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Publication date
2024

Document Version
Final published version

Citation (APA)
Klijn, F. (2024). *Towards a robust and well-functioning Rhine River system that can sustainably provide its geo-ecosystem services*. Abstract from NCR DAYS 2024, Wageningen, Netherlands.

Towards a robust and well-functioning Rhine River system that can sustainably provide its geo-ecosystem services

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Keywords — Robustness, Discharge capacity, Transformation

The context

The policy programme Integrated River Management (IRM) aims to anticipate climate change and to redress the negative consequences of earlier river engineering interventions. Its objective is to first and foremost ensure a well-functioning river system that can provide its essential 'public' geo-ecosystem services: safe discharge of floods, reliable freshwater supply, reliable waterways to the hinterland, and good conditions for aquatic and terrestrial ecosystems in the floodplains and beyond. Challenges, however, relate to the changing discharge regime resulting from climate change, and to the conflicting requirements of the various river functions and values. These pose real dilemmas about when to act, how to act, which function or value to support and which one to curb.

A geo-ecosystem perspective

The reflection on the current state of our rivers (Klijn et al., 2022) revealed a number of worrying developments, partly caused by earlier engineering interventions and due to neglected feedback mechanisms, which now make things hard to control. Examples are the unequal scouring of the river bed in the upstream stretches of the various Rhine branches, the sedimentation on the floodplains, and the well-known 'levee effect' that at the same time makes society more vulnerable to flooding and limits the possibilities to enlarge the discharge capacity of the river by realigning embankments. Understanding these feedbacks requires a systems approach, and the recognition of their nature – hydraulic, morphological and ecological – calls for a geo-ecosystem perspective, instead of a over-simplified engineering perspective.

Climate change and its consequences for the Rhine's discharge regime

Every few years KNMI and Deltares translate the new IPCC climate scenarios into discharge scenarios for the rivers. The KNMI'23 scenarios have so-far only been translated into mean and low discharges, so for exterme high discharges we need to fall back on the KNMI'14 scenarios (Sperna Weiland et al., 2015). These revealed that floods will occur more frequently and that the Rhine River's extreme discharge may increase with about 10-15% by 2100.

Safely discharging this extra discharge is one of the key challenges for IRM, which is complicated even further by the fact that this discharge can be distributed over three river branches and may have to be temporarily stored for some time when the sea level is already higher and discharge to the sea is hampered by prolonged northwesterly winds. The Expertise Network Flood Security (ENW) therefore recommended to investigate various discharge distributions, as this ultimately determines which portion of the extra discharge each Rhine Branch must be able to safely discharge in the future.

Reasons to reconsider the discharge distribution

Firstly, not every Rhine branch is equally long. And a longer route means less inclination, slower flow and higher flood levels.

Secondly, not each branch can be equally easily enlarged: the Nederrijn-Lek is narrow, crosses deep lowland peat areas and has hardly any floodplains in the most western stretches. This was reason for the government to decide to not further load this branch into the future after having increased the discharge capacity to 16.000 m^3s^{-1} by making Room-for-the-River.

By looking at the behaviour of the water levels in the three branches at various discharges, we also ascertained that the Waal branch is kind of 'hyperventilating', whereas the IJssel branch breathes quietly (Klijn et al., 2019). Reason is that we squeeze a relatively large proportion of the discharge through the Waal. This 'breathing behaviour' made us hypothesize that it could be a good metric to express a river's robustness: (absence of) sensitivity to uncertainties and/or increasing discharges.

And related to this, it was established that this distribution can only be delivered by strong control of the distribution at the junctions by maintaining artificial bottlenecks (Fig. 1), which is reflected by the different water level slopes of the branches at the junctions (Fig. 2). Whereas, according to Kleinhans et al. (2013), the natural tendency of the river would be an avulsion.

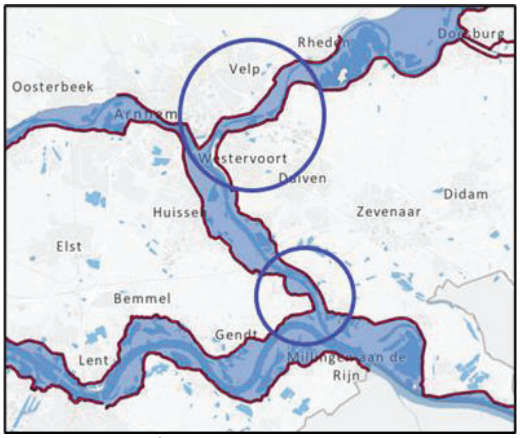

Figure 1. The artificial bottlenecks needed to ensure that the discharge distribution of the three Rhine branches at 16.000 m^3s^{-1} meets the requirements of the policy decision

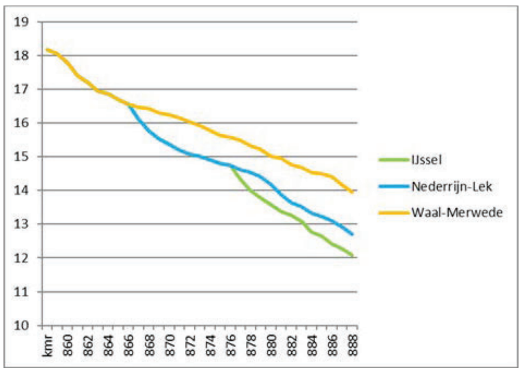

Figure 2. Slope of the water level in the three Rhine branches at the junctions at 16.250 m^3/s^{-1}, reflecting the bottlenecks

Postponing a policy decision about by which route to sluice the increase in extreme Rhine River discharges towards the sea requires that space must be earmarked for possible future interventions (e.g. by so-called Barro reservations) along each Rhine branch. That would impede further spatial development. Therefore, the ministry has now commissioned a policy analysis into the desired flood discharge distribution for the far future, because of the path-dependency of decisions to be made. '*Better narrow down the spatial options to further explore sooner than later*'.

Criteria to consider and past proposals

Criteria for this policy analysis encompasses, among other things, the flood vulnerability of the protected areas along the branches, the respective storage capacity of the IJsselmeer and Rhine-Meuse estuary, and the possibilities to increase the discharge capacity by means that would also benefit other policy objectives, such as biodiversity (Klijn et al, 2002).

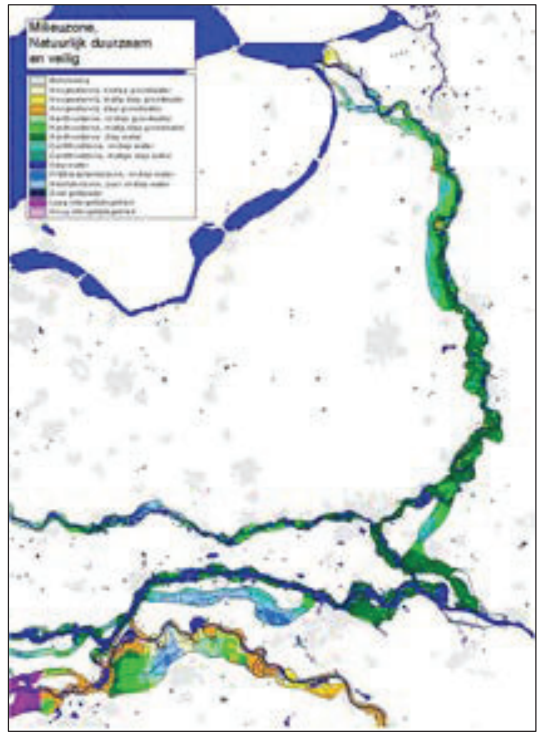

Figure 3. A proposal to enhance the discharge capacity of both Waal and IJssel that benefits typical river ecosystems and their diversity at the national scale (Klijn et al., 2002)

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