SOME PRACTICAL ASPECTS OF THE NEW POLICY ON WATER MANAGEMENT IN THE NETHERLANDS POLDERS[1]

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ABSTRACT

After two river floods in respectively 1993 and 1995 and several local heavy rainfalls in the past decade in The Netherlands there is reconsideration concerning effective strategies and approaches on flood protection and water management. The general feeling is that we have to try to live more with the water than to fight against it. As far as flood protection is concerned a policy has been developed to give more room for the rivers.

As far as water management is concerned a basic distinction can be made between the low part and the relatively high part of The Netherlands. In the low part the polder systems dominate, where the water levels are basically controlled with drainage systems and where the surplus rainwater is pumped out into surrounding watercourses and lakes. Here the focus is on an increase in storage capacity for surplus water during wet periods, instead of on the increase the capacities of the pumping stations. In the relatively high part an improved water management is envisaged where due attention is being given to the water management requirements of the various types of land use.

This paper deals with water management in the polder areas. Some aspects of the application of the new policy in practice will be illustrated. With respect to this a distinction has been made into rural and urban areas. Special attention has been given to the impact of the increase of urban areas in polders and the effects of vertical differences between urban and rural areas.

1 INTRODUCTION

After two river floods in respectively 1993 and 1995 and several local heavy rainfalls in the past decade in The Netherlands there is a reconsideration concerning effective strategies and approaches on flood protection and water management. The general feeling is that we have to try to live more with the water than to fight against it. As far as flood protection is concerned a policy has been developed to give more room for the rivers.

As far as water management is concerned a basic distinction can be made between the low part and the relatively high part of The Netherlands. In the low part the polder systems dominate, where the water levels are basically controlled with drainage systems and where the surplus rainwater is pumped out into surrounding watercourses and lakes. Here the focus is on an increase in storage capacity for surplus water during wet periods, instead of on the increase the capacities of the pumping stations. In the relatively high part an improved water management is envisaged where due attention is being given to the water management requirements of the various types of land use.

This paper deals with water management in the polder areas. Some aspects of the application of the new policy in practice will be illustrated. With respect to this a distinction will be made into rural and urban areas. Special attention will be given to the impact of the increase of urban areas in polders and the effects of vertical differences between urban and rural areas.

2 PHYSICAL CONDITIONS OF THE NETHERLANDS

2.1 Scope

The Netherlands is a low lying, densely populated country bordering the North Sea. The major part of the country consists of lagoon and delta type areas, originating from the deltas of the Rhine, Meuse and Scheldt rivers. The Dutch have made this area inhabitable by reclamation and protection against the water. But for this creation of their country the Dutch had to fight for centuries against water coming from the North Sea, the rivers, rainfall, or from waves on the lakes during storm surges. The present land area comprises 3.4 million ha. As a result of land reclamation and subsidence about one third is situated below mean sea level, whereas about 60% of the land is protected against flooding.

The history of water management shows how the original natural landscape was transformed into a man-made landscape in a never-ending struggle with the water. At present the low part of the Netherlands in particular, virtually constitutes one hydraulic work, mainly created by man: a patchwork of lands gained on the sea, polders and drained lakes, crossed by innumerable ditches and canals. The fight against water that resulted in the present situation of The Netherlands started in the ninth century on a minor scale involving a small number of inhabitants with modest demands. People were faced with technical problems that required solutions. However, the provisions that had been made entailed new problems all the time. In the ninth century people started to move into the huge peat areas, which were situated a few metres above mean sea level, in many places. They lowered the groundwater table of these lands by digging a system of ditches or watercourses to the lower situated adjacent waters. This cultivation process was rounded off in the fourteenth century. The expansion of these, at first massive, interventions in the hydrological situation repeatedly stagnated in the course of the twelfth and thirteenth centuries as a result of a series of severe storm surges, swallowing up large parts of the cultivated land. In this period local communities that were located in the first danger zone started to connect their local dikes. This was the start of collective dike construction. This second radical intervention in the natural hydrological system caused a chain reaction that is still going on (De Bruin and Schultz, 2002).

The cultivation of the peat lands caused a considerable drop of the surface due to subsidence and oxidation. The subsidence of the deeper situated layers, due to natural causes, continued as well. These processes resulted in a drop of the ground level, amounting to two to three metres in the course of the centuries. This made it necessary to impolder the old cultivated grounds, initially by means of small sluices that could be opened at low outside water. In the course of the fifteenth century windmills were to bring help. During the nineteenth century these windmills, in their turn, were to be replaced by steam-driven pumping engines and in the twentieth century by electric and diesel pumping engines. Thus, one simple intervention in the natural condition of the delta has had far-reaching consequences.

2.2 Meteorological aspects

The Netherlands has a temperate maritime climate with a rather even distribution of rainfall over the year. The mean annual rainfall is about 785 mm. The mean annual reference evapo-transpiration is about 550 mm. Owing to the relatively even distribution of precipitation over the year, the intense evapo-transpiration during summer and low evapo-transpiration during winter, The Netherlands has under average conditions a rainfall deficit during summer amounting to 60 mm and a rainfall surplus of 300 mm during winter (Figure 1).

If we look closer to the development of annual rainfall over the years, then the longest time series that is available is the series of station Hoofddorp. Sound daily data are available for the period from 1867 to present. The annual figures are given in Figure 2.

If we screen the data series for consistency based on Spearman’s rank correlation method, then we find that during the periods 1867 - 1934 and 1960 - 2001 no trend can be observed (Table 1). In this table T is the calculated value according to Spearman’s formulae, T tab 0.025,(n-2) is the value for the Student T distribution at the two sided significance level of 2.5%. Based on these results the data from 1960 - 2001 have been used in the simulations.

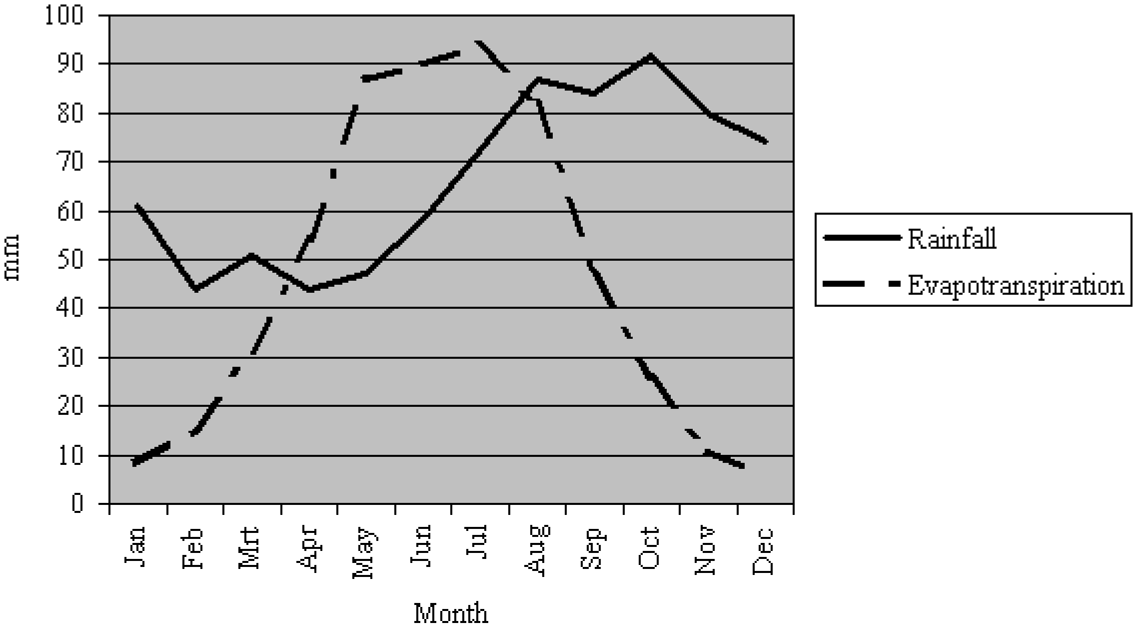

Figure 1 Average monthly rainfall and reference crop evapotranspiration

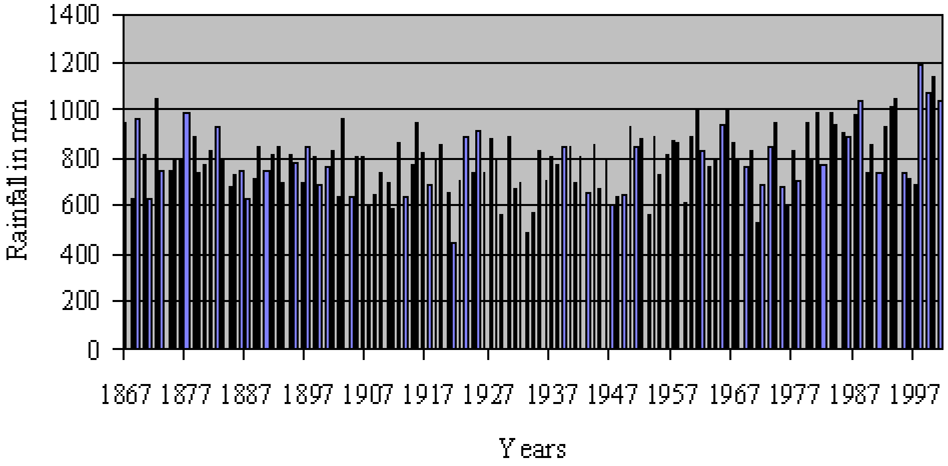

Figure 2 Annual rainfall data for station Hoofddorp, The Netherlands, period 1867 - 2001

Table 1 Test for trend at 95% confidence level

Year	Number of data	T Spearman's	T tab 0.025,(n-2)	Trend
1867 - 2001	2001	2.745	1.960	Yes
1867 - 1934	68	-2.058	2.000	no
1935 - 2001	67	3.399	2.000	yes
1956 - 2001	46	2.064	2.004	yes
1960 - 2001	42	1.880	2.021	no
1959 - 2001	43	2.333	2.020	yes

Extreme rainfalls are quite moderate. In Figure 3 the rainfall duration frequency curves based on the data of station Hoofddorp for return periods of 2, 10 and 100 year are given.

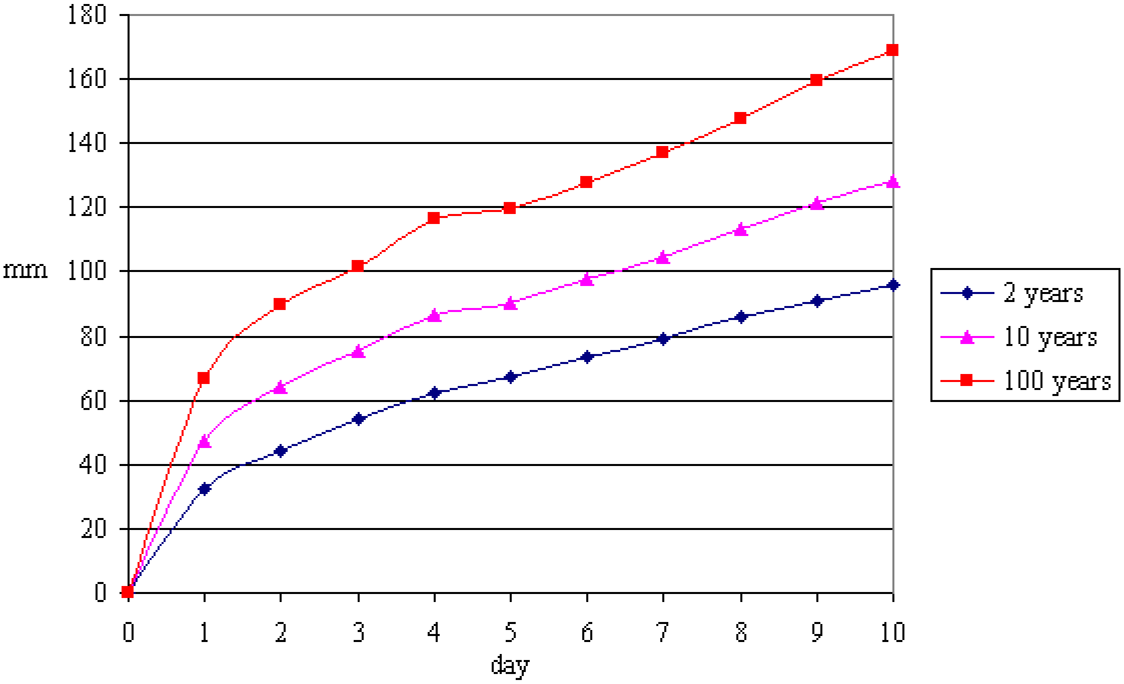

Figure 3 Rainfall duration frequency curves for station Hoofddorp (1960 – 2001)

2.3 The polder concept

A polder can be defined as a level area, in its original state subject to high water levels (permanently or seasonally, originating from either ground water or surface water), but which through impoldering is separated from its surrounding hydrological regime in such a way that a certain level of independent control of its water table can be realized (Segeren, 1983). The polders have primarily facilities for flood protection (dikes) and drainage. The drainage system caters for removing surplus rainwater and seepage water, and consists of a field drainage system to control the groundwater table, a main drainage system or hydraulic transport system to transport the water from the field drains to the outlet, and an outlet structure to evacuate the water from the area (Figure 4) (Schultz, 1982).

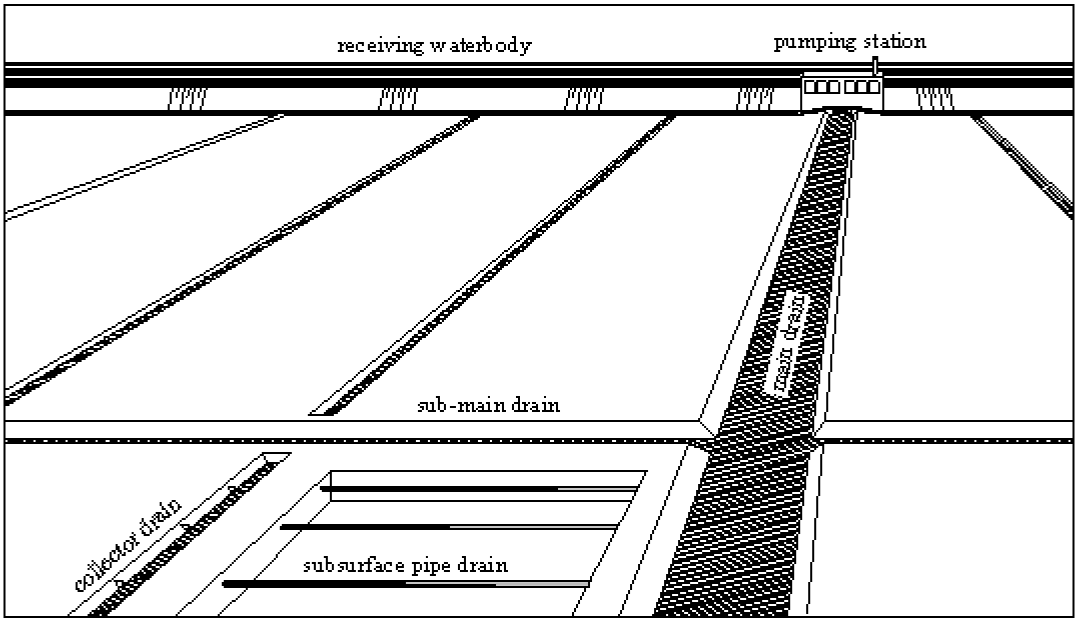

Figure 4 Schematic presentation of a drainage system in a Dutch polder (Schultz, 1982)

Three principle field drainage systems may be distinguished in the polders:

- *subsurface drain pipes*, which are generally applied in the clay soils;
- *open field drains*, which are generally applied in peat soils;
- *collector drains*, which are locally applied in sandy clay soils.

In the main drainage systems collector drains and main drains can be distinguished. Collector drains receive the drain water from field drains and transport it to the main drains, which on their turn transport the surplus water to the outlet. Several flow control structures, like weirs and culverts, may be installed in the main drainage system.

The outlet of the drainage systems in the polders may be a discharge sluice or a pumping station. The water level at the outlet constitutes the drainage base for the area concerned. This level, relative to the surface level, governs the amount of hydraulic head available for the drainage flow, as it determines to which extent the water levels may be lowered below the surface. It also determines whether the area can be drained by gravity or requires pumping. At present by far the majority of the polders require drainage by pumping. Therefore only drainage by pumping will be analysed in this paper.

The drainage systems have to convey and store the drainage water from the fields in such a way that the water levels in the polders remain at acceptable levels. The design criteria for drainage systems have generally been developed as follows:

- *preferred normal conditions*. These are the conditions one would like to maintain in the polder area. They result in a preferred water level, or water levels and operation rules for the pumping stations. The criteria are strongly linked to the soil type, or other land uses like urban, industrial, recreation and nature conservation;
- *design conditions*. These are the conditions on which the design of the drains and pumping stations is based. In general they are formulated as:
    - exceedance of the preferred water levels;
    - duration of the exceedance;
    - return period for which the prescribed exceedance occurs;
- *extreme conditions*. Although this is generally not a design criterion, control computations can be made for extreme situations.

In these situations bankfull storage is generally accepted. When the results are unacceptable, the design criteria may be modified.

The above principles and considerations have resulted in the characteristic dimensions of different types of polders as shown in Table 2 (Luijendijk and Schultz, 1982).

Table 2 Characteristic dimensions of different types of polders (Luijendijk and Schultz, 1982)

Type of polder	Percentage of open water	Polder water level in m-surface	Pumping capacity in mm/day
Peat polder	5 - 10	0,20 - 0,50	8 - 12
Old clay polder			
meadows	3 - 10	0,40 - 0,70	8 - 12
arable land	5 - 10	0,80 - 1,00	8 - 12
IJsselmeerpolders	1 - 2	1,40 - 1,50	11 - 14
Urban polder	3 - 8	1,50 - 1,80	15 - 30
Greenhouse polder	3 - 10	0,80 - 1,00	20 - 30

Most of the polders in The Netherlands were originally reclaimed for agricultural purposes. Since the last decades more and more other forms of land use are developed in the existing polders, like: industry, urban areas, recreation, and nature conservation. This implied that the original designs had to be reviewed and adjusted.

3 WATER MANAGEMENT POLICY IN THE NETHERLANDS

In 1968 the 1st Policy Document on Water Management was published. It concentrated mainly on the item: 'water managers should cover the enormous water need of the future for agriculture, for flushing of salt, for drinking water and for other purposes'. The water situation in The Netherlands, with problems of salinization and pollution on one hand and an increasing demand for drinking, irrigation, cooling and processing water on the other, made it necessary to pay special attention to the main water infrastructure. An intensive study named 'Policy Analysis of Water Management in The Netherlands (PAWN)' was made by the Ministry of Transport, Public Works and Water Management and the Rand Corporation (Blumental, 1982). The primary objectives of this study were to:

- develop a methodology for assessing the multiple consequences of water management policies;
- develop various water management policies and compare their consequences;
- create a capability in The Netherlands for further analyses.

The 2nd National Policy Document on Water Management (1984) was supported by the policy analysis as developed by PAWN. This document was based on the cost-benefit relation of the water development and on the multiple use of water. The document elaborated on the need for water, whereas it also emphasised the relation between the uses of surface and ground water.

The 3rd National Policy Document on Water Management (1989) was based on 'integrated water management', and related ground water with surface water and water quantity with water quality. Water systems were identified, and the document specified that 'the water systems had to be managed and developed so that they satisfy their ecological objectives and functions'. The 4th National Policy Document on Water Management (1999) took the different water systems as the basis for decision making. It therefore went one step further than the 3rd Policy Document. Since then The Netherlands focused on integrated water management. During the last decades the whole legal and organizational structure has been reorganized and modernized, anticipating on this approach.

After two river floods in respectively 1993 and 1995 and several local heavy rainfalls in the past decade there developed, however, a reconsideration concerning effective strategies and approaches on flood protection and water management. Since then for the water management systems in the polder areas the focus is on an increase in storage capacity for surplus water during wet periods, instead of on the increase the capacities of the pumping stations. In addition more safety was considered to be required to prevent to a large extent that valuable elements likes buildings, infrastructure and greenhouses in polder areas would be inundated. These problems are to a large extent caused by the rapid expansion of urban areas, infrastructure and greenhouses in polder areas, especially in the densely populated western part of The Netherlands. With this expansion the specific conditions of water management in polder areas has not always been adequately taken into account.

4 ANALYSES OF THE WATER MANAGEMENT CONDITIONS IN POLDER AREAS

In addition to the temporary storage of surplus rainwater in the unsaturated groundwater zone, which may be quite significant

(Saiful Alam and Schultz, 1987), temporary storage occurs especially in the collector and main drains. The question is to what extent the present systems are already working at their capacity, or if there is still room in these systems. In order to get an impression of the present conditions and to analyse the effects of urbanisation and vertical differences between urban and rural areas on the water management in polder areas the following items were analysed:

- actual pumping data of the Northeast polder;
- fluctuations in the open water level in a theoretical polder under different percentages of urban area and different vertical levels of the urban and the rural area.

4.1 Analyses of the actual pumping data of the Northeast polder

The Northeast polder is one of the IJsselmeerpolders in the former Zuiderzee (Schultz and Verhoeven, 1987). The polder fell dry in 1945. It is provided with three drainage pumping stations. The installed capacity of the pumping stations enables to remove a water layer of 14 - 15 mm/day counted over the total area of the polder, which is 480 km^2. Daily data of the discharge by the pumping stations are available for the period 1945 - 2001. In figure 5 the frequency distribution of the pumped amounts of water during the said period is shown.

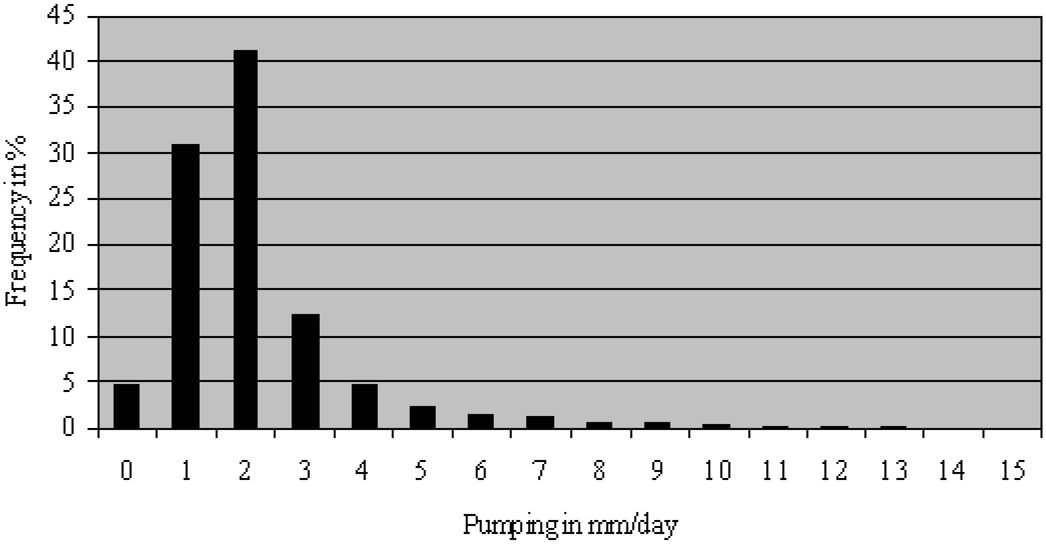

Figure 5 Frequency distribution of the pumped amounts of water from the Northeast polder

From Figure 5 some characteristics can be derived. It is shown that 89% of the time 3 mm/day or less have been pumped out, which is less than one fifth of the installed capacity. 98% of the time 7 mm/day or less have been pumped out which is about 50% of the installed pumping capacity. With respect to these figures it has to be realised that the seepage in the Northeast polder is almost 1 mm/day (Schultz and Verhoeven, 1987) and that the additional water is due to surplus rainfall.

Only two days in the total period the installed capacity of 15 mm/day has been used and 14 days a capacity of 14 mm/day. Although water levels are only available for part of the period, these data show that exceedances of more than 0.30 m above the preferred water level of 5.70 m-MSL almost never have occurred (Van de Ven, 1996). While the preferred water level in this polder, with predominantly clay soil, is at least 1.2 m-surface, an exceedance of the preferred polder water level with 0.30 m under extreme conditions will not do any harm. Only in very exceptional periods some local inundations have occurred, which were generally not caused by insufficient pumping capacity, but by insufficient infiltration capacity of the soil, or discharge capacity by the local drainage system.

Although the Northeast polder is not representative for all the polder systems, the results show that there may be quite some room in the drainage systems of the polders under extreme conditions. It is therefore of importance that representative water management systems are carefully analysed on their performance before generally costly measures to increase the storage capacity in a polder area are being taken.

4.2 Analyses of fluctuations in polder water levels

In polder areas the value of property per unit area is much higher in the urban areas compared to the rural areas. For the polder Flevoland, which is one of the IJsselmeerpolders, it was found in 1990 for example that the total value of public and private property was about € 3 million per ha, while the total value in the rural area was only about € 15,000 per ha (Schultz, 1992). Since then the difference became even more pronounced. In order to keep the damage due to excessive rainfall under extreme conditions as low as possible it is therefore advisable to situate the urban areas at a certain level above the surrounding rural area.

In order to analyse the effects of urbanisation in a polder area some theoretical examples have been analysed for respectively a clay polder and a peat polder. The polder areas are considered to be completely flat. The analyses have been made with the relatively simple model POLDER, which is basically a water balance model. In this model the hydraulic gradients in the watercourses are neglected, which in polder areas - due to the relatively low flow velocities - generally doesn't result in significant differences with the results of hydrodynamic models. For both the clay polder and the peat polder the chances for inundation of the respective surfaces have been investigated in number of days during the total period, as well as in percentages. It has to be realised that these percentages refer to the days of occurrence and not to the years in which such events have occurred. The following data have been used in the analyses:

- *both the clay and the peat polder:*
    - polder area 50 km^2;
    - daily rainfall series of station Hoofddorp 1960 - 2001;
    - percentages of urban area in the polder of 5, 10 and 50%;
    - vertical surface level distribution in the urban area: streets 0, footpath and squares +0.10 m, ground floor in houses +0.20 m, green areas +0.15 m and preferred water level in the urban canals –1.00 m (reference level) (Figure 6);
    - horizontal surface distribution: streets 10%, footpath and squares 10%, houses and buildings 40%, green areas 37%, urban canals 3%;
    - vertical differences between the preferred water level in the urban canals and the water level in the surrounding rural area of 0, 0.25 and 0.50 m;
    - in the rural area the computation of the runoff is based on the daily soil water balance. For the urban area a runoff coefficient of 80% is used for the paved area and for the green areas a similar computation as for the rural area;
    - it is supposed that the urban area discharges its surplus water over a weir into the watercourses in the rural area. The theoretical length of the weir is determined in such a way that under free overflow the water level rise in the urban canals is not more than 0.40 m at a return period of ten years (Figure 3). The surplus water from the total polder area is removed with a pumping station from the water courses in the rural area;
- *clay polder:*
    - open water 5%;
    - polder water level 0.90 m-surface, road level 0.1 m-surface, ground floor level of farm houses 0.10 m+surface
- pumping capacity 11 mm/day;
- *peat polder:*
    - open water 7%;
    - polder water level 0.40 m-surface, road level 0.1 m-surface, farm level 0.10 m+surface
    - pumping capacity 11 mm/day.

In Table 3 the results of the simulations for the clay polder are given and in Table 4 the results of the simulations for the peat polder.

Table 3 Results of the simulations for the clay polder

Item																		
Width of the urban weir in m	36						66						316					
Percentage of urban area	5						10						50					
Difference in level in m	0		0,25		0,5		0		0,25		0,5		0		0,25		0,5	
Days/frequency	n	%	n	%	n	%	n	%	n	%	N	%	n	%	n	%	n	%

Streets	7	0.05	2	0.01	2	0.01	8	0.05	3	0.02	3	0.02	36	0.23	23	0.15	17	0.11
Footpath and squares	3	0.02	0	0.00	0	0.00	5	0.03	2	0.01	1	0.01	25	0.16	18	0.12	15	0.10
Houses and buildings	1	0.01	0	0.00	0	0.00	2	0.01	2	0.01	0	0.00	24	0.16	17	0.11	12	0.08
Green areas	1	0.01	0	0.00	0	0.00	2	0.01	2	0.01	0	0.00	20	0.13	15	0.10	10	0.07
Rural area																		
Road	6	0.04	6	0.04	6	0.04	9	0.06	8	0.05	8	0.05	57	0.37	70	0.46	89	0.58
Agricultural area	4	0.03	4	0.03	4	0.03	4	0.03	4	0.03	4	0.03	44	0.29	50	0.33	61	0.40
Farm house	1	0.01	1	0.01	1	0.01	3	0.02	3	0.02	3	0.02	25	0.16	35	0.23	36	0.23

Total number of days of simulation from 1960 to 2001 = 15341 days
n = number of days of inundation
% = frequency in %

Table 4 Results of the simulations for the peat polder

Item																		
Width of the urban weir in m	36						66						316					
Percentage of urban area	5						10						50					
Difference in level in m	0		0,25		0,5		0		0,25		0,5		0		0,25		0,5	
Days/frequency	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Streets	4	0.03	2	0.01	2	0.01	6	0.04	3	0.02	3	0.02	21	0.14	15	0.10	7	0.05
Footpath and squares	3	0.02	0	0.00	0	0.00	4	0.03	1	0.01	1	0.01	17	0.11	8	0.05	4	0.03
Houses and buildings	1	0.01	0	0.00	0	0.00	3	0.02	0	0.00	0	0.00	14	0.09	6	0.04	3	0.02
Green areas	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	9	0.06	4	0.03	2	0.01
Rural area																		
Road	25	0.16	24	0.16	24	0.16	30	0.20	28	0.18	29	0.19	217	1.41	241	1.57	247	1.61
Agricultural area	14	0.09	14	0.09	14	0.09	20	0.13	18	0.12	18	0.12	150	0.98	173	1.13	179	1.17
Farm house	4	0.03	4	0.03	4	0.03	7	0.05	7	0.05	7	0.05	63	0.41	77	0.50	86	0.56

Total number of days of simulation from 1960 to 2001 =15341 days
n = number of days of inundation
% = frequency in %

Urban area ***Rural area***

street level surface level rural area

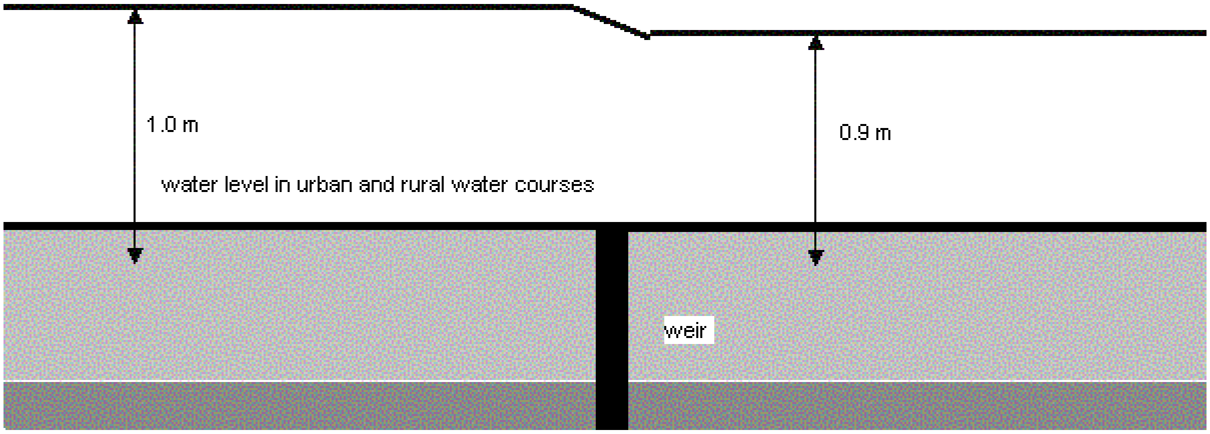

Figure 6 Relative levels in the rural and urban area in the reference case for the clay polder where the water levels in the water courses in the rural and the urban area are supposed to be the same

It has to be stressed that the results of this analyses are indicative, while the simulations have been done in a quite simplified manner and possible soil storage during extremely wet periods has been neglected. For the urban area possible insufficient discharge capacity of the sewers has been neglected. However, the trends in the results are clear.

For the clay polder the results show that, under the conditions as specified above, when the preferred water level in the urban area is 0.25 m above the preferred water level in the rural area, which implies that the street level in the urban area is 0.35 m above the surface level in the rural area, in fact no inundations have to be expected in the urban area, when the percentage of urban area in the polder is up to 10%. In these conditions occasionally an inundation of the rural area could be expected, but only in exceptional cases an inundation of the ground floor of the farmhouses. When this ground floor would be situated a little higher, say 0.10, or 0.20 m no inundation would have to be expected.

For the peat polder more frequent inundations in the rural area may be expected with little difference in the urban area, as long as this area doesn't take more than 10% of the total area. This increase in possible inundations in the rural area is primarily caused by the relatively high polder water level, which is required to prevent a too rapid subsidence of the peat soil.

5 CONCLUDING REMARKS

In this paper some practical aspects of the new policy on water management in the Netherlands polders have been analysed. A distinction has been made into rural and urban areas. Special attention has been given to the impact of the increase of urban areas in polders and the effects of vertical differences between urban and rural areas.

Although the simulations as used in the preparation of this paper are of a general nature the results show that there is in general still quite some room in the existing water management systems. In addition it is shown that it is advisable to locate urban areas higher than the surrounding rural areas. As a consequence of such an approach possible inundations will primarily occur in the lower parts of the polder area where the value of property is relatively low. When proper vertical differences between land use components are being realised within the polder area damage due to extreme wet conditions can be kept relatively low. It will be clear that such measures cannot be taken overnight, but they could be a basis for new developments in polder areas.

6 ACKNOWLEDGEMENT

The authors like to thank the Water-board Zuiderzeeland, the Government Record Office in the Province of Flevoland and the Royal Meteorological Service (KNMI) for the submission of the data that have been used in this paper.

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[1] Paper No 114. Presented at the 9th International Drainage Workshop, September 10 – 13, 2003, Utrecht, The Netherlands.

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