head in the underlaying aquifer. The piezometric head itself is calculated with a finite element model. Also subirrigation was studied.
Diankov's model has in addition a horizontal ground water inflow from the higher parts near the river polder. His results show very clearly the attenuation of the amplitude and the phase shift of the piezometric head mentioned earlier.

Barends extends the theory as illustrated in paragraph 1 with the compressibility and subsidence of the semi-pervious layer. Recall that under steady conditions the total seepage into an extensive Dutch Polder Profile is equal to

$$Q = (M-h_o)\sqrt{KD/c}$$

with M as the steady water level outside the polder and h_o the controlled polder level, whereas

$$\phi - h_o = (M - h_o) \exp(-x/\lambda), \quad \lambda = \sqrt{KDc}$$

Barends calculates with an analytical formula the response of a stepfunction in the river level outside the polder, with steady state as starting point. At the base of the covering semi-pervious layer, a formula for $(\phi - h_o)$ quite comparable to the above mentioned holds, only the leakage factor λ has become time dependent, increasing with time to the limit $\sqrt{KDc}$ after several years.
On the other side the total seepage into the polder increases with time until the maximum value at steady state is reached. One may ask however whether in this case the assumption of time independency of the permeability of the semi-pervious layer holds. Consolidation of the claypeat layers may result after several years in a higher c value and a lower total seepage into the polder.

Wesseling's paper deals with an extensive study in the province North-Holland. The hydrogeological scheme consists of three leaky aquifers above each other, covered by the claypeat complex.
The resistance of the separating silt layers was calibrated with the aid of water balance studies and piezometric data.
As a result of the hydrological computations the contribution of various sources to the surface water quality could be calculated namely from the saline underground (deep) seepage, effluents of industry and households, artificial gas-wells, inlet water, agriculture and rainwater and salt used in winter against ice on roads. Main contributors for chloride are seepage (62%) and inlet water (21%), for nitrogen natural leaching plus fertilizers (35%) inlet water (23%) and seepage (18%) and for phosphorus: households (46%) natural leaching plus fertilizers (28%) and seepage (10%), stressing the important influence of seepage on water quality. It should be noted that leaching from soil and loss of fertilizers combined were obtained as closing entry of the balance and not by direct measurements.

The paper of Kirkham falls somewhat beyond the subject of this report. The writer has developed a potential theory for the shape of the cone of depression for the classical problem of an unconfined well centered in a circular island. At the well face, where ground water leaves the aquifer, a seepage surface exists, nevertheless the formula of Dupuit for the well discharge is correct which can be easily seen by considering the function

$$\Phi = \int_0^{h_r} \phi(r,z)dz - \tfrac{1}{2}h_r^2$$

with h_r as phreatic level, $\phi(r,h_r) = h_r$,
giving

$$\frac{d\Phi}{dr} = \int_0^{h_r} \frac{\partial\phi}{\partial r}\, dz = \frac{-Q_w}{2\pi K r}$$

with boundary conditions filled out and integrated

$$\Phi_r = \tfrac{1}{2}h_R^2 + (Q_w/2\pi K)\ln R/r$$

$$Q_w = -\pi K \frac{h_R^2 - h_w^2}{\ln(R/r_w)}$$

Kirkham compares his results with laboratory model data of Hall (La Houille Blanche, 1955)

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Kirkham, D. Free surface potential theory for a gravity well

THEME B 2. CONSTRUCTION ASPECTS

SUB-THEME: DIKES AND EMBANKMENTS

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Abstract

There are many thousand kilometres of dikes surrounding polders all over the world. Very high overall costs are involved in investment and maintenance. It is encouraging to see that the scientific base for dike design, construction and maintenance is broadening because in the long run this will result in savings to the people living in these polders while also their safety will increase.

Fourteen*) papers were submitted on this sub-theme. Subjects treated in the papers concerned design as well as construction and maintenance. Major features highlighted by the papers are:

- a better scientific approach of problems in the hydro-geological and geo-technical field than practiced in the past;
- a growing understanding of the need for regular inspection and maintenance of dikes using modern geo-technical equipment;
- introduction of scientific design of revetments in sea defences.

*) As four papers are dealt with by Mr.Hammond the overall total for Theme B is 20.

1 Introduction

The outsider looking at the sometimes somewhat shapeless ridges of earth surrounding a new polder or at the tree lined friendly looking low embankments covered by grass and wild flowers which are typical for old polders will not see these "structures" as dikes performing a necessary function. Most probably this outsider would laugh if you told him that there is much engineering involved in designing, aligning, building and maintaining these dikes. Nevertheless, the engineering of dikes is the subject of this report and, looking at the many interesting reports submitted, one can say that many engineers with dedication are daily devoting their time and skill to the matter.

Why do people build dikes around their polders? A general answer is easy to give: to keep the water out.But as usual a general answer is never completely correct. It would appear that there are four reasons why people build dikes around polders:

1) To prevent flooding of the reclaimed land due to:
   - high astronomical tides in estuaries and along the coast;
   - wind set-up caused by storm surges;
   - high river discharges caused by rainfall on the catchment.
2) To prevent saline water intrusion along estuarine and sea/oceanic coasts.
3) To limit seepage from outside to inside of a polder.
4) To prevent a further regression of the coastline or meandering of the riverbank.

In short: a dike is a protective device against the forces of nature, the latter being demonstrated in the behaviour and consequences of the tides, the rainfall and the wind.

2 Design requirements and subjects to be studied

The authorities anxious to have such an embankment built, generally have three requirements in mind:

a) the above mentioned reasons 1) to 4) inclusive must be borne in mind and the design developed accordingly;

b) the design must be "economical", i.e. as much as possible use must be made of locally available materials while the design criteria must be met without "over-designing" the embankment profile.
Moreover, an economic evaluation must be made of investment and maintenance costs for alternative designs in order to select the least cost solution;

c) a general human feeling of safety must be established through design and safety margin (freeboard, safety factor) and, subsequently maintained through regular inspection and maintenance.

Bearing these three basic design requirements in mind a process of design, construction, management, operation and maintenance of polder dikes can start. In order to do this a number of different subjects asks our attention. We will list seven here (Table 1) but the number can easily be extended by listing less relevant ones or by sub-dividing the original seven subjects. Most of the subjects have a bearing on the various stages of an embankment project (design, etc., up to maintenance).
How important all these subjects and aspects are in relation to each other is not known as their relative importance varies from project to project and as it are in fact the local circumstances which determine for each project the major issues to be looked into. However, one thing must be very clear: though the subjects are listed as separate items the design process requires the integration of all subjects and aspects.
This means that during the design process continuous adaptation of parts of the design is necessary in order to arrive at an optimum solution without "conflicting" parts. As such this process of iteration is a typical engineering method which is not always found in or appreciated by other disciplines involved in polderization.

Table 1: Seven subjects to be studied in the course of design and implementation of an embankment project

Subject	Aspects involved
1 Coastal and river hydraulics, hydrology and morphology.	- waves - frequency of high water levels - erosion/sedimentation - wind set-up - local rainfall
2 Hydro-geological and soil-mechanical characteristics of sub-soil and embankment materials.	- seepage underneath and through dyke body - stability - embankment profile to be selected - construction method
3 Availability of construction materials for:	- dambody - revetment - toeprotection - closure works
4 Structural design of revetment.	- wave impact - perviousness - flexibility versus differential settlements of dambody - construction in tidal zone
5 Environmental issues.	- road-rail connections - erosion of foreshore, meandering - urban and rural settlements - ecology - landscaping
6 Construction methods.	- closure works (if any) - manual labour versus equipment - dry/wet construction
7 Management structure, operation and maintenance.	- inspection procedures - data collection and processing - flood warning system - maintenance

In the following sections we will deal with each of the seven subjects mentioned and see how they are treated in the papers presented for this sub-theme.

3 Papers submitted

On the subject of dikes a total of 14 papers was submitted. For convenience sake four papers (nos 94, 96, 142 and 329) are dealt with in Mr.Hammonds Report. These four papers will therefore only ask for some global remarks from our side. All fourteen papers are listed in Table 2.

Table 2: Papers submitted on design and construction of polder dikes

Ref. no	Authors and their country of origin	Title of paper	Country where project(s) situated
88	Sadami Kuwano (Japan)	Effective protection of polder dike.	Japan
94*	L.S.A.van Elzen and H.L.Jansen (Netherlands)	Possibilities of dike enlargements increased by Colbond vertical drainage system.	Netherlands
96*	G.J.Flórián and H.J.Vinkers (Netherlands)	Calculation of hydraulic head for river embankment design using a numerical groundwater method.	Netherlands
142*	J.van Duivendijk and J.R.Pieters (Netherlands)	Design and construction of the sea defences of Guyana.	Guyana
144	J.J.L.M.Enneking and M.M.Vierhout (Netherlands)	Design and construction of flood control dikes around 43000 HA of irrigation areas in the Rharb Plain, Morocco.	Morocco
151	G.W. Beetstra and P.V.F.S.Krajíček (Netherlands)	Reliability of Dutch Polderdikes.	Netherlands
152	W.Broeders, J.Huis in 't Veld, J.Stuip (Netherlands)	Strategics and methods for closing dyke breaches.	Netherlands

Table 2 (continued)

Ref. no	Authors and their country of origin	Title of paper	Country where project(s) situated
161a	F.Smith (Netherlands	Management of catchwater embankments in "De Oude Veenen" drainage district.	Netherlands
187	R.Dresnack, E.B.Golub, J.R.Pfafflin (U.S.A.)	Statistical risk assessment of polder protection structures.	U.S.A.
209	G.P.Bourgüignon (Netherlands)	Reclamation in deltaic regions.	Various
287	Dr.Béla Hajós (Hungary)	Use of hydromechanization for hydraulic earthworks in Hungary.	Hungary
296	A.M.van Nispen tot Pannerden (Netherlands)	The Zuiderzee project; construction of dikes.	Netherlands
329*	D.L.Gudgeon and M.E.Hannah (United Kingdom)	The raising of the defences of Convey island to resist a one in 1000 year tidal surge.	United Kingdom
501	B.Wesseling (Netherlands) and Ir.Madsalim (Indonesia)	Labour-intensive polder construction in Indonesia	Indonesia

*) These reports are dealt with by Mr.Hammond in his Report.

4 Contents of papers in relation to subjects to be studied

In Table 1 (Section 2) seven subjects were given which normally require our attention when designing and constructing a dike. In the following sub-sections we will review what the authors of the papers have said about each of these subjects.

4.1 Coastal and river hydraulics, hydrology, morphology

Though this subject is as important for dike design as the other six, only a few authors refer to it. This is understandable as both coastal and river hydraulics as well as hydrology and morphology are the subject of periodic congresses, conferences and seminars which are held all over the world and during which all aspects mentioned under this subject are discussed in detail.

This is probably the reason why the authors of papers 142, 144, 296 and 329 only briefly touch this subject. One may say that the outcome of hydraulic and hydrological calculations and considerations are considered by the dike designers (mainly civil engineers) as a boundary limit, a condition imposed by others.

The authors of paper 187 are in fact the only ones who discuss in detail one of the aspects related to this subject i.e. the fitting of data (water levels) to the proper statistical distribution. They state that it is possible to super impose an extreme value distribution of storm surges over a normal distribution of astronomically generated tides.

Because of the interrelationship of crest elevation of dikes, (determined in first instance by hydraulic/hydrological considerations) construction cost and maintenance requirements it is recommended to discuss this aspect during the afternoon session on October 4th. Then also related political, social and safety implications can be discussed.

4.2 Hydro-geological and soil mechanical characteristics of subsoil and embankment materials

Not less than eight papers (88, 94, 96, 142, 144, 209, 296, 329) discuss one or more aspects of this subject. Papers 94, 96, 142 and 329 are reviewed in Mr.Hammonds Report to which reference is made.

The other papers are now briefly summarized.

Paper 88 presents an interesting case of measures carried out in Japan for decreasing the seepage through a dike built up of rather coarse material. By driving 19.0 m long steel sheetpiles into the centre line of the dike over a length of approx. 600 metres the daily seepage of 10 000 m^3 decreased to 200 m^3.
It would be interesting to know the cost of these remedial works in relation to the original construction cost of the polder dike and what extra initial construction cost would have been needed to prevent the leakage all together.
The Reporter is happy to note that the authors were willing to present in detail a case of something which went wrong. We, engineers normally learn most of mistakes either made by ourselves or by others and any discussion on such mistakes and subsequent remedial measures taken is very welcome.

Paper 144 describes in some detail the development of the cross-section of dikes in the Rharb plain in Morocco on the basis of two kinds of available material. It is interesting to hear about the special problems posed by the use of montmorillonitic clay and what experiments were carried out in this respect before a decision was made about the cross-section to be adopted.

In Paper 209 it is pointed out that settlement of the soft subsoil underlying a dike body may have serious consequences and what measures can be considered to reduce this settlement as much as possible.

Paper 296 provides an overall picture of the design and construction of the dikes of the Zuiderzee (now called IJsellake) including the dikes around the polder in which the "Polders of the World" seminar is held. These dikes were built over a period of 50 years and their total length amounts to several hundreds of kilometres while their height in places exceeds 15 metres which in turn signifies them as "large dams" *). For the construction of the polder dikes soft layers in the

*) According to the definition of ICOLD.

sub-soil were removed first and replaced by sand to avoid stability and settlement problems.
For many centuriės the design and construction of polder dikes has been based mainly on emperical data. It is encouraging to note that more recently the establishment of a sound geo-technical base of investigations, tests and calculations is becoming a general feature of dike design and construction.

4.3 Availability of construction materials

In fact only a few authors (papers 88, 142, 144, 287, 296) indicate that the availability of a certain construction material in the neighbourhood of the dike's alignment has been a factor of importance in the establishment of the dike design. It can nevertheless be confirmed that in daily practice the designer first looks around to see what is available and then ensures that his design and construction are matched to the properties of these available construction materials. This practice is followd also for large earth- and rockfill dams and it would appear to be a must for economical engineering. It is however pointed out that use of large dredging equipment may sometimes allow to divert from this principle (Paper 296) while such diversion may also be comtemplated for other reasons (recreational constraints, only limited loading of subsoil possible, etc.).

4.4 Structural design of revetment

Generally speaking a revetment is only required when the seaward/riverward/lake side slope is subjected to continuous wave action. This is certainly not the case for many dikes built for non-frequent high waters or along rivers. Consequently, only typical sea defences (Papers 88, 142, 209, 329) and the dikes bordering large lakes like the IJsellake (Paper 296) require revetments. Also here for many centuries and until 30 years ago the revetments consisted of open type revetments: open filters, stone pitching, rip rap while also concrete

was used with differing results. Thickness of layers and size/weight of individual units was purely a matter of experience and of availability of materials (Papers 142, 209, 296, 329).
Nowadays, an effort is made to really design the revetment with the aid of wave formules and model tests while at the same time bitumen is introduced (Paper 88, 142).

In general, modern revetment design is considered to be a part of coastal engineering and it is therefore understood that only limited attention is given to this subject in the papers presented by the authors.

4.5 Environmental issues

Only two papers (144, 329) indicate that the environment may play a role in design or re-design of the polder dyke. Most probably there is more on this subject in the papers submitted under Theme B-5 ("Environmental aspects").

4.6 Construction methods

4.6.1 Closure works

When a polder is constructed in an area of tidal currents (a swamp on the coast, an island in a river delta or a sandbank in an estuarium) it might be necessary to employ elaborate methods for closing the last tidal channel by means of a dike. Such a closure will also be necessary when the dikes of low-lying polders are breached during storm surges and so-called flow gaps develop (Paper 152).
In The Netherlands and also elsewhere (Bangladesh) various more or less elaborate methods have been developed through the centuries to close tidal channels of various sizes.
Papers 152 and 209 summarize these methods. As, again, this subject is considered by the Reporter as belonging to the field of coastal engineering he will not treat this subject in further detail. Provided

the dikes of a polder are safe (no overtopping, no collapse) closure works will only ask for attention during initial construction and not again during its lifetime of many centuries.

4.6.2 Equipment and labour

The authors of Paper 501 give an interesting review of labour-intensive construction of polder works in Indonesia. They conclude that although manual execution was slightly more expensive than mechanical execution the quality of the manually constructed embankments was considerably better than that of the embankments constructed by heavy equipment. The additional cost was also justified by increased employment opportunities.
The other papers touching the subject of construction methods (144, 287, 296) invariably refer to the use of equipment for construction of earthworks.

Papers 287 and 296 both refer to the placing of fill by hydraulic means. Paper 296 was already briefly reviewed in Section 4.2 to which reference is made. Paper 287 describes the placing of fill borrowed from the river bed in flood control embankments along the rivers in Hungary. The author states that not less than 4200 kilometres of dikes are involved. He describes in detail the planning of actual fill placing and the advantages and disadvantages of various methods.
It would be interesting to hear from the authors of both Papers 287 and 296 more specific information on weekly production rates, pipe diametres used, grain size of material, capacity and type of dredgers used, transport distances, etc.

4.7 Management structure, operation and maintenance

Designers, in general, have a tendency not to worry too much about maintenance. Firstly, the cost of maintenance does not count much in economic

evaluations (because of the conventional discounting method used and the application of high interest rates) and, secondly, most designers do not see what they can contribute towards this subject anyhow.
A third reason is that only during the last 30 years adequate means (instrumentation, geo-technical equipment) have been developed to actually inspect embankments other than possible by means of visual observations.
The Reporter would like to ask more attention for the relationship initial design/maintenance and on the need for good regular inspections.
A good design and costly initial construction may save on future maintenance costs while a cheap design and bad construction may result in very high maintenace costs. The whole matter would be easy if dike behaviour could be predicted. Practice is however that dikes because of their length are subjected to a statistical process of deterioration caused by loading, quality of construction, damage by man and animal, properties of construction materials and subsoil condition; each of these reaching values which are a function of time and place.
Only regular and thorough inspections may bring to light what is wrong and when (Paper 151) and where action is urgently needed (Paper 161a).

The Reporter assumes that many thousands kilometres of polder dikes are in operation all over the world. He knows that for instance large dams in some countries are already inspected regularly to prevent serious accidents. It would be interesting to hear during the seminar what is being done outside The Netherlands on the regular inspection of polder dikes.

SUB-THEME: MISCELLANEOUS CONSTRUCTION ASPECTS

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Abstract

Report on papers dealing with miscellaneous construction aspects of Polders of the World. This group of 10 papers deals with geotechnical, hydrogeological aspects of polder development together with papers on the control and testing of polder pumping equipment. The papers range widely from schemes dealing with the protection of polders from sea attack to the possibilities of the use of underground storage of water in suitable geological formations for irrigation. The engineering approach in all these papers is innovative and interesting to those engaged in construction.

List of papers

Theme B2: Construction Aspects

	Authors	Title	Location
142	J. van Duivendijk & J.R. Pieters (Netherlands)	Design and Construction of Sea Defences	Guyana
329	D.L. Gudgeon & M.E. Hannah (UK)	Raising of the Defences of Canvey Island	UK
39	L. van't Leven (Suriname)	Construction of Polders	Suriname

11	M.A. Viergever (Netherlands)	Foundation on Soft Marine Deposits in a Recently Reclaimed Polder	Netherlands
94	L.W.A. van den Elzen & H.L. Jansen (Netherlands)	Possibilities of Dike Enlargements increased by use of the Colbond Vertical Drainage System	Netherlands
96	G.J. Flórián & H.J. Vinkers (Netherlands)	Calculation of Hydraulic Head for a River Embankment Design using a Numerical Groundwater Model	Netherlands
503	Peter H. Reiter (Finland)	Test Runs and Acceptance Tests of Polder Pumping Stations	Finland
132	D. Dejas, A. Reinhard & W. Trzeciak (Poland)	Control of Pumping Aggregates and Measurement of Discharge in Polder Pumping Stations	Poland
23	Arata Masumoto (Japan)	Possibility of Using Underground Dams to Irrigate Polders in Tropical Areas	S.E. Asia
108	Antonino Vázquez Guzmán (Spain)	Construction Aspects in the Polders of the Left Bank at the Low Quadalquivir Marshes	Spain

In the group of papers on construction aspects of polders, two relate to the protection of land from the sea in the difficult foundation conditions found in estuaries; four papers relate to the drainage and consolidation of embankments and their stability problems; two papers deal with the provision of pumping plant and its control; one paper gives an interesting insight to the possibilities of underground storage of water necessary for polder irrigation and the last paper deals with the construction of a polder development in South Western Spain.

The first paper on the design and construction of the sea defences at Guyana by van Duivendijk and Pieters deals with the design methods adopted for constructing sea defences in an exposed coastal area of Guyana where erosion of protective mud banks is subjecting the coastline to heavy wave attack and higher wave run-up. The author sets out the inter-dependence of the parameters causing erosion and the reasons which led to the selection of a new sea defence line inshore of the original embankments. This new alignment gave the engineers an opportunity of designing a sea defence system which would stand up for a minimum of 100 years without major repair. The paper details wave observations, the design of slopes for wave run-up, surge etc. and the model testing which was carried out, gives an explanation of the possible reasons for the previous failures and the steps proposed to ensure the security of the new defences on the exposed Guyanian coast.
The problems in Guyana are repeated on the Thames estuary where a paper by Gudgeon and Hannah sets out the methods adopted to protect the Canvey Island area of the north eastern Thames estuary against the continuing ground settlement and increase in tidal levels in this corner of the UK together with the increasing frequency and height of surge tides in the North Sea. The very weak clays underlying the embankments in both Guyana and Canvey Island pose the greatest problems to the engineer. It is interesting to see how these problems have been solved. In the case of Guyana, the use of sheet piling driven at the toe of the embankment has been discontinued, whereas at Canvey Island the piling is used to create a new raised core on the centreline of the embankment. This core is cantilevered to act as a toe to the raised downstream embankment.

In Guyana an embankment profile is used with a substantial berm located at low water and then relatively steep excavation at the face of the berm provides the fill for the embankment. At Canvey Island an alternative arrangement using pulverised fuel ash from local power stations was considered for the upstream segment of the raised embankment, backed by sandfill, both protected by suitable drainage layers. The methods at Canvey are more elaborate than those at Guyana and this no doubt is justified by the need to protect a relatively large population living on the island and the associated major industrial base. The Guyana protection is tailored in some respects to the value of the polders protected and of the likely consequences of failure. Judgment of the value of protection works is difficult and in the end must be subjective.

The next group of papers relate to the problems of poor foundations, drainage and consolidation met with during construction.
The paper "Construction of polders in Suriname" by van't Leven gives an interesting description of the conditions found during polder construction in the inland coastal region of Suriname. It describes the methods adopted to enable drainage canals to be excavated in riverine jungle where the bearing capacity of the soil is so low and the forest so dense that normal construction equipment cannot be brought into use initially. The step by step approach sets out the methods used, first to provide access and then to dewater the zone to be excavated, and the final consolidation of embankments. The load bearing capacity of the soil and presence of non-cohesive layers in the excavation itself coupled with a high external groundwater table make the problem of the stability of channel sides a major one. The gradual approach on excavation adopted and the method developed to work with nature paid off so that the cost of new construction was kept to a minimum and the project properly programmed to completion.
The paper by Viergever entitled "Foundations on soft marine deposits in a recently reclaimed polder" deals with similar settlement and stability problems encountered on work in Holland. The author sets out the methods adopted to adapt the fixed structures, such as bridges, pipelines, buildings, etc. to the high settlements encountered in newly reclaimed land. He deals with the problem of taking pipelines or sewers into relatively stable areas from a zone in which movement is continuing. Some examples of methods developed for overcoming differential settlement are set out as are the investigations necessary to give the engineer an indication of the deformations to be expected and the likely magnitude of settlement and subsidence.
The paper by van den Elzen and Jansen covers a specific method of enabling existing embankments to be raised where they have settled or new embankments constructed on poor foundations by utilizing drainage methods which reduce foundation pore pressures by the introduction of a

proprietary "Colbond" vertical drainage system. Vertical holes are first augered, reamed or driven into the foundation to a fixed depth and the drainage membrane consisting of an outer filter jacket and an inner central core which allows the free release of water is then slipped into the hole. The vertical holes are interconnected by a horizontal drainage layer before the surcharge of the embankment is placed. The consolidation occurring from the pore pressure reductions due to drainage can be calculated by the Terzaghi formulae and the eventual stability of any embankment raising carried out on the drained foundations can be established. The "Colbond"system is formed from polyester fibres for both the coarse inner layer and the external porous filter. This type of proprietary vertical drain is used in place of the more conventional sand drain and is a commercial application of this well known technique.

The paper by Florian and Vinkers deals with the calculation of the hydraulic head acting under an embankment, the foundation of which is connected by a pervious layer to the higher head in an adjacent river. The method used adapts a numerical groundwater model to determine head loss. In the case studied, a permeable coarse sand and gravel layer is intersected by a river but continues as a confined aquifer underneath adjacent continuous surface clay deposits. The head in the river thus exerts uplift pressures on the clay on which construction of embankments was to take place. The slip circle analysis of the stability of these embankments had to take into account the uplift pressures occurring beneath them. These uplift pressures were reduced by the head loss occurring in the pervious strata interconnected with the river. The two dimensional groundwater flow model has been developed so that the figures obtained from the model can be utilized in the conventional stability analysis of the embankment. An interesting contour projection has been made showing the calculated hydraulic heads to be expected from the pervious layer and the zones in which these heads could prove critical.

Of the papers dealing with pumping plant at polder pumping stations, the first by Reiter details the methods used to measure the discharges from polder pumps and the problems to be overcome in the method of measurement of large quantities pumped at relatively low heads. Reiter details the information required and the range of accuracies which can be expected and which must be taken into account in assessing the ability of the pump to meet contract guarantees. The author sets out a number of suggestions for suitable measurement equipment and points out the additional requirements to test to ensure that cavitation is not taking place and that the power input meets specified limits.

The paper on the control of pumping aggregates and the measurements of discharge in polder pumping stations by Dejas, Reinhard and Trzeciak describes a method of measurement developed in Poland to achieve the automatic control of the quantity pumped by utilizing a system of electrodes in the pumping well linked with measurement of the pump flows from venturi system. The automatic control system has been working for two years in three pumping stations with satisfactory results. The method outlined in the paper is simple and appears relatively robust and can be adapted to meet the requirements of a number of differing inputs and outputs required from a polder pumping station.

The paper by Masumoto deals with the possibility of constructing underground dams in pervious formations to provide storage of irrigation water for polders in tropical areas. The paper gives some details of the experience obtained on the construction of underground storage in the permeable area underlying Myako Island on Okinawa and suggests that this method of operation could be adopted in other parts of the world. The author suggests that the large limestone or permeable volcanic zones underlying irrigation areas in Indonesia offer such possibilities. If potable water can be held in these permeable areas rather than allowing free discharge to the sea, the reservoir created can reduce the need to take water for irrigation from slightly saline estuaries and so improve rice yield. The methods used at Myako are set out in some detail including the methods used to restrain groundwater outflow to the sea by the construction of grouted membranes in the permeable layer. The author suggests the provision of an underground spillway to restrict the retention of water in the aquifer to an acceptable level. The author sets out the means by which underground water supplies can be conserved and augmented in areas of high intensity rainfall and long droughts. He suggests that this approach could prove useful in a number of tropical areas, particularly on islands where pervious zones such as coral are present. Similar work to that described at Myako has also been successfully carried out in the south of France in cavernous limestone areas adjacent to the sea. The provision of storage by the construction of underground dams is interesting and unusual and the extension of this method to the corals and volcanic ashes in tropical countries deserves further attention.

The paper by Guzman on the construction aspects of polders on the left bank at the Low Quadalquivir Marshes in Seville gives a very brief description of the methods used in construction of the polders and the irrigation system installed. The paper outlines the drainage methods adopted to control salinity and gives some details of the access arrangements to the polder zones. The paper as submitted is in general terms and it is hoped that the author will be able to expand his written paper at discussion and thus give more information at the Symposium.

Conclusion

The ten papers reviewed in this section on the construction of polders are varied and interesting and it is hoped that they will stimulate discussion.

THEME B 3. AGRICULTURAL ASPECTS

AGRICULTURAL ASPECTS

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Abstract

Polders possess some characteristics that make them different from other agricultural areas: soils of high fertility that are drained systematically and often better than elsewhere, plot dimensions designed to obtain low costs, and selected farmers. The combination of these characteristics may well lead to higher yields.

Introduction

The major aim of reclaiming polders is agriculture and, indeed, farming is the main activity in polders in The Netherlands and in other countries of the world. Hoeve's paper on the significance of agriculture in the Dutch IJsselmeer polders shows the changes in land use in four polders reclaimed in succession over a period of forty years. Even in the most recently reclaimed polder, more than 50 per cent of the land is used for agriculture, the rest being reserved for urbanization, forestry and recreation.

Only relatively few papers have been presented on agricultural aspects of polders, warranting the assumption either that the number of papers is inversely proportional to the importance of the topic or that agriculture in polders is not particularly different from agriculture elsewhere.

Indeed none of the papers reveal any systematic difference between polders and other areas, in crops, soil tillage, sowing, crop protection, and harvesting. As elsewhere, parts of polders can be used for forestry. In the early IJsselmeer polders, forestry was limited to soils unsuitable for agriculture, but in the later polders forestry covers a larger area because planners are devoting more attention to recreational needs.

Nevertheless the papers presented at this symposium show that there are some significant agricultural differences due to the intrinsic nature of polders.

Soils

Soils in polders are alluvial in origin, either marine or fluvial, so their topography is flat. Since the watertable is already shallow under natural conditions, artificial drainage is always necessary. With the systematic application of field drainage, watertable control in polders is usually better than elsewhere. The drainage systems are either surface or subsurface systems.

Surface drainage is generally applied in tropical regions, e.g. in Surinam and Indonesia. There are several reasons for this: high rainfall intensity, low permeability of clay soils, or no need for a deep watertable in areas where rice is grown. The paper of da Costa, 'Agricultural aspects of banana cultivation in polders in Surinam', underlines the need for drain maintenance, notwithstanding its high cost, since epxerience has shown that a deterioration of the drainage system results in a rapid decline in production. In Westerhout's paper, 'Agricultural development of tidal lands in Indonesia', water management is considered the key factor for successful development. Acid sulphate soils pose a special problem. They require a careful, gradual lowering of the watertable to control the acidification and the removal of acids.

Traditionally, surface drainage was also applied in Dutch polders. Gradually, on arable land, it was replaced by subsurface drainage, whereas on grassland it continued to be applied for a longer time. The rapid development of high-intensity dairy farming in the past thirty years required improved water management to increase the bearing capacity of grassland and to minimize the damage caused by poaching. This explains the tendency of lowering the water level in the ditches and of replacing surface drainage by subsurface drainage. In the IJsselmeer polders subsurface drainage is applied everywhere, on grassland as well as on arable land.

Polder soils are normally fertile soils. Where peat soils occur, oxidation of organic matter releases a considerable amount of nitrogen for the crops but is also the main cause of subsidence. As pointed out by van Wallenburg and Westerveld in their paper 'Peat polders in the western part of The Netherlands', maintenance of the ditches by dredging and deposition of the mud mixed with manure gradually changed the composition of the top soil by increasing the mineral components, sand and clay, and in this way led to a change in land use suitability.

Crops

The choice of the crops in polders depends on watertable control. In shallow watertable areas, grass is the main crop in a temperate humid climate and rice in a tropical humid climate owing to their shallow root systems. Arable crops and tree crops require a deep watertable. The paper presented by van Goor, Groenhuis, and Jacobs: 'Forestry and forestry research' shows the importance of the poplar as a pioneer species in the IJsselmeer polders.

Plot dimensions

Newly reclaimed land offers the opportunity of choosing optimum plot dimensions.
As pointed out by Moens in his paper 'Agricultural mechanization and plot dimensions in polder development projects', plot dimensions have an impact on yield levels, on the cost of constructing and maintaining road and drainage systems, and on the cost of agricultural production. The problem in planning consists in deciding on plot dimensions that offer the best solution for the immediate future but do not impede long-term developments in farm size and mechanization. Van Dijk, Erdman, and Idoe, in their paper 'Mechanized rice production in Surinam', show the effect of large mechanized estates on the mechanization level of small farms.

Farmers

In the selection of farmers for the IJsselmeer polders, technical

skills, financial means, and personal qualities such as leadership are taken into account.
Westerhout's paper on 'Agricultural development of tidal lands in Indonesia' mentions spontaneous and transmigrant settlers, but no selection criteria are applied. The aim of this development is to provide landless rural people and poor farmers with a piece of land. One may, however, assume that only the most active among landless people and poor farmers are willing to transmigrate and thus form the majority of the new farmers. This means that here, too, the farmers in the polder are a selected group.

Yield level

Young polders often show a higher yield level than elsewhere. For example, the yields in Eastern Flevoland, one of the IJsselmeer polders, are 20 to 50 per cent higher than the average for The Netherlands, winter wheat showing the smallest difference and potatoes the largest. Van der Zaag, comparing Eastern Flevoland with older polders in The Netherlands in his paper 'Yield and quality of potatoes produced in the new polders in The Netherlands', points out that not only is the yield better but also the quality. He ascribes the difference to a better water supply, which, in turn, leads to greater root activity and deeper rooting of the crops.

On the other hand, shortcomings in the water management may cause serious drawbacks in further developing agriculture in polders.
Van Boheemen et al., in their paper 'Effects of fresh water supply of Schouwen Duiveland, The Netherlands' discuss a model that allows the need for fresh-water supply in a polder to be determined. They provide data of the effect that supplying fresh surface water to a polder may have on the agricultural production. An important item of this type of forecasting is the possibility for the farmers to change their cropping patterns by including in them crops with high market values. When fresh water is available, even under humid climatic conditions, farmers can thus raise their income.

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THEME B 4. SOCIO-ECONOMIC AND PHYSICAL PLANNING ASPECTS

SUB-THEME: PHYSICAL PLANNING

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1 Introduction

Relating to the development of the Dutch IJsselmeerpolders Constandse states: "The fact that these polders are so clearly a product of their time is probably typical for polders as such, because polders are flat, are rather undifferentiated, have hardly any historical landmarks, and give therefore the planners a high degree of freedom for designing. This is in itself fascinating, but it gives also a heavy responsibility and the absence of guidelines present in the existing environment, causes decision making to be often laborious" (Constandse, 1982).
This statement clearly marks the features of the challenging task peculiar to planning in newly reclaimed polders. Moreover it applies to the planning task to be executed in large reclamation projects, not necessarily comprising polders as such, examples of which can be found throughout the world, e.g. the extensive transmigration schemes in Indonesia as well as the desert-reclamation-projects in Egypt.
Therefore it should be borne in mind, that the papers presented in this report, as well as the discussion points evoked, in principle do have significance concerning these polderless projects.

Considering the statement cited above as marking the specific features of physical planning in polders it appears that only three out of the eight papers presented within this theme directly deal with the subject involved. These papers will be discussed in par. 2.
More indirectly covering some of the features presented are two papers,

to be presented in par. 3.
Physical planning and polders appear to be put together in a rather different way, in the other three papers received.
This papers actually deal with the process of physical planning at the national level, putting up the relation between (aspects of), the national policy and the development - or non-development - of the IJsselmeerpolders. They will be dealt with in par. 4, using the last IJsselmeerpolder-to-be (Markerwaard) as an illustrative case.

2 Physical planning in polders, methodologies used

Within the past millenary of Dutch polder-development major changes have taken place (Constandse, 1982)

- successive scale-enlargement

  Starting from small-scale reclamations in order to enlarge one's own land, large polders up to hundreds of square kilometres have been reclaimed

- monofunctional to multifunctional

  From pure agricultural use to complex use as housing, industry, agriculture, recreation and natural areas.

- growing state-involvement

  While enlarging scale of the polders and mostly due to the growing complexity of the goals set, involvement of the state to develop a comprehensively planned society became indispensable.

Considering (polder-)reclamation projects throughout the world one may observe that in most countries the first two changes did occur in little time or no time at all, while appropriate state involvement within the task of comprehensive planning isn't a matter of course, mostly due to lack of "planning history".
The papers reported upon in this paragraph do offer some valuable history-based experiences which may be applicable in current reclamation projects.

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Rijpert in "Shops and shopping centres in the IJsselmeerpolders" deals with the approach developed to obtain a balanced retail trade composition within the IJsselmeerpolders. Although directed, specifically, to the retail trade sector, this approach in an adapted way may be of use in planning other sectors in a reclamation area.

Rijpert goes through the shopping history of the 20th-century Dutch polders seeing with respect to the Wieringermeerpolder (1930).

"The only statement was to be found on the allocation of shopping facilities in the new polders said that it was to be expected that settlements of people would arise on the main crossings of roads and canals and that possibilities had to be created for the establishment of shops. And that was all there was said to it".

The planning effort confined itself to the monofunctional agricultural purpose of the polder and due to non-planning the retail trade sector shopkeepers without enough professional knowledge could open a large amount of shops and "for a long period of time there was a chaotic situation during which supply and demand were completely out of balance".

Concerning the North-East Polder (± 1946) it is pointed out that a, theoretical demand and supply model has been applied - looking at things after the event simple and imperfect, but at the time 20 years ahead of common use in the Netherlands - being "effective in the sense that the chaotic and unbalanced situations of the Wieringermeer did not exist" and developments could be kept in sight and regulated to a great extent. A crucial role in the model's implementation was played by the Development Authority, which built a certain amount of shops and thoroughly selected the shopkeepers.

At first only based on general experience, the theoretical side of the model used, was built upon the practical experiences of shopkeepers and customers, this being the starting point of distribution planning "Gradually a policy was developed to establish retail trade facilities in a responsible way based on theoretical principles".

And during the colonization of Eastern Flevoland (± 1967) this model - outlines presented by Rijpert - was used to "determine at any moment in the future the amount of square metres necessary for shopping facilities in the defined area". Rijpert in his paper more in detail discusses the regular surveys, carried out, to adjust the model applied. Concluding this report I would like to put forward some more general theses:

- To establish a well functioning retail trade (or any other) sector in a new polder (reclamation area) careful selection, or adapted education of tenants is needed. A state-owned Development Authority is the best way to do so.
- Planning developments in a polder (reclamation area) - forced by the special circumstances - are commonly far ahead of the developments in this field on a national scale. (Rijpert presents evidence to this thesis, with respect to the planning of retail trade).
- It has to be attempted to adjust the experience based Dutch polder-planning for appliance in countries, confronted with relatively sudden, large scale, multifunctional impoldering (reclamation) projects.

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In their paper "Land evaluation for agricultural development in Leziria Grande, Portugal", Reis, Perdigao and Perdigao present a case in which the F.A.O. Land evaluation methodology was applied in Portugal for the first time. In this project the following goals had to be reached: "increasing land productivity, providing more employment opportunities, obtaining more export produces and avoiding imported ones, as well as promoting a better income distribution".
As the authors already signal the nearly impossible task to clearly present the methodology in their limited paper - however actually succeeded in trying this - I won't try to do so in an even more restricted way. Their conclusion however is worth to be cited as by using the methodology described it appeared that: "the present productive capacity of Leziria is very much below its potentialities. With the land improvements some of the limitations can be totally or partially removed, resulting in higher yields, landuse intensification, increasing irrigated area as well as introduction of new crops and landuse systems".
In spite of the formulated multifunctional goals, the description of the methodology used as well as the conclusion drawn, do give the impression

of a rather monofunctional (agriculture) macro economic approach. In the history of Dutch polder planning on the contrary gradually next to economical, sociopolitical factors have been taken into account, while multifunctionality replaced monofunctionality.
In my view both approaches are valuable up to a certain "moment". The question is however, which features do indicate this "moment". Is it the size of the reclamation project, the distance to the nearby already structured "old land", the structure of the old land as such, the country's available planning capacity, the origin of the future population, the regional or national market conditions? Or do other features play a role and how should the desired extensiveness be determined of the approach to be applied.

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"Qualitative spatial planning models for new urban fringe areas" are presented in Wezenaar's so-called paper. This paper actually reflects the planners' high degree of freedom in designing and the laborious decision making process in polder planning.
With respect to Almere's Buitenruimte (Outer Area) Wezenaar sketches the sheer infinite opportunities presented by the site itself, while on the other hand the absence of guidelines in the existing environment and the inexperience with the planned rate of growth do hamper the planning task.

The planning philosophy, with respect to the Buitenruimte - based upon the principles of coherence and diversity - is elaborated. The future users being involved in the planning process, by playing a so-called preference budget game. This involvement - in which the future inhabitant is asked to select a number of attractive environments, considering a limited purchase capacity - appears to be a success both to participants as well as to planners.
"For future urban fringe areas where not yet a development like afforestation took place, another elaboration of the general development strategy was handled. Reason for this was the preference budget game model being based upon certain recreaction designations. It gives no clue for all possible urban fringe elements of non-recreational character. So a structural theme, a "leitbild" is needed. The following concept has

been chosen: the phenomenological orientation with regard to the town. It has to organize the spatial planning on micro level. The base for this concept is the idea that cities are artifacts and worlds of artifice placed at varying distances from human conditions close to nature".

Wezenaar extensively deals with this model and finally concludes "The described model has been tried out in four historical old land urban fringe areas. Because the model matches the real situation it can also be used outside the polders".

Another evidence of the innovative potentialities of the challenging task of "polder planning"?

3 Opportunities and restrictions

Braaksma in "Polders and landfills as alternative sites for major airports" briefly considers the opportunities of polders and landfills in locating space-consuming airports. This because of "many of the major cities of the world are located adjacent to bodies of water".

The landfill concept appears to be applied for several airport extensions while also parts of new airports have been based upon landfills. Several examples are sketched.

"The polder concept can be used where the depth of water, or the availability of fill precludes the construction of a landfill alternative". Although several feasibility studies have been performed - depths from < 5 to 40 metres below sea-level-"to date the polder concept has not been used .....".

Presenting (off-shore) site evaluation criteria, a summary of (dis-) advantages is given, but actually Braaksma's last conclusion totally explains the present-day situation. "Economically, offshore airports appear to be difficult to justify. They require huge capital investments. In the light of the current economic state of the world it is therefore not surprising to note that very few offshore airports have been built".

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In "Do polders adapt to their environment" Bos states "it must be clear that a new entity, e.g. a polder, has got its own spatial identity and that is fully appreciated. But life can at any scale make social, functional and through these also spatial links between old and new, making old and new one divers but organic pattern". Examples of different scale are presented. With respect to the Haarlemmermeer ".... the suburbanization pressure of these two cities (Amsterdam and Haarlem) was such that new residential areas were being planned in the polder ....". The North Eastpolder: "..... East of the polder the area is of poor agricultural value and poorly populated, but of high touristic value. This caused the two woods along the east border to become centres for recreational activity" and "..... three villages in the south east section of the polder attract quite a few people, commutors from the old land .....".

Thus Bos shows that "through quite a few functions old and new land mutually influence each other, thus integrating the polder in its environment".

With respect to Singapore and Almere it is shown that city planning techniques are quite able to transcend the border line.

I can endorse Bos' answer "they should" to his own posed question with respect to the social and functional linkage of old and new land.

But in my view, no convincing arguments - at least on the larger scale - have been put forward to endorse this answer with respect to the spatial linkage, although from the examples given it is obvious that polders "could" adapt to their environment. Can't a sharp bordering line give as much spatial satisfaction as an integrated one?

4 The Markerwaard case

At the Barrier Dam of the IJsselmeer there is a monument on which is sculptured the famous slogan "A nation that is alive, builds for its future". Reclamation of the Markerwaard - the last part of the Zuiderzee project - at the moment however is no longer a matter of course.

The Markerwaard, being the main issue in the Netherlands, when discussing polders and physical planning on a nation wide scale is discussed in three papers.

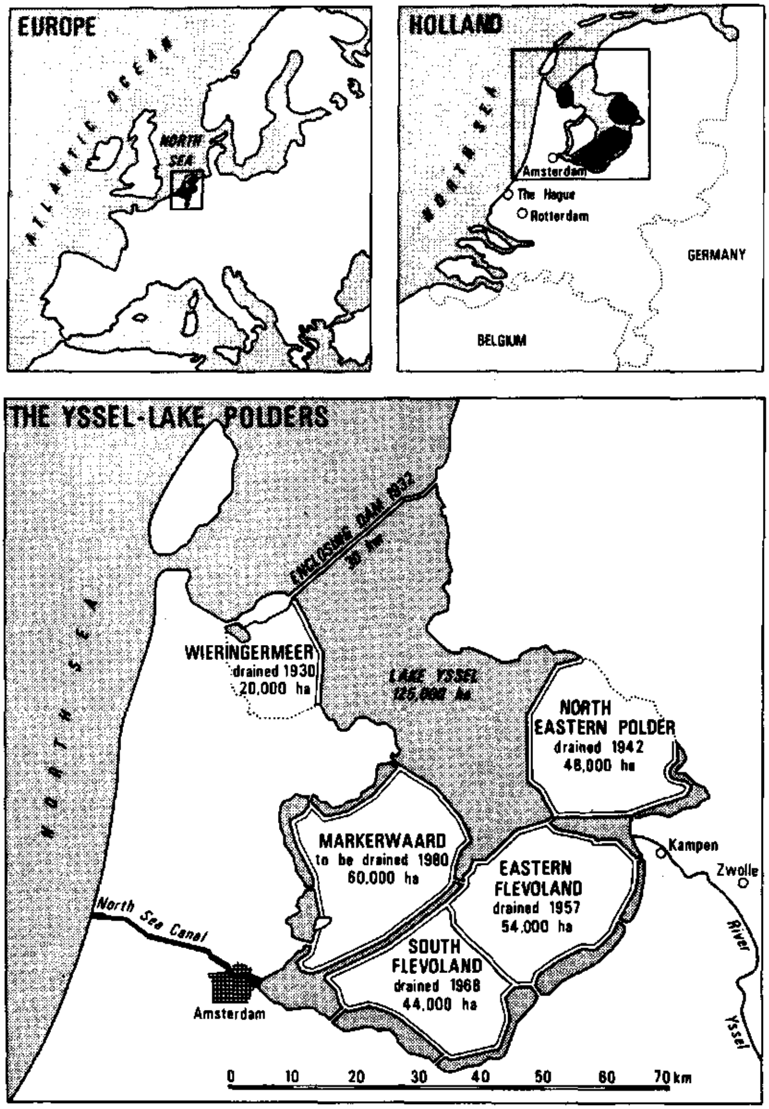

Figure 1: Realised part of the Zuiderzee project and the planned Markerwaard alternative.

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Spierings in "Urbanization in Dutch polders; the evolution of the Randstad conception" only incidentally mentions the Markerwaard, however his paper is important when trying to retrace the development in the role of the polders, with respect to the national physical planning policy, within the past twenty years.

In a very compact way Spierings deals with the "continuing contest between contracting and widening forces" within Dutch physical planning policy.

With respect to the role of the polders in this policy he shows the significant change in goals which has taken place. After the publication of the first "Report on physical planning in the Netherlands" (1961), this policy was implemented in the long-term planning of the IJsselmeer region "A structure plan for the Southern IJsselmeerpolders" (1961). In this plan Lelystad "being designed as the regional centre of the Noordoostpolder, the Markerwaard and both parts of Flevoland (intended number of inhabitants 30.000), its function and size had been put moreover in relation to the urbanization process in view in the northern Randstad (new target: about 100.000 inh.)".

The original widening trend in physical policy, turned into a contracting trend in the seventies and ".....recommended adequate housing production and urban renewal, so advertised more concentration of all urban functions within certain areas, the agglomerations and the near vicinity". The polders did offer opportunities to meet this challenges Lelystad (target: 100.000 inh.) and Almere (target - as being a pure satellite of Amsterdam -: 250.000 inh.) actually reflect the tremendous change in physical policy designating polders originally meant for agricultural use to areas as a habitat for about half a million of people.

Spierings does present - without stating so explicitly - the ability of the southern IJsselmeerpolders to fit within the changing physical planning policy - due to their very own nature of rather unrestricted opportunities. With respect to the last polder to be reclaimed he concludes "As far as the reclaiming of the Markerwaard is concerned, the future developments on spatial policy and practice will influence deeply the functions of this last polder in the IJssellake region, designed in the 19th century, when it will be drained".

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In "The IJsselmeer area: The protection of a natural fresh water area of international importance" van Grondelle calls attention to the importance of the process of " reorientation on the necessity of reclaiming the Markermeer". In his view the reclamation scheme for this lake - as proposed by the Dutch government - "is a clear violation of the Wetlands Convention (1972; ratified by the Dutch government) according to which the conservation and careful management of this wetland of international importance should prevail". Moreover he states "In view of this development - the change of physical planning policy to a much stranger concentration of urban development (see Spierings' papers) - one can understand that serious doubts arise about the necessity of the Markerwaard polder". Continuing he adds "To build the new polder would be to fight the symptoms instead of the true reasons.....will mean a free hand to the space-wasting process which increases the problems.....is therefore contrary to the government policy on physical planning".
His major point of critism concerning the decision-making process is the lack of alternatives in the government's draft decision for reclamation, especially "the lack of an elaborated alternative for the development of the IJsselmeer area without the Markerwaard polder". He presents a short sketch for this development defining "the values of ecology, landscape and cultural history of this area as the basic values", combining these with other functions of the area.
Concluding he states "in my opinion, it is necessary together with every proposal for reclamation - where ever it may be in the world - to also seriously consider the alternative: development without reclamation".

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Goverde in "Decision criteria: differences and shifts between insiders and outsiders in Dutch polder decision making" attempts, by using the Markerwaard case, to illustrate his theoretical proposition that "there is a strong relation between the competition of individuals, groups and institutions for better power positions and the decision criteria which will be used in the final decision taking".

In my view, within the Markerwaard decision process during the last decade, the decision criteria did not change, but the set of criteria used, has been completed by outsiders and a considerable change of importancy level of the criteria considered has taken place. However renouncing discussion on this matter of definitions, I would like to put forward some important features of the decision process, as presented by Goverde.

In 1972 the minister of Traffic and Waterstaat publishes a discussion nota concerning the Markerwaard. Six reclamation options (including the non-reclaiming one are presented.

These six options are put to public participation, while in the meantime one alternative is elaborated by the Development Authority and added into the participation process, already being on its way.

Partly due to the arguments added by the public participation it appears that some advisory boards are largely divided, large minorities not (yet) being convinced of the desirability of the new polder.

The Cabinet decides to a more extensive and formally regulated public participation procedure. Only one (large scale) reclamation scheme (the one elaborated by the D.A.) can be discussed upon. During the participation process a substantial amount of "new" alternatives emerges. Actually the problem setting as a whole did change. Formally the government still poses one option, but pressure is put upon alternatives.

This profound change took place because, as Goverde states, the accessibility of the decision takers to the insiders of the Markerwaard opposition did fairly increase, and the once exclusive support for the pro-Markerwaard position (scientific research, planning procedures, symbols) is now also used by the opponents. "In summary the power balance sheet was slightly shifted toward the anti-Markerwaard position..... For the decision takers, however, the present-day condition of the power balance sheet is an uncomfortable one. Therefore the most likely prospect for the future will be a deliberate policy of non-decision making".

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To complete the Markerwaard picture - as far as possible within this brief context - I will present some main features of the 1980 government's draft decision.

Reclaiming the Markerwaard offers opportunities to a number of space consuming activities. The value of a Markerwaard with respect to the spatial development of the Netherlands as a whole however is more important, than the value to specific activities. (Corresponding with the ability of adjusting to changes in physical policy as shown by Spierings).

Due to its geographical position and the nature of its underground the Markerwaard offers specific opportunities to several sectors like urbanization, agriculture, forestry, recreation (with exception of large scale shipping) a second national airport, a large military training ground.

An essential element in weighing the need for reclamation is the expectation that physical pressure in the Netherlands keeps increasing. As first use of a polder can only be made 13-15 years after the start of reclamation, in view of increasing spatial pressure reclamation has to start pretty soon. For the same reason of time-span detailed planning at the moment isn't possible.

The reclamation scheme proposed, does give enough remaining opportunities to sectors which will be affected by the reclamation as fishery, nature conservation, landscape and cultural history.

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It is difficult to extract general features of the Markerwaard issue, worth to be discussed by a foreign audience. Therefore I would confine myself to some reflections. not necessarily comprising the key features of the issue, but meant as incentives for discussion (and not necessarily reflecting the author's opinion).

- During a long term reclamation process the Development Authority involved, acquires a lot of specific experience and knowledge. In a continued planning process this may lead to technocratic planning principles for prestigeous self invented objects, as decision takers are no longer able to demand a neutral problem setting. In a reclamation process possibly to be terminated the Authority's need to survive may also obscure the problem setting. The question arises whether Development Authorities do need a specific democratic control, and if so in which way this should be realised.
- The first Dutch polders were reclaimed, without considering alternatives. Usefulness or even necessity of reclamations was obvious.

Nowadays in many countries the same situation applies to most reclamation projects. Grondelle however actually does plead for a worldwide considering of the non reclamation option. Questions arise such as, from which scale alternatives have to be considered or even can be considered and to which extent alternatives have to be considered (e.g. within the total national physical policy).

- Uncertainty nowadays is a keyword in Dutch polder decision making. The Flevopolders afterward appeared to offer important opportunities in realising the changing physical policy advocated. Timespan needed to reclaim the Markerwaard is about 15 years and uncertainty exists with respect to the future situation. Is it responsible to rely - as the government does - upon the Markerwaardpolder playing a corresponding role in the year 2000. Even if all existing options fail to exist, at least a large natural area has been created?

5 Conclusion

From the papers presented it has to be concluded that the theme physical planning in polders does have many facets. Most of these facets equally being applicable to reclamation projects in general.
This report only deals with very little of the relevant facets. Many reclamation/impoldering projects throughout the world are on their way, each undoubtedly confronting a complex task in the field of planning. Therefore appropriate ways have to be found to transfer the large amount of experience-based knowledge and expertise from where it has been gathered, to where itis needed.

Reference

Constandse, A.K., 1982. From Spontaneous Settlement to Integrated Planning and Development. Paper to be presented at "Polders in the World", October 4-10-1982, Lelystad, The Netherlands.

SUB-THEME: SOCIO-ECONOMIC ASPECTS

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1 INTRODUCTION

For the discussion in the workshop socio-economic aspects of polder development, 14 papers were made available to the reporters. Ten of the papers focus on the IJsselmeerpolders or at least on The Netherlands and four are dealing with settlement activities in other countries, be it not only polders. It is clear that through this set of papers not a balanced picture is presented on the socio-economic problems with regard to polders in the world.
The papers have been divided into two main categories.

1 papers dealing with polders and settlements outside The Netherlands (Awan and Latif; Oyedipe; Smit; Steenwinkel).
2 The IJsselmeerpolders (Netherlands)
   Papers in this category are rather arbitrarily organised in four groups.:
   a sociological and historical aspects (Constandse; Hoeve; Schenk)
   b management and administration (Den Hertog; van der Spek)
   c role of new centres and employment (Fels; Scherjon and Verhoef)
   d landuse and recreation (Ter Haar; Hengeveld; Hoeve)

A short abstract of the fourteen papers is is given hereafter.

2 SHORT ABSTRACT OF THE PAPERS

2.1 Papers on polders and settlements outside The Netherlands

- The paper of Awan and Latif deals with *'Socio-economic aspects of water management of salinity control and reclamation project no. 1 in Pakistan: a case study'*. The results of the pre- and post-project evaluation and the socio-economic impact of the project are discussed. In this pilot project of 0.5 million hectares in the Indus-plain tubewells are installed who should lower the very high groundwatertable, decrease water logging, help to reclaim salt-affected soils and provide more irrigation water. Although the high investment in the tubewells was justified in terms of higher cropping intensity and expected higher yields, the results show quite a different picture. Due to the high capacity of the tubewells installed and their positioning, combined with inadequate and irregular organization of water allocation, operation and maintenance, irrigation water supply to the farmers is not reliable and insufficient. An increase in cropping intensity is only due to the additional installation of private tubewells. In 1981 the yields are only 50-60% of the expect ones. A result, the benefit cost ratio is less than one and the internal rate of return is only 5.7%.

The farmers who often have salt-affected lands, are hardly able to pay their waterfees: loans and the selling of animals must fill in the gaps.

- Oyedipe describes in his paper *"Innovative potentials of Kainji Lake Basin for Fadama farming: a study of three settlements'* the situation in three settlement villages. He explains the role and functions of the 'chief farmers' in relation to the World Bank promoted training and visit system for extension service. He concludes 'that meaningfull change for development has to come from outside the rural areas'. and that innovations have to be administered carefully.
- In the paper *'The origin and early stages of the Herman Göring polder (Tümlauer Koog) in Schleswig-Holstein, Germany'*, Smit stresses the influence politics and ideology can have on polder development. In the case discussed the need for a quick political success led to a hasty implementation of the empolderment and the construction of (farm) houses which resulted in many technical problems. Conflicting political views and institutional interests can be perceived in the layout of the new land, the architectural design and the selection of settlers. Due to the fact that the settlers had to start under poor natural and social conditions and had to depend heavily on each other in the early stages, a considerable amount of solidarity and community-spirit was developed. Even after handing over their farms to the second generation of farmers and often living outside the polder, they stick together. Under the second generation the ideological character of the polder, both social and economic, has disappeared.
- Steenwinkel's paper *'Policy and settlement aspects of tidal swamp land development in Indonesia'*, discusses some of the problems concerned with the reclamation of the last remaining land resources of this nation.

  Indicated are the concequences of high and low costs development and the possibilities to combine four main policy options: 1) A fast and certain increase of rice production; 2) a maximum income for farmer from 2 ha; 3) maximizing the transmigration from Java and Bali to the Outer Islands; 4) keeping development cost per ha at minimum level. Furtheron, criteria are indicated for settlement planning, such as the location of houses, the services to be provided on basic, primary and secondary level, and its location.

2.2 Papers on the IJsselmeerpolders (Netherlands)

a. Sociological and historical aspects

- Constandse in his paper *'From spontaneous settlements to integrated planning and development'* indicates the changes in character of land reclamation and its settlement in The Netherlands. Initially the aim of polders was to protect the land against flooding and occupy it permanently and safely. During the next phase investment considerations of rich urban merchants were the reasons for polder construction. From the 19th century on the state intervened in polder construction. This state intervention was at the beginning a very minimal and purely technical assistance: settlers were really pioneers. Gradually the state-intervention became more and more comprehensive until it reached its present-day all-comprehensive character.

  The character of the various IJsselmeer-polders that were constructed during several decades, reflect the changes in Dutch society, through differences in landuse, agricultural layout, settlement pattern, service centres and recreational facilities: each polder is an expression of the time just before its construction.
- The paper of Hoeve *'Allocation of land to agricultural uses in the Dutch IJsselmeerpolders'* indicates that since 1910 there is a trend to allocate more of the land that through reclamation becomes available, to urban use, recreation and natural reserve. Furtheron the paper indicates the trend of further specialization in agriculture, the great increase in farmsize and plotsize, the criteria for settler selection and the two legal forms of land lease to settlers and special agriculture-related enterprises.
- In his paper *'New structures in newly reclaimed land? The development of social structures in Flevoland, (IJsselmeerpolder) The Netherlands,'* Schonk pays attention to the three main tasks sociologists can have in helping to build a new community, 1) make a thourough study of the intention and aims of the polder in connection with the social structure of the future population; 2) advising in land use and service building in order to improve the quality of life; 3) evaluation of the quality of life and following and explaining, the social changes that occur.

He focusses his attention on the two main cities in the polder: Lelystad and Almere. Lelystad was started by a small group of 'colonists' who in both working and leisure time were strongly involved in building the town and the community.
The atmosphere of 'participation' changes, when the commuters of Amsterdam settled, whose main reasons to move were to find better houses in a safer surrounding and with more outdoor recreation facilities. In Almere Haven the same process took place but in Almere stad no 'colonists' mentality was developed. This made the start of community life much more difficult. Without special and guided efforts the immaterial aspects of the quality of life of the new settlers will not be any better than the situation where they are coming from: new and more integrative social structures do not come autmatically into existence to replace the social luggage settlers took with them to their new environment.

b. Management and administration

- Den Hertog in his paper *'The Zuiderzee project in The Netherlands'* describes some of the administrative changes that took place with regard to several polders. Once the decision was taken that it should be the central government to finance and carry out the Zuiderzee polders, specialised authorities were created by law to carry out the work and for the further development of the polders (IJsselmeer Polders Development Authority), both under the Ministry of Transport and Public Works. After completion of the polders and before the start of settlement, different organizational arrangements with different degrees of autonomy were founded for the various polders to incorperate them (provisionally) into the normal administrative structure. However, it is only in the case of the Wieringermeerpolder authority that it governs settlement plus management and water control. In the North East polder, initially a commissioner was appointed as sole manager with the power of a municipal council and its executives. With the increase of the number of inhabitants, four municipalities were formed up till now. Conclusive arrangements for watercontrol (volume), waterdefences and the provincial structure for the polders are still pending.

- The paper of van der Spek *'Management as a task, polder administration as a means for an integral management of rural areas'* makes the suggestion to extend the responsibility of the present polder-administration unit. Quality and quantity of water and its level influence strongly certain valuable ecosystems. Canals and embankments are or can become important recreation areas with only minor adaptions to be made (slightly higher bridges for the passing of canoes, etc.; simple pavement of inspection roads to make them attractive for fisherman, walkers and cyclers etc.) Due to the close interrelationship between control of water for agricultural purposes, nature management, landscape management and recreation in rural areas, an integrated management via the polder administration units is advocated.

c. Role of new centres and employment

- Fels in his paper *'Employment planning in new towns in the IJsselmeerpolders'* describes the influence changes in the economy and new insights with regard to the role of new towns can have an employment forecasts Emmeloord and Dronten, planned as agricultural centres show now an employment structure where the service sector and manufacturing industry dominates.

  Lelystad changed it position of new town, from regional economic centre to overflow town with employment growth lagging behind demand. Almere has reasonally fulfilled its employment targets in 1981 but the composition of the labour force is different from what was planned. Instead of the manufacturing sector it is especially the wholesale sector which shows particular interest in moving from the Amsterdam-region to Almere. Employment planning is supported by attractive services, low-costs facilities and tax-stimulants to encourage enterprises to start their business there.
- Scherjon and Verhoef in their paper *The regional economic policy in the new towns Almere and Lelystad'* discuss the functions those two towns have to fulfill in the national framework of The Netherlands. The main function was to relieve the overcrowded conditions of the Randstad by offering housing facilities and to create at the same time a living environment that could meet both housing and jobneeds.

Due to two developments this policy had to be reconsidered 1) There was a failure in matching jobs and skills. This forces polders resistent to commute to the Randstad for jobs 2) The present recession in the economy, makes firms hesistant to move from one place to another.
But the authors claim that these towns have comparative advantages for small and medium sized enterprises.

d. Land use and recreation

- Ter Haar's paper *'Recreation in new areas. The IJsselmeerpolders as a case-study'*, shows a considerable change in the attention given to open-air recreation since the first polders were started. In the planning of the first polders attention was only given to open-air recreation of the 'following type': small forests and parks, central open spaces in villages, swimming pools etc. were clearly meant for the recreation of the local residents. With the construction of the subsequent polders, the responsable authorities were surprised by the enormous interest of one-day tourists for the new borderlakes with their freshwater beaches and watersport facilities. The polder area itself turned out to be a tourist goal as well.
  In response to this interest it was decided upon in the early sixties to consider open-air recreation as a stimulating factor for regional development: both 'following' and 'stimulating' type of open-air recreation facilities were included in the regional physical planning. Areas around and close to borderlakes have been arranged in such a way that they now attract and can absorb many tourists from all over the country and even from outside the national boundaries.
- Hengeveld's paper on *'land evaluation for urban development in the Netherlands'* indicates that applications of land evaluation procedures for urban development can provide important information for planning and design of urban area development.
  Since soil- and hydrological surveys are necessary for local urban development anyway, such a land evaluation should be done at the beginning of the planning process, when it can be done without extra costs.

- In his paper *'Cost benefit analysis for a planned part of the IJsselmeerpolders project'* Hoeve shows first of all that there are many practical and theoretical problems related to cost-benefit analysis, because one has to do with direct and indirect - material and immaterial effects. Furtheron the paper makes clear that cost-benefit analysis is wide open to political and other types of manipulation.

3 SOME COMMENTS AND SUGGESTED THEMES FOR DISCUSSION

It was laudable that the organisers of the international symposium on *'Polders in the World'* have made room for the human being in these polders. After all, polders are made by people for people (Schonk).
However we are faced now with the question what it is in polders that influences human behaviour in such a way that it is different from other areas.
One element that clearly makes a difference is the influence of the eternal fight against the water on human character and society. Without following all the way long Huntington's opinion in his book *'The climatic factor' (1914)* it cannot be denied that the habitant has a profound influence on society (Forde; Habitat, Economy and Society, 1934).
In a polder - environment a community must necessarily find an internal organization form in such a way that it effectively can protect itself from the potential calamity that in one night could destroy the community (like what happended in The Netherlands in 1953). A fairly high degree of internal organization of the polder population and polder management is necessary not only with a view to eventual calamities but also to cope with the daily operation and maintenance of the rather complex watersystem and waterdefences. As compared to large irrigation projects there is a vital need for adequate maintenance and operation.
Another possible difference in polders compared to other areas is that once man has driven out the water, he has land that is tabula rasa, both physically and socially. This gives the opportunity to create a physical environment that is completely man-made at a specific point in time and requires hardly any adaptation (Constandse; Steenwinkel).

Polders therefore reflect very clearly the social and even the political situation at the time they were created (Smit and other authors). However, the latter point is not specific for polders. One has only to think about the Geziria-scheme in Sudan. Which means that in fact the social problems encountered in polders during their initial stages of settling the 'colonists' and later on during the growth of a new society are basically the same as those met in (large) settlement schemes in empty areas all over the world.
Our conclusion is that polders represent a special form of settlement-scheme in empty land with high requirements for drainage facilities (and irrigation eventually) and for internal organization and management.

Of the papers presented, several of them are dealing with subjects that are not specific at all for polders or even for settlements in general. Most of the contributions to this section of the symposium are of a descriptive nature; they supply us with interesting information but do not compare their information with experiences from elsewhere. Neither are we supplied with efforts towards a more general or systematic approach based on information the authors might have, as was for instance done by R. Chambers his book *'Settlement schemes in tropical Africa'* (Routledge and Kegan Paul 1969), by G.B. Palmer in his article *'The agricultural settlement scheme: a review of cases and theories'* (in Antropology and Social Change in Rural Areas, B. Berdichewsky ed, Mouton 1979) or by C. Takes in *'Land settlement and resettlement projects'*, ILRI 1975.
Nevertheless, in many papers directly or indirectly themes are indicated that are encountered all over the world where large scale polders or settlement schemes are planned and implemented. Some of these themes will be mentioned here.

- The influence of politics, ideology and the national image on the start, the layout and the speed of implemention of polders and irrigation and settlement schemes. It is often related to a catastrophe or the threatening of it that the political will becomes strong enough to devote considerable shares of public funds to realize schemes that have lingered often for a long time on the drawing boards of the civil engineers. The Netherlands is a case in point.
  For political purposes polders and schemes must be inaugurated at a

specific time. Since this time in many cases is earlier than desirable, the speeding up often has a detrimental effect on the quality of the technical works and affects the level of living and its quality for the new inhabitants for many years in an adverse way. Smit's paper presents a clear example on this item. The same phenomena is happening on a much larger scale in the Mahaweli Ganga Scheme in Sri Lanka.
An example of political motives to revise the civil engineering design is presented by the Syrian Government who required a cheaper and higher design of the Euphrates dam because it wanted to have the highest dam in the region (higher than Egypt's high dam). Consequently, settlement was delayed.
It is interesting to find out how instrumental or how dysfunctional political forces have been in the start, design and speed of development of polders and other settlement schemes.

- Large polders and settlement schemes require a specific type of organisation that is powerfull and can coordinate the many different types of activities that are involved in such works. The 'authority' is a well known and preferred type of institution for these activities. They have considerable advantages but also disadvantages. To create an organization is easy but once its task is over or declining in size and importance, it is so far more difficult to diminish it in size or to liquidate it.
  Could it be that the slow integration of the new areas in the political system of the Netherlands (municipal, provincial system). (Den Hertog) was also partly due to some hesitance of the IJsselmeer Development Autority to lose some of its influence?
- One of the most interesting sociological aspects of polders and large settlement schemes in empty areas is the creation of new communities. Several important issues can be distinghuished.
  • First their is the selection of settlers with such problems as the question whether to given prefence to highly qualified settlers in order to make the polder/settlement an economic success or to give chance to poorer farmers from the old land (Steenwinkel, Smit). Should selection be done on an individual basis, often resulting in a deformed demographic structure with serious concequences for the school and health systems, or should one take whole communities or parts of them in order to have at least some basis for the develop-

ment of 'new' community. In the latter case it is likely that the 'social luggage' (Schonk) will survive longer and can retard modernisation.

Often, due to the excisting social and political structure, selection of settlers is also based on certain quota's with regard to specific groups in the society. A specific distribution over religious groups has strongly influenced the society in the North East Polder. The same kind of distribution took place in Suriname with regard to racial groups and in Africa with regard to tribal groups.

- Another interesting aspect in how far the settlement agency should take care of all aspects: what efforts can be expected from the settlers themselves. Apart from the economic and financial aspects (often of great importance in developing countries) there are also some interesting consequences that have to be taken into account by making this decision. There is for example the community spirit. From several papers (among others Schonk, Smit, Scherjon and Verhoef) one can draw the conclusion that a settlement agency preferably should not take care of everything but instead should leave the settlers with building and organizing a part of their new environment. These common activities, often to be carried out under difficult conditions, enhances a colonisers' spirit that makes the building of a new community and the integration of settlers in it, much easier. When the 'late' settler arrives most things have already been organised and found its place, and communication patterns have been established, which make his integration in the young community much more difficult. People are making polders for people (Schonk) but what is the say of the settlers in the physical and social environment in which they and their children have to live? In other words is there any room for participation (and what kind of participation) of settlers in the design and implementation of polders and settlement schemes?
- It is quite normal that the governments' objectives leading to the construction of a polder, are revised during the construction period which extends over a number of years. Pressing problems and new insights might lead to revised wishes like higher demands for urban development and industrial facilities, or for a modified type of agricultural exploitation and related settlement. The IJsselmeerpolder Authority, under sometimes heavy political pressure, has been

able to adapt its plans for the physical infrastructure to accommodate the new wishes. It is an interesting question how much flexibility can be built into the initial plans for layout and physical infrastructure that might come up during later stages of planning and implementation. How far in the planning procedure could flexibilities be maintained at what extra cost? These questions are not only relevant to polders and settlement-schemes, but do apply to irrigation projects in new areas or in already populated areas as well. Giving room for new insights in regional development, in farm economics and for settler-participation looks worthwile to be considered.

- From theoretical point of view it is interesting to discuss under which social, economic and ecological conditions polders are/were constructed. Under the social conditions one could imagine a high population pressure, the fear for a calamity, an adequate level of technology, a fairly high degree of internal organization and differentation plus a sufficiently strong central government to allocate the necessary funds and required manpower for the construction and operation (Wittfogels' hydraulic society?). The economic conditions require a.o. such a high surplus production that the investment capital can be supplied and that future demands for the high cost agricultural and industrial goods or facilities to be produced in the polder, is high enough to justify the investment as compared to investing it in further intensification on the existing land. Ecological conditions could be that the prevailing (agricultural) production system fits into the polder environment, and that the creation of the polder does not interfere too much with the natural conditions necessary for food production and healthy living conditions in other parts of the country.

It is clear that only some of the themes mentioned by the various authors of the papers have been indicated: the selection of the themes indicated above is strongly influenced by the experiences and interests of the reporters.

THEME B 5. ENVIRONMENTAL ASPECTS

ENVIRONMENTAL ASPECTS

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Abstract

Eleven papers were presented to this theme. Nine of them are from The Netherlands, one is from Suriname and one deals with the protection of the city of Venice and its Lagoon. Three papers deal with general aspects of polder environment, its functions and influences. Developments in the Ysselmeer-polders and the Wadden Sea area are described. For part of the latter region, a project assessment study was discussed. The ecological effects of a proposed reclamation project were quantified for use in a cost-benefit analysis. Another project assessment was related to a land consolidation project. The methodology of these assessment studies should be given widespread use. Similarly, the use of modeling techniques, as presented in a paper on eutrophication processes, can help to understand effect-cause relationships and to take the right decisions on safe-guarding or improving our environment.

1 Classification of papers

Eleven papers have been submitted to the theme B5 "Environmental aspects". Nine papers are describing polder environments in the Netherlands, one paper is from Suriname and one deals with the protection of the city of Venice and its lagoon. All papers are listed in Table 1. If the title did not give full information about its subject or area, additional information has been given in the column "Remarks".

A classification of the papers was made as follows :

A General aspects

in the Netherlands

Paper 1 by De Jong and Wiggers

Paper 2 by Klein

in Suriname

Paper 3 by De Jong

B Developments in the Ysselmeerpolders

Paper 4 by Driebergen

Paper 5 by Polman

C Developments in the Wadden Sea area

Paper 6 by Drijver

Paper 7 by Joenje

D Project assessment

Paper 8 by Dankers

Paper 9 by Asjes

E Water quality

Paper 10 by Bernardi et al.

Paper 11 by Smits and De Rooij

Paper 8 could be also classified under the heading C. Each paper will be summarized and discussed according to the aforementioned classification but cross-references will be made to the other papers whenever appropriate.

2 Summary and discussion of papers

A General aspects

Paper 1 by De Jong and Wiggers is mainly a descriptive review of the historical development of the four main polder areas in The Netherlands : polders in the downstream flat river catchment areas, polders in peat areas, polders on the bottom of drained lakes and polders created by coastal embankments (Figure 2). The authors describe how the original habitat was changed in each of these areas and how land use and parcelling was affected by the type of reclamation (Figures 3, 4 and 5). Improvement of farming conditions has often resulted in a decrease of bird species and floreal va-

lue (see Paper 2). The land accreation areas along the coast are recognized as having a very high ecological value. New embankment constructions in the Wadden Sea are therefore unlikely to be executed (see Papers 7 and 8). But it is also noted that large parts of the new polders have been developed into nature sanctuaries and forests (see Papers 4 and 5). The authors briefly discuss the change in land use since 1900 (Figure 8) i.e. the decrease in agricultural land, estimated nowadays at ca. 13000 ha per year, lost by urban expansion. They introduce so-called disturbancy zones around towns and villages in order to assess the effect of urbanization upon the region (Figures 9 and 10). Pollution effects, such as eutrophication of canals and lakes and waste dumping, are mentioned (see also Papers 10 and 11).
This paper gives the general reader an interesting overview on the subject of this session. It is in fact an introduction to many of the other papers of this session. Detailed information, e.g. about increase or decrease of number of bird species, etc. ..., can probably be found in the literature listed at the end of the paper.
For easy reference, however, it would have been preferable, if the literature cited had been also quoted in the text. Maybe the authors could specify during the discussion how they define "disturbancy zones".

Paper 2 by Klein details about the ecological developments and relationships in new polder areas. The author discusses briefly the soil ripening, the influence of the hydrological conditions (leaching processes and capillary rise) and the microbial development. The vegetation development is affected by dispersal, spatial differentiation and prevailing wind direction. Management measures, e.g. the sowing of reed, help to establish favorable conditions. Human interference, by reclamation activities and road building, etc... offer opportunities to study the spatial dynamics of various species.
It is surprising to note that plants spread more rapidly

than animals.
Nature conservation and nature-engineering or habitat-building is discussed (see also Papers 4, 5 and 7). Detailed inventory prior to embankment and development and regular surveys are strongly recommended. The use of remote sensing techniques is suggested.
This paper points rightly to the extraordinary possibilities for research on ecology in new polder areas. These studies form the base for environmental impact studies (see Paper 8). As most of the referenced literature is from Dutch origin, the author indicates the need for more research elsewhere in the world. Would it be useful to draw minimum criteria for this kind of research ?
Finally, it is worthwhile to note that 53 references have been collected by means of an online search using computerized literature data bases : a method to be promoted.
Paper 3 by De Jong may be seen as an answer to the request of Klein, urging for more research on new polder areas elsewhere in the world. The estuarine area of Suriname has a high natural fish productivity. Reclamation of the area for rice production will enhance very important effects on the ecology of the environment. Among these effects are decreased fresh water runoff, alteration of the forest habitat which is very important for fish populations, contamination of drainage water by pesticides.
It is recommended that the whole estuarine zone should become a Special Management Area and that planning assessment should be performed prior to development. The reference list includes local research on the ecological effects.
The reporter missed a map of the region involved and an indication about its size.

B Developments in the Ysselmeerpolders

Both papers 4 and 5, respectively by Driebergen and by Polman, deal with so-called shallow borderlakes of the Ysselmeerpolders. These lakes have been designed for multiple water management purposes. Drontermeer and Veluwemeer, discussed by Driebergen, have a closed water management system since 1956. During the period 1957-1961 a rich and varied plant and animal life developed. During the sixties and the seventies the transparancy indicator decreased drastically from 1 m to 0.2 m. The cause is the pollution by domestic and agricultural waste waters. The high contents of nitrates and phosphates increase algae growth, especially Blue-green algae which limit severely development of other plants and animal life. The original rich environment deteriorated rapidly. Several steps have been taken to limit the phosphate content of the waters discharged into the lakes from 0.5 to 1.5 grams per m^2 per annum. The estimated load in 1975 was 3.7 grams per m^2 per annum. These steps are often very costly. Therefore, results of this type are very useful. A reference list at the end of the paper would have improved the interest of this paper.

The Oostvaardersplassen (Paper 5 by Polman) in Southern Flevoland are just south of Lelystad and have been planned as a nature reserve of 5500 ha. The original area developed in a natural way into a very important resting, foraging and breeding area for numerous species of birds. Therefore, it was decided to further develop the area as a nature reserve, especially for waterfowl. An artificial water level has to be maintained by embankment and by artificial water supply in dry years or water discharge in wet years.

This extensive paper gives a detailed account about experiences, discussions and targets of both the original area and the new development. A main technical point is the water level in winter and summer. My question is : what is the cost benefit relationship for developing and maintaining these artificial ecosystems.

C Developments in the Wadden Sea area

Paper 6 by Drijver lists the recent reclamation projects in the Wadden Sea region, either completed, rejected or planned in Denmark, Germany and The Netherlands. The author stresses the irreplaceable role of the existing salt marshes and mud flats for the biological life. Efforts are made to express this role both quantitatively and economically and to incorporate the total environment of the Wadden Sea area with its connection to the North Sea. The author's arguments are impressive, but do they imply the rejection of all diking projects in the area ?

Paper 7 by Joenje, at the other hand, discusses the ecological developments in new embanked polder areas in the same area, which "... however, by no means (compensate) the losses of saltmarsh and wadden ecosystems ..." (quotation by the author).
The case of the 9100 ha Lauwerszee-polder , embanked in 1969, is described.The general question, whether nature management should be a "laissez-faire" or some mode of nature exploitation, is answered in favor for some "active"management.. But even then, different and conflicting options may exist. Moreover, some management methods may be limited by cost considerations. The nature reserve in the Lauwerszee-polder has several management programmes side by side in different zones. They are still very much a matter of trial and error. This study holds a challenge for many years to come, as stated by the author.

D Project assessment

Paper 8 by Dankers gives an account about an ecological study of the Balg-zand tidal flats made in such a way that the information could be used in a cost-benefit analysis of a proposed reclamation project. The author lists 25 functions of the Wadden Sea area and discusses their interaction. I think that this list is a very useful one and should be an example for all studies on environmental impact assessment. The environmental effects are divided into primary, secondary and tertiary effects. They are called a "factor train".

The description of this factor train is again a very welcome step towards a more rational and methodological approach of this type of studies. The author recognizes that some functions cannot readily be quantified. Could he explain how they have been introduced into the analysis ?

Paper 9 by Asjes treats the subject of land consolidation in an older polder area versus conservation of nature areas and landscape. The assessment method made a comparison between several variants of land consolidation schemes and their effects on agricultural development, nature value and landscape value. The conservation of nature value was measured by the number of meadow birds. The size of a bird sanctuary was taken variable. Likewise the number of farm resettlements was a variable versus the openness of the land scenery. The increase in renumeration for the farmers and the internal rate of returns were the base for comparison. It is clear that conflicting interests exist. Could the author discuss how the decisionmaking process will use the information resulting from this assessment method ?

E Water quality

Since water is one of the main substances of the environment, it is not surprising that two papers are essentially related to water quality s.s. Paper 10 by Bernardi et al. presents the problem of monitoring water quality of the fresh water discharged into the Lagoon of Venice. The large number of inflow channels does not allow a full control. Moreover, the tidal flow with its salt wedge and changing water depth necessitates monitoring at several depths and different hours. Symptotic values of total water, salt and heat flow are derived. An even more complex problem is the exchange of matter with the bottom sediments of the Lagoon. A circulation model is being developed. The authors could maybe give some more details about present state of the project.

The last paper of this session (Paper 11 by Smits and de Rooij) is an extensive one about eutrophication processes and their modeling in the Westeinder Plassen, a lake of 9 km^2 and average depth of 2.9 m, situated in the Rijnland Polder system. The authors describe the model CHARON-BLOOM II where CHARON stands for the chemical part and BLOOM II for the phytoplankton part. Both models as well as the coupled version have been applied elsewhere in The Netherlands. Calibration results for the years 1977/1978 are satisfying the authors. I would like to know somewhat more details about the calibration method : how was the procedure to adjust equation coefficients ? Was a residue analysis applied systematically ? The literature cited will certainly give answers to these questions ? This modeling study resulted in an important conclusion: phosphate is far from limiting for phytoplankton growth. Therefore a decrease of phosphate load will be only effective if the reduction is very substantial. This result is probably a very exemplary one in showing the usefulness of careful modeling techniques.

2 Conclusions

Reporting on theme B "Environmental aspects" has been a most profitable exercise for the reporter. All papers have aroused my interest and widened my knowledge. Many introduced methods or definitions which, in my opinion, are most useful and should become standard procedures in these studies.
One author reghtly concluded that new polder areas are excellent opportunities to study developing ecosystems. Another author pointed out that relatively few studies on polder environments are known outside The Netherlands. May this session be a step towards increasing interest into these studies which should be the strong base for preserving or managing nature while serving humanity.

Table 1. List of papers

Paper No.	Authors	Title	Remarks
1	Jong and Wiggers	Polders and their environment in The Netherlands	review of the historical development of the polders in The Netherlands and the changes in the natural environment and land use
2	Klein	Flying or creeping : the immigration of organisms between reclamation and cultivation	development and relationships of populations of plants, animals and microbes in new polder areas
3	De Jong	Ecological impacts of polderconstruction in Suriname	
4	Driebergen	Environmental developments in two of the borderlakes of the Ysselmeerpolders in The Netherlands	
5	Polman	The Oostvaardersplassen, the developing of marshy ecosystems especially for waterfowl	The Netherlands - Ysselmeer
6	Drijver	Cumulative ecological consequences of diking projects in the Wadden Sea area	significance of salt marches and mud flats for biological life
7	Joenje	Nature in new Wadden-polders conservation by exploitation	plant colonisation, management practices and wildlife protection in a new nature reserve in the Lauwerszee-polder

8	Dankers	Quantifying the loss of functions of a natural area as a means of impact assessment for reclamation projects	environmental aspects of the (abandonned) plans of the development of a deep sea harbour and adjacent industrial area in the Balgzand tidal flats of the Wadden Sea
9	Asjes	The assessment of the land consolidation project Eemland	planning and assessment of alternative plans for safeguarding nature areas, landscape and improvement of agricultural structure
10	Bernardi et al.	Protection of the city of Venice and its lagoon : flow of fresh water and pollutants into the lagoon	
11	Smits and de Rooij	Modeling eutrophication processes in a polder area	The Netherlands-Rijnland (Westeinder Plassen)