Delft University of Technology

Developing a Model to Study the Climate Change Impact on River Bifurcations in Engineered Rivers

Chowdhury, M. Kifayath; Blom, Astrid; Ylla Arbos, C.; Schielen, Ralph M.J.

Publication date
2024

Document Version
Final published version

Citation (APA)
Chowdhury, M. K., Blom, A., Ylla Arbos, C., & Schielen, R. M. J. (2024). *Developing a Model to Study the Climate Change Impact on River Bifurcations in Engineered Rivers*. Abstract from NCR DAYS 2024, Wageningen, Netherlands.

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.
For technical reasons the number of authors shown on this cover page is limited to a maximum of 10.

Developing a Model to Study the Climate Change Impact on River Bifurcations in Engineered Rivers

M. Kifayath Chowdhury[a,*], Astrid Blom[a], C. Ylla Arbós[a], Ralph M.J. Schielen[a,b]
[a] *Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands*
[b] *DG Rijkswaterstaat, Ministry of Infrastructure and Water Management, Utrecht, The Netherlands*

Keywords — river bifurcation, Rhine River, climate change, long term morphological change, Pannerdense Kop

Introduction

Climate change is responsible for global shifts in precipitation patterns and an overall increase in global temperatures. The transitions are anticipated to modify the river hydrograph and sea level. The changes to the hydrograph are also likely to influence sediment flux. These alterations imply shifts in both upstream and downstream boundaries for river bifurcations. However, the resulting bifurcation response remains uncertain and warrants further investigation. Our objective is to understand the extent of large-scale and long-term response of river bifurcations to climate change. We take the Upper Dutch Rhine bifurcation region as our case study and develop a 1D hydro-morphodynamic model representing the system to achieve this goal.

General Model Specifications

We set up a 1D hydro-morphodynamic model of the Rhine branches suitable for mixed-size sediments using the 1D numerical solver SOBEK-RE. The upstream boundary of our model domain is at Cologne at the Niederrhein. Vuren, Schoonhoven, and Keteldiep are the downstream boundaries of the Waal, Nederrijn, and IJssel branches, respectively. The downstream boundaries are located upstream of the estuarine zone. We smoothen the initial bed, channel cross sections, and initial texture to exclude local variations. Using a 1D model excluding the local variations allows us to efficiently focus on the large-scale and long-term response of the bifurcation region to climate change scenarios. Further details on the model and schematization technique can be found in Ylla Arbós et al. (2023).

Model Initial Conditions

Chowdhury et al. (2023) indicated that the flow partitioning trend at the Pannerdense Kop bifurcation changed following a sequence of peak flows in 1993 and 1995 (and possibly 1998). To capture and better understand the phenomenon, our initial state of the model corresponds to the situation during 1980-1990. We focus on bed material load in this model and consider five-grain size classes- fine sand, medium sand, fine gravel and two coarse gravel fractions based on data availability. Our initial bed composition is representative of 1980-1984 and based on the bed texture surveys of 1984 along the Rhine branches and 1981-1983 for Niederrhein (e.g., De Ruijter (1988)). We averaged the data over the width and smoothened the data using shape-preserving interpolation through 3rd-order splines (Fig.1).

Model Calibration

We perform a hydraulic calibration of the model. We calibrated the model against the water level at Arnhem and Nijmegen (Fig. 2) and the annual mean flow partitioning ratio at the Pannerdense Kop and IJsselkop bifurcations, using the total friction per branch as a calibration parameter.

We are currently performing a morphological calibration of the model against the channel bed aggradation rate and the annual mean flow partitioning ratio trend at the bifurcations from 1985 to 2010. Calibration parameters include sediment transport pre-factor, critical shields stress, and nodal point relation per fraction. The verification period of the model is between 2010 and 2020.

Boundary Conditions and Climate Scenarios

We develop our scenarios of boundary conditions (hydrograph and base level) for the model based on KNMI 2023 scenarios covering different magnitudes of change till 2150 (KNMI, 2023).

Our base case hydrograph is a cycled hydrograph with a daily discharge for 20 years with the same statistical properties as the historical record. A cycled hydrograph allows us to capture natural flow variability and guarantees the existence of an equilibrium state. We adjust our hydrograph for climate scenarios by using the flow duration curve statistics from KNMI 2023 scenarios (Buitink et al., 2023) to calcu-

*Corresponding author
Email address: m.k.chowdhury@tudelft.nl (M. Kifayath Chowdhury)

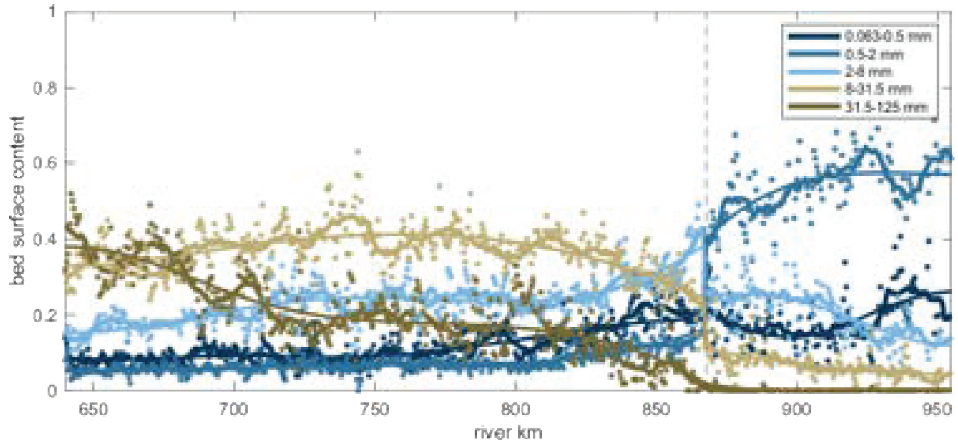

Figure 1: Schematized initial bed surface content for Niederrhein-Bovenrijn-Waal based on 1980-1984 survey. Dots represent data and solid lines represent the spline approximation.

late a factor reflecting relative changes in percentile discharge for each scenario (Ylla Arbós et al., 2023). We approximate the downstream boundary water level relative to sea level by using the De Vries (1994) empirical fit to the analytical solution of the backwater equation (Ylla Arbós et al., 2023). We include sea level rise (SLR) scenarios based on KNMI (2023).

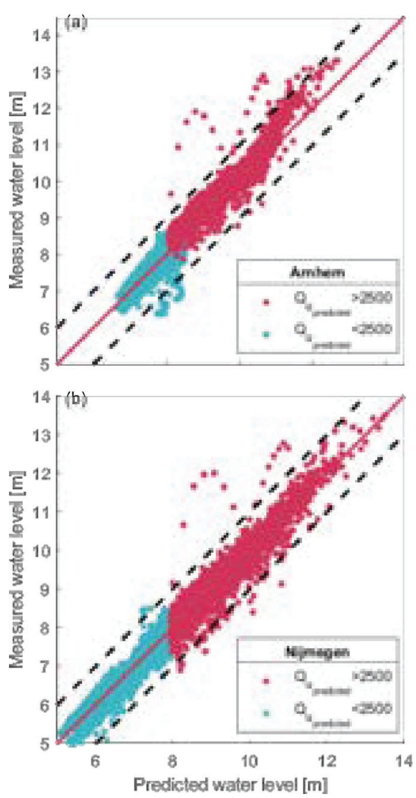

Figure 2: Measured and predicted water level data from (a) Arnhem and (b) Nijmegen for hydraulic calibration.

Based on the scenarios for climate change, the model is expected to provide insight into the morphological response and related flow distribution adjustment at the bifurcation region due to the various magnitude of changes in the upstream hydrograph and base level in the North Sea due to climate change.

Acknowledgements

This study is part of the research program Rivers2Morrow, financed by the Dutch Ministry of Infrastructure and Water Management. We thank the technical staff of Rijkswaterstaat for sharing the data used in this study.

References

Buitink, Joost, A. Tsiokanos, T. Geertsema,C. ten Velden,L. Bouaziz,F. Sperna Weiland, 2023. Implications of the KNMI'23 climate scenarios for the discharge of the Rhine and Meuse. Deltares

De Ruijter, H. , 1988. Bodemmonsters 1984 Pann. kan.- Nederrijn- Lek: km 868 - km 946.750 : zeefanalyse. [Ministerie van Verkeer en Waterstaat, Rijkswaterstaat, Directie Gelderland (RWS, GL).

De Vries, M., 1994. Unsolved problems in one-dimensional morphological models. In IAHR-AD. IAHR.

M.K. Chowdhury, A. Blom, Ylla Arbós, C., M.C. Verbeek, M.H.I. Schropp, R. M. J. Schielen, 2023. Semicentennial Response of a Bifurcation Region in an Engineered River to Peak Flows and Human Interventions. Water Resources Research 59.

KNMI, 2023. KNMI National Climate Scenarios 2023 for the Netherlands. The Royal Netherlands Meteorological Institute (KNMI), De Bilt, 2023

Ylla Arbós, C., A. Blom, C.J. Sloff, R. M. J. Schielen, 2023. Centennial Channel Response to Climate Change in an Engineered River. Geophysical Research Letters 50.