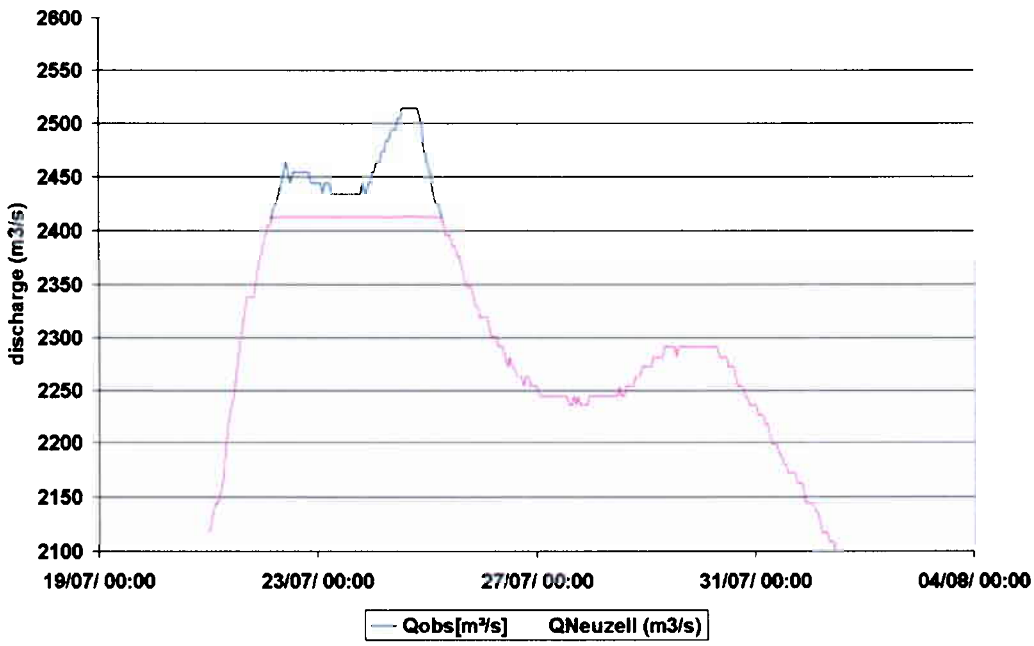
The simulation of two polders for flood protection in the German part of the Oder catchment



Ad de Roo

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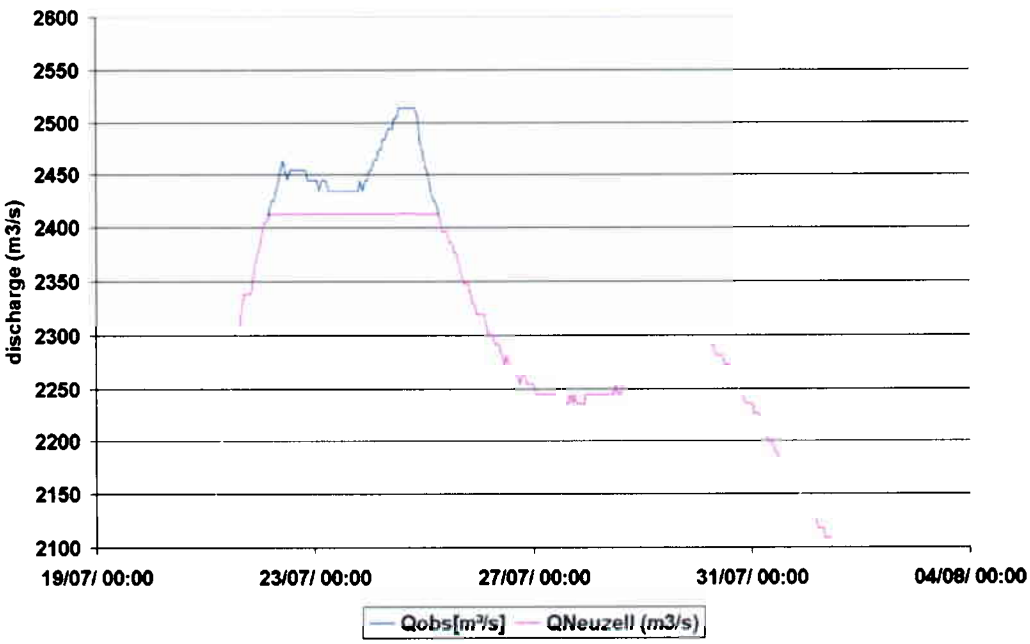

Ad de Roo
European Commission
Joint Research Centre
Institute for Environment and Sustainability
TP 261, 21020 Ispra (Va), Italy

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Contacts: Dr. A.P.J. de Roo & Dr. G. Schmuck
European Commission, Joint Research Centre
Institute for Environment and Sustainability
LM Unit
Via E. Fermi, TP261, 21020 Ispra (Va), Italy
Tel: ++39-0332-786240
Fax: ++39-0332-785500
Email: ad.de-roo@jrc.it / guido.schmuck@jrc.it

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Summary

A detailed study has been carried out to simulate the effect of two polders, Neuzell and Ziltendorf, on discharge in the Oder river during a flood situation. To achieve an optimum effectiveness of the storage capacity in the polder, the management of the polder inflow and outflow are of utmost importance. Several scenarios have been evaluated and an attempt has been made to define the optimum polder management strategy.

Introduction

Within the Oder-LISFLOOD project, several calculations have been carried out to simulate the influence of the polders Ziltendorf and Neuzell (scenario group "Brandenburg"; scenarios d-n, d-z, d-nz; De Roo & Schmuck, 2002). Within that study, the simulations have been carried out using an assumption that the polders would open if the waterlevel exceeds 750 cm in the Oder. To optimize the performance of these polders, the starting time of activating the polder should be made flexible according to the expected flood wave and the capacity of the polders.

Since the calculations of the Oder-LISFLOOD report (De Roo & Schmuck, 2002), the way in which polders are simulated has been slightly changed, allowing a more flexible and realistic simulation of polders. Therefore some additional calculations on the polders are done in this study.

Summary of the results in the Oder-LISFLOOD study of July 2002

Within the Oder-LISFLOOD project, several calculations have been carried out to simulate the influence of the polders Ziltendorf and Neuzell (scenario group "Brandenburg"; scenarios d-n, d-z, d-nz; De Roo & Schmuck, 2002). Within that study, the simulations have been carried out using an assumption that the polders would open if the waterlevel exceeds 750 cm in the Oder.

Based on this assumption, the calculated waterlevel reduction was 1 cm for Neuzell, 2 cm for Ziltendorf, and 6 cm if the polders were both used. From the simulated hydrographs (page 54, 55 and 58) it could be seen that another choice of the activation of the polder would result in a larger reduction of waterlevel.

Additional questions

A number of additional requests were made, out of which the following scenarios were selected and defined, with the 2001 scenario as the reference scenario:

	Neuzell	Ziltendorf	Polish polders	Qmax (m3/s)
N100	x			100
N200	x			200
Nopt	x			opt
Z100		x		100
Z200		x		200
Zopt		x		opt
NZ100	x	x		100
NZ200	x	x		200
NZopt	x	x		opt
2020crp	x	x	x	opt

Table 1. List of polder scenarios addressed in this study. N=Neuzell, Z=Ziltendorf, 100 and 200 are the maximum throughflows through the polder-opening (Qmax), Nzopt=scenario where both polders have an optimized inflow; 2020crp=scenario from the ODER-LISFLOOD report containing all proposed measures until 2020 (cross section changes, polders and reservoirs).

Table 2 lists the location of the opening of the polder and the maximum volume.

	Opening at km	Volume (Mm3)
Neuzell	549	45
Ziltendorf	574	38

Table 2. List of polder data.

The following questions were put forward:

- When should the polders be activated in order to get the maximum reduction of flood peak at Frankfurt?
- What is the resulting water level and discharge reduction at Frankfurt?
- How large should the polder opening be?
- Which size of opening is needed for the Neuzeller Niederung if the throughflow is max. 500 m3/s?
- Which size of opening is needed for the Neuzeller Niederung if a reduction in the water level at gauge Frankfurt e.g. by 50 cm is required, and which discharge/inflow in the polder corresponds with this size?

Working methods

Because the dyke-breaks that did occur during the 1997 flood are not taken into account in the LISFLOOD simulations, the simulated discharges are larger than the measured ones. The optimization of the polders will be different if we would take the observed (lower) discharges into account or the simulated (higher) discharges. Thus, there are two approaches to estimate the effects of the polders:

1. Estimate the optimization based on the observed discharges using simple spreadsheet calculations
2. Simulate the effects of polders with a model such as LISFLOOD

Polder optimization calculations based on observed 1997 discharges and spreadsheet calculations

Simple and straightforward spreadsheet calculations show, that a 500m3/s discharge decrease cannot be obtained by activating both the Ziltendorfer and Neuzeller Niederung. If one performs a simple calculation based on the observed 1997 discharges.

Table 3 shows an overview of the results. As a baseline condition, the observed discharge at Eisenhuettenstadt was taken.

Scenario	MaxQin_N	MaxQin_Z	MaxQ	Q_N	V_N	Q_Z	V_Z	dQ	Qstart_N	Qstart_Z
baseline	X	X	2514	X	X	X	X	X	-	
N100	100	X	2414	2414	12.0	X	X	100	2413	
N200	200	X	2314	2314	44.5	X	X	200	2313	
Z100	X	100	2414	X	X	2414	11.7	100		2414
Z200	X	200	2331	X	X	2331	37.7	183		2331
NZ100	100	100	2314	2413	12.0	2314	32.0	200	2413	2314
NZ200	200	200	**2242**	2313	44.5	2242	38.0	272	2313	2242
NZ200+	202	70	**2242**	2312	44.9	2242	37.6	272	2312	2242

Table 3. Results of polder calculations based on observed 1997 discharges with a variable polder inflow. N=Neuzell; Z=Ziltendorf; MaxQin=Maximum inflow in polder in m3/s; MaxQ= peak discharge in Oderin m3/s; Q_N/Z=Discharge in Oder after activating the polder in m3/s; V_N/Z = Volume of water in the polders in Mm3; dQ=reduction of discharge in the Oder river in m3/s; Qstart_N/Z = discharge at which polder is activated.

Table 3 shows, that if polder Ziltendorf is used alone, and the opening only allows for a discharge of 100m3/s at maximum, the polder will only be filled with 11.7 Mm3, so far below its maximum of 38 Mm3. The same is true for Neuzell, which will be filled only

with 12Mm3 if the river peak discharge is reduced with 100m3/s, which is below its maximum of 45 Mm3. A river peak discharge reduction of 100 m3/s corresponds to a waterlevel reduction of 10cm.
The polder simulations assume here a highly regulated and variable inflow, to keep the resulting remaining river discharge at a constant level. This is done because the main importance is to reduce the peak-discharge. Figure 1 shows an example for polder Neuzell, if a variable inflow is used with 100m3/s maximum, resulting in a longer period of the reduced peak flow, or if the inflow is constant at 100 m3/s, resulting in only a short but equal peak discharge. The last approach would have advantages for areas further downstream, because more water is taken away from the system. Also, the pressure on the dykes is less, because the duration of the peak-flow is shorter.

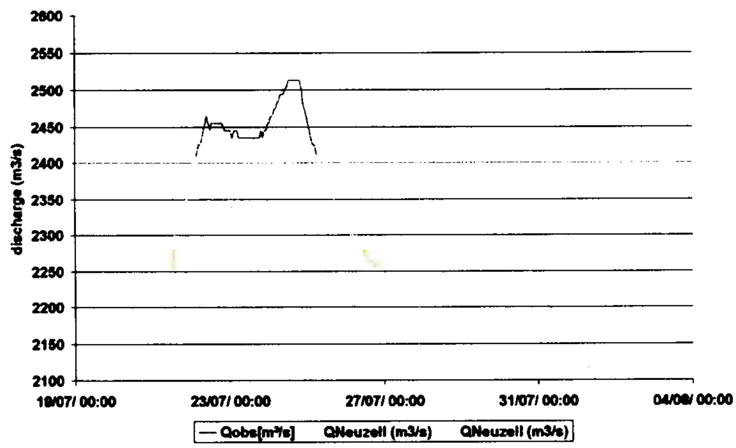


Figure 1. Discharge in the Oder when polder Neuzell is activated with a maximum inflow of 100m3/s. Two alternatives are shown: a constant inflow of 100m3/s, or alternatively a variable inflow based on the actual river flow with a maximum of 100m3/s.

Table 3 also shows that if the maximum inflow rate is increased to 200 m3/s, the capacities of both the Neuzell and the Ziltendorf polder would be used entirely. If both polders were activated with both inflow rates at a maximum of 200 m3/s (scenario NZ200), a peak discharge reduction of 272 m3/s could be obtained. The peak discharge will thus be 2242 m3/s (H=687 cm) instead of the original 2514 m3/s (H=715 cm). The waterlevel is reduced 28 cm. Scenario NZ200+ shows, that the same result can be obtained if the opening at Neuzell allows for 202 m3/s inflow, and the opening Ziltendorf allows for 70 m3/s inflow at maximum. This last option can probably be achieved at lower costs.

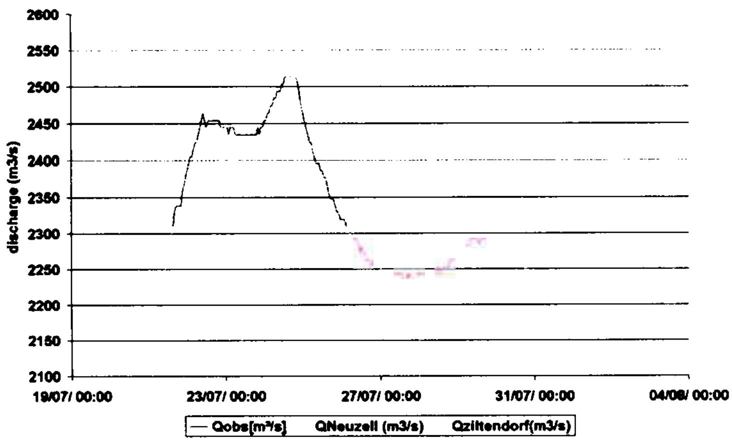


Figure 2. Discharge in the Oder when polder Neuzell and Ziltendorf are activated with a maximum inflow of 202 and 70m3/s respectively. Two alternatives are shown: a constant inflow of 100m3/s, or alternatively a variable inflow based on the actual river flow with a maximum of 100m3/s.

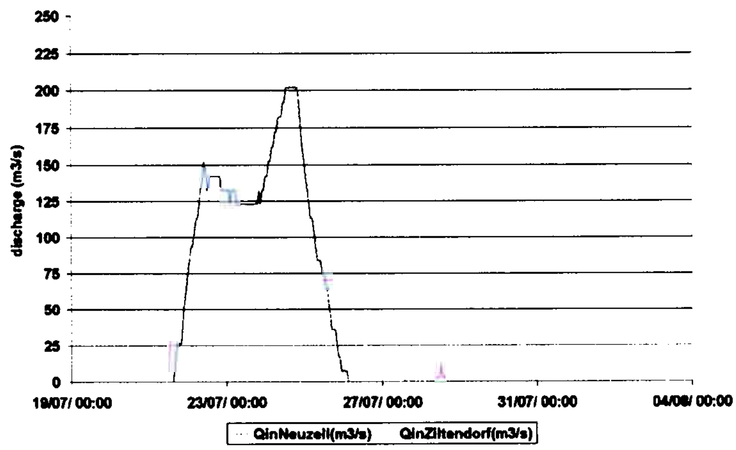


Figure 3. Inflow in the polders Neuzell and Ziltendorf (scenario NZ200+). Maximum inflow is 202 and 70 m3/s respectively.

If polders would be activated with a constant inflow rate, the results would be different (Table 4). In principle, if a constant inflow rate would be used, the filling of the polder and the resulting remaining discharge in the Oder would not be optimal.

Scenario	MaxQin_N	MaxQin_Z	MaxQ	Q_N	V_N	Q_Z	V_Z	dQ	Qstart_N	Qstart_Z
baseline	X	X	2514	X	X	X	X	X		
N200	200	X	2314	2313	44.5	X	X	200	2313	
N142c	**142**	**X**	**2372**	**2372**	**45.0**	**X**	**X**	**142**	**2376**	
Z200	X	200	2331	X	X	2331	37.7	183		2331
Z125c	**X**	**125**	**2389**	**X**	**X**	**2389**	**37.6**	**125**		**2395**
NZ200	200	200	2242	2313	44.5	2242	38.0	272	2313	2242
NZ200+	202	70	2242	2312	44.9	2242	37.6	272	2312	2242
NZ142c	**142**	**80**	**2292**	**2372**	**45.0**	**2292**	**33.4**	**222**	**2376**	**2300**

Table 4. Results of polder calculations based on observed 1997 discharges. The scenarios indicated with a "c" at the end, have a constant polder inflow. N=Neuzell; Z=Ziltendorf; MaxQin=Maximum inflow in polder in m3/s; MaxQ= peak discharge in Oderin m3/s; Q_N/Z=Discharge in Oder after activating the polder in m3/s; V_N/Z = Volume of water in the polders in Mm3; dQ=reduction of discharge in the Oder river in m3/s; Qstart_N/Z = discharge at which polder is activated.

Table 4 shows that with a variable inflow rate, the Neuzell polder could lead to a peak flow reduction of 200 m3/s while almost completely filling (44.5 Mm3). Using a constant inflow rate, a peak flow reduction of only 142 m3/s can be reached. This corresponds to a waterlevel reduction of 14 cm (2514 m3/s= 715 cm; 2372 m3/s= 701 cm). For Ziltendorf, a reduction of 183 m3/s (waterlevel reduction 19 cm: 2514 m3/s= 715cm; 2331 m3/s= 696 cm) can be reached with variable inflow, and a reduction of 125 m3/s (waterlevel reduction 13 cm: 2514 m3/s= 715 cm; 2389 m3/s= 702 cm) can be reached with constant inflow. Figures 4 shows this effect graphically. When both polders would be activated, the variable inflow option would lead to a 272 m3/s peak discharge reduction (waterlevel reduction 28 cm: 2514 m3/s= 715cm; 2242 m3/s= 687cm), compared to a 222 m3/s reduction in the constant inflow situation (waterlevel reduction 23 cm: 2514 m3/s= 715 cm; 2292 m3/s= 692 cm). Figures 5 shows this effect graphically. Another important issue is that the time of activating is different depending on the fact if the inflow is variable or constant. For example in the case of Ziltendorf, with variable inflow the polder needs to be activated at Q=2331, whereas with a constant inflow (125 m3/s) the polder should be activated later, when the discharge in the Oder is 2395 m3/s.

It should be noted that all these calculations are based on the fact that discharges are perfectly known beforehand. During the crisis phase obviously, this is not the case: the only information available is a forecast of expected discharge.

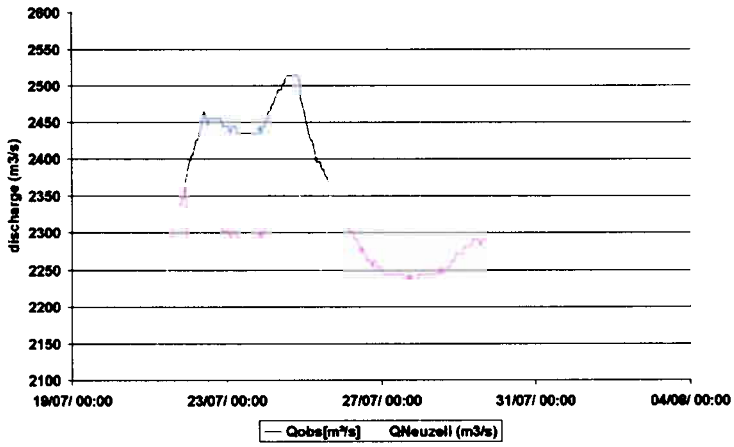


Figure 4. Discharge in the Oder when polder Neuzell is activated with a constant inflow of 142m3/s.

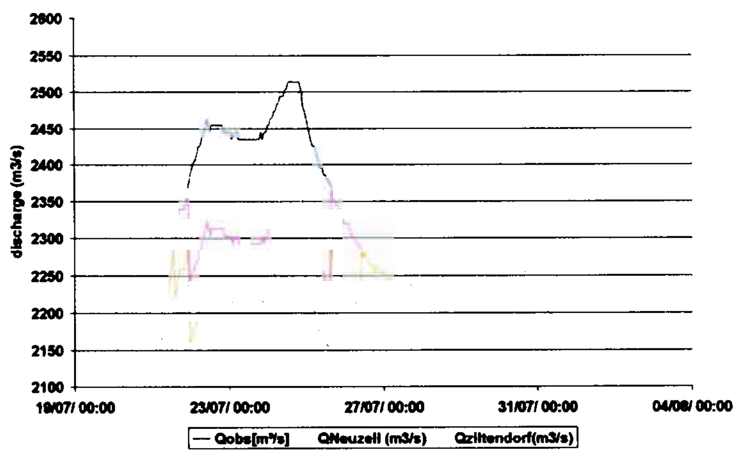


Figure 5. Discharge in the Oder when both polders Neuzell and Ziltendorf are activated with a constant inflow of respectively 142m3/s and 80 m3/s.

A possible uncontrolled opening of a polder (by using dynamite for example) has the disadvantage of not having any control on the throughflow whatsoever.

Polder optimization calculations based on simulated 1997 discharges with LISFLOOD not taking into account dyke breaks

The definition of optimum polder management using the LISFLOOD model is complicated for the 1997 event due to the occurrence of dyke-breaks which are not simulated. The model could be fed with observed discharges of 1997 to overcome this, but this is not done here.

Using a modelling approach over the spreadsheet calculation approach of the previous paragraph has the advantage that the flow and propagation of the flood wave are simulated more realistic.

Again, the polders can be simulated assuming a constant inflow rate or a variable inflow rate. The variable inflow rate is to be preferred, but probably more difficult and more costly to achieve.

Since no dyke-breaks are simulated, in general the activation threshold of the polders based on simulated discharges is larger than if the calculations were based on the observed discharges.

For example, polder Neuzell is activated optimally here if the discharge reaches 2922 m3/s (n.b. ignoring the effect of dykebreaks!!) in the Oder, in case this is the only polder along the Oder (Figure 6). The maximum in inflow-discharge through the opening is 200 m3/s and is variable here. The discharge reduction in this case is 181 m3/s (3176 m3/s compared to 2995 m3/s, corresponding to a waterlevel reduction of about 19 cm).

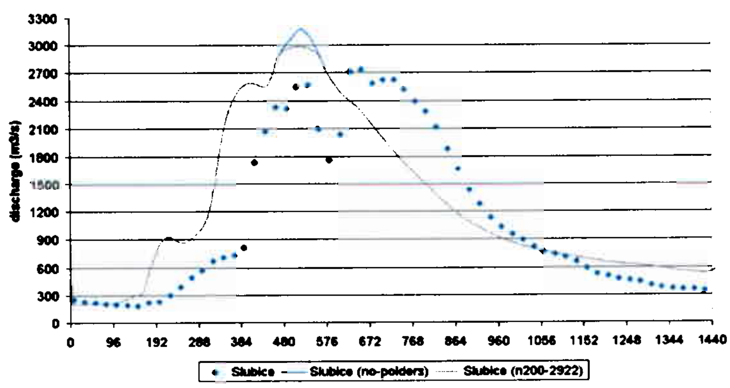


Figure 6. Simulate discharge at Frankfurt/Slubice when polder Neuzell is activated at Q=2922 m3/s with a maximum inflow of 200 m3/s.

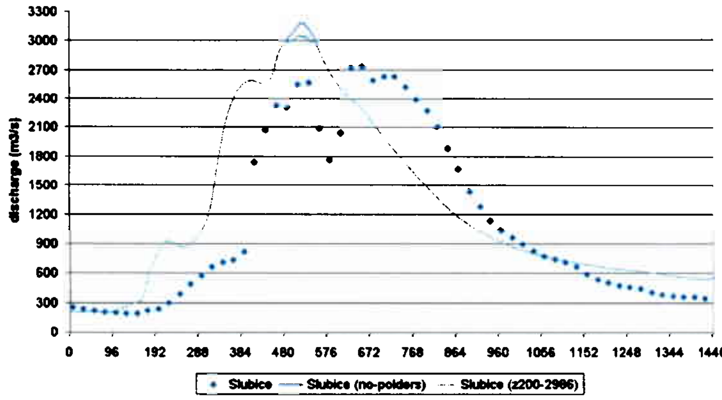


Figure 7. Simulate discharge at Frankfurt/Slubice when polder Ziltendorf is activated at Q=2986 m3/s with a maximum inflow of 200 m3/s.

Figure 7 shows a result for Ziltendorf, activated at 2986 m3/s and with a maximum inflow of 200 m3/s. The discharge reduction in this case is 132 m3/s (3176 m3/s compared to 3044 m3/s, corresponding to a waterlevel reduction of about 13.5 cm).

Simulation and optimization of the polders used in scenario 2020crp of the Oder-LISFLOOD report using a constant inflow discharge, yields in a much larger effect of the polders (Figure 8) then was the case in the Oder-LISFLOOD study. This is obtained mainly by a number of trial-and-error simulations optimizing the time of opening of each polder individually. This optimization process is not carried out perfectly yet: probably even larger peak discharge decreases could be obtained if more simulations are carried out. Figure 8 shows that 2020crp-sc5 leads to the largest reduction of peak discharge at Slubice: 2566 m3/s compared to 3176 m3/s – a reduction of 620 m3/s, corresponding to a waterlevel decrease of approximately 71 cm. The inflow conditions used are listed in Table 5.

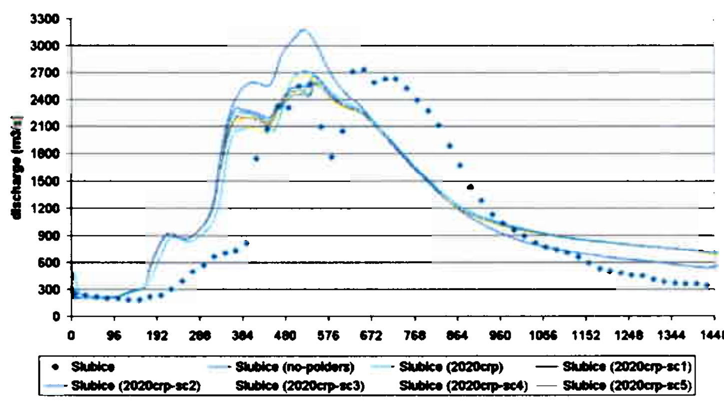


Figure 8. Simulate discharge at Frankfurt/Slubice of the scenario 2020crp, with different optimizations of the polder activation and inflow discharge; scenario 2020crp is as it was simulated in the Oder-LISFLOOD report; sc1-5 are different optimization runs.

De Roo (2003) Simulation of polders along the German part of the Oder river

Nr	Name/Code	Volume	QinStart	Qinflow	QoutStart
		Mm3	m3/s	m3/s	m3/s
10	**Polder Raciborz**	170	1538	max	250
15	**Polder Bukow**	58	1000	max	250
35	**Polder Rzymowka**	12.5	600	max	50
36	**P27**	5.4	1750	50	250
16	**P7**	23	1800	50	500
37	**P28**	20	1850	50	500
17	**P8**	41	1900	50	500
38	**P29**	4.9	1950	50	250
39	**P30**	9.9	2050	50	250
40	**P31**	3.8	2150	50	250
56	**Polder Neuzell**	45	2250	142	500
57	**Polder Ziltendorf**	38	2350	80	500

Table 5. Characteristics of the polders and the activation as used in scenario 2020crp-sc5.

As stated before, the polder optimization process is not carried out perfectly yet: probably even larger peak discharge decreases could be obtained if more simulations are carried out.

Conclusions

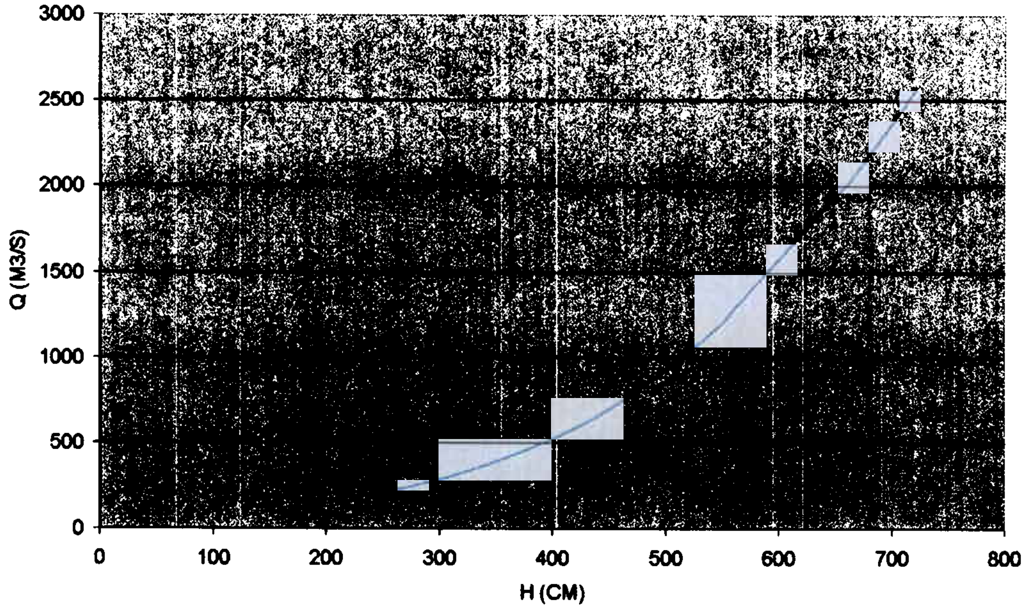
To achieve an optimum effectiveness of the storage capacity in the polder, the management of the polder inflow and outflow are of utmost importance. However, defining an optimum strategy for the regulation of polder inflow is not easy. This is partly caused by the fact that every flood event will be different, and that it is not known how much water can be expected, unless a very good flood forecast is available. The calculations in this report are based on the 1997 event.

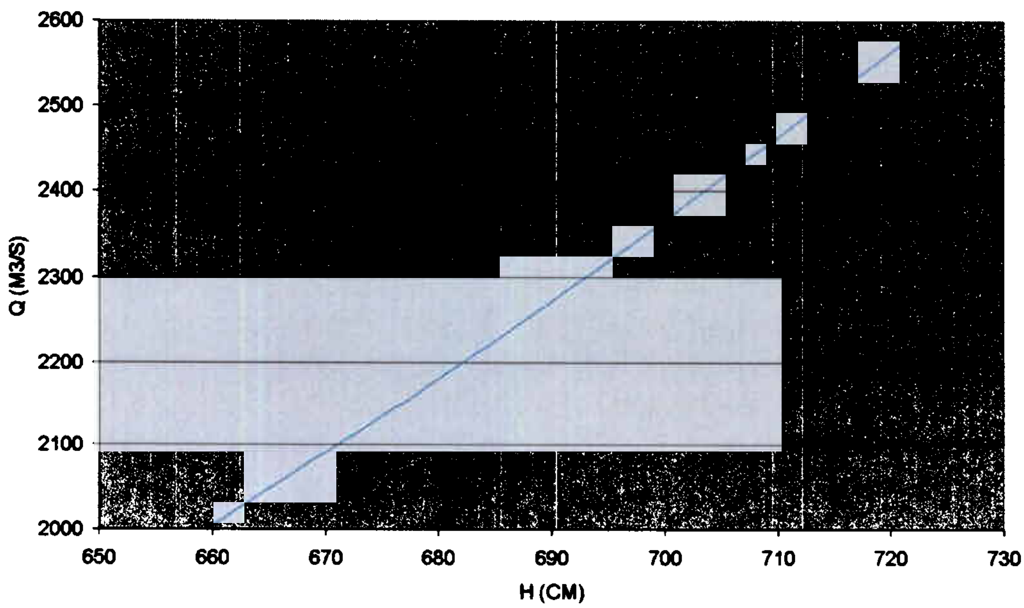
Simple and straightforward spreadsheet calculations on the observed discharges show, that a 500m3/s discharge decrease cannot be obtained by activating both the Ziltendorfer and Neuzeller Niederung. The capacity of the polders is just not large enough for this reduction: the polders would fill before the event is over, such that the second half of the original wave cannot be buffered, leading to more or less the same peak discharge as without any polder. What can be achieved using the Neuzell and Ziltendorf polders together is a 272 m3/s (=28 cm) reduction of peak discharge if the inflow is variable, and a 222 m3/s (=23 cm) reduction of peak discharge when the inflow is constant: 142 m3/s for Neuzell and 80 m3/s for Ziltendorf. With these inflows, the polders will be filled to their maximum capacity, and cut of the peak of the flood wave. This reduction can only be achieved if they are opened at the right time: Neuzell should be opened when the local Oder discharge reaches 2376 m3/s and Ziltendorf should be opened at 2300 m3/s. It is assumed that the polder instantaneously reaches the maximum inflow.

Simulation and optimization of the polders used in scenario 2020crp of the Oder-LISFLOOD report using a constant inflow discharge, yields in a much larger effect of the polders then was the case in the Oder-LISFLOOD study. The estimated peak discharge is now 2566 m3/s (a reduction of 620 m3/s, corresponding to a waterlevel decrease of approximately 71 cm), as compared to the 2801 m3/s estimated previously. This is due to an optimization of the time of opening of the polders and optimized and constant inflow.

A possible uncontrolled opening of a polder (by using dynamite for example) has the disadvantage of not having any control on the throughflow whatsoever.

Appendix A: Stage-Discharge curves used for Frankfurt/Oder (based on file: Q_ohuhzn.xls provide by LUAB): entire curve (a) and an enlarged upper-part (b).





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