CONTROLLED DRAINAGE IN THE NETHERLANDS REVISITED?[1]

Dr.Ir. P.J.Th. van Bakel[2]

An overview of recent developments in surface water level manipulation and results of case studies

ABSTRACT

In the Netherlands most Waterboards generally manipulate surface water levels in order to influence phreatic groundwater levels. The main aim is to improve working conditions for agricultural crop production.

This type of water management is questioned because the hydrological effectiveness is rather low and it may lead to unwanted effects on aquatic ecosystems and on adjacent nature areas. Together with a tendency towards self-regulating systems, these unwanted effects may lead to the idea that partly or fully controlled drainage has become an anachronism.

A number of developments ask for a revitalisation of controlled drainage such as a) the problem of 'Verdroging' (unwanted effects of improved drainage, water withdrawal and water supply on nature) can partly be overcome by surface water level management directed towards structural raising the groundwater levels in the winter period in buffer zones around nature areas b) growing awareness of farmers of the importance of water table management of 'their' water courses for reducing drought damage or for reducing the amount of sprinkling irrigation and c) the governmental and waterboards policy to reduce the peak flows in order tot deal with the effects of climate change. Surface water level manipulation can have positive or negative effects on the peak flows.

The paper will elaborate these new developments and will analyse results of field studies and model calculations which specifically deal with the problem.

Keywords: Controlled drainage, Surface water level manipulation, Case studies

1 INTRODUCTION

In general in the Netherlands two types of surface water level management can be distinguished. In the free draining regions (roughly the South and the East) Waterboards generally manipulate surface water levels in order to influence phreatic groundwater levels. The main aim is (was) to improve working conditions for agricultural crop production. In the 'polder' areas the Waterboards are legally obliged to maintain a certain surface water level because of civil interest, such as damage to building foundations and the stability of dikes. The emphasis in this paper is on the design of the drainage system and operation of the surface water level with the purpose to influence drainage and occasionally make subsurface irrigation possible. In most cases it is certainly not fully controlled drainage. We will start with an overview of recent developments. Next a number of case studies and finally some conclusions will be presented.

2 RECENT DEVELOPMENTS

In general the ideal groundwater depth for agriculture is low in early spring and during the harvest period and high during the periods of high evapo-transpiration demands. The natural regime is just the opposite. Therefore most water managers have designed a surface water level manipulation system where by the surface water level in a control unit is manipulated between certain bounds means of adjustable weirs and inlet structures. To give an idea: the winter and summer level is 1.20 and 0.80 m below mean soil surface level, respectively. The transition from winter level to summer level is around 1st of April and 1st of October and vice versa. A more sophisticated type of water management is to couple the surface water level with the actual groundwater level on one or more representative locations (see also Van Bakel, 1986 and Bierkens et al., 1999).

The rational of this type of water management is questioned for several reasons:

- the hydrological effectiveness in most regions is low very because the water level in the small water courses and pipe drains are not or only partly influenced. The reason is that the height of the bottom of these watercourses or the height of the drains is above the highest surface water level. Even in areas with favourable conditions water supply efficiency (defined as the quotient of average increase in evapo-transpiration and extra water supply) is not more than 20% (Van Bakel, 1986). As a consequence the economical feasibility is questionable;

- intensification of agriculture has led to an increase in sprinkling irrigation. With sprinkling irrigation there is less need for additional water supply through controlled subsurface irrigation;
- the use of pipe drains for infiltration is hampered because farmers think that drains under water has negative effects on its functioning. In some types of soils this is confirmed by experiments (Kalisvaart, 1958; Working Group Drainage, 1997);
- the primacy of agriculture has come to an end. So the basics of surface water manipulation may have changed drastically;
- water level manipulation for agriculture may lead to unwanted effects on the ecological functioning of water courses and of adjacent nature areas;
- to maintain a high summer water level external water supply is needed. In many cases this results in a deterioration of the surface water quality;
- high summer levels have effects on the growing of the vegetation in the water courses with negative effects on the stability of the side slopes;
- in wet areas water water courses are sometimes used as a fence or as a source for drinking water for the cattle. More and more the cattle stay indoors during the summer so this function of surface water management will become less important.

On the other hand we see developments which ask for more emphasis on surface water level manipulation/controlled drainage:

- the groundwater levels in many parts of the Netherlands are structurally lowered causing the so called 'Verdroging' problem (unwanted effects of improved drainage, water withdrawal and water supply on nature). With water supply for sprinkling irrigation or subsurface infiltration the lowering of the groundwater level in agricultural regions is reduced with positive side effects for adjacent nature areas.
- regions must be self reliant with respect to water. Surface level manipulation is an effective means to conserve part of the precipitation surplus for the summer period. By raising the surface water level in spring at the right time drainage cn be reduced. Also during the summer period precipitation due to storm events can be conserved. The average amount of water conservation is about 20 mm per season;
- in some projects buffer zones around wet nature areas have been designed. The hydrological functioning depends on the groundwater level regime: the higher the better. By water supply for subsurface infiltration the groundwater level can be kept on a higher level in the summer;
- New technical developments in the construction of water level regulating structures have lead tot lower prices (and therefore feasible applications on individual farms become possible) and less labour requirements due to automation;
- Climate change will result in higher peak discharges. An important item: can these peak discharges be reduced by a different design of the surface water system and a different operation of surface water levels;
- many Waterboards in the 'polder' areas are no longer bound to one fixed, legally obliged, surface water level but change to protocols or legally fixed relations between water levels and change of exceedance;
- for the production of drinking water there is a tendency to shift from groundwater extraction to surface water extraction. A problem is the low discharges in the summer. Controlled drainage can raise the low flows.
- a problem is that a number of desired changes in surface water management have negative effects on other desired changes. E.g. raising the groundwater level may result in higher peak flows because the storage possibilities in the unsaturated zone is reduced. Only a comprehensive analysis of the hydrological system can bring up such antagonisms (see also Van Bakel et al., 2001.)

In the next section we will discuss a number of studies performed in the last 2 decades which deal with one or more of the above mentioned aspects.

3 CASE STUDIES

3.1 Introduction

In this section a number of case studies will be discussed. The experiences with new forms of controlled drainage are seldom based on practical experiments. The reason is that the effects are not so big so it is difficult to distinguish them from the strong variations in the hydrological situation due to the variation in the weather conditions from year to year. Besides most plans are still in the stage of planning. Therefore in this section I will give an overview of results with numerical experiments with physically based calibrated groundwater flow models.

3.2 De Monden

De Monden is an area of about 10.000 ha in the North of the Netherlands, mainly used for arable purposes. It is part of a reclaimed raised bog peat area. During the reclamation, canals were dug at distance of about 170 m. these canals are now used for surface water management (drainage, water conservation and subsurface irrigation). The Waterboard is manipulating the surface water level on a daily or weekly schedule based on a model study (Van Bakel, 1986). The range between summer and winter level is rather large: up to 0.70 m. The study indicates a rather low efficiency of water supply despite the favorable physical circumstances. When the low lying parts of a control unit are pipe drained, the surface water level can be raised with approx. 0.20 m while the average evapo-transpiration is higher due to less water logging damage. Also the efficiency of water supply slightly improves. So, the installation of pipe drains has positive effects on agriculture and nature. Another important conclusion of this model study is that is the introduction of a formal coupling between surface water level and groundwater depth, makes water management more objective and more transparent. Monitoring of the groundwater depth indicates that its dynamics are strongly reduced and in agreement with the model predictions.

3.3 Groote Peel

This remnant of a former raised bog peat area in the South of the Netherlands, on the border of the provinces Noord-Brabant and Limburg, with an area of 1340 has the status of a National Nature conservation area because of the high potential of becoming an important wetland.

The area is suffering from the hydrological measures in the surrounding agricultural area and an important question was the optimization of hydrological measures in a buffer zone of 2 km around the nature area. The following measures were investigated:

- installation of pipe drains;
- sprinkling irrigation;
- manipulation of surface water levels, with and without external water supply;
- water withdrawal from the groundwater system for drinking water.

The effects were calculated with the model Simgro (Querner and Van Bakel, 1989) and are described in more detail in Van Walsum (1990). Only the results with controlled drainage will be discussed here.

In the present situation 9% of the downward seepage of the nature area (which must be as small as possible) is caused by pipe drainage and sprinkling irrigation. The autonomous development will cause an increase of 9%. A stand still of drainage and sprinkling irrigation in the buffer zone reduces this unwanted effect with 80%. Extra water supply to the agricultural land, to keep the surface water level during summer on 0,70 m minus soil level, results in a decrease in downward seepage of the nature area with 15%. A more significant improvement of the hydrological conditions for peat growth is possible when the buffer zone is wetted drastically, by raising the water level to the soil level, in combination with water supply and pipe drains for subsurface irrigation.

3.4 Bargerveen

The Bargerveen is a high bog peat reserve of about 2000 ha in the North of the Netherlands on the Dutch-German border. Drainage in the surrounding agricultural land causes lowering of the water levels in the peat area and an increase of the downward seepage, comparable with the Groote Peel case. With the model Simgro a great number of scenarios to restore hydrological conditions for peat growth were evaluated (Van Walsum, 1998). Especially the results of scenarios with controlled drainage in the agricultural area will be discussed here.

Raising the surface water levels in the Dutch part of the buffer zone (approx. 1000 ha), to the surface elevation heights and without water supply has a moderate effect on the increase of the area suitable for peat growth (2.5 ha). With water supply the groundwater levels in the buffer zones can be raised up to 0.50 m in winter. As a result the area suitable for peat growth increases with approx. 10 ha.

3.5 Beerze and Reusel

The catchment area of the small rivers (rivulets) Beerze and Reusel is about 44 000 ha and is situated in the South of the Netherlands. It is a weak undulating lowland stream landscape with high potential for nature development. Because of drainage of agricultural areas and the so-called improvement of the discharge capacity of the drainage system, nature has deteriorated. The question was: do measures to restore nature effect the peak flows and can measures to lower the peak influence hydrological conditions in a positive or negative way. The results are investigated with the numerical model Simgro and described in Van Bakel et al. (2002).

The main conclusion is that it is almost impossible to restore the hydrological conditions in nature areas without unwanted effects in agricultural area land and that only a part of these effects can be compensated with smart controlled drainage. This does not hold for peak flow reduction: a reduction of 30% of peak flows with a recurrence time of 50 years is possible.

3.6 Tungelroysche Beek

The Tungelroysche Beek is one of the tributaries of the river Meuse. Its catchment area of approx. 12 000 ha is situated in the middle of the province of Limburg and for a small part in Belgium. The main aims of the study were to investigate the effectiveness of measures to reduce the peak flows and to diminish the 'Verdroging' and drought damage in agriculture. From model calculations with Modfow and Sobek it 'was concluded that rewetting the area gives higher peak flows whereas raising the weirs during the peak situation during a limited number of days reduces the peak flows considerably. Furthermore the installation of a large number of small weirs operated by farmers may result in higher peaks because most of them operate locally and not regionally (TAUW, 2000, Van Bakel et al, 2001).

3.7 Benelux-Middengebied

In the late nineties in 4 provinces in the South of the Netherlands and the north of Belgium 1888 small weirs are installed. The farmers themselves control these weirs in order to conserve water by raising the weir level in spring at the right time, depending on the actual groundwater depth. The European Union finances this project. The average raise of the surface water level in spring is about 0.40 m. The hydrological effects, calculated with a numerical groundwater flow model (see Table 1), are equivalent with about 20 $mm.yr^{-1}$ on 17.000 ha. The effect of water conservation per weir of about 1750 $m^3.yr^{-1)}$ is much more than effect on the increase in evapo-transpiration (475 $m^3.yr^{-1}$). The latter is not more than 1% of the total evapo-transpiration of the influenced area. These results indicate that water conservation for agriculture is not so effective but the effect on groundwater conservation are worthwhile. For more information, see De Louw (2001).

Table 1 Average calculated effects of water conservation

	Total	Per weir
Water conservation ($m^3.yr^{-1}$)	3.3 Million	1750
Reduction in water shortage ($m^3.yr^{-1}$)	0.9 Million	475
Influenced area (ha)	17000	9

3.8 Flexible surface water management in low peat areas

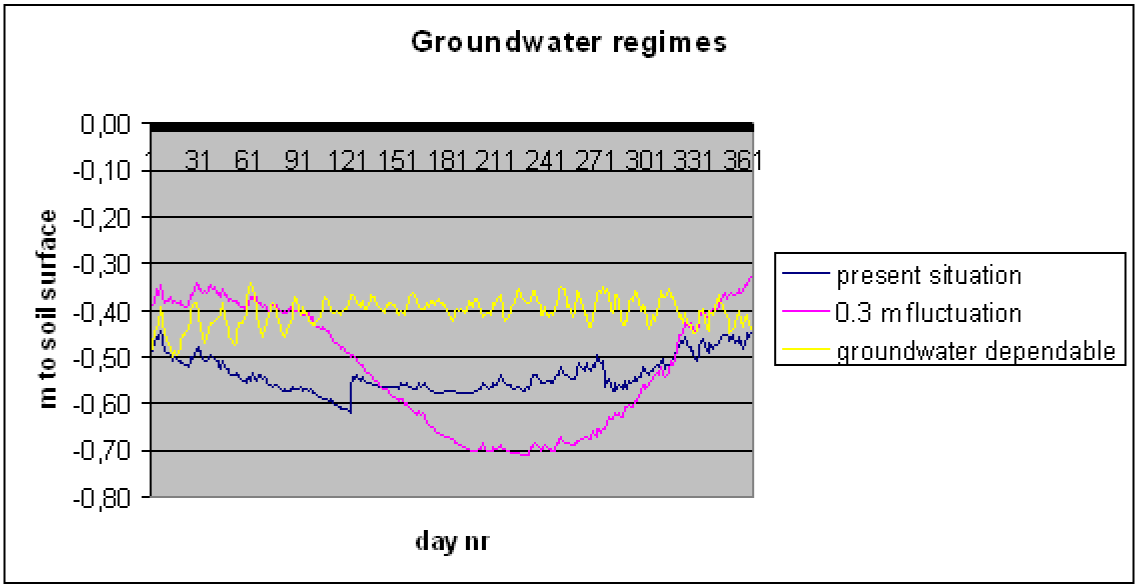
In the West and North of the Netherlands approx. 300 000 ha low peat areas are allocated. They face a mayor problem: a surface water level which makes agriculture possible (at least 0.50 m below soil surface) results in the decay of the peat soil with a number of unwanted effects associated with it, such as bad surface water quality and on the long term a complete loss of the peat soil. The Waterboard of Rijnland investigates the possibilities of flexible surface water levels in areas. Up till now the surface water levels have been kept constant (within a few centimeters).

Preliminary calculations with the computer code Multi-SWAP (in this case 2 soil columns connected with one surface water reservoir), modeling an experimental site in the neighborhood of the Nieuwkoopse Plassen, show that by allowing more variation in surface water level (0.30 m) the amount of water supply reduces to 30% compared with no variation. With an extreme form of groundwater depth dependable surface water level manipulation (surface water level 0.20 m minus soil surface in case groundwater depth is more than 0.70 m; 0.70 m when groundwater depth is less than 0.30 m) the 'normal' groundwater lowering during the summer (on the average 0.10 m) is turned into a raise of 0.05 m. This has favorable effects on the decay of peat because wet conditions in periods with high temperature decrease the decaying process. It must be emphasized that the experimental site is only representative for situations with a very intensive relation between surface water and groundwater which in most cases only can be achieved with pipe drains.

4 CONCLUSION

Partly or fully controlled drainage, in order to improve the hydrological conditions for agriculture, was common practice in areas in the Netherlands with a moderately to densely intensive surface water system. The rational of this type of surface water management is questioned and some Waterboards tend to reduce their efforts in this respect. Recently there are a number of developments with ask for a re-evaluation. On the one hand: firstly the low winter levels are a mayor cause for the unwanted lowering of the groundwater levels and reduction of upward seepage of nature in the sandy area. Secondly, the water supply in the summer periods in order to keep the high summer levels has negative effects on the ecological quality of surface water bodies. On the other hand results of calculations with integrated models indicate that controlled drainage in agricultural areas can result in conservation of part of the precipitation surplus of the winter period and in a reduction of the lowering of the groundwater level during the summer period. Both have favorable effects on agriculture and nature. In peat areas the deterioration of the peat soil can be reduced by raising the groundwater level during the summer. Results of calculations also indicate that the effectiveness is strongly improved when pipe drains are installed in the agricultural area. Although controlled drainage is against the actual preference for self-regulation, the demands on water management from society become so high that is it is almost obligatory to investigate the possibilities of controlled drainage. On basis of the results one can state that controlled drainage needs revitalization.

Figure 1 Average groundwater depth during the year for 3 types of surface water management.



5 ACKNOWLEDGEMENTS

The author is most grateful to Henk van Hardeveld of Waterboard Rijnland for the permission to use his unpublished results of model calculations.

6 REFERENCES

Bakel, P.J.T. van, 1986. Planning, design and operation of surface water systems. A case study. Thesis Agricultural University Wageningen.

Bakel, P.J.T. van, Hoogendoorn, J., Luijendijk, J., Peerboom, J., 2001. Hoogwaterreductie vanuit regionale stroomgebieden: samenhang of tegenstellingen? In: H_2O #3: 27-29.

Bakel, P.J.T. van, Walsum, P.E.V. van, Groenendijk, M., Querner, E.P., 2002, Waterberging en verdrogingsbestrijding. Een nadere analyse van de mogelijkheden en beperkingen aan de hand van modelberekeningen in 2 stroomgebieden. Rapport 640. Alterra, Wageningen.

Bierkens, M.F.P., Bakel, P.J.T. van, Wesseling, J., 1999. Comparison of two models of surface water control using a soil water model and surface elevation data. Geoderma 89: 149-175.

Kalisvaart, C, 1958. Subirrigation in the Zuiderzee Polders. ILRI-publication 2

Louw, P.G.B. de, Vermeulen P.T.M., Stuurman, R.J., Reckman, J. , 2001. Waterconservering en peilbeheer in het Benelux-middengebied. Deelrapport 3: Bepaling van de effecten van waterconservering. TNO-rapport: NITG 01-055-B.

Querner, E.P., Bakel, P.J.T. van, 1989. Description of the regional groundwater flow model Simgro. Report 7. Staring Centre, Wageningen.

TAUW, 2000. Hydrologisch onderzoek Tungelroysche Beek. Hydrologische modellering en systeemanalyse. Final rreport.

Walsum, P.E.V., 1998. *De waterhuishouding van het Bargerveen en het herinrichtingsgebied Schoonebeek. Scenario-analyse Waterbeheer*. Rapport 534.2. Staring Centre, Wageningen.

Walsum, P.E.V. van, 1990. *Waterbeheer rondom de Groote Peel. Verkenning en evaluatie van scenario's*. Rapport 106. Staring Centre, Wageningen.

Working Group Drainage, 1997. *Drainage onder water*. Final report. Begeleidingscommissie Onderzoek Waterbeheer Zeeland.

---

[1] Paper No 012. Presented at the 9th International Drainage Workshop, September 10 – 13, 2003, Utrecht, The Netherlands.

[2] Senior research scientist Hydrology, Alterra, Wageningen