Compensating human interventions at a river bifurcation

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Introduction

Human interventions in a bifurcating river system can disturb the discharge distribution at the river bifurcation. This causes unwanted water level increases in the branch which receives additional discharge. To avoid this, a set of compensating interventions can be designed such that they counteract each other's effect at the bifurcation. However, this may be challenging due to inherent uncertainties around discharges and hydraulic roughnesses. Therefore, in this study we assess the impact of compensating interventions on system-wide water levels considering a range of discharges and roughness conditions.

Methodology

An idealized 1D model is set up in the SOBEK environment with a schematization that is roughly based on the dimensions of the Dutch Rhine branches (Fig. 1). The branches have a uniform compound cross-section. The upstream boundary condition is a constant discharge ranging from 1000 to 18,000 m^3/s. The hydraulic roughness of the main channel and floodplain are set as stochastic, normally distributed variables with independent values for each of the branches.

Several configurations of the model schematization are used: 1 without any intervention and 3 with various combinations of compensating interventions implemented in the Waal and Pannerdensch Kanaal (Table 1). Interventions are either a dike set-back or a floodplain excavation, which are both typical 'Room for the River' type interventions. The compensating interventions are designed such that for a discharge of 16,000 m^3/s the effects of the interventions exactly offset each other at the bifurcation.

We run a quasi-random Monte Carlo Simulation to estimate the water level distributions for each model configuration and under each discharge condition. The effect of the intervention is quantified by subtracting the water levels in the non-intervened configuration from the water levels in the intervened configuration for each sample in the Monte Carlo Simulation. This results in a distribution of water level effects from which a mean effect and a 90% confidence interval of the effect is derived. We specifically look at downstream locations in the Waal and IJssel branch, where water level effects are fully determined by changes in the discharge distribution.

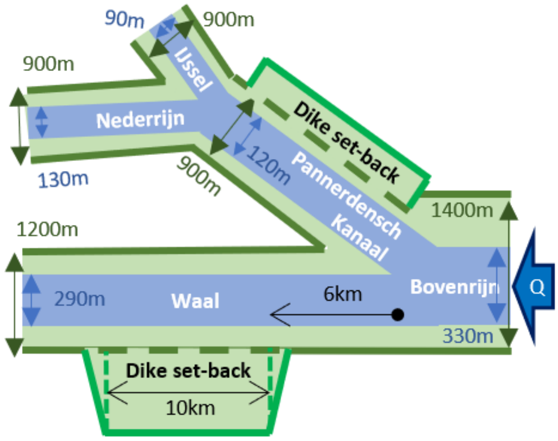

Figure 1. Model schematization, in the configuration in which two dike set-backs are implemented (see Table 1). The Waal, Nederrijn and IJssel are 93km, 107km and 113 km long, respectively.

Table 1. Model configurations, which include combinations of compensating interventions. Interventions types are a dike set-back (DS) and a floodplain excavation (FE)

Configuration	Waal intervention	Pannerdensch Kanaal intervention
No interventions	-	-
Compensation 1	500m DS	120m DS
Compensation 2	500m DS	0.39 FE
Compensation 3	1.46m FE	120m DS

Finally, we link the discharges to their corresponding return periods from GRADE (Prinsen et al., 2015). Then, for each configuration, we quantify design water levels with return periods of 100 years and 1250 years at downstream locations in the Waal and IJssel branch. This is done using Bayesian model averaging, whereby accounting explicitly for all discharge and roughness conditions.

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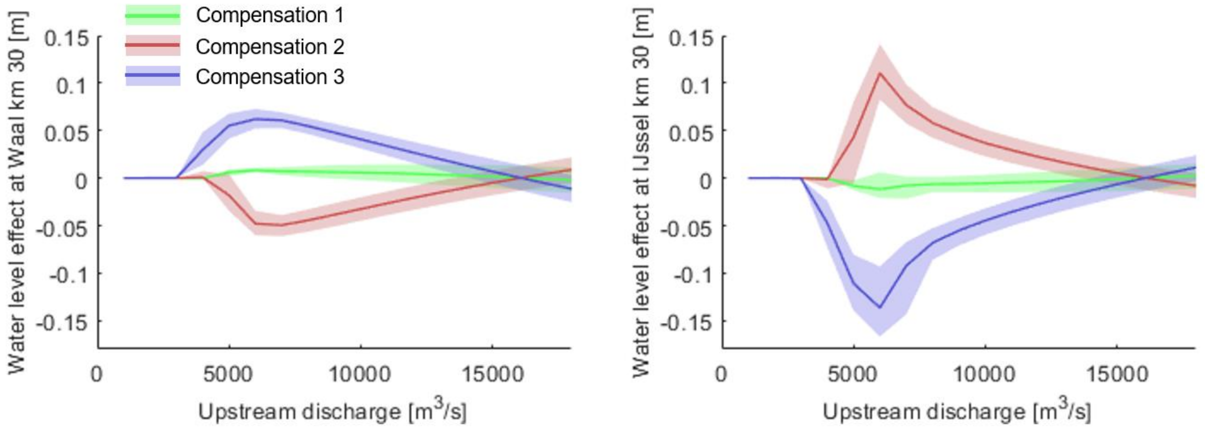

Figure 2: Effects on water levels at downstream locations in the Waal (left) and IJssel (right) branch caused by the 3 variations of compensating interventions (see Table 1). The continuous line marks the mean effect and the shaded area marks the 90% confidence interval.

Results

Water level increases along downstream reaches in the system occur for various discharge conditions if the compensating interventions are not of the same type (Fig. 2). For moderately high discharges, a floodplain excavation is relatively more effective at reducing water levels than a dike set-back, therefore attracting additional discharge and increasing downstream water levels. Effects of the interventions on water levels along the smaller IJssel branch are higher in comparison to those along the Waal branch as IJssel water levels are more sensitive to discharge variations (Gensen et al., 2020). Consequently, the implementation of a floodplain excavation in the Pannerdensch Kanaal and a dike set-back in the Waal (i.e. compensation 2) leads to a significant increase in water levels in the IJssel for a discharge just over the bankfull level. Near perfect compensation is only achieved when two dike set-backs are used (i.e. compensation 1). Still, downstream water levels can be affected, even for the design condition of 16,000 m^3/s, because of uncertain roughness parameters.

Table 2 shows that the changes in water levels also impact design water levels (DWLs). These values are a good presentation for the changes along the entire branches, except for the most upstream reaches where the interventions are implemented. Interventions in the vicinity of the bifurcation point thus affect DWLs throughout the entire system. For both return periods, the DWLs are mainly affected by the water level changes at moderately high discharges. Thus, DWLs increase along the branch in which the floodplain excavation is implemented. Although the changes in DWLs seem small, Dutch regulations state that river interventions should not lead to water level increases of over 1mm under design conditions (Rijkswaterstaat, 2019).

Table 2. Changes in design water levels at downstream locations in the Waal and IJssel for return periods of 100 years and 1250 years.

	Change in design water level			
	100yrs		***1250yrs***	
Config.	*Waal$_{km30}$*	*IJssel$_{km30}$*	*Waal$_{km30}$*	*IJssel$_{km30}$*
Comp. 1	+0.4cm	–0.4cm	+0.2cm	–0.2cm
Comp. 2	–1.7cm	+1.7cm	–0.4cm	+0.4cm
Comp. 3	+2.2cm	–2.2cm	+0.6cm	–0.8cm

Conclusion

Compensating river interventions nearly always lead to unwanted water level increases along one of the downstream branches. This also impacts the design water levels. These negative effects can be minimized by implementing interventions of the same type. It is recommended to explicitly consider a range of discharge conditions and model uncertainties in the design of compensating interventions such that negative side-effects may be avoided.

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