WATER MANAGEMENT MEASURES ANALYSED FOR DUTCH BASINS TO REDUCE FLOODING

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Introduction

Worldwide there has been an increase in the number of floods and droughts that effect large number of people and cause enormous economic losses. In the period 1990 to 1998 the number of recorded flood disasters in Europe was higher than in the previous three and a half decades. Because of this situation it is clear that measures have to be taken to reduce the impact of these extreme hydrological events. During recent extreme rainfall events in the northern part of The Netherlands the rapid flow from the upper parts of the basin caused flooding of some polders and resulted in a serious threat of flooding of densely populated areas. After a Dutch national study "Water Management in the 21st Century" a policy was adopted to retain more water in the upper part of river basins in order to avoid flooding in the downstream parts. In this study the SIMGRO model was used. This model simulates the flow of water in the saturated zone, the unsaturated zone and the surface water. The model is physically-based and therefore suitable for use in situations with changing hydrological conditions.

In order to give solutions for an integrated river basin management plan for the northern part of the Netherlands, one of the problems to solve is how to reduce the peak discharge. The question is how to retain more water in a river basin. To analyse such situations and possible mitigation measures, tools were used to evaluate them in terms of eco-hydrological impact and the effect on agriculture. In this paper a report is made on a project carried out to assess the possible retention of water in the upper and lower part of two adjacent river basins. First a very brief description of the SIMGRO model is given, followed by the schematisation of the study area, the scenarios and the results.

SIMGRO model

SIMGRO is a distributed physically-based model that simulates regional transient saturated groundwater flow, unsaturated flow, actual evapotranspiration, sprinkler irrigation, stream flow, groundwater and surface water levels as a response to rainfall, reference evapotranspiration, and groundwater abstraction. The model is used within the GIS environment Arc-View. It gives the possibility of using digital data, such as a soil map, land use, watercourses, etc., to serve as input data for the model and to show results. It is also a tool for analysis and discussion, because interactively data and results can be presented.

Study area and model schematisation

The modelling area covers 1200 km^2 and is located in the northern part of the Netherlands (Figure 1). The area of main interest is approximately 750 km^2 and covers the basins of the river Drentsche Aa and Peizerdiep. The ground surface slopes from about 24 m+MSL in the south to about –1 m in the north. The area consists of sandy soils in the upper parts with clay and peat in the stream valleys and the lower part. Land use is predominantly

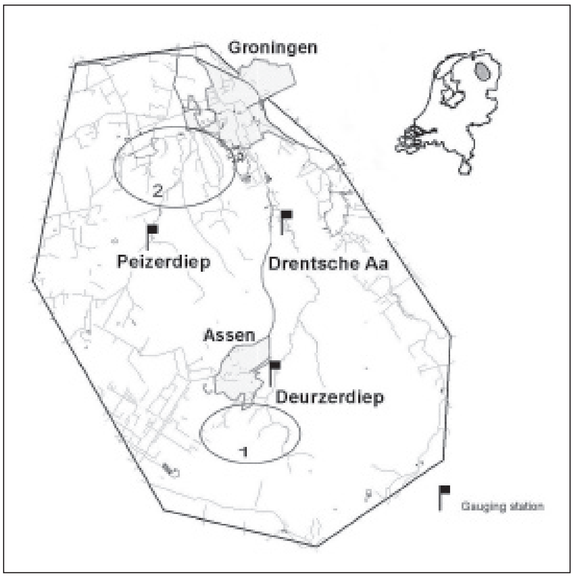

Figure. 1. Location of the modelling area and the water courses in the northern part of The Netherlands. In region 1 measures are taken in the upper part of the basin and in region 2 in the lower part

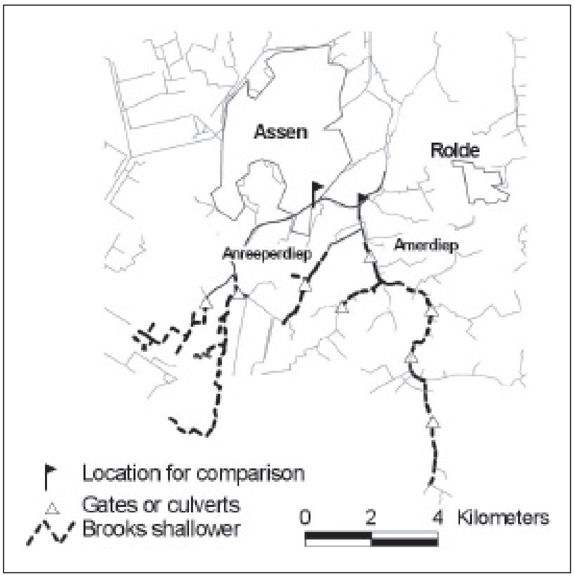

Figure 2. Location of the mitigation measures carried out in the water courses of the upstream part in the Drentsche Aa. See Fig. 1 for the location in the pilot area

agricultural and forest. For the SIMGRO model the groundwater system needs to be schematized by means of a finite element network. The network, comprising 49 050 nodes, is spaced at about 200 m in the interest area, but in the stream valleys it is spaced at 75 m. For the modelling of the surface water the basin is subdivided in 5625 sub-basins. The geology of the area is quite complex, due to influences from the Pleistocene period, permafrost, tectonic movements, and influences from wind and water. A major influence on the groundwater flow patterns are the resistant layers formed by boulder clay that cause large areas with perched water tables. The initial SIMGRO model was not able to simulate the perched water tables caused by the boulder clay (model layer 2). In large areas this resulted in phreatic groundwater levels that were 1–3 m too low. Therefore the model was improved that, on the basis of the hydraulic head below and above the boulder clay, the vertical resistance is adjusted to simulate the flux through this clay layer correctly. Also the storage coefficient above and below the clay layer needs to be changed during the calculations depending on the presence of the perched water table. After the model was improved, calculated phreatic levels were close to the measured ones (see next section).

Simulations were carried out for a period of 10 years (1989–1999). The results were compared with measured river discharges (nine locations) and groundwater levels (about 800 piezometers). Details are given in Querner *et al.* (2005). The differences between measured and calculated results were regarded as small, so it was concluded that the final model can be used to analyse possible measures to hold water in the upstream part of the basin.

Mitigation measures and the impact

Mitigation measures were defined that would reduce the peak discharges to acceptable volumes. In this research the following measures were analysed:

1. restrict peak discharges; peak flows can be restricted by installing sluice gates or culverts of such a dimension that only the higher peaks are reduced. In the simulations, the opening of these constructions was such that the flow will be restricted when the flow is higher than occurring once a year.
2. make the brooks shallower; reducing the depth of the water course will result in water overtopping the side banks and it will be stored on the flood plain. The storage of the water on the over banks will reduce the flow propagation and thus reducing the peak flow.
3. flood storage; in a designated area in the lower part of the Peizerdiep under high water conditions flood water is stored.

Table. Change in discharges ($m^3 \cdot s^{-1}$) for two sub-basins and the two scenarios as shown in Figure 2

Location	Scenario	Discharge for a given recurrence interval				
		10 year	5 year	1 year	5x/year	15x/year
Amerdiep	Reference	13.18	9.62	5.42	3.08	2.23
	Gates	5.32	4.98	4.60	3.14	2.25
	Reduction (%)	60	49	15	–2	-1
	Shallower streams	10.08	9.06	4.99	3.07	2.25
	Reduction (%)	24	7	8	0	-1
Anreeperdiep	Reference	9.12	5.81	3.38	1.94	1.47
	Gates	6.97	3.74	3.02	1.97	1.48
	Reduction (%)	24	36	8	–2	0
	Shallower streams	8.47	5.53	3.44	1.93	1.43
	Reduction (%)	7	4	2	1	1

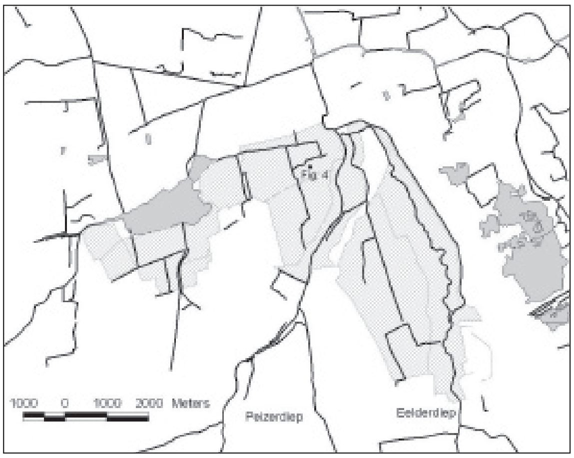

Figure 3. Location of the flood storage area in the lower part of the Peizerdiep basin. See fig. 1 for the location in the pilot area

In figure 2 the measures in the upstream part of the Drentse Aa are shown. At eight locations the flow was restricted and over a length of 29 km the streams were made shallower. In Table 1 the results are given for the two sub basins; it gives the discharge for the reference situation, the two measures and the change in flow. The impact of the first measure (restrict peaks) is more than the second (shallower streams). Limiting the flow by introducing gates or culverts, means a decrease in peak flow in the order of 25–50%. The large variation depends on local conditions and the number of structures in a stream. Limiting the flow has very little influence on groundwater levels, because the water flow is obstructed only for a number of days or weeks. Local flooding may occur and thus groundwater levels rise. This small and short rise, often in winter time, has no apparent effect on agriculture or nature. In the second scenario, when the stream is made shallower, the reduction of peak discharges is in the order of 5–20% (table). The consequence of this measure is higher water levels in both wet and dry periods. The flow reduction is mainly caused by the water overflowing the river banks and flooding the valley. As a consequence, the groundwater levels adjacent to the stream will be higher. In general the higher levels may have a positive influence on the presence of rare and protected marsh species.

In scenario 3 flood water storage is considered in the downstream part of the Peizerdiep basin (Figure 3), where an area is designated for flood water storage (Royal Haskoning, 2006). This area used to be agricultural, but over the last fifty years it was partly changed to a nature area, because of the too wet conditions encountered. The region consists of peat land and subsidence of the soil surface has resulted in a situation that excess water from the area had to be pumped into the river, thus it became a polder. The anticipated flood storage area is around 22.1 km^2. In this scenario it has been considered that the water flow in the brooks Peizerdiep and Eelderdiep is flowing thru the flood storage area (Figure 3). The dikes along both sides of the rivers, separating it from the polders, will be removed. During flooding of this area, water retention will take place and results in lower surface water levels. Before and after the flooding there will be in the polder a strong interaction of the surface water with the groundwater. Such complicated situation made it clear that a model was needed to simulate the effects of measures which integrates groundwater and surface water.

In figure. 4 the groundwater table is shown for a location in the anticipated flood storage area. In the present situation the target water level for the polder is -1.30 m above MSL, but the groundwater table is in summer (dry period) even lower. In winter time the groundwater table is close to ground level, being -0.9 m+MSL. In the flood storage scenario the groundwater table remains very close to the ground level, and during wet periods the area is inundated and surface water level and groundwater table are above ground level. Under these situations water is stored in the area, as occurs frequently (Figure 4). Especially during the months Oct-Nov. 1998 the inundation is around 0.45 m deep.

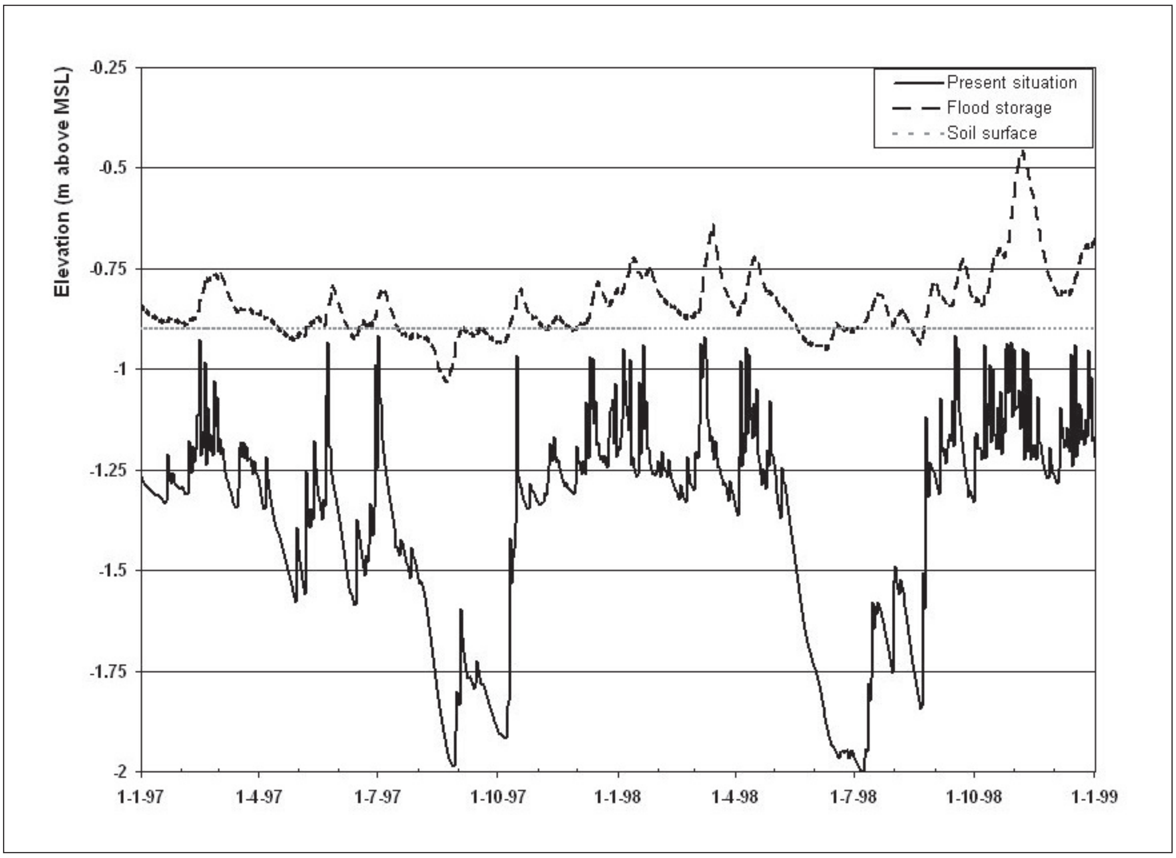

Figure 4. Groundwater table for the present situation and the flood storage scenario (figure 3. shows the location of the node)

Conclusions

This study has shown that ecosystems of lowland catchments where the groundwater levels have been lowered by extensive land drainage can be restored by restricting the flow from the upper parts. Holding water in the upstream parts of the basins is feasible. The delay of the peak flow is significant. Also the storage of water in designated areas is effective, but is an expensive measure.

For extreme situations, such as occurred in October 1998, it is also possible to use measures to reduce peak flows that have a recurrence of once in 10 or 50 years. In that way the choice is explicitly to accept local flooding in the upper parts of a catchment where mostly agricultural land is situated, instead of flooding high densely populated areas more downstream.

References

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