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OPEN POLDER IN THE DELTA OF THE PROVINCE OF ENTRE RIOS, ARGENTINA

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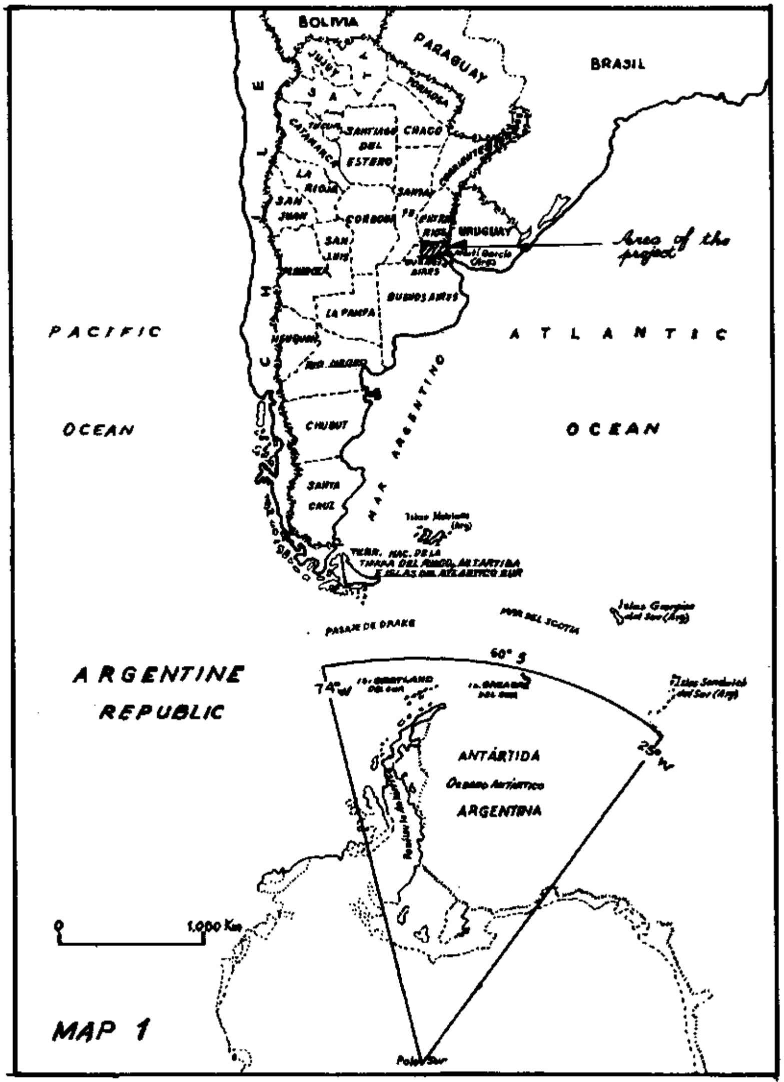
Abstract

In the Delta of the Paraná River there are 440,000 ha. with good possibilities for economic development, but subject to frequent floods. As a possible solution, the idea of an open polder was devised, with a dam 50 km. long and two auxiliary canals to facilitate drainage and allow for the outflow of rain water.

A Description of the Project Area

In the Argentine Republic (Map 1) the Delta of the Paraná River is located at the confluence of the Paraná and Uruguay rivers with the River Plate (Map 2). The Paraná river contributes with the greater proportion of sediments (6,000,000 tons/year). It comprises 1,800,000 ha. extending from the city of Diamante up to the River Plate.
Its geographical center is located 170 km. from Buenos Aires. The area is also known as the Delta of Entre Rios, because it falls under that province.
Its geographical limits are: West - Gualeguay river; South - Paraná river with its branches Paraná Ibicuy, Paraná Guazú and Gutierrez; East - Uruguay river and North - Provincial route up to the Médanos Station and then the Southern watershed of the Ñancay stream.


BOLIVIA
PARAGUAY
BRASIL
CHILE
CHACO
SANTIAGO DEL ESTERO
CATAMARCA
LA RIOJA
SAN JUAN
CORDOBA
SAN LUIS
URUGUAY
Area of the project
BUENOS AIRES
LA PAMPA
PACIFIC
OCEAN
ATLANTIC
OCEAN
CHUBUT
SANTA CRUZ
MAR ARGENTINO
PASAJE DE DRAKE
ARGENTINE
REPUBLIC
60° S
74° W
25° W
ANTÁRTIDA
ARGENTINA
1,000 Km
Polo Sur

MAP 1

A.2 Geomorphology

The project area is a vast concave flatland with a scant S.E. slope of low height compared to the rivers surrounding it. This flatland has greater heights on the river banks, forming embankments which occupy 15% of the area and rise up to 1.50 m. above the natural terrain with widths ranging between 10 and 100 m.
This configuration hampers the drainage of the land as normally required by plantations during the rainy season and the extraordinary outflow required by the floods.
There are other natural elevations formed by fixed sand dunes rising up to 10 m. which are of great importance as they serve for the settlement of works such as the Urquiza railway line.
The main rivers according to their importance are: the Paraná river, with its branches Paraná Ibicuy, Paraná Guazú and Gutierrez, the Uruguay river and the Gualeguay river.
Within the project area we may mention the Paranacito river which originates West of the project area and advances to the East toward the Uruguay river.
There are other short streams flowing into the Uruguay river: Las Animas Mosquito, Martinez, La Tinta, Sagastume, Baltasar, etc. The other rivers found in the area are very short brooks of little importance.
At the mouth of these streams there are embankments. Most of the rivers, specially those of little importance, are covered with vegetation, which hampers the drainage even further.

A.3 Use of the land

Total population is at 14,000 inhabitants. The area with greater population density is that near the Uruguay river.
In the West, the main productive activity is extensive cattle breeding, and some agriculture. In the East the predominant activity is extensive forestry with cattle breeding as a supplement jointly with agriculture and fruit growing. Forestry has favoured the installation of saw mills, and cellulose and particle-board factories.

A.4 Soils

The soils are of the alluvial type, supported by a base of marine banks. The final layers of the accumulated sediments which rise above the waters are composed in the 0.70 m. closer to the surface of organic matter, clay, slime and fine sand. Below one meter depth, the main component is fine sand. These layers of clay and clayish sand are precisely those which determine the low permeability for the infiltration of rain water and also for lateral conduction. On the other hand, the chemical characteristics of the soils make them fit for the development of vegetable species, pasture, agriculture and forestry.

A.5 Climate

The weather is temperate humid, without dry season. The temperatures are moderate due to the proximity with the ocean and the river environment. The mean annual temperature is 17.6 °C with Summer means of 23°C and Winter means of 9°C. Rainfall is regular, more intense at the beginning of Autumn and end of Spring, with a monthly average of 100 mm which decreases from June to August to 65 mm per month. The annual average is 1000 mm.

A.6 Hydrology

The zone is subject to relatively frequent and extended floods (most of them - and the most serious ones - due to the rise of the Paraná river). The advance of the waters is due to the spillage of the Paraná Ibicuy and Gualeguay rivers and the duration of the floods results from the concave geomorphological configuration of the terrain and the insufficiency of the rivers of the Entre Rios Delta to drain the waters. Local rains may worsen the situation and the Southeasterly winds produce wind-tidal floods from the River Plate and delay the drainage.
In the Uruguay river floods are not so frequent and less important. The floods caused by each of the rivers have partial effects, but when added together, as is the case under certain circumstances, they can

reach catastrophic magnitudes. This is not so much due to their height (1.05 m. maximum in certain areas) or their velocity (5 km/day) as because of their extension (which may cover the whole area) and their duration (up to several months with consequences persisting over a whole year).

A.7 Waterbalance

The waterbalance shows there are annual deficiencies in the range of 14 mm. This deficit does not affect the growth of adult plants; however, if it coincides with extended low water periods in the river, it may cause the drying up of plantations of young trees.
On the other hand, the excess of water can reach important levels (200 mm) due to the season in which it occurs (May to October). As this is the period with the lowest water demand, with the lack of good infiltration or superficial runoff, water accumulates covering the land.

B. Goals and strategies

B.1 Reasons for impoldering

The floods cause social damages with the forced exodus of the population due to the flooding of housing and/or isolation; suspension of school activities; interruption of family income derived from the lack of economic activity and economic losses of young crops and forest plantations and animals; forced removal of cattle to higher lands; impossibility to fell trees; lack of productivity of fields during and after the flood; suspension of industrial and commercial activities; isolation of the area resulting from the barring of local roads.

B.2 New functions of the area

Solving the problem of the floods would allow for the maintenance of the area's current function while promoting greater development.

B.3 The project as part of a regional plan

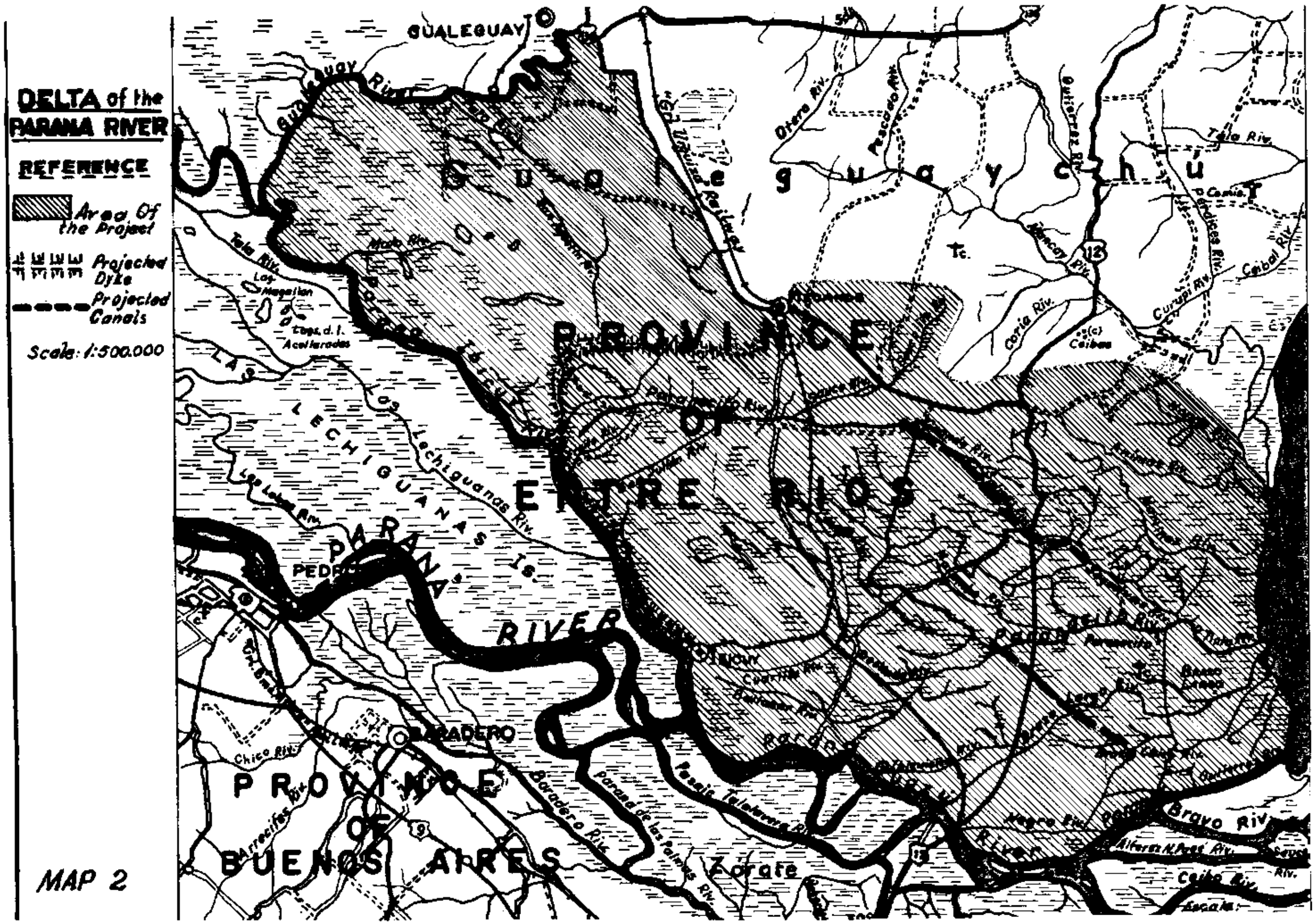
The project is part of an idea with a larger scope, consisting in the impoldering of the whole Delta of the Paranã river. But this river is not regulated (Q_m=16,000 m3/s and Q_{max}=25,000 to 30,000 m3/s) and it would be very risky to carry out such a plan yet, because of the lack of thorough studies. Before designing the hydraulic engineering project, it would be necessary to count with numerous and precise hydrological data. There already are some polders and projects in the Delta of the Paranã river (see References).

C. Technical and economic feasibility

The work is considered to be technical and economically feasible. However, the lack of sufficient data to develop a definite project prevents its implementation. A rough cost estimate of the works is in the region of U.S. dollars 20,000,000. It would therefore be necessary to create a coordinating body to channel the efforts of all sectors and manage the available economic and technical resources.

D. Design

To avoid the aforementioned damages, several general and partial projects and studies were developed (see References). The project at hand (Map 2) consists basically in the construction of a dyke starting from the Medanos station in a NW-W direction on the current sand dunes line, up to the point where their height decreases, and then SW up to the Paranã Ibicuy river. This dyke would have a lateral canal serving for drainage and to provide filling material. The dyke would have a length of 50 km. with a maximum height of 6 m. and 2.50 m. width at the top, with a 1:2 to 1:3 slope and 50 to 100 m3 per linear meter. The dyke would prevent the inflow of the water from the Paranã and Gualeguay rivers and to the West would leave an expansion area of 90,000 ha. for the floods. The unprotected area is used nearly exclusively for cattle breeding and when floods are about to occur, the cattle could be moved to the other side of the dyke, i.e. to the protected zone.


DELTA of the PARANA RIVER
REFERENCE
Area Of the Project
Projected Dyke
Projected Canals
Scale: 1:500.000
GUALEGUAY
Gualeguay Riv.
Tala Riv.
Otero Riv.
Pescado Riv.
Gutierrez Riv.
Perdices Riv.
Ceibal Riv.
Curupi Riv.
Conia Riv.
Ceibas
Malo Riv.
"Gral. Urquiza" Railway
PROVINCE OF ENTRE RIOS
Paranacito Riv.
Las Lechiguanas Riv.
LECHIGUANAS Is.
Las Lobos Riv.
PARANA RIVER
PEDRO
BARADERO
Chico Riv.
Arrecifes Riv.
Baradero Riv.
PROVINCE OF BUENOS AIRES
Parana de las Palmas Riv.
Pasaje Talavera Riv.
Zarate
Bravo Riv.
Alferez N.Pose Riv.
Ceibo Riv.

MAP 2

The protected zone would become an open polder (an idea successfully implemented in the Delta of the Orinoco river in Venezuela) protected from the most important floods (Paraná and Gualeguay rivers).
To improve the outflow of rain water and floods, the project includes the construction of two auxiliary canals with a length of about 20 km., connecting the Paranacito river from the points of deflection of its course toward the Uruguay and Paraná rivers. It would also be necessary to debrush the area and channel all the rivers and streams so they may increase their capacity to the maximum, with the added benefit of improving their navigation.
In some interior rivers it would be necessary to place gates and small pumping stations to control the water level.

E. Management and operation

No studies or ideas have been put forth as yet, but it follows that they should be under a coordinating body as mentioned in the last paragraph of point C, because the different tasks required in a multidisciplinary regional project necessitate the participation of various national and provincial agencies, as well as private activities which would otherwise hinder the type of dynamism required to tackle such a project.

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Studies and proyects

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Marsán R.H. 1974. Endicamientos en el Delta. Boletín de la Asociación Forestal Argentina, pp. 32-65.

INTA 1977. Estudio ecológico y socioeconómico del Delta Entrerriano. Estación Experimental Agropecuaria Delta del Paraná. Entre Rios. Argentina, 590 pp.

NEDECO. 1962. Reclamation proyects in the Parana River. NEDECO. The

Hague. Netherlands. 160 pp.

Completed polders along the Delta of the Parana River

Lechiguanas: 23.500 ha.- Mazaruca: 5.000 ha.- Don Ernesto: 500 ha.- Tajber: 800 ha.- INTA: 56 ha.- Las Carabelas: 1.000 ha.- Don Antonio: 3.700 and 900 ha.- Victoria: 4.900 ha.- Don Mario: 575 ha.- Don Humberto: 720 ha.- Don Orlando: 1.970 ha.- Iporá: 800 ha.

SUBSURFACE DRAINAGE FOR SALINE SOIL RECLAMATION

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Abstract

In India, there are nearly 1.2 m ha of inland saline soils which lie barren. An area of this nature, near Bidaj (30 km from Ahmedabad, India), was selected for reclamation by construction of open seepage drains of 200 m spacing, leaching the salt by ponding and adopting suitable crop rotations. An experiment with closely spaced open drains at 15 to 25 m spacing (1.5 m deep on average) was also started in June, 1978 in one of the critical areas (barren land) of the farm. Changes in the salinity levels of soil and water were monitored and salt and water balance analysis made. Results of this study have indicated that this drainage system reduced flood losses, the salinity in the soils and the groundwater levels and increased the cultivated area and the crop yields. In the drainage experimental area, the improvements were significantly higher in the area having drains at 15 and 20 m spacings.

1 Introduction

In India, there are nearly 1.2 m ha of inland saline soils, which lie barren and wait for some feasible reclamation technology for their improvement. The Bidaj farm (30 km from Ahmedabad on the Ahmedabad-Baroda highway) of the

National Dairy Development Board (N.D.D.B.), Anand, India is one such area (with about 80 ha) whose productivity was low due to high soil salinity and waterlogging conditions.

1.1 Soils and water quality

The soils of the Bidaj farm are heavy textured clay loams (Narayana et al. 1981) and highly saline in nature. The pH varied from 8.0 to 8.2 and EC varied from 7 to 32 mmhos/cm. The shallow ground waters are medium to high in salinity (2 to 4.5 mmhos/cm) but at some depth (60-75 m), the ground water with salinity in the range of 1.6 to 2.0 mmhos/cm are available.

2 Reclamation

The programme of reclamation (Narayana 1981) in this area included the following measures :

a) construction of two main open drains and laterals at 200 m spacing;
b) systematic layout of fields with irrigation channels at the head and the drains at the tail ends of each field;
c) adoption of suitable crop rotations in the reclaimed area.

To accelerate the desalinization of these soils, an experiment with closely spaced open drains at 15, 20 and 25 m (1.5 m deep) was started in June, 1978 in one of the fields, seriously affected by soil salinity.

3 Performance evaluation

Soil and water samples were collected during November, 1976 (for providing bench-mark data prior to reclamation) and again from time to time after the reclamation was started. Sampling was also done from the experimental area, where closely spaced drains were provided. The extent of saving in flood losses due to drainage in terms of farm inputs and crop yields were recorded.

The performance of the drainage system and the relative effect of drain spacing on the rate of soil amelioration is also evaluated by monitoring the changes in the levels of salinity of the soil profile and the water table.

3.1 Water and salt balances

The water and salt balances of the area are computed by following the procedure outlined by Luthin (1957).

$$I + P = E + R + RO + W \qquad (1)$$

where, I = amount of irrigation water; P = amount of precipitation; E = amount of evapotranspiration; R = amount of deep percolation; RO = runoff from the study area; and W = change in the amount of moisture stored.

$$Z' = (IC_i + PC_p + GC_g - RC_r) \times 10^{-5} \qquad (2)$$

where, C = salt concentration in ppm; i = suffix representing the concentration of irrigation water; P = suffix denoting precipitation; g = suffix denoting groundwater; r = suffix denoting drainage water; and Z' = change in salt content of the 100 cm of soil profile in tonnes/ha.

For this purpose, data were collected from the experimental area with close spaced drains and also from the total farm area at Bidaj. This analysis was conducted with suitable assumptions for three periods viz. a) rainy season (June 15 to November 15), b) winter season (November 16 to March 31) and c) summer season (April 01 to June 14).

4 Results and discussion

4.1 Flood losses

The drainage system installed on the farm have brought down

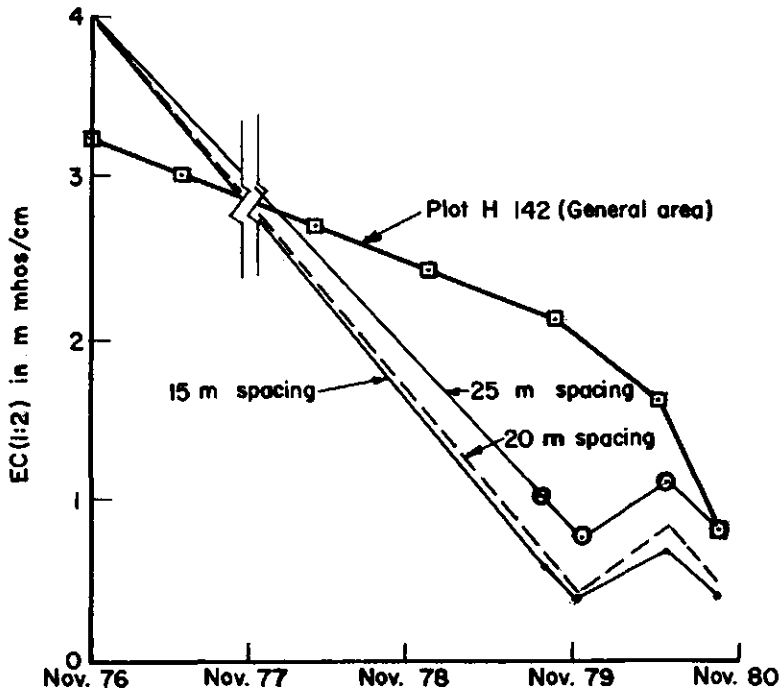

Figure 1. Change in soil salinity status — 0-15 cm depth

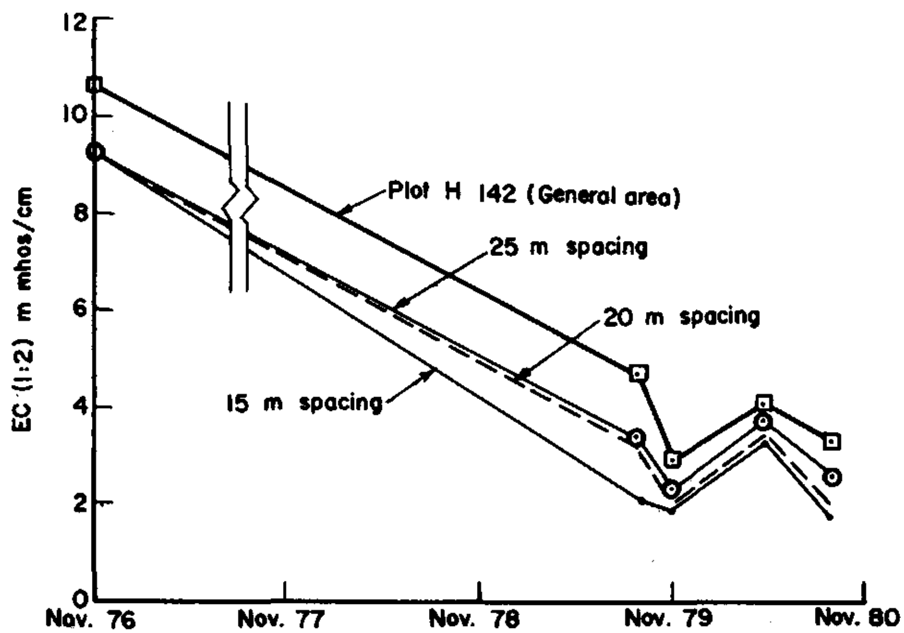

Figure 2. Change in soil salinity status — 1 m profile

the flood damages from Rs. 133,000 in 1976-77 to Rs.66,000 in 1978-79 and increased the corresponding cultivated area from 28 ha to 42 ha (Anonymous 1979).

4.2 Soil improvement

The soil salinity in the lower depth ranges, that is below 30 cm, has been reduced by more than 50 percent of the 1976 levels (Figures 1 & 2).

In the experimental area (Table 1), the present values of soil salinity, in all the treatments, are within the tolerable limits for crop production. However, the plots with drains at 15 m spacing are relatively in better condition followed by 20 and 25 m spaced plots.

4.3 Ground water

In 1976, the ground water levels in the November month were almost near the surface. However, during September, 1979, the water levels were at a depth of 40 to 95 cm below the ground level (Figure 3).

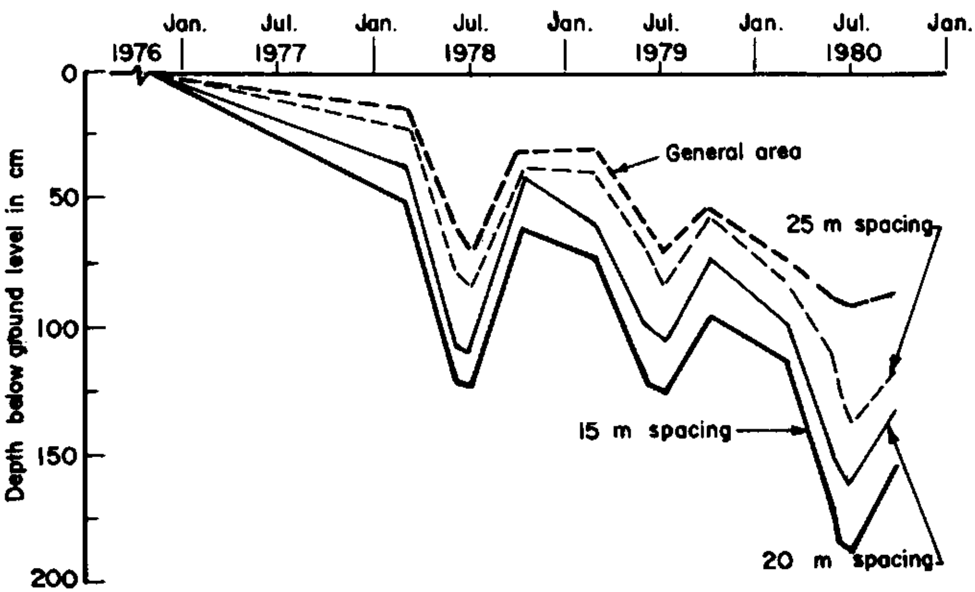

Figure 3. Changes in water table levels in the plots with drains at different spacings

Table 1. Comparison of computed and observed values of salt content (tonnes/ha)

		Initial	1978			1979			1980
			1	2	3	1	2	3	1
15 m	C	31.5	15.8	19.9	22.9	16.2	18.3	21.1	5.7
	O	31.5				8.4		14.3	6.4
20 m	C	31.5	15.8	19.9	22.9	16.2	18.3	23.5	8.1
	O	31.5				7.7		14.6	7.1
25 m	C	31.5	15.8	19.9	27.3	20.6	22.7	27.9	12.5
	O	31.5				7.1		9.9	12.2
General	C	38.7	23.8	27.0	33.6	22.4	23.1	32.2	13.1
	O	38.7				9.0		11.0	9.0

C - Computed value   O - Observed value   (Observation values are taken initially in 1976 and subsequently in 1979 & 1980 after drains were installed during 1976-78).

Computed and Observed Initial values are same.

4.4 Water balance

The results of water balance analysis conducted for the general farm area and those areas treated with drains at different spacings are presented in Table 2. The values of water surpluses in period 1 (rainy season) and 2 (winter season) under different drainage treatments (15, 20, 25 m spacings) do not differ very much. However, the water deficits in period 3 (summer) differ within the drainage value. These differences are due to the fact that no crops are grown in the drainage experimental area while some forage crops are grown in the general area during the summer. Further the water table situation which control the evaporation, particularly during summer (water deficit period) also varied from treatment to treatment as shown by Figure 3.

4.5 Salt balance

The salt balance analysis, presented in Table 1, indicate that maximum salt removal (nearly 15 to 16 tonnes/ha) takes place in all the treatments during the monsoon season (period 1). During this period, on an average, about 500 mm of water surplus is leaching the salts through the soil profile. On a rough estimate, from the leaching curves (Narayana and Kamra 1981), this is sufficient to leach nearly 40 percent (15.5 tonnes/ha) of the original salts i.e. 38 tonnes/ha (Table 1).

In the winter season (period 2), there is slight increase (4 tonnes/ha) in the salinity status in all the plots because the ground water, containing about 1600 ppm, is pumped out from deeper aquifers and applied as irrigation water to various crops. It is in period 3 (the summer season) that the effect of close spaced drains is reflected on the salinity changes. In the general study area, where the drains are spaced at 200 m and in the experimental area where the drains are spaced at 25 m, 6 to 8 tonnes/ha of salt was added during period 3 because the water table depth below ground level was less than 100 cm (Figure 3). In the experimental area with 15 and 20 m

Table 2. Water balance of saline soils at Bidaj

	1978 Periods			1979 Periods			1980 Periods
	1	2	3	1	2	3	1
Rainfall (mm)	811	41	78	674	55	20	964
Actual evapotranspiration (mm)							
(a) 15 m spacing plots	565	483	63	686	449	0	596
(b) 20 m spacing plots	565	483	63	686	449	67	596
(c) 25 m spacing plots	565	483	190	686	449	67	596
(d) General area (widely spaced drains)	396	302	222	480	280	234	417
Canal water supply (mm)							
(a) 15,m, 20m and 25m spacing plots	260	220	-	200	200	-	100
(b) General area (widely spaced drains)	240	170	-	280	180	-	230
Ground water pumpage (mm)							
(a) 15m, 20m and 25m spacing plots	200	400	-	300	450	-	260
(b) General area (widely spaced drains)	120	200	100	200	250	100	140
Moisture stored in soil (mm)	150	100	100	150	100	100	150
Runoff from general area only (mm)	130	-	-	98	-	-	145
Water surplus (+) or deficit (-)(mm)							
(a) 15 m spacing	+556	+ 78	- 85	+338	+156	-80	+578
(b) 20 m spacing	+556	+ 78	- 85	+338	+156	-147	+578
(c) 25 m spacing	+556	+ 78	-212	+338	+156	-147	+578
(d) General area (widely spaced drains)	+495	+9	-144	+426	+105	-214	+622

spaced drains, the corresponding salinity build up was less than 3 tonnes/ha. As a result, the rate of soil desalinisation was much faster in the closely spaced drainage area than in the area with widely spaced drains. However, with proper management of rain water during rainy season, it is seen that these soils can also be reclaimed gradually even with widely spaced surface-cum-subsurface drains.

A comparison of the computed and observed values of salinity in the top one meter profile (Table 1) during 1980 shows that the values agree well.

4.6 Crop responses

The crop yields in the study area have been increasing both in the kharif and rabi seasons. The average yield of the rice in 1978 is approximately 4.1 tonnes/ha as compared to 3.8 tonnes/ha in the previous year. In the drainage experimental area itself, the rice crop yield (5.0 tonnes/ ha) in 15 m spacing plots was significantly higher than in the other plots as well as the average yields of the farm. It may be pointed out that this area was one of the worst salinity-affected plots on the Bidaj farm and no crop could be raised prior to 1978 i.e. before the drains were laid (Figures 4 & 5).

References

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Narayana, V.V. Dhruva, 1981. Improvement in land utilization resulting from drainage. State-of-the-art Publication No. 2, ICID, New Delhi.

Figure 4. A view of the problem area before drainage

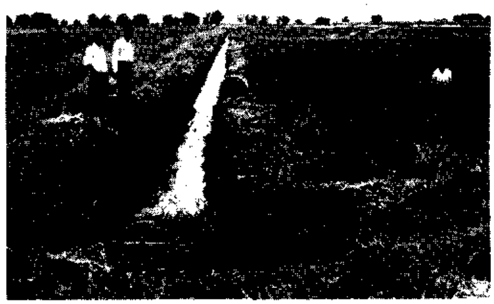

Figure 5. A view of the problem area after drainage

Narayana, V.V. Dhruva, I.P.Abrol and D.S.Thakur 1981. Subsurface drainage for saline soils at Bidaj (Gujarat). Indian Farming, February, 1981 issue.

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MODERN TECHNIQUE IN BANK PROTECTION

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Abstract

In the last twenty years a rapid development in design and construction of revetments could be observed. This paper will explain modern bank protection technique using non-woven geotextiles and prefabricated interlocking concrete blocks. Fundamentals of the application of geotextiles also are presented including filtration properties and long-term behaviour.

1 Introduction

Polders are deep lying marshlands being reclaimed from the sea. Normally they are enclosed by dikes and intersected by drainage canals. Therefore a lot of banks normally built up from soils in the range from silty sands to clay have to be protected.

Modern bank protection technique has to fulfil the following requirements considering the special polder conditions:

- optimum technical layout for long-term use and for minimizing the maintenance cost

- approved installation technique for quick and safe installation in the dry and underwater

- most favourable layout considering environmental aspects.

As a standard solution on the banks of dikes and drainage canals revetments were placed, built of a filter layer and a cover layer. The filter layer has to stabilize the subsoil by a sufficient soil tightness and permeability to water. The cover layer is an armour layer protecting the revetment against the attack of waves, currents, ice and damage by ships.

The development in revetment construction shows the growing use of synthetic filter fabrics (geotextiles) as filter layers and of prefabricated mattresses as cover layers.

Figure 1 for example is showing a construction method for bank protection on large canals with traffic of sea-going vessels like the Kiel-Canal or the Suez-Canal, recommended 1982 by the Working-Group 14 "Synthetic Materials for Underground Construction and Hydraulic Engineering" of the German Society of Soil Mechanics and Foundation Engineering

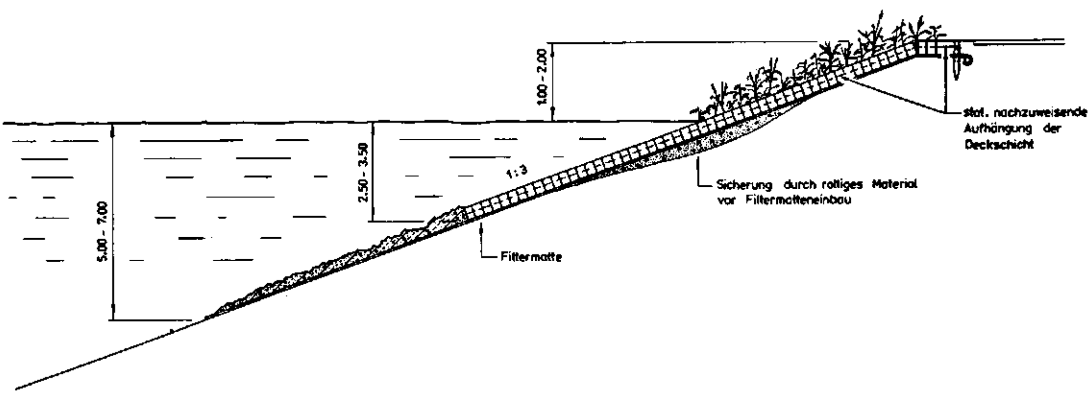

Figure 1. Revetment construction for large canals, Zitscher (1982)

2 Revetment design

2.1 The filter layer

As mentioned above the filter layer in a revetment construction has to stabilize the subsoil with a sufficient soil tightness and permeability to water. Layers of sand, gravel or bushy twigs are traditionally used but also with the use of synthetic filter fabrics (geotextiles) a good experience of more than 20 years is given. Some results of the long-term resistance of geotextiles in coastal engineering are given by Heerten (1980).

2.1.1. Kinds of geotextiles

A lot of different synthetic filter fabrics are offered and we have to distinguish woven geotextiles and non-woven geotextiles. Non-woven geotextiles could be thermal bonded, resin bonded or needle-punched. The properties of fabrics are very different, influenced by the polymer properties and by the manufacturing process. For woven fabrics for example we have to distinguish the kinds of threads (multi-filament, mono-filament, tape threads), the kind of woving, the used polymer and the finish (e.g. PVC-coating). Non-woven fabrics also are produced by different polymers and we have to distinguish the method to obtain the cohesion of the fibres or filaments.

Because of its high resistance against ultra-violet irradiation, high specific strength and specific gravity the use of geotextiles produced of polyester fibres is advantageous especially for under water installation.

2.1.2. Mechanical properties of geotextiles

Selecting a geotextile for a given application the engineer has to consider the fabric load and the fabric function. The requirements to fabric strength, elongation, penetration resistance and buoyancy mostly have to consider only the fabric loads during installation because these loads mostly are sometimes higher than under regular conditions in the revetment completed. In Table 1 some minimum values for the mechanical properties of geotextiles in revetment constructions after guidelines of the Federal Institution of Waterways Engineering (BAW, Karlsruhe) and the Ministery for Nourishment, Agriculture and Forestry of NRW are given.

Table 1. Requirements to mechanical properties of geotextiles

	Federal Institution for Waterways Engineering (BAW)	Ministry for Nourishment, Agriculture and Forestry, Nordrhein-Westfalen	
Application	Inland and coastal waterways	little rivers, creeks and ditches	
		woven	non-woven
fabric weight	-----	≥ 200 g/m²	≥ 250 g/m²
fabric thickness	3,5 to 6,0 mm (depending on revetment typ and sub soil)	-----	≥ 2,5 mm
fabric strength	≥ 600 to 800 N (DIN 53858, depending on revetment typ)	≥ 1600 N (DIN 53857)	≥ 300 N (DIN 53857)
	in addition the BAW recommendations on puncture resistance, abrasion, strength at 50% elongation and filtration properties have to be considered		

2.1.3. Filtration properties of geotextiles

After the workmanlike installation of filter and amour layer the long-term working of the bank protection mainly depends on the filtration properties of the filter layer.

The traditionally used filter materials like sand and gravel are dimensioned after the well known filtration rules e.g. from Terzaghi or the U.S. Corps of Engineers. By this a coordination between the diameters of the soil particles of the subsoil and the filter layer is given. In many cases the filter on fine soils has to be built up from two or more separat filter layers. Limited by the accuracy of installation technique by underground construction work with heavy machines like excavator and bulldozer the thickness of these filter layers has to be 20 cm minimum. This minimum thickness is not given by the filtration rules mentioned above but is given by experience of underground construction work. But Wittmann (1981) showed that the thickness of a filter layer also is very important for its working. Many of the filter layers designed by the given filtration rules would fail having not the thickness of"filtration length" of about 20 cm minimum. A filter layer of soil particles is not working as a thin sieve but is working as a filtration body with a given pore size distribution built up from all the soil particles of the filter layer and the incorporated sub soil particles. The interaction of the original sub soil and the soil particles of the filter layer is very important for forming a stable, long-term working filter layer.

Discussing the filtration properties of geotextiles we have to distinguish the properties of woven and non-woven fabrics. The filtration properties of woven fabrics are given by the mesh size or the fabric openings. The woven geotextile is acting as a thin sieve. The filter conditions could be stable with nearly all soil particles being larger than the mesh size or unstable with nearly all soil particles being smaller than the mesh size (Figure 2). This unstable conditions often are given on sub soils in the range from silty sands to clay as they mostly could be found in polders.

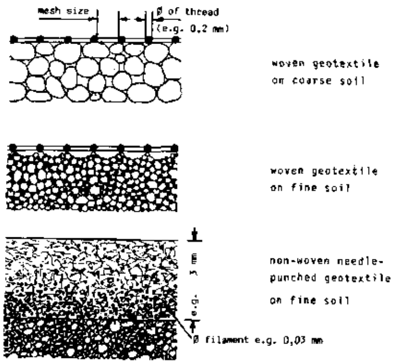

Figure 2. Filtration characteristic of geotextiles

The filtration properties of non-woven geotextiles are influenced by the fibre size, the fabric weight and thickness. Thermal bonded non-woven fabrics are relatively thin and they would act nearly as a woven fabric with irragular openings. Needle-punched non-woven fabrics are considerable thicker than all other types of geotextiles. Caused by the needle-punching process the voids volume of needle-punched geotextiles is about 85%. The filter conditions are comparable to soil-filter conditions (Figure 3). The interaction of fibres and soil particles is forming a stable, long-term working filter layer. Own investigations have confirmed these conditions (1981 and 1982). In figure 3 some data of virgin non-woven fabrics (porosity n, permeability k_n) and of the dug out fabrics (pore space clogged by soil, remaining porosity n', remaining permeability k_n') are given.

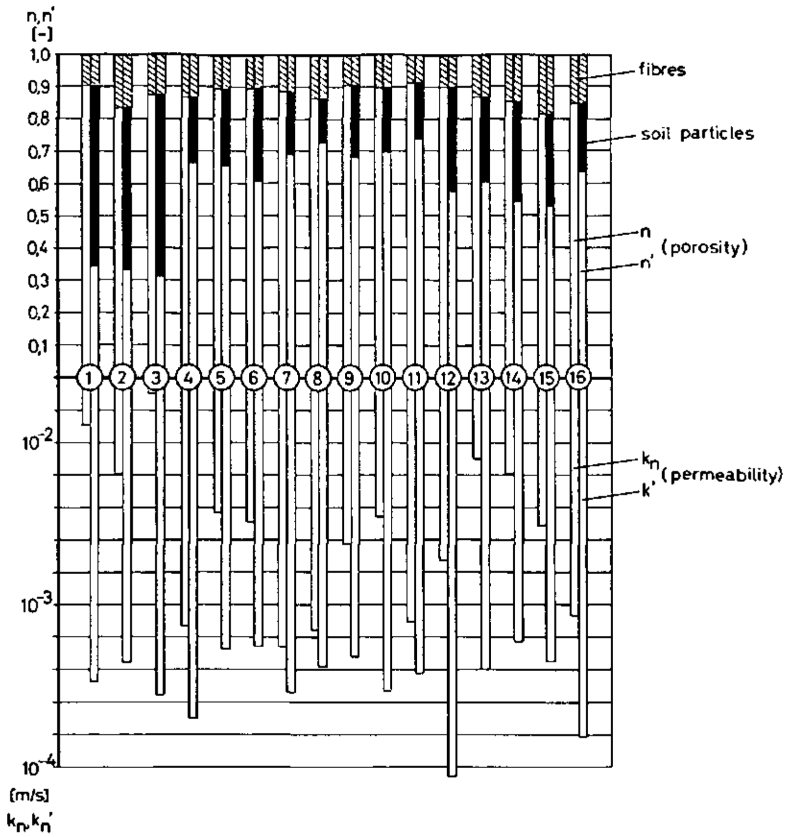

Figure 3. Clogging of voids volume and decrease of permeability of non-woven needle-punched fabrics

The estimated permeability of the clogged geotextiles is 5 to 12 times higher as the measured soil permeability, which is in the range of $k \sim 1{,}0$ to $5{,}0 \cdot 10^{-5}$ m/s. The remaining porosity of n' = 0,32 to 0,74

guarantees a sufficient long-term permeability. In contrast to these results for most of the investigated woven fabrics a lower permeability as given by the soil was estimated. The relation of the permeability of the woven geotextiles and the permeability of the soils was in the range of 0,16 to 1,8.
These results underline the advantageous filtration properties of non-woven needle punched geotextiles.

2.1.4. Filtration rules for geotextiles

The effective opening size D_w (similar O_{90}) and the permeability coefficient k_n are the main filtration parameters of geotextiles, estimated in special laboratory tests (Heerten, 1981).

D_w required is given by filtration rules as a function of the particle distribution curve of the soil and the load conditions. The filtration rules to fulfil the sand-tightness are determined as follows (C_u = uniformity d_{60} / d_{10}):

a) non cohesive soils

static load conditions:		$C_u \geq 5$ $D_w < 10 \cdot d_{50}$
	and	$D_w \leq d_{90}$
static load conditions:		$C_u < 5$ $D_w < 2.5 \cdot d_{50}$
	and	$D_w \leq d_{90}$
dynamic load conditions:		$D_w < d_{50}$

b) cohesive soils and all load conditions:

$D_w < 10 \cdot d_{50}$ and

$D_w \leq d_{90}$ and $D_w \leq 0,1$ mm

Static load conditions are given by laminar flow including the change of flow direction. Dynamic load conditions are given by high turbulent flow, wave attack or pumping phenomenon.

In a second step the hydraulic conditions have to be controlled by estimating the permeability - reduction factor as described by Heerten (1981, 1982). By this the interaction of soil and geotextile is considered and hydraulic over-pressures in a revetment construction are prevented.

2.1.5. Selection of geotextiles considering environmental aspects

A modern revetment design should be environmental friendly and the banks should be greened over in a short time. It is a special advantage of needle-punched geotextiles that the fibres remain moveable against one another after the needle-punching process. By this a unhindered growth of plants and their roots is guaranteed without changing the filtration properties of the non-woven geotextile. The conditions by using woven geotextiles are less advantageous because the roots will stunt in a fixed mesh size (e.g. pvc-coated) or the filtration properties will inadmissible change with a moveable mesh size.

2.2. The revetment armour layer

To protect the banks of rivers, canals and dykes against the attack of waves, currents, ice and damage by ships the filter layer has to be covered with an armour layer. Often these armour layers were built up from riprap or grouted riprap. But a growing use of prefabricated mattresses in revetment construction work could be observed.

A well known example of these new bank protection technique is the "terrafix"-revetment system, built up from a needle-punched non-woven geotextile and interlocking concrete blocks. The special shape of the blocks, shown in Figure 4, with moulded-on conical pegs and corresponding holes guarantees an optimum interlock in horizontal and vertical direction permitting tilt and rotation movements of the blocks and keeping the whole revetment structure flexible. Due to the interlock between the blocks, the weight per unit area of the system can be reduced considerably in comparison to a heavy weight riprap layer, which generally derivesits stability from the stone dead weight alone.

The "terrafix"-revetment can be installed in the dry, but however, a special advantage of the system becomes apparent where underwater installation is necessary. Block sections of 8 m in length and 4 m in width have been installed by crane (Figure 5) and block sections of 15 m X 6 m

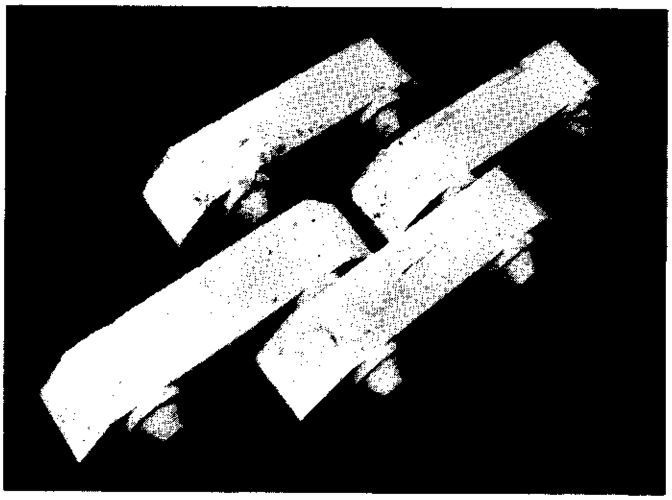

Figure 4. Interlocking concrete blocks of the "terrafix"-revetment system

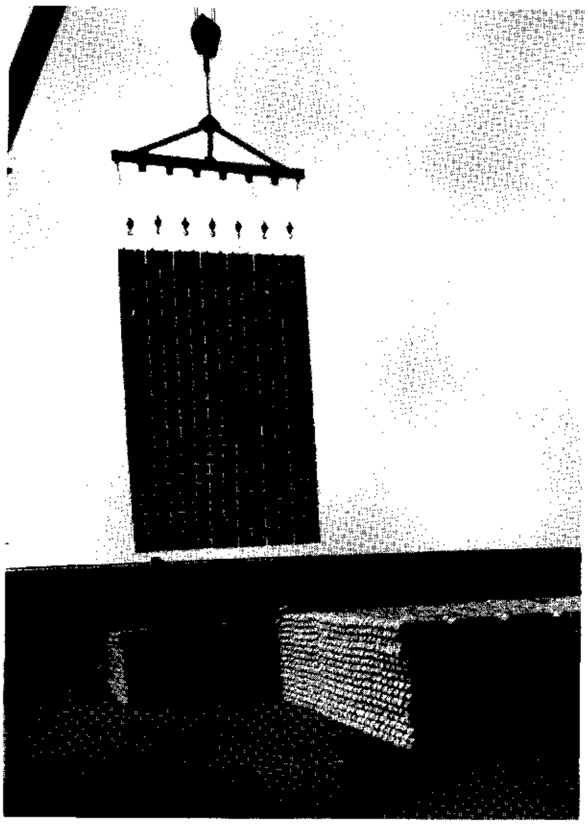

Figure 5. Installation of "terrafix"-block sections by crane

have been installed with a special floating barge (Figure 6). The wires (stainless steel, coated wires) drawn in the block sections are anchored at the crest of the slope forming a hanging revetment. This hanging system eliminates the problems perhaps caused by low friction forces between the revetment and the subgrade and in addition, it ensures that adequate toe protection is provided which has been a traditional problem in the revetment design.

Only a few vegetation periods are necessary to green over the "terrafix"-revetment (Figure 7). Caused by the needle-punched non-woven geotextile and the special joints between the concrete blocks aquatic growth generally developes above and below the water level, also encouraging the development of small marine life.

3. "terrafix"-Installation at Flevoland Polders

About 70.000 m² of the "terrafix"-revetment system have been installed on the banks of the Hooge Vaart and Lage Vaart at Flevoland Polders and could be specified as follows:

a) filter layer
"terrafix"-geotextile, non-woven needle-punched polyester fibre fabric, fabric weight 300 g/m², thickness 3,1 mm, opening size 0,07 mm, permeability $5,7 \cdot 10^{-3}$ m/s

b) armour layer
Naue interlocking concrete blocks, dimension 55 cm long, 17 cm wide, 8 cm high, weight of single block 16,5 kg, weight of armour layer 150 kg/m², block sections 6,0 m long, 3,8 m wide, fitted out with stainless wires Ø 5 mm, block section weight 3700 kg

After the first installation of the "terrafix"-revetment system in 1979 in the meantime the interlocking concrete blocks are greened over in the Flevoland Polder and the canal banks are well protected. The "terrafix"-revetment system has proofed that all requirements on modern bank protection technique are fulfilled.

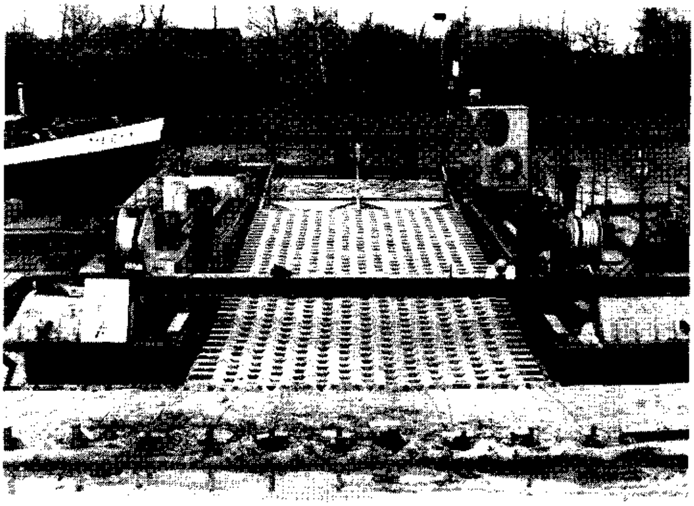

Figure 6. Installation of "terrafix"-block sections by a floating barge

Figure 7. "terrafix"-revetment greened over

4. Conclusions

The requirements on modern bank protection technique - minimizing, installation and maintenance costs, quick and safe installation in the dry and underwater, environmental friendly - lead to the development of special revetment systems. The "terrafix"-revetment system a combination of a non-woven needle-punched geotextile and interlocking concrete blocks is an example for modern revetment design performing all requirements mentioned above. More than 500.000 m^2 "terrafix"-revetment system are installed in Europe, USA, Canada and Australia.

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HYDRAULIC PROBLEMS RELATED TO PLANNING OF POLDERS, SOLVED BY USING PROGRAMMABLE POCKET CALCULATORS

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Abstract

Backwater calculations are essential for any important polder project and have to be accurate enough to provide a basis for comparing the economics and the social implications of alternative designs.
Methods have been developed by which the capability of pocket calculators, with limited functions, was used to compute the backwater effect of the polder works.

1 Introduction

In many cases, as in those of polder projects elaborated by Haskoning and Nedeco in Bangladesh, Morocco and Kenya, it was required to carry out all studies in the respective countries, sometimes close to the project site. Computer facilities to run mathematical models were not always directly available to the designers.
Given the wide variety of possible effects of dyke systems on water levels during floods, a large number of alternatives had to be analysed within a short period by quick calculations, using programmable pocket calculators.

2 Calculation of the effects of flood control projects

In all the cases analysed in this paper the time of travel of the flood peaks between both ends of the conveyance system under consideration was at least a couple of days, with an average speed of propagation of less than 0,2 m/sec and a very slow variation of the river stages during floods (less than 0,1 m per day).

For the above mentioned reasons, water surface profiles were computed for steady discharges, equal to the peak flows of floods of some specified frequencies.
Because the water depths were always greater than critical at all points, calculations started at the downstream end of the study areas and were carried back upstream until the water surface profiles with and without project became almost identical.

According to the type of the watercourse, to be described below, two methods of computation were used to determine the shape of the flow profiles; namely the standard step method and the direct-integration one.

3 Main characteristics of the flood plains under study, schematization and boundary conditions

Four different types of natural watercourses or artificial channels were studied :

a A flat, broad and wide flood plain, where the main channel can be hardly defined from maps which show contour lines. It was the case of the Rharb Plain in Morocco.

b A broad and wide flood plain which shape could be fairly approximated by a parabola, in case of the Garsen -Lango la Simba flood plain in the Delta of the Tana River in Kenya.

c A rather narrow, flat and unsymmetric flood plain but with the main channel highly incised. That is the case of the flood control projects along the Atrai River, a tributary of the Brahmaputra River in Bangladesh.

d Improved natural channels or artificial channels where it was possible to define, with a fair approximation, reaches having a constant cross section and grade.

In the first two cases the main problem was to define the cross sectional areas which are effective in conducting the flow and to avoid regions where the water is quiescent or eddying.
When available, aerial photographs were used to draw the flow pattern, as showed in Figure 1 and 2.

Figure 1   The flood plain of Rharb River in Morocco

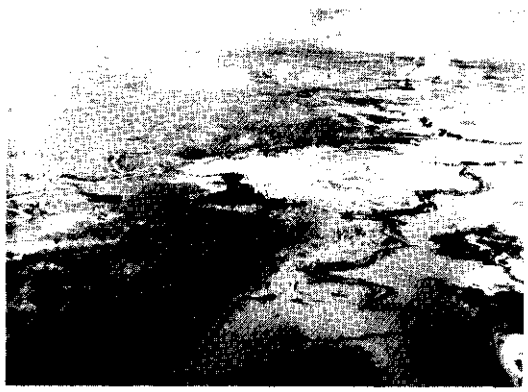

Figure 2   The flood plain of Tana River in Kenya

When aerial photographs were not available, or when they covered only part of the area under consideration, a flow net construction was used to determine the flow pattern.

As a rule, the conveyance channels were divided into reaches ending at sections where the width or the depth or both egin to increase or decrease or where changes of roughness or bottom slope occur.

Roughness of the main channels was determined, from actual observations when available, taken from streams in the area under study. However, the roughness of the flood plains was in most cases estimated.

An example of flow pattern in case without project, during high floods, is given in Figure 3.

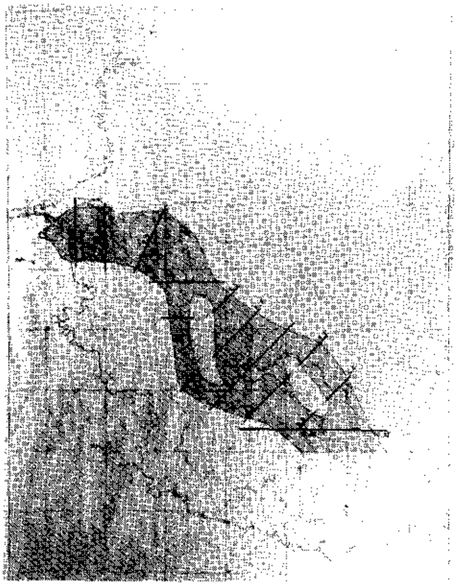

Figure 3 Flood plain of Tana River in Kenya

4 The Standard Step Method

For the first cross section the total head line elevation for a given discharge has to be known.
The water surface elevation in all but one cross section is obtained by trial and error, matching the two values obtained for the elevation of the total-headline calculated :

- by adding the flow velocity head to the water surface elevation (E_m);
- by adding the head losses along the reach under study to the elevation of the total-headline at the lower end of the reach (E_s).

It is assumed that no change of mass or momentum occurs between flow in the main channel and the overbank flow.

The following equation is used :

$$(E_m)_i = (E_s)_i \pm \Delta e \text{ , in m} \qquad (1)$$

where i is the index number of the section and

Δe is the accepted error, in m.

The average friction slope over the reach under study is approximated by taking the mean of the values computed at its both ends. If overbank flow or if roughness varies with channel stages, the friction slope is given by

$$S_f = (Q/ k)^2 \qquad (2)$$

and the velocity head is calculated for the average velocity in the main channel (V_m), as

$$\alpha V^2_m/2g = (\alpha/2g) S_f (K_m/A_m)^2 \qquad (3)$$

where Q = discharge, in m^3/sec

$K = K_m + K_l + K_r$, in m^3/sec

K_m, K_l, K_r = conveyances of the main channel, and of the left and right flood plain, respectively, in m^3/sec.

When the Chêzy formula is used.

$$K = CAR^{0.5}\text{, in m}^3\text{/sec} \qquad (4)$$

where C = the Chêzy's coefficient, in $m^{\frac{1}{2}}$/sec

R = the hydraulic radius, in m

A = wetted area, in m^2

5 Programs for small calculators

Programs developed for the following calculator types : HP-67, HP-41c, Ti-59, allow for calculation of the water surface profiles using the standard step method along channels with compound cross sections, i.e. main channel and flood plain. They can also provide, if desired, the average velocity in the main channel and the distribution of discharges, in case of overbank flow, over the main channel and the flood plain.

The programs use as much as possible the facilities of the calculators for automatic data processing.

Depending on the storage capacity of the calculators, calculations can be done more or less automaticaly. A trial value of the water surface elevation has to be used for successive stations except the first one.
For HP-67 and Ti-59 all the calculations, including testing of the two terms of the equation 1 for a given accepted error and the decision to accept or to reject the results for a certain step calculation, are automatic, but if the assumed value of the water surface elevation was not correct a new trial value has to be used.
The values of the hydraulic properties, such as wetted area and hydraulic radius, have to be entered manually for each step, if the channel cannot be schematized as an uniform one.
An example of such a program developed for a HP-67 calculator is given in Figure 3.
In this specific case the flood plain was very flat and it was defined only by the average bottom elevation on both sides (H_L, H_R), the average width (B_L, B_R) and the roughness (n_p). Area-elevation data and hydraulic radius data for each section were calculated in advance only for the main channel.

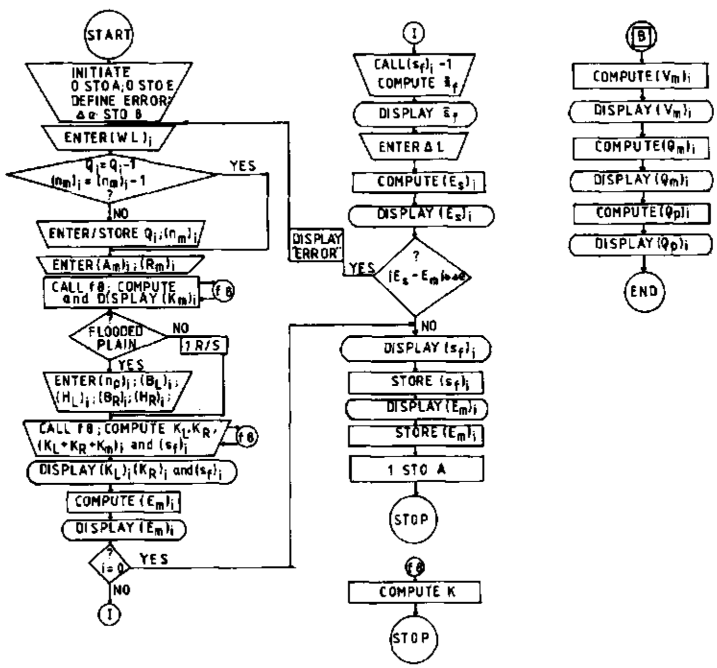

Figure 4 Flow chart of a program for computing the water surface profile for a channel with compound section

In other cases as that of backwater calculation for very large discharges along the flood plain of the Tana River in Kenya, the cross sections were fairly schematized as parabolas.
Each cross section was defined by the width of the channel at unit depth (b) and by the bottom elevation.
The wetted area (A) and the wetted perimeter (P) are given by :

$$A = 2/3\ b\ y^{1.5},\ \text{in m}^2 \tag{5}$$

$$P = M + (b^2/8)\ \ln\ ((2y + M)/(B\ y^{0.5}/2)),\ \text{in m} \tag{6}$$

where $M = (4\ y^2 + b^2\ y/4)^{0.5}$ (7)

y = flow depth, in m

In this case, only one trial value has to be used for each cross section, because, if the difference between the two terms of the equation 1 is larger than the accepted error, the program allows for automatic new trials using larger or smaller values for the water surface elevation until the difference between the two terms of the equation will be less than the accepted error.

6 Method of Direct Integration

When dealing with uniform channels having a constant slope or when natural water courses can be divided in reaches where the cross section and slope can be assumed uniform and the hydraulic exponents are determined, the water surface profiles were sometimes determined directly by integrating the differential equation of the gradually varied flow. This method affords a direct computation without need of successive steps.

In applying this method a serious draw back lied in the difficulty of using accompanying tables.

Let us take the example of the equation developed by Bakhmeteff for a channel with positive bottom slope.

$$S_o L/y_o = ((u_2-u_1)-(1-\bar{J})(F(u_2,N)-F(u_1,N)) \tag{8}$$

where L, y_o and S_o = length, normal depth in m and bottom slope, respectively

u = dimensionless stage variable : (y/y_o)

y = depth of flow, in m

$\bar{J}$ = dimensionless quantity : $(\alpha C^2 S_o T/gP)_{av}$, averaged over the reach under study

α = Coriolis coefficient

C = Chézy's coefficient, in $m^{\frac{1}{2}}/sec$

T = top width, in m

P = wetted perimeter, in m

g = acceleration due to gravity, in m/sec^2

$F(u,N)$ = varied flow function : $\left(-\int_0^u \frac{du}{u^N-1}\right)$

N = hydraulic exponent : $(2 \log (K_{av}/K_o)/\log(y_{av}/y_o))$

K_{av} = conveyance calculated with the average depth (y_{av}), in m^3/sec

K_o = conveyance calculated with the normal depth, in m^3/sec.

In the past, the solution of this equation was found by the use of the varied-flow-function tables, which gives values of F (u,N) for different u and N. With the pocket calculators the values of the varied-flow-function can be directly calculated in the following way :

By using series method we can integrate the varied-flow-function term by term to obtain :

For $u > 1$

$$F(u,N) = \frac{u^{1-N}}{N-1} + \frac{u^{1-2N}}{2N-1} + \dots \qquad (9)$$

For $u < 1$

$$F(u,N) = u + \frac{u^{N+1}}{N+1} + \frac{u^{2N+1}}{2N+1} + \dots \qquad (10)$$

The number of terms to be used depends on the desired accuracy.

A special program was developed to calculate F (u,N) for any N and u, for a HP41C pocket calculator.

Refering to values given by Ven Te Chow (1959), up to 20 terms have to be taken to get three significant figures if u is close to unity, say u = 1.07 and not more than 4 terms if u is larger than 2.
When using a HP-41C, the longest series is calculated in not more than 25 seconds and the shortest one in less than 5 seconds.

Three main problems can be solved by using the method of direct integration for a channel reach with given geometry and roughness and positive slope :

a given channel discharge Q and flow depths in two consecutive sections, 1 and 2, it is required to find the distance between 1 and 2 or the depth in a certain section situated between 1 and 2.
The computation is easy because the average value of the parameter j and that of the hydraulic exponent N in the Bakhmeteff formula can be calculated with the given information at both ends of the reach under consideration.

b given channel discharge Q and only the depth at one end of the reach under study, say y, it is required to find the other depth, say y_2, at a distance L.
This case is more complicated because the flow depth at only one end of the reach is know and the value of the hydraulic exponent (N) and that of the parameter j in the Bakhmeteff equation can not be calculated as before.
According to Chertousov (1957) the following procedure of computation was used. We can write :

$$E = S_o L/y_o - (1-\bar{j})F(u_1,N) + u_1 \qquad (11)$$

which value can be calculated assuming in a first approximation that $y_{av} = y_1$
and also

$$F(u_2) = u_2 - (1-\bar{j})F(u_2) = E \qquad (12)$$

and solving by trial and error the above equation for U_2, a first value of y_2 is obtained. This value is used to recalculate y_{av} and the procedure is repeated until the desired accuracy is obtained.
A special program was written to perform these calculations.

c given the depths y_1 and y_2 at both ends of the reach under study and its length L, it is required to find the discharge Q.
Because the discharge is unknown the equilibrium depth cannot be calculated directly.

The equation of Bakhmeteff can be written

$$y_o((u_2-u_1)-(1-\bar{J})(F(u_2,N)-F(u_1,N))=f(y_o)=S_oL, \quad (13)$$

where S_oL is known.

The equation $f(y_o) = S_oL$ has to be solved by trial and error and after knowing the value of the equilibrium depth (y_o) with the desired precision, that of the channel discharge (Q) can been easily found by using Chézy's formula.

The solution of such a problem is generally tedious if programmable pocket calculators are not used.

7 Conclusions

In spite of the specific limitations of the programmable pocket calculators, the combination of their internal logic and the external mathematical logic will enable the analysis of a wide variety of backwater problems inherent in designing dykes and other flood protection structures for polder projects.

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LAND EVALUATION FOR URBAN DEVELOPMENT IN THE NETHERLANDS

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Abstract

Applications of land evaluation procedures for urban development in The Netherlands show that important information can be provided for planning and design of urban extensions.

1 Introduction

A large part of The Netherlands consists of polderareas. The greater part of the Dutch urban areas are located in polders in the western part of the country. Soil conditions, watermanagement, natural and artificial elevations and waterways have been the most important physical elements in forming the spatial structure (Hengeveld et al., 1977; Lambert 1971). Although the pre-urban cores were founded on higher, dry places with a good bearing capacity, from mediaevel time on extensive engineering works were necessary to make growth of the cities possible.

The necessity of extensive engineering works also exists today. The total set of works is called bouwrijp maken (building-site preparation). It includes:

a) earthworks
b) a subsurface drainage system
c) a sewersystem
d) a system of urban watercourses
e) pavement

f) green areas

g) foundation of buildings

In the polders, with a peat or claysoil and a groundwatertable mostly above 0.50 m below surface, earthworks are necessary because:

- when driving over the soil, the permeability of the soilsurface in wet conditions decreases to almost zero.
- under wet conditions the bearingcapacity of the soils are insufficient to drive over it and to store materials.

Two types of solutions for this problem are applied:

- the urban quarter is covered by a landfill with a 1 to 2 meter thick layer of sand. A subsurface drainagesystem is installed.
- under paved surfaces and buildings a layer of sand is caried in a digged groove. An intensive subsurface drainagesystem is installed.

The necessity of bouwrijp maken results in high costs of the new developed urban land. Table 1 gives a rough indication of the resulting costs. In 1981 about 20% of the total costs of a dwelling of about f 110.000,-- were costs to develop the land. During the last 15 years the municipalties had to invest about f 2 * 10^9 per year in bouwrijp maken, on a total investment of about f 10.0 x 10^9 per years for the total sector earthworks, road- and dikeconstruction and watermanagement (prices 1982).

Table 1. Cost indication of bouwrijp maken in The Netherlands.
(f per hectare; 35 - 50 dwellings per hectare; prices 1982)

acquisition	50.000,--	-	75.000,--
earthwork and watermanagement	50.000,--	-	250.000,--
pavement	150.000,--	-	250.000,--
sewage system	100.000,--	-	200.000,--
urban green	60.000,--	-	100.000,--
large infrastructure works		p.m.	
foundation of dwellings	20.000,--	-	400.000,--

The costcalculation of every plan is assessed by the Ministry of housing and physical planning. In principle, the total costs of an urban extension have to born by the plan itself. Only large infrastructural works with functions for (a larger part of) the city are calculated by ratio of use.

2 Land evaluation for urban development

Given the costs and costdifferences as mentioned in paragraph 1 it is clear that to select the best location for new urban areas an assessment of the existing situation of the soil and of the watermanagement is desirable. Several systems are developed to assess data which are gathered in a survey. These assessment systems are called land evaluation. Land evaluation is defined as the process of assessment of land performance when used for specific purposes, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to indentify and make a comparison of promising kinds of land use in terms of applicable to the objectives of the evaluation (FAO, 1976).
In a land evaluation procedure for urban development, the existing situation of the soil and the watermanagementsystem is compared with the requirements to meet for the buildingsite. The existing situation has to be investigated in a soil-hydrological survey. Works are necessary to abolish the limitations of the existing situation. These works differ from place to place, seen on a regional scale as well as on a local scale. These differences in works give differences in costs. As a criterium for the evaluation of potential locations for urban development is used the costs of bouwrijp maken. To relate the costs of bouwrijp maken to the data of the survey, it is necessary to have a frame of reference, a standard, to measure the relative seriousness of the limitation. The result is a map which indicates in one way or another the capability of subareas in the planningarea for urban development. The indication will be the costs per subarea. If the land evaluation is a part of a more general potential surface analyses, the costfigures are converted into a point-score, which can be combined with other scores (Buchanan, 1978). Another reason for the conversion is to be free from

the actual amounts of money which, given the rough measure of detail, have to be handled with care.

To measure the capability via the costs, the method of bouwrijp maken has to be established for every subarea. Depending on the level of detail, elements of the method of bouwrijp maken can be distinguished. At the outset of a local plan one can distinguish general works and specific works (Heidemij, 1979). General works have to be made over the whole surface of the subarea . They are independent of a specific urban design. Normally two groups of works are distinguished:

1) earthworks, leveling and groundwatercontrol
2) that part of construction of watercourses and sewage system that depends on the soil

Specific works are related to a specific land use type within the urban area and thus related to the urban design, e.g.:

3) foundation construction for dwellings
4) foundation for roads
5) earthworks for urban green

Working on regional level the bouwrijp maken is subdivided in less elements because an urban design is not under discussion. An average urban design can be used and specific works can be taken together.
The land evaluation is elaborated and illustrated with some studies done in The Netherlands. A number of evaluations have been made during the last ten years and described by Hengeveld (1982-a).

3 Land evaluation on regional level

The objective of the evaluation of regional level is to generate information for the selection of locations for new urban extensions. In the polderarea between the rivers Waal and Meusse, the locations of new urban quarters have to be selected (Grontmij, 1972). An urban quarter in this study is defined as a micro-structure with low-rise houses and an average land use of

- parcels for houses and gardens 45%
- urban green and water 30%

- roads and paths 25%
- average density 25 dwellings per hectare

With this average land use type two sets of limitations are distinguished:

- "soil and water"; the works to overcome this limitation are the numers 1), 2) and 4) mentioned in paragraph 2.
- "depth of sand"; the work to overcome this limitation is the construction of the foundation.

To asses the limitation "soil and water", the soil map is simplified in such a way that subareas are formed with a distinct difference in costs for bouwrijp maken. This soil map is combined with data of the level of groundwater, waterlevel in the polders, surface levels and a geotechnical judgement of the Holocene deposits.
Summarized, it gives the frame of reference as shown in Table 2 together with a costmap (figure 1).

Table 2. Frame of reference for the limitation "soil and water". Costs of bouwrijp maken in f/hectare (prices 1972)

group 1	dry sand	128.000,--
group 2	wet sand	158.000,--
group 3	dry loam	140.000,--
group 4	moderate dry loam	156.000,--
group 5	wet loam	184.000,--
group 6	moderate dry heavy clay	170.000,--
group 7	wet heavy clay	191.000,--
group 8	wet heavy clay on peat	217.000,--

To assess the limitation "depth of sand" a map with the thickness of the Holocene layers is made. Dwellings have to be founded on the underlying Pleistocene layers. The frame of reference is given in Table 3.

Figure 1 Part of the costmap for the limitation "soil and water" for urban development. The numbers are the groups of Table 1

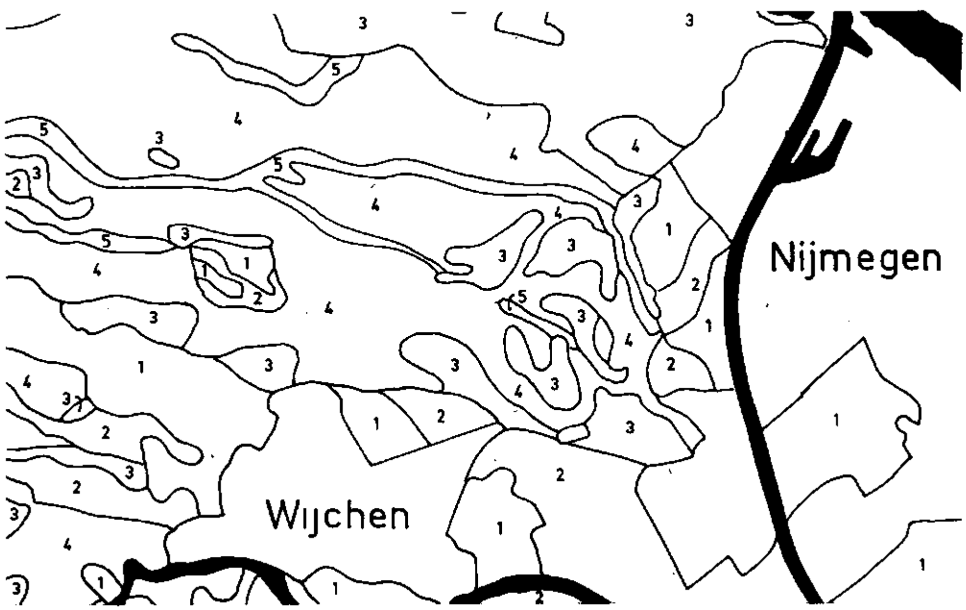

Figure 2 Part of the land evaluation map for urban development. 1 indicates the cheapest terrain, 5 the most expensive

Table 3. Frame of reference for the limitation "depth of sand"; Costs of the construction of the foundation in f/hectare (prices 1972)

group 1	average depth of foundation	0,80 m	65.000,--
group 2		1,75 m	104.000,--
group 3		2,50 m	124.000,--
group 4		4,00 m	135.000,--
group 5		5,50 m	141.000,--
group 6		8,00 m	154.000,--

The necessary works have to be designed and the costs have to be calculated. The results are given in Tables 1 and 2.
The total result is a map with the costs of bouwrijp maken for every subarea. In this planningregion the costs vary between f 260.000,-- and f 420.000,-- per hectare (Fig. 2).

4 Land evaluation on local level

The objective of the land evaluation on local level is to generate information for the urban design, that is for the location of land use types as low rise houses, blocks of flats, roads, urban green, or any other type of land use to be distinguished in the local plan. The proces is the same as discussed in paragraph 3. In the example discussed here a single-value costmap is made for every type of work mentioned in paragraph 2 and in Table 4 (Heidemij, 1979). Table 4 gives the cost-classes as distinguished in the planningarea for every type of work.

Figure 3 gives for a part of the planningarea some single-value costmaps. For every type of land use a combined-value cost map has been made depending on the desired surface use of the plan. In one of the alternatives the surface of the area for low-rise houses exist of 23% houses, 29% roads and 48% gardens and urban green.

Table 4. Frame of references for all limitations. Costs in f/m^2
(prices 1979)

types of work	costs					
earthworks	5,10	9,21	9,76			
watermanagement etc.	4,25	9,25	8,25	5,75	13,00	20,50
roads	13,75	21,50	1,00			
foundation blocks of flats	270,00	305,00				
foundation low rise houses	77,50	157,00	177,50			
foundation bungalows	70,00	115,00	131,50			
urban green	2,90	1,40	0,75			
sports fields	3,20	2,95	5,70			

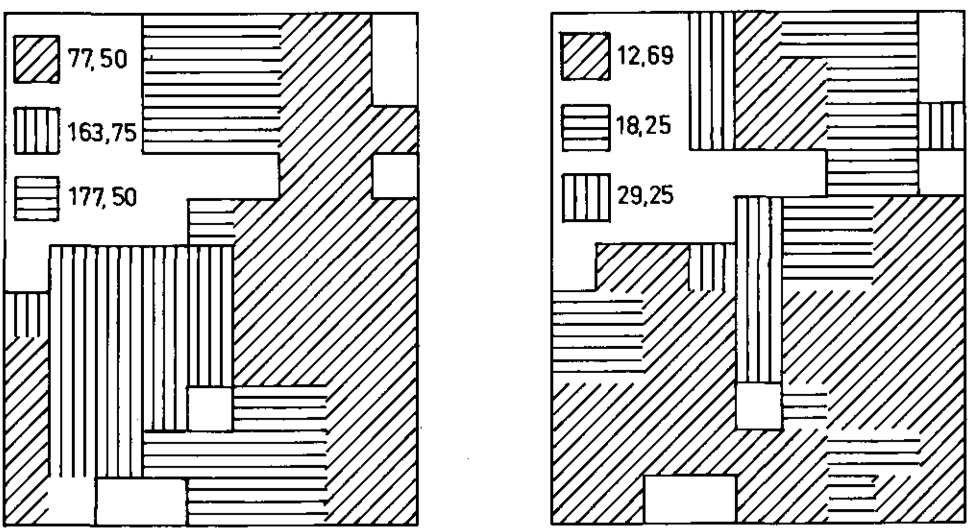

Figure 3 Part of some single-value maps: a) foundation low rise houses, b) roads. Costs in f/m^2

The costs of a low rise house area are calculated as:

- 100% of the costs of earthworks, plus
- 100% of the costs of watermanagement etc., plus
- 23% of the costs of the foundation construction, plus
- 29% of the costs of roads, plus
- 48% of the costs of green.

Figure 4 gives the combined-value costmap for low rise houses.

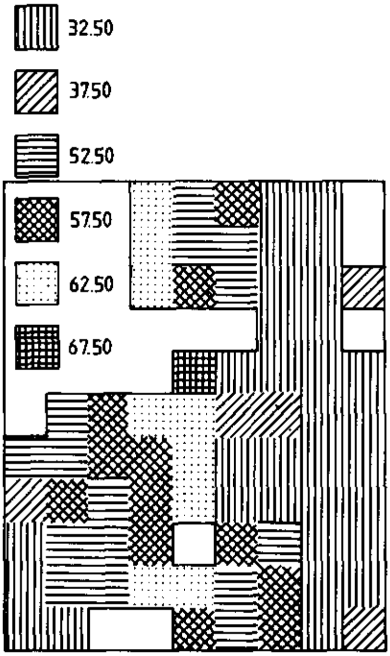

Figure 4 Part of the combined-value costmap for low rise houses. Costs in f/m^2

The total result is a costmap for every land use type. The calculations and drawings can be done by computer.
The results can be used in different ways during the design proces. At first, the different combined-value costmaps can be used by the urban planners as an underlay. Secondly, the total costs of alternative plans can be calculated easily. Thirdly, it is easy to examine cost consequen-

ces of changes in surface use. At last a plan with minimal costs can be computed by a optimization program (Figures 5 and 6).

Besides the place-bound costs also the costs of infrastructure are very relevant for urban planning. Threshold Analysis is a planning technique which combines the land evaluation with the calculation of the cost of infrastructure (Hengeveld, 1982-b).

6 Evaluation and conclusions

The land evaluation procedures as described in the paragraphs 2 to 5 hardly knows any methodological problems: they are simple techniques. Problems can arise with the collection of adequate soil-hydrological data versus costs. Applications on regional level cannot afford extensive surveys. In the Netherlands it proved to be possible to collect the necessary information from existing maps and archives. Soil- and hydrological surveys are necessary for local urban development anyway. When the survey is done in the beginning of the planning proces a land evaluation can be made without extra costs for a survey.

It can be concluded that a land evaluation generates important information for urban planning (Hengeveld, 1982-a). In the Dutch polder situation, the costs of works depending on soil and water in a planningarea varies up to 300 % for different locations. The costs of constructions of the foundations are 1 to 3 times as large as that of the rest of the bouwrijp maken and they vary up to 300% for different locations in regions of the polders. Also the costs of infrastructure, utilities and management of the urban areas are considerable as well as the variation in it.

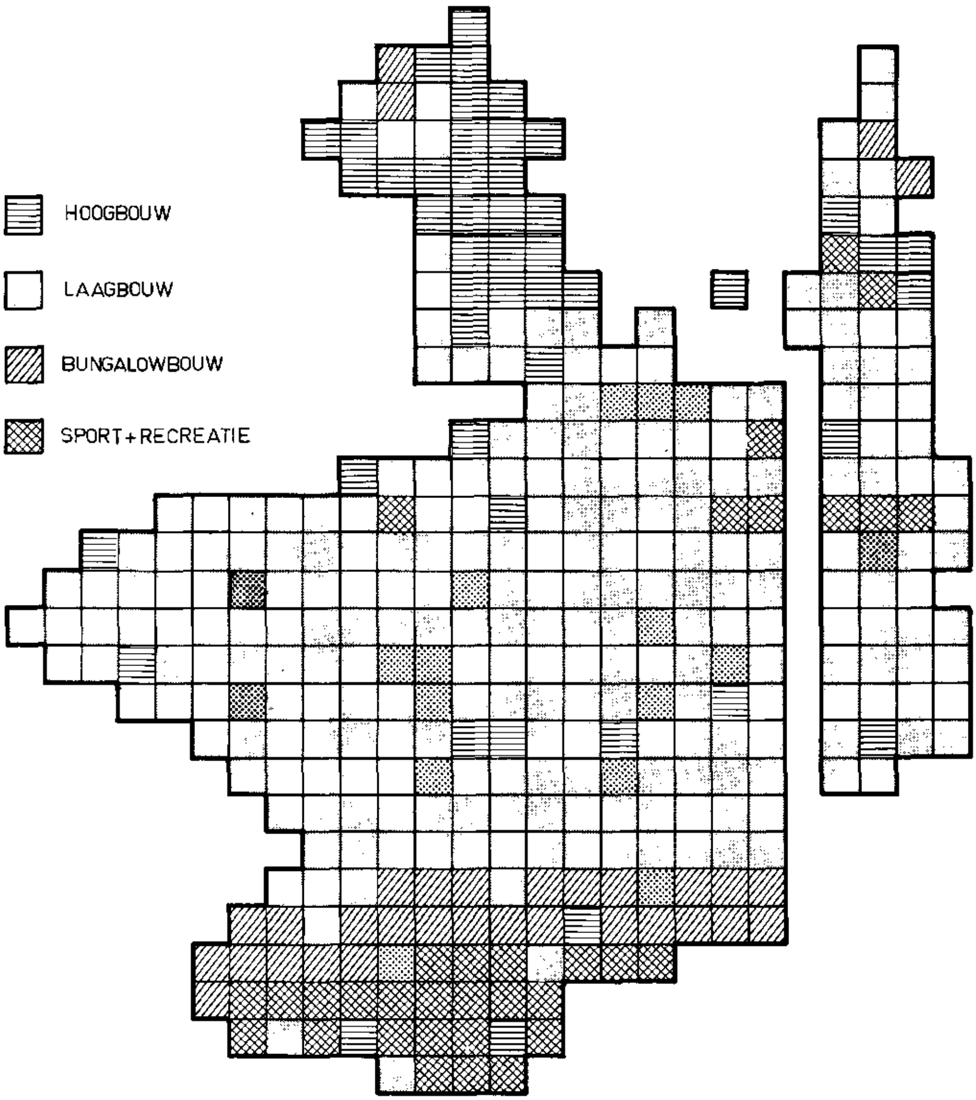

Figure 5 Alternative with cost minimization with 9000 low rise houses with a density of 36,4 dwelling/hectare. Total costs f 132.000.000,--

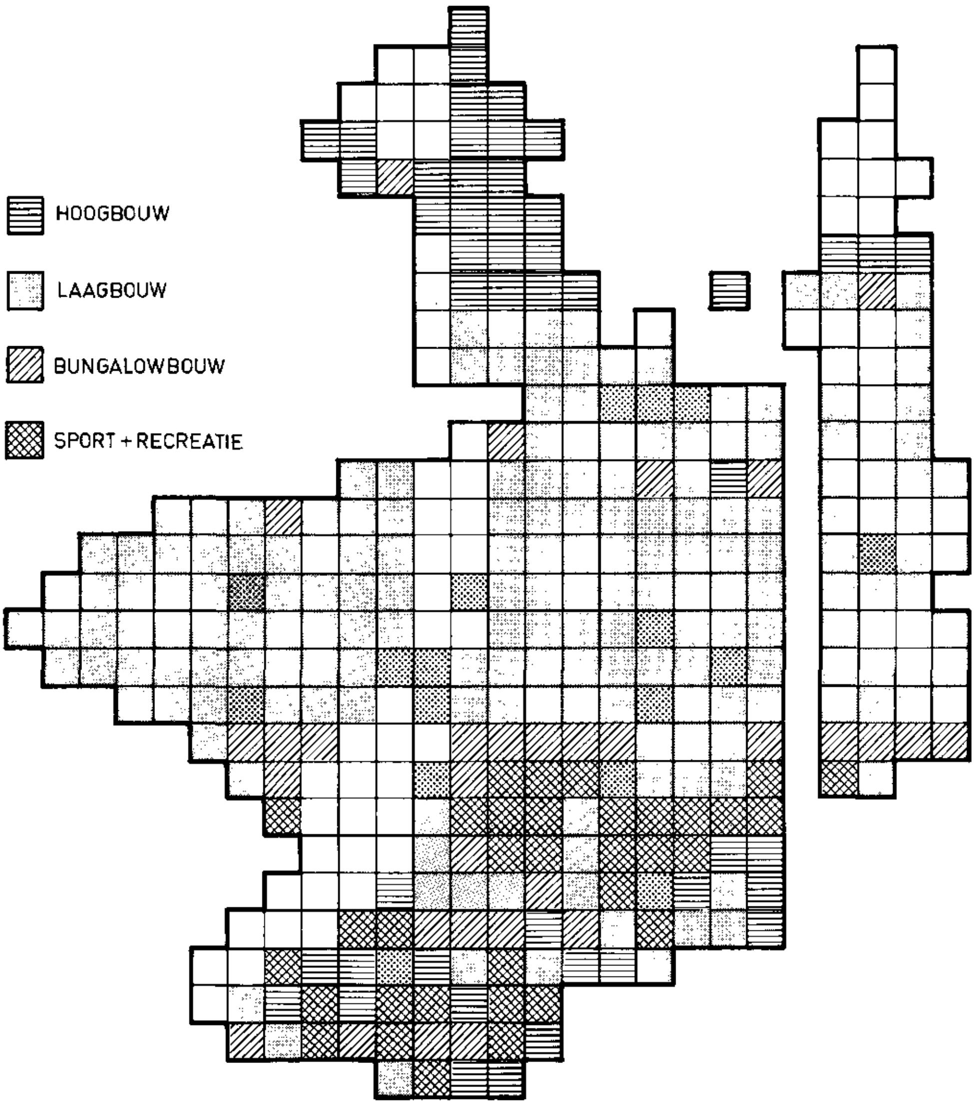

Figure 6. Alternative with costminimization with 9000 low rise houses with a density of 49,5 dwellings per hectare. Total costs f 116.700.000,--

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EFFECTS OF RECLAMATION OF TIDAL FLATS AND MARSHES IN THE NETHERLANDS ON FISHES AND FISHERIES

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Abstract

It is generally accepted that coastal waters are important for fisheries. They are usually rich in food, are the sites of important maricultures and serve as nurseries for several species of fish. Reclamation of coastal habitats thus has the potential to affect the size of fish stocks and fisheries negatively.
Two main types of effects may be expected, viz. destruction of the habitat of fishes, i.e. the place were they live, and destruction or decrease of the food supply of fishes. On the basis of existing knowledge on the ecology of coastal waters an assessment is made of these effects. The theoretical considerations are compared to a number of field observations made after reclamations in the past 50 years. Various estimates of the damage to fishstocks and fisheries are discussed and compared to the estimated profits of the new polders.

1 Introduction

About 0.1% of the total sea area of the world yields more than 50% of the world fisheries production. This 0.1% is made up by coastal upwelling areas and shelf seas. Similarly, the North Sea, containing only 0.004% of all sea water, yields about 5% of world fisheries production. These few figures may serve to illustrate the importance of shallow seas for the world's fisheries.

The edges of these seas are considered to have extra importance (Odum, 1971; Zijlstra, 1972, Clark, 1977, Turner, 1977) as sources of food, as spawning areas and/or nurseries of young fish and as the sites of various mariculture activities and coastal fisheries.
Around the North Sea the estuarine Wadden Sea and the river estuaries have been indicated to be extremely important as nurseries of some commercially exploited species of fish (Zijlstra, 1972) and as the sites of highly productive cultures of shellfish (Korringa, 1969). Coastal fisheries in these areas are of minor importance nowadays, but have been valuable in the past (Postuma & Rauck, 1978).
Along the East coast of North America, an area rich in estuaries, the notion that salt marshes deliver organic matter and hence food to estuaries and estuaries do so to the open sea has been an article of faith for many years (Odum, 1971; Clark, 1977), but this has never been demonstrated for marshes around the North Sea (Wolff et al., 1980; Dankers et al., in prep.). Nowadays, this theory has been challenged in North America as well (Nixon, 1980).
Whatever this may be, it will be clear that reclamation may have a serious impact on various important aspects of estuarine ecosystems.
The Dutch North-Seacoast with its numerous embankments going on for centuries already provides us with interesting possibilities to investigate the impacts of polders on estuarine fishes and estuary-dependent fisheries.
This paper tries to indicate which effects are theoretically possible and which effects have actually been observed. It continues with an attempt to quantify some of the effects of polders in coastal areas of the North Sea and finally tries to compare the benefits of new polders to the costs of lost fisheries.

2 Effects of polders on fishes and fisheries: hypotheses

Three main effects of embankments may be hypothesized, viz.:
- loss of habitat;
- loss of migration routes;
- loss of food sources.

Loss of habitat occurs when salt marshes and tidal flats are reclaimed. Species of fish and invertebrates living in these areas, in some cases only during part of the tidal cycle, loose their possibility to occur in these areas. Depending on the population dynamics of these species such a loss of area and food may imply a reduction of the size of the population of these species, but only when area, food or a similar factor limits the population size. Limitation of the population size by area is very obvious in sedentary invertebrates such as cockles and mussels, but is difficult to demonstrate in fishes and mobile invertebrates. This is even more so when different life stages occur in different areas, e.g. when tidal flats are used only as a nursery for the juvenile stages. So far, indications for the presence of a limiting factor related to area have only been found for plaice (Pleuronectes platessa) and sole (Solea solea) (Rauck & Zijlstra, 1975), but actual proof has never been obtained.

Along the coasts of the North Sea it is highly unlikely that reclamation of salt marshes will result in loss of habitat for fishes, since hardly any species lives in the intricate network of salt-marsh creeks. Embankment of tidal flats and shallow water, however will lead to loss of habitat for several species, e.g. flatfishes, mullets, brown shrimps and possibly herring.

Loss of migration routes will be important in particular for migrating species with different life-stages in the open sea and in fresh (or brackish) water. When the connection between these two types of habitats is disrupted by a reclamation project, the species concerned will not be able to complete their life-cycle and thus decrease in number, eventually down to zero. This will even be true when the habitats themselves remain unaffected.

Loss of food sources will usually be identical to loss of habitat, unless the food is derived from another habitat where the species concerned does not occur. A theoretical example is fishes living in coastal waters being dependent, directly or indirectly, on food produced in salt-marsh areas where the fishes cannot live. Of course, the food obtained in this way should be a limiting factor for the population size, since otherwise no effects will occur when such salt marshes are embanked.

It is evident that when a fish population is affected in some way by a reclamation, a fishery dependent on this species will be affected as well.

3 Effects of polders on fisheries: observations from the Netherlands

3.1 Loss of habitat

In 1932 the Zuiderzee was changed from a tidal, brackish-water area into a stagnant freshwater lake. This meant the loss of an important area of habitat for estuarine fishes. Havinga (1954) summarized the changes observed in the fish populations and the fisheries (Table 1). His data very clearly show how estuarine fish have been replaced by freshwater species and how the fisheries changed accordingly. In addition, the total yield for human consumption declined from about 18,000 tons annually in 1926-31 to about 7000 tons in 1946-51, when freshwater conditions were well established (Zijlstra, 1976).
The Zuiderzee reclamation also presents us with one of the most convincing cases that embankments affect the population size of a species. The Zuiderzee was the area where a local race of herring (Zuiderzee herring) had its spawning area as well as its nursery. On average about 10 million kg of this type of herring were caught in the Zuiderzee annually. After the closure of the dam this catch rapidly dropped, eventually to zero. Outside the dam, in the Wadden Sea, 1.6-3 million kg were caught annually before the closure. In 1931, when the dam was partly completed, 4.4 million kg were caught outside it and in the period 1933-36 10.7-15.1 million kg were caught annually. The animals spawned at the outer side of the dam. The larvae did not develop to young fish, however, and ultimately the population declined. In 1937 7.4 million kg were caught, in 1938 1.2 million and in 1939 only 12,000 kg. The fishery has stopped in that year (Havinga, 1954).
A similar story relates to the anchovy (*Engraulis encrasicholus*) which also spawned in the Zuiderzee. In late spring these fish migrated to this only larger area in Dutch coastal waters where salinity conditions were satisfactory and temperature high enough in some years for development of eggs and larvae. On average about 2 million kg were caught in the Zuiderzee annually. After the closure the Zuiderzee population

disappeared and was hardly or not able to use the Wadden Sea as a replacing spawning area (Havinga, 1954; Postuma & Rauck, 1978).
At none of the subsequent and smaller reclamations in the Netherlands comparable observations on the effect of habitat loss on fish stocks have been made. Although the loss of habitat was clear in all cases, an effect on fish stocks could not be demonstrated. This lack of evidence for changes in fish stocks as a result of embankments may have two causes. The first is that there was no effect on the fish stocks, since the area of habitat does not limit the population size. However, the second possibility is that an effect was present, but could not be demonstrated due to its smaller scale and the large year-to-year variability in the recruitment and thus size of the fish stocks. This may be illustrated by the following figures. Since there is evidence that juvenile plaice prefer tidal flats as a habitat (Kuipers, 1973), the loss of habitat due to reclamation may be expressed as the area of flats lost. Reclamation of the Grevelingen estuary caused the loss of 40 km^2 of tidal flats. Assuming that all flats around the North Sea have equal value as nurseries, this would mean a loss in nursery area of less than 1%. A similar result may be obtained by using data on plaice densities. Wolff et al. (1981) estimated an average density of 276 two-year-old plaice per 10^4 m^2 of tidal flats in the Grevelingen estuary just prior to its closure in 1971. With 40 km^2 of tidal flats this would imply that the closure of the Grevelingen estuary would have caused the loss of about 1 million plaice. This figure should be compared to the average size of the North Sea plaice stock at 1-2 years of age of 337 x 10^6 individuals (Bannister et al., 1974). So even a relatively large loss of habitat would mean a reduction of not much more than 0.5% of the total stock. Since year-class size can vary between years by a factor of 3, the effects of an embankment on recruitment are usually hidden in the naturally occurring year-class variations. However, it has to be stressed that this does not mean that reclamations have no effects on fish stocks.
The situation is different for sedentary invertebrates. Especially in the case of mussels (Mytilus edulis) embankment of sufficiently large areas (Braakman, 1952; Grevelingen, 1971) is reflected immediately in the yield of the mussel culture.

3.2 Loss of migration routes

In most reclamations loss of migration routes coincides with loss of habitat and the effects of the latter will be enough to explain any changes. In the case of closures of river mouths the habitats involved may remain unaffected whereas their connection may be blocked. However, the only case in which the effects of this could be studied, concerns the Rhine estuary. Here so many other influences affect the fish stocks (notably pollution) that any effects of closure of the river mouth cannot be demonstrated (Wolff, 1978).

Table 1. Changes in the fisheries yields of the former Zuiderzee due to its closure in 1932. All figures denote tons per year. After Havinga (1954).

	Herring	Anchovy	Flounder	Smelt	Eel	Freshwater species
1930			3,647	1,285	838	7
31		3598	2,321	1,349	941	8
32	c.10,000	378	1,273	476	1,048	14
33	12	0	1,265	337	2,125	11
34	0	0	1,124	447	2,688	25
35	0	0	232	317	1,907	32
36	0	0	48	271	2,405	60
37	0	0	43	130	3,595	145
38	0	0	25	209	2.588	243
39	0	0	27	24	2,108	2920
40	0	0	45	7	3,205	1674
41	0	0	63	73	4,563	1782

3.3 Loss of food sources

It is conceivable that fish stocks, or rather the food organisms of such stocks, depend on food sources produced outside their habitat. Examples are particulate organic matter originating form salt marshes and transported by tidal currents to shallow coastal waters as well as matter produced in estuaries and exported to the open sea. Embankment of salt marshes or even complete estuaries would terminate such a transport of potential food and thus could have an impact on fish stocks. We do not know of any example of salt-marsh reclamation in the North Sea causing a reduction of fish stocks due to removal of food sources. We also consider it unlikely that such effects exist, since it seems that North Sea salt marshes act as net importers instead as exporters of particulate organic matter (Wolff et al., 1980; Dankers et al., in prep.).

It might be argued that reclamation of entire estuaries causes a decrease of fish stocks in the adjacent open sea because of the termination of estuarine 'outwelling' (Odum, 1971). However, apart form the hypothesis that net 'outwelling' of particulate organic matter does not occur in North Sea coast estuaries (Postma, 1954, 1961; Wolff, 1977), such an effect would be very difficult to distinguish from the effects considered in chapters 3.1 and 3.2. Moreover, as already stated in these chapters, such effects have never been demonstrated.

4 Discussion

The only demonstrable negative effect of reclamations on fish stocks and fisheries in the coastal areas of the North Sea is due to loss of habitat. Clear examples, discussed in chapter 3.1, are loss of spawning habitat for two species of fich resulting in decline or disappearance of fish populations, and loss of habitat for mussels resulting in decrease of the mussel stock.

Not demonstrated but likely to occur are negative effects of loss of habitat on other coastal species of fish and invertebrates. In fact, Anonymous (1974), Dankers (1978) and Anonymous (1979) assumed that these would occur when they estimated the effects of reclamation of part of the Wadden Sea.

Not demonstrated but likely to occur are also the negative effects of disrupted migration routes for species of fish.

Not demonstrated and unlikely to occur are negative effects of reclamation of salt marshes on fish and invertebrates. The only effects demonstrated resulted from reclamation of tidal flats and shallow coastal waters.

Assuming that all effects demonstrated or likely to occur, do so indeed, we may be able to estimate the effects of reclamation on stocks of fish and marine invertebrates and on the fisheries yield. The Netherlands Institute for Fisheries Research did so in the late sixties for two potential reclamation schemes in the Dutch Wadden Sea (Anonymous, 1974). When an error in the report is corrected, the damage to the fisheries on plaice, sole, herring and brown shrimp may be recalculated per ha. The capitalized damage (rate of discount 10%, period unlimited) arrives at about Hfl. 3700.- for a scheme near the island of Ameland and at Hfl. 1700.- to Hfl. 3300.- for a scheme at the Balgzand tidal flats. It is not clear what has caused the differences.

Dankers (1978) made a reassessment for the Balgzand tidal flats and he estimated that the loss of 1 ha of tidal flat habitat on average would result in the annual loss for the fisheries of:

1500 kg of plaice;
100 kg of sole;
17.5 kg of brown shrimp;
unknown amount of herring and other pelagic fish, but comparable to the total loss of plaice, sole and shrimp together;
50 kg of cockles;
unknown amount of mussels produced by mariculture.

The yield of lugworms for bait (about 4000 per ha) is not included, since the lugworm fishery is not limited by the available lugworm stock. Capitalizing the estimated amounts lost (rate of discount 10%, period 20 years) suggested an economic loss of nearly Hfl. 40,000.- per ha (see NEI & RIN, 1978), thus considerably higher than the earlier estimate, even after accounting for the rate of inflation. Although the cockle fishery is a new development since the earlier estimate, Danker's estimate is almost certainly too high. He seems to have overestimated the number of plaice present and not to have accounted for mortality of plaice between the juvenile stage and the recruitment to the fisheries. Moreover, his assumptions on the amount of herring dependent on tidal flats are not supported by recent observations.

Finally, Rijkswaterstaat published a study (Anonymous, 1979) on the costs and benefits of the embankment of salt marshes and tidal flats near Zwarte Haan, Friesland. For these high-lying tidal flats, which

have less importance for fisheries (mainly plaice and shrimps), the yield was calculated by the Netherlands Institute for Fisheries Research at about Hfl. 925.- per ha per year. Capitalizing this amount in the same manner as has been done in the earlier studies would result in a value of about Hfl. 5400.- per ha. It seems that this is a relatively low estimate which is not representative for the average tidal flat area in the Wadden Sea. Therefore, considering the various estimates made about economic losses to the fisheries in relation to the reclamation of tidal flats in the Dutch Wadden Sea, the capitalized losses might range between Hfl. 5000.- and Hfl. 10,000.-.
The economic value of areas reclaimed either for agriculture or other human uses, generally will be higher than this value for fisheries. Reclamation usually involves considerable costs, however. Therefore in the final cost-benefit analysis the negative benefits of lost fisheries yields may play a highly important role.

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NATURE IN NEW WADDEN-POLDERS CONSERVATION BY EXPLOITATION

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Abstract

In recent engineering projects along the North Sea coasts large areas of tidal sandflats have been embanked, which often gain a nature reserve status. The plant colonisation and primary succession is described; nature management practises, notably grazing, and the significance for wildlife protection are discussed, exemplified by the Lauwerszee polder 9100 ha, embanked in 1969.

Introduction

The application of modern technology along the North Sea coast now renders solid solutions to the old problems of security, land reclamation and fresh water management. Only gradually the far reaching ecological impact of these huge mutations in the highly valuable coastal fringe of our marine wetlands gains a general concern (Saeijs 1982, Wadden Sea Working Group, in press), but in the meantime over 5000 ha of saltmarsh and tidal flats are being diked in the Wadden Sea area alone and plans exist to embank well over 20.000 ha.
One answer to the problems of storm surge danger and of the inundations in the coastal plain by excess riverdischarge is rather specific. With the straigtening of the bending old dikes, new dams enclose seabed and reservoir-lakes with a free drainage on the low tide by large sluices (Figure 1). Several extended areas in bights and estuaries of the Wadden

Sea have thus been and will be embanked as a by-product of this design. More or less the same holds for the saline stagnant lakes and sandflats created in the Dutch Delta region.

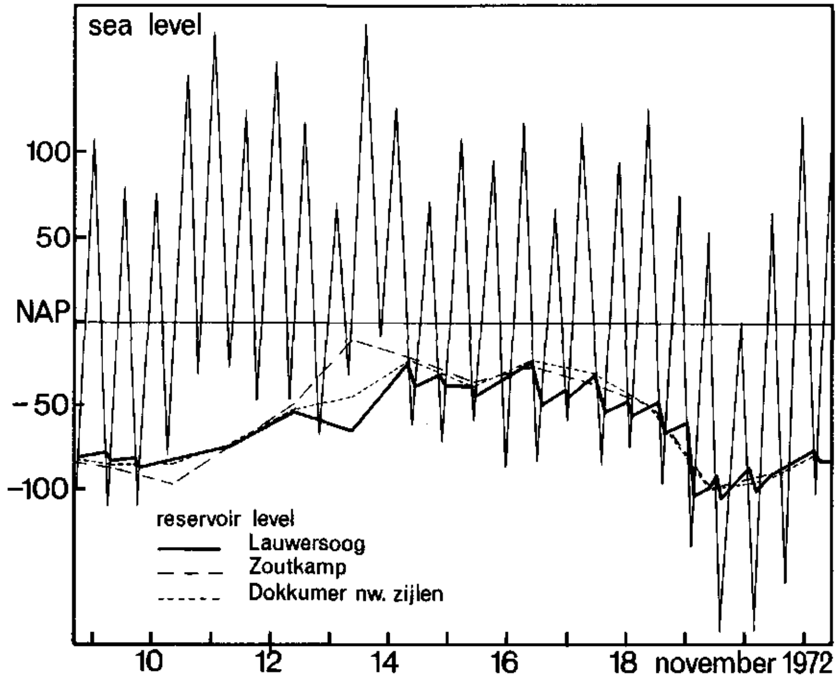

Figure 1. Storm effect on water levels in the reservoir-lake and at sea, showing the limits of the hydrological control.

The sandflats in the new polders often are left to spontaneous succession of natural phenomena. However, by no means the losses of saltmarsh and wadden ecosystems can be compensated in the new nature developing at the landward side of the dam (Heydemann 1981); here the creative developments provide us a new reality, which may gain significance for nature conservation.

A clear example is the Lauwerszee-polder, 9100 ha embanked in 1969 as an estuary of the Dutch Wadden Sea. Other comparable situations are to be found in the German part, e.g. the Hauke-Haien-Koog 1958 (Brehm 1977) the Meldorfer Bight 1972, 1978, the Eider estuary 1972, whereas another 2100 ha embankment at the german-danish border is under construction. In a wider perspective the newly created basins in the Dutch Delta

(Saeijs 1982, Beeftink 1975) and polders along the English eastcoast are worth mentioning (Gray 1976, 1977).
Biological studies into the processes of ecosystem development up to some stage of maturity have not yet been undertaken, long lasting as they would be; our knowledge is limited to the first stages, the possibilities for research often being excluded by cultivation, e.g. in the Wieringermeer (Feekes 1936), the Lake IJsselpolders (Feekes & Bakker 1954, Bakker 1960) and also in Japanese polders (Iwata & Ishizuka 1967).
This paper focusses on the Lauwerszee-polder (Figure 2), which presents a model for the study of natural succession and subsequent nature management practises (Joenje 1977, 1978, 1982)

2 The environment

Different from 'man-made' polders uniformed by agricultural adjustments, the embanked sandy wadden shallows consist of a number of different environments. The essentials appear to be the height- and soil gradients and the lack of artificial drainage structures (Figure 2).

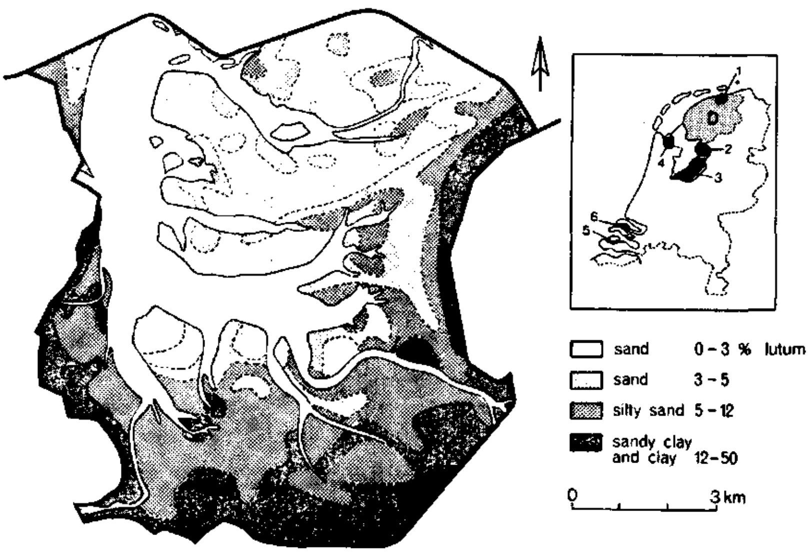

Figure 2. Soil types in the Lauwerszee-polder. Lutum refers to fraction <2 μm. Inset : the discharge area D (200.000 ha) and some other embankments (2) Noordoostpolder, (3) Flevopolders, (4) Wieringermeer, (5) Veerse Meer, (6) Grevelingen.

The highest coarser grained parts of the sandflats show a quick desalination, especially the upper zones of height-gradients, where rainwater laterally percolates through the soil. The horizontal parts and the low lying finer sands, still poor in humus but with a few % of clay, loose salt much slower and in some locations a high salinity e.g. 10 to 20 g NaCl per liter soil moisture, will persist for several decades, caused by the lack of local drainage and the slow flux of saline ground water from the higher sandflats.
Characteristic groundwater fluctuation patterns show an extended waterlogged winterperiod and summertables descending to 80 - 120 cm below the soil surface, more or less independent from the absolute height. These abiotics, together with the low-nutrient status of the sediments offer a variety of natural environments on a large scale, open to colonisation by plants and animals and subsequent primary succession, which is in itself a rare phenomenon (compare the Krakatao islands or retreating glaciers). The ground water regimes resemble those of dune slacks, but also the natural condition in pleistocene coversands underlain by boulderclay, a widespread soil type in the North of the Netherlands and Germany, the natural water-regime of which is now almost confined to nature reserves escaped from ameliorations.

3 Colonisation

Emerging from seeds already present on the seabed and originating from the surrounding saltmarshes, three annual halophytes seize the opportunity to colonize the saline flats, though in low densities (*Salicornia europaea* 0 to 300 plants per ha, *Suaeda maritima* to 10 and *Atriplex hastata* to 2 plants per ha). The densities related to the dispersal by tidal forces in the last winter before the enclosure. From this very sparse pioneer vegetation, the 'memory' of the tidal condition, the next generation grew up optimally, in wide aggregates around the parent plants: no interference by other species , since only a few individuals of other halo-tolerants are dispersed into the new land. These, most being perennial (*Spergularia media, S. marina, Aster tripolium, Puccinellia capillaris, P. distans* a.o.) , will appear to be the next dominants. On the well drained edges of creeks and on top op musselbanks a large

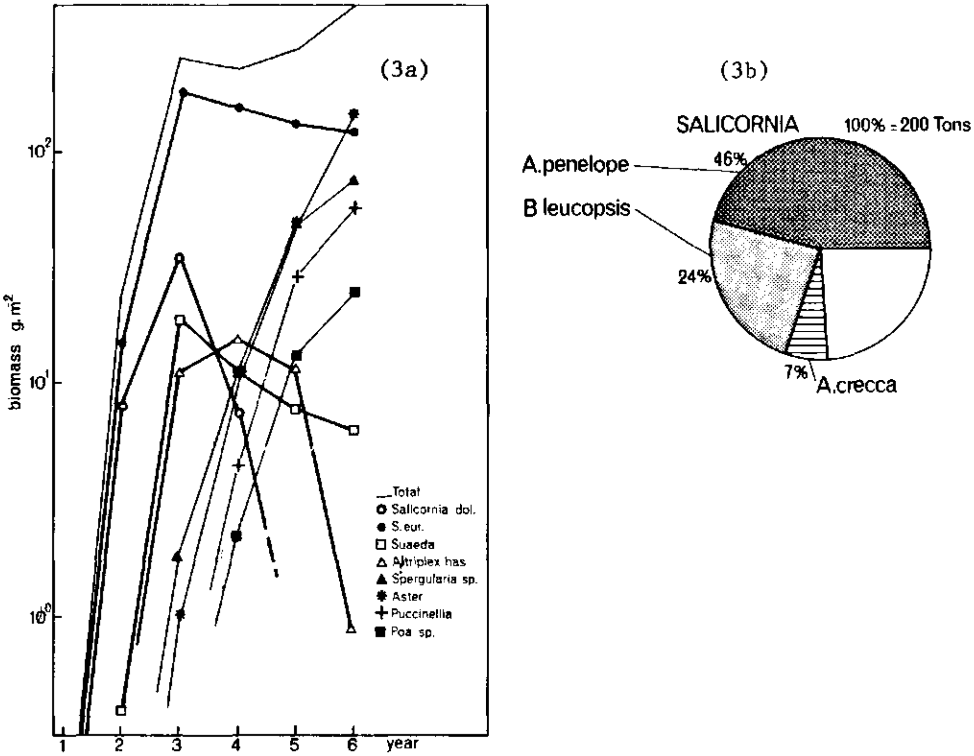

Figure 3a. Annual biomass production of the principal colonising species in the first 6 years.

3b. The consumption of *Salicornia* in the Lauwerszee-polder by widgeon , teal and barnacle goose (after Van Eerden,in press).

number of plants from fresh environments indicate the effectiveness of dispersal by wind and water. From Figure 3a the process by which the vast plains are flooded by the green wave can be read. This exponential increase of the annuals until the carrying capacity of the spot is reached, is followed by the less conspicuous increase of the perennials dominating after 6 years. The interesting question arises whether the succes of the later colonising species is due to their more efficient use of space and soil, or to the changes in the habitat, such as desalination and soil ripening ; probably both.

4 Vegetation development

From the studied migration and colonisation it seems probable that the principal colonising, salt tolerant species find no major dispersal problem in reaching the area in time, i.e. as soon as their proper desalination stage presents substantial surfaces. Differences in the share they take are related to the starting densities and their intrinsic capacities for population increase.

It appears that the early changes in the abiotic environment , governed by precipitation and aeration (desalination, soil-ripening) produce more and more habitats suitable for ever more glycophyte species. The desalination process acts as the 'échappement' for succession. The difference with the hurried succession in more productive fresh polders is most striking (Van der Toorn 1969).

Then gradually, other factors including biotic, begin to exert their influence, e.g. drought and diminishing nutrient content (especially N) on the higher sands, or inundations of low zones by fresh and nutrient-rich water from the reservoir lake, as well as natural grazing by waterfowl (Van Eerden, in press)(Figure 3b), hare and mice.

Apart from leaching, a substantial amount of nutrients becomes fixed in litter, the decay of which is rather slow.

4.1 Sands

After 8 years a number of communities have evolved, differing in number of species and structure, but generally low in production. The vegetation on the highest sands is very sparse and rich in species. Here a ca 2 cm sheet of organic debris of vascular plants and mosses covers the sand. Summer drought with water tables well below 110 cm select deeper rooting species such as tap-root perennials, trees (notably *Salix spp.*) and winter annuals and mosses with their growing season in the wetter part of the year, as well as aphreatophytes (independent of a ground water-table). When deeper soil layers are desalinated the standing crop of these communities may rise considerably and, together with *Phragmites australis* , the woody species increase, such as *Hippophae rhamnoides* , *Rubus caesius, Salix repens, S. alba, S. cinerea a.o.*

4.2 Silty sands

After 8 years the still brackish sands on lower level and the even more saline silty sands carry a meagre meadow of *Puccinellia* and *Poa* towards *Spergularia*, *Aster* and *Salicornia* mixtures, only slowly increasing in cover and number of species. Here the mass-grazing in autumn by waterfowl removes the biomass and continues the mineral surface favourable for germination of the annual halophytes they prefer so much.

Figure 4 . The effect of autumn grazing on the annual vegetation in the 10th year, demonstrated with an exclosure.

In ungrazed exclosures the surface is rapidly covered by a dense mat of perennial grasses, notably *Alopecurus geniculatus* and *Agrostis stolonifera*. Together with *Juncus gerardii* these perennials increase from the lower siltier parts towards higher zones of silty sands. And *Phragmites australis* follows as soon as the decreasing salinities permit.

In persistently saline areas the vegetation develops the aspect of a saltmarsh with swards of *Puccinellia maritima* and *Juncus gerardi* with the other halophytes already mentioned and occasional plants of *Artemisia maritima*, *Limonium vulgare*, *Triglochin maritima*, *Carex extensa* and *Plantago maritima*.

4.3 Dominance

Although natural succession rendered a variety of phytocoenoses in which well over 320 species of vascular plants participate, it becomes clear, that only a few develop mass stands in which other species tend to be extruded and excluded. Indeed in vast areas the accumulating biomass and litter of *Agrostis stolonifera* and *Phragmites* virtually exclude any other species from germinating.

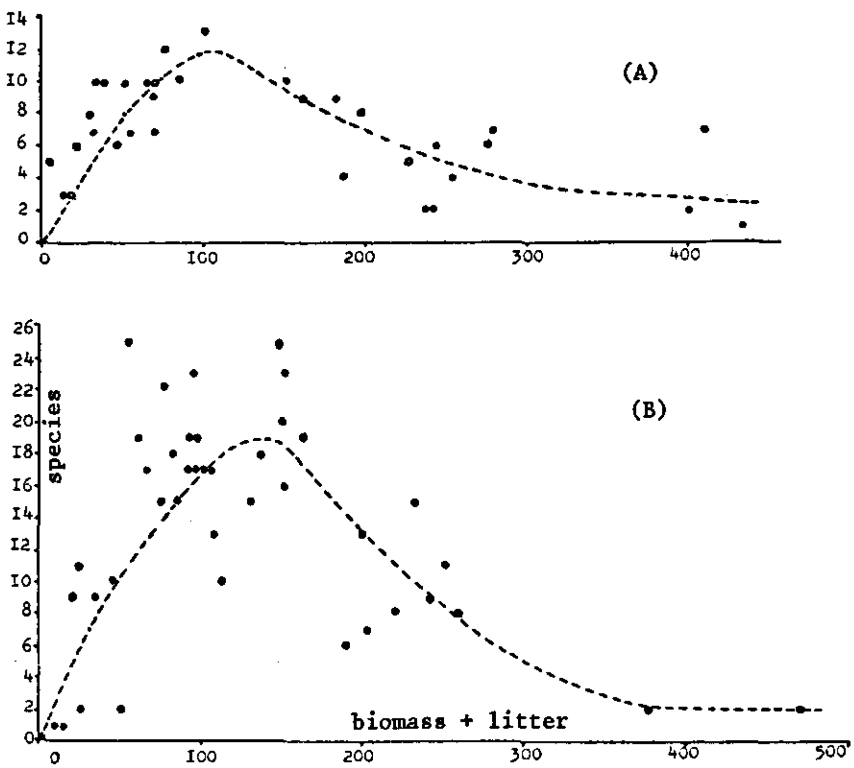

Figure 5. The relation between species density (per .25 m^2) and biomass + accumulated litter (g dwt. per .25 m^2) in various samples from the Lauwerszee-polder (A) and from the mainland (B).

This general phenomenon is illustrated in Figure 5, which gives the relation between the species density and the amount of biomass + litter (after Hendrikse & Wuring 1981). The comparison with the exploited grasslands in sandy regions of the mainland (Drenthe) with a larger number of species present, suggests that we might be able to increase species-diversity in the more productive polder areas by removing biomass and litter, i.e. by some mode of harvesting.

5 Nature management

Here we enter into the open discussion whether nature management of these polder communities should be a 'laissez-faire', which probably will result in long lasting stages of extended and impenetrable reed and willow stands, poor in species, but with unexpected establishments (compare the Oostvaarders Plassen case, South Flevoland).
or on the other hand, should be some mode of nature exploitation, such as mowing, grazing, reed cutting a.o. The point however is more general. Man has for long replaced the large herbivores in their functioning as consuments of plant biomass. Most nature reserves in Europe have'always' been subjected to some interference by man with respect to exploitation of primary production. Any cessation in the removal of biomass generally leads to deterioration of the reserve and loss of species. Therefore some 'active' management must be considered in any Nature Management Plan However, different and conflicting options may exist for the management of one area and a system of priorities is needed : should botanical diversity or even the development of populations of rare or appreciated plants (orchids, parnassia) prevail, or is the function as a breeding ground foreither reed swamp or meadow birds preferable, or else, is the internationally famous value as a hibernating area for waders and waterfowl a top priority to be optimized ? (Viz. note 1).
Because of the large surface of the nature area in the Lauwerszee-polder there are possibilities to operate several management programmes side by side in different zones, as will be discussed below.It must be pointed out, that the management of nature reserves in new polders is still very much a matter of trial and error, base on professional judgement and luck. With a lack of quantitative models for succession, predictions

can hardly be made and thus, in practice the management tends to be experimental and needs careful adjustments.

5.1 Grazing

5.1.1. Sheep

Within the central nature reserve (ca 4000 ha, Reitsma 1981) experimental sheep grazing on a year around base started in the 9th year on 330 ha low-saline and high-desalinated sandflat. After three years a study of the use of the area by 68 sheep and ca 115 lombs (the latter removed in autumn) revealed the following (Van Dijk 1981, Figure 6).

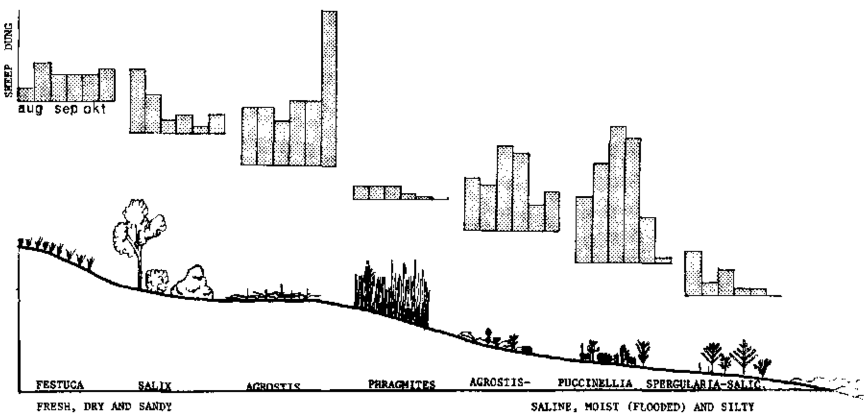

Figure 6. Distribution of sheep dung in the period August to November 1977 in the principal vegetation zones of the sheep-grazed area in the N part of the Lauwerszee-polder (after Van Dijk).

In early summer the use of the area and the consumption in different communities was evenly distributed. In September the brackish *Puccinellia*-zone was highly preferred, until in October the waterlogged surface and the goose dung made the animals change towards the higher *Agrostis*-communities. Very little use was made of *Phragmites, Festuca rubra* or the annual halophytes in the lower zone. In Figure 6 the use of the area is shown, as measured from the distribution and production of sheep dung. A significant correlation between this factor and the grazing pressure was found. Based on close estimation of the amount of damage from grazing per plant species on a large number of plots, a grazing preference list of the common plant species was made (Figure 7, after Van Dijk l.c.)

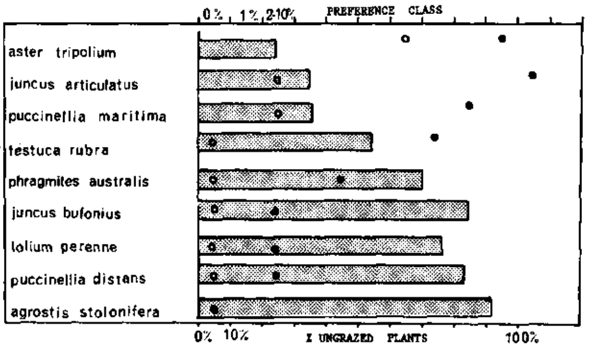

Figure 7. Columns indicate the percentage ungrazed plants of 9 species in vegetation samples of the sheep-grazed area (Figure 6); Grazing preference class of these species is indicated by open (mean) and solid dots (90 % of the species samples are in that class).

A general conclusion is that the animals show a strong preference for a few low-frequent species, and use the dominant grasses only superficially, with the exeption of *Puccinellia maritima*.
Sheep grazing in such low densities apparently accentuates the differences in standing crop and it seems unlikely that the rougher communities will be reduced. Total consumption was estimated 7.5 % of the total standing crop.
The number of sheep has been raised since then, and in the 14th year 1982, this experimental grazing is intensified by adding cattle (April to November), aiming at a total consumption of 50 to 80 % of the estimated available production. This certainly will change the system drastically as may be judged from observations in a nearby zone,given below.

5.1.2. Cattle

In another zone of 300 ha cattle grazing started in the same year (1982) at density of 1 animal to the ha, aiming at a consumption of 60 % of the estimated production (June to October). The area presented an uninfluenced vegetation after 14 years of natural succession.
Within a fortnight the cattle had removed the flowering stalks in the *Phragmites*-zones and had disrupted young *Salix*-bushes. They took a preference for the lush *Agrostis* sward occurring in a wide zone within reach of inundations. The higher zone of *Aster tripolium-Poa trivialis* was quickly exploited and probably must be renamed. Species as *Triglochin maritima, Plantago maritima, Carex otrubae* a.o. were highly preferred. On the other hand the flat growing species and low vegetation of *Puccinellia maritima* remain relatively ungrazed. Trampling caused a visible damage and a loss of nests.

These preliminary observations sustain the preset aim of the management, i.e. to create a large area with short (grazed) grassland communities in order to guarantee the refuge and grazing function for waterfowl and the breeding area for meadow birds and waders.
Whether the first mentioned sheep + cattle grazing will be positive, cannot yet be stated. Here the grazing should diversify the area by diminishing the reed and *Agrostis*-dominance and is expected to increase botanical variety.
Other large zones in the central nature area comprise the practises horse and/or cattle grazing ; a 'laissez-faire' still has its reference of unaltered succession on over 600 ha.

5.2 Other management practises

It stands to reason, that in management of nature reserves the costs must be low and often grazing presents the only profitable or least costly method, especially in larger areas with low costs of fencing and care. This holds true for the Lauwerszee-polder and for most of the comparable new polders mentioned earlier. In addition the cutting of reed and rushes is practised on a small scale.

Mowing for hay is relatively expensive and has not been practised significantly, but it would probably produce species-rich meadow communities in the silty desalinated inundation zone.
In some areas the ground watertable is kept on a high level in order to continue conditions a.o. for dune-slack type communities or elsewhere saltmarsh vegetation (seepage area behind the primary dam).
In future other more expensive management activities might include cutting of brush (*Hippophae rhamnoides*) burning, or the creation of slacks and isolated ponds on the most extended sandflats.

6 Future

The new polder habitats show many unusual features of nature at work in a wide landscape, but increasingly influenced by man.
Regarding the nutrient-poor soils, the characteristic water regime and the most probable nature (exploitation) management, the evolving grasslands may well provide a refuge for many threatened plant and animal species. On the one hand, as the internationally recognized wetland, for the huge bird numbers , on the other hand as a new basis for the prolonged existence of the threatened plant and animal life from the low-productive and species-rich grasslands in nature reserves of the nearby mainland and of the Wadden islands.
The study of the development of the new natural communities adjusted by management holds a challenge for many years to come.

Note

Apart from the use as a grazing area by waterfowl (barnacle- and grey lag geese, widgeon and teal; mute swan and Bewick's swan harvesting Potamogeton root nodules), the value as a breeding ground for various meadow birds and waders is well documented in reports. The quiet, wide landscape provides hunting grounds for a number of birds of prey nesting in the polder (kestrel, marsh-, hen- and montagu's harrier, short-eared owl) and many temporary visitors are reported, including osprey, peregrine falcon. The permanent presence of 10 to 20 flamingo's and the breeding success of the spoonbill refer to ecological conditions which have become rare in Nortwestern Europe.

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