Assignment
Creation of a side channel in the IJssel

Relevance of this assignment

The goal of is this assignment is to bring the theory and methods taught in the unit into practice. Herewith, you achieve a higher level of learning than just reproducing theory.

Learning outcomes

The learning outcomes for this assignment are that you will be able to:

~~*LO1. Describe how physical, biological, sedimentary and chemical processes are connected and interact in hydraulic systems.*~~ (This learning objective will be tested in the written exam)

LO2. Assess the impact of engineering interventions on ecosystem sustainability and climate resilience across a range of spatial and temporal scales in the design process.

LO3. Apply physical principles to design engineering measures for scour protection, bed stability, and sediment management in dynamic hydraulic systems.

LO4. Integrate building with nature concepts and principles in the design of hydraulic systems by considering physical, engineering, environmental, ecological and societal aspects.

Instructions

An explanation of the problem to be solved can be found on the following pages. Tutorials guide you throughout the process of finding a suitable solution. They will act as building blocks leading to a comprehensive synthesis. They do not necessarily result in a complete technical report, therefore the lecture weeks 7 and 8 offer opportunity to integrate the results of the tutorials in a report. Because reporting is not a primary learning outcome of this unit, a report template shall be used to structure and lay-out the report.

The project simulates a real-world design process where teams must analyse the system, identify stakeholder needs, evaluate interventions, and propose a multi-scale solution that combines engineering performance, ecological enhancement, and socio-economic feasibility.

The work is done in groups of three students. Enrolment must be done in the groups available on BrightSpace (Collaboration --> Groups --> View available groups (so, not at Group Self Enrolment!). Be sure that the selected group category is "Groups unit HE Solutions").

Resources

The lecture presentations and prescribed course materials are important sources of information. In addition, any relevant and useful other information can be used. In case you want to review additional information, the systematic literature review process can be improved by using semantic understanding rather than basic keyword matching. The Research Rabbit (https://researchrabbitapp.com) tool provides a dynamic research networks by exploring academic papers through connections based on citations, topics, and authors. It allows users to create their own research collections by topics. The Connected Papers (https://www.connectedpapers.com) tool provides relationships between papers starting from a single point, typically a key paper or topic. It generates a graph showing how that paper connects to others, focusing on visual exploration of research networks.

Product

1. A written report.

The report is structured according to the template available on BrightSpace with clear reasoning and concise wording. The results must be reproducible. The report should not be a chronological account of your design process: just improve earlier parts if you have found out later that they needed correction or completion. The report doesn't have to be a complete technical report – you only have to fill in the sections indicated with section titles. (and add a list of references). Use the report template that is available on BrightSpace. The tutorials are intended to start writing the chapters of the report.

2. An oral presentation.

The oral presentation is used for giving feedback and stimulating discussion.

Assessment criteria

Before the final report submission, students present their project to their peers to receive feedback as a formative assessment (not graded). The final report will be assessed and counts for 70% of the final grade for this unit.

Supervision and help

The tutorials aim at helping you with your assignment. In weeks 7 and 8 there are supervised group sessions. Before submitting the final report, each group makes an oral presentation of their work to receive feedback from their peers as a formative assessment. The feedback provided during the oral presentations in week 8 can be used to further improve the work.

Submission and feedback

Reports are submitted on Brightspace, Assignments in your group folder. The deadline is Friday 30 January 2026, 17:00.

AI Usage Disclosure

Students need to submit a statement declaring the use of AI tools, the specific purpose (e.g., grammar check, outlining, etc.), and the prompts used. Anyway, students are responsible for the contents of the delivered work and must be able to motivate the choices and methods and be able to explain the results and conclusions.

Brief problem description

The Room for the River Programme

The Netherlands lies in a low-lying delta where rivers like the Rhine, Meuse, and Scheldt flow into the sea. Without proactive measures, two-thirds of the country would be vulnerable to flooding. The 'Room for the River' programme, launched in the early 2000s, was a response to severe floods in the 1990s and has since become a global model for climate-resilient water management.

The main principle of the 'Room for the River' approach is to give rivers more space to safely manage higher water levels, rather than simply building higher dikes. Instead of fighting against rising water, the Netherlands embraced a nature-inclusive approach. This means allowing rivers to overflow into designated areas—like widened floodplains or bypasses—so that excess water can be conveyed without threatening urban centres.

This modern approach has followed a period of river training, in which the river flow was constrained ~~in~~ between river groynes. This, together with bend cutoffs and excessive sediment mining, has led to erosion: a lowering of the bed level. This is especially the case in the Waal. The result is a change in discharge distribution of the Rhine branches: the amount of water through the Waal increases. In future, if the design discharge of Rhine water at Lobith would increase from 16 000 m^3/s to a new value of more than 20 000 m^3/s, there are ideas to distribute the 4.000 m^3/s extra discharge 50% through the Waal and 50% through the Pannerdensch Kanaal. For this assignment, assume that this will be decided upon.

Some of the most common interventions are:

- Lowering floodplains to increase water discharge conveyance
- Relocating dikes further from the river to widen the riverbed (floodplains)
- Creating side channels to divert flow
- Constructing flood bypasses to relieve pressure during peak flows
- Removing obstacles like bridge abutments or structures that restrict flow

The programme wasn't just about flood control - it also aimed at improving the spatial quality of river areas, while maintaining or restoring ecological values like biodiversity and sediment dynamics and maintaining the navigability of the river. Meanwhile, it might enhance recreational functions.

Currently, freshwater distribution is another point of attention. The integrated approach marks a shift from traditional (grey) hard infrastructure for flood protection (e.g., dike reinforcement) to adaptive (green/blue - soft) delta management, which balances safety, sustainability, and spatial development.

A potential measure for reducing erosion of the riverbed in the IJssel in line with the Room for the River approach is to create a bypass in de IJssel between Dieren and Brummen.

Overview of the project area[1]

The IJssel river starts at the IJsselkop near Westervoort and flows approximately 127 kilometers northward into Lake IJssel. In the upstream section of the IJssel, referred to as the Boven-IJssel, an average bed erosion is observed of 0,05 m/year (Huppes, 2021). The Beneden-IJssel, downstream of Deventer, shows no significant erosion (0,00 m/year on average). Therefore, implementing a bypass to mitigate bed erosion is particularly relevant in the Boven-IJssel.

[1] The data for this assignment are based on the MSc-thesis of Lennart Nijsse (2025).

For this assignment, the part between Dieren and Brummen is used as the project area (Figure 1). The floodplains have been designated as a Natura 2000 area.

Figure 1 The project area selected for this exercise (Open StreetMap)

Groynes are present along various locations in the project area. Generally, these groynes are located on both banks of the river or in the outer bends. Figure 2 shows a cross-section of the summer bed of the river. For this assignment, it is allowed to simplify the cross-section to a trapezoid shape.

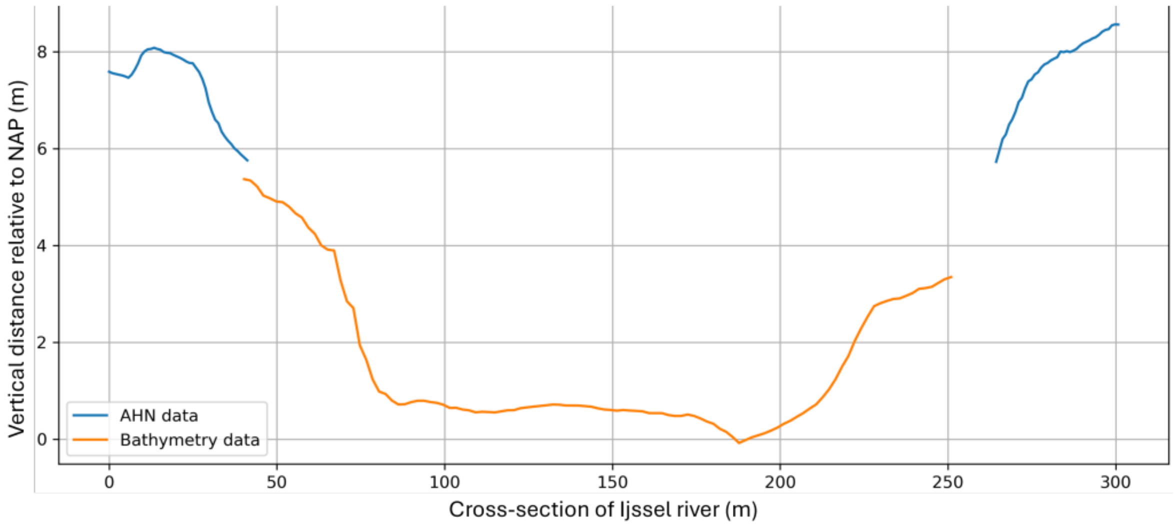

Figure 2 Cross-section of the IJssel river that can be considered typical for the selected project area. The indicated levels vary over the longitudinal river axis (Nijsse, 2015).

At present, the discharge through the IJssel is 15% of the discharge the flows in the Rijn at Lobith (Figure 3).

Figure 3 Distribution of the Rhine discharge over the main river branches (M. Dörrbecker, Wikimedia Commons)

In the IJssel, the maximum allowed class of vessels is CEMT class Va, corresponding to a length of 110 m and a width of 12 m. The waves generated by vessels can be divided into primary and secondary waves. The maximum wave heights are 0,64 m for primary vessel waves and 0,34 m for secondary vessel waves. According to national guidelines, the IJssel should have a navigation channel of at least 40 m wide with a water depth of at least 2,50 m in OLR conditions (agreed-upon low river level, *overeengekomen laag water*) (Rijkswaterstaat, 2019). OLR is the water level that corresponds to a low discharge value of 1020 m^3/s of the Rhine at Lobith.

The main issues for the IJssel in the future situation are rising water levels during high discharge conditions, increasing the flood risk, and dropping water levels in periods of drought, decreasing navigability of the river.

Tutorial 1 Begin of the design

With this tutorial, you make a begin of your design and the reporting of it. As the report doesn't have to be a complete technical report (because reporting is not a learning objective for this unit), the problem analysis has not to be included in your report because it is already more or less given in this assignment description. A summary and preface or not needed as well.

Use the report template available on Brightspace to report the following tasks.

1. Briefly formulate a problem statement and a project goal related to this assignment.
2. Make an inventory of involved stakeholders, list them grouped by category
3. Briefly describe how you would involve these stakeholders in the design process if it were a real project.
4. Briefly describe how you make sure that the stakeholders' interests will be considered in the development of your proposed solution.
5. Perform a function analysis, distinguishing principal, preserving and additional functions.
6. Create a list of requirements and evaluation criteria and explicitly relate them to the analysed functions and / or stakeholders' interests.

Tutorial 2 Effect of the bypass on flow and morphodynamics

Question: are we trying to make this a bed incision problem, or a water level management problem? For now, let's keep this part a water level management problem.

The IJssel river channel has a discharge capacity of X, however as floods gradually increase in magnitude, the government has mandated that a side channel be constructed to increase the total discharge capacity of the reach to Y to prevent an increase in local water level during high flows. Furthermore, side channel cannot decrease the water level in the main channel below its current water level for a discharge of Z to ensure channel navigability during low flow periods. Flow over the weirs regulating the side channel depth should remain sub-critical. At the design low discharge, the side channel can be dry. Below are the necessary steps:

1. Solve for side channel discharge capacity: Y-X
2. Solve for change in water height along main channel reach length, L, for discharge X.
3. Realise that side channel entrance weir height is set by shipping depth requirements: 2.5m
4. Select an initial design width for side channel. Assume a consistent friction factor for both the main and side channels.
5. Solve for change in water height along length of side channel for total system discharge Y for selected side channel width.
6. Is your change in water level along your side channel less than or equal to your change in water level along the main channel? This is a design criterion. Iterate your design to satisfy this requirement.

Tutorial 3 Flocculation and sedimentation

In the previous tutorial you modelled how the bypass alters flow and where sediment moves. In this tutorial, we add the water quality controls on the sediment behaviour. Fine sediment does not behave as individual grains: it flocculates. Flocculation depends on water quality and determines whether fine sediment remain suspended, form fluid mud, or consolidate as a stable bed. The insight you gain here will allow you to evaluate whether your intervention will increase dredging needs, influence turbidity levels, or create conditions that benefit or harm ecological functioning.

In this tutorial, you will investigate how variations in water chemistry (e.g. such as salinity and organic matter) affect the flocculation behaviour of fine sediments. Through hands-on experiments, they will learn to quantify sedimentation rates using settling tests and apply theoretical approaches (e.g., Stokes' Law) to interpret the influence of floc properties on settling dynamics. This will be used to evaluate how interventions in hydraulic systems can unintentionally accelerate or slow down sedimentation in certain areas, directly affecting waterway accessibility and maintenance dredging volumes. Below are the step-by-step needed to be addressed in this tutorial. The detailed guide will be uploaded before the practical, in the BrightSpace section related to this tutorial.

1. Induce flocculation by varying the suspension's organic content (through the addition of starch) and salinity (through the addition of salt) in different settling columns. The flocculant and salt should be tested at multiple concentrations.
2. Monitor the water-sediment interface height at regular intervals to determine the sedimentation rate for each test.
3. Plot the height of the settled layer versus time.
4. Compute the sedimentation rate.
5. Compute the settling velocity.
4. Evaluate how water chemistry changes the settling behaviour and sedimentation rate of fine sediments.

Tutorial 4 The effect of interventions on waterway accessibility

In this tutorial, you will assess the effects of engineering interventions on inland navigation. You will begin by analyzing how water levels, flow patterns, and sedimentation rates (as determined in previous tutorials) are influenced by the proposed measures. These physical changes will then be evaluated against established nautical criteria to determine their impact on navigability and accessibility.

You will explore how modifications to the river system may affect vessel traffic, available depth, and safety margins under varying flow conditions. Special attention will be given to identifying potential bottlenecks or shallow zones that could restrict vessel movement. This analysis will help you understand the interdependence between hydraulic behavior and navigation performance.

Ultimately, this tutorial will guide you in applying engineering judgment and data analysis to evaluate whether the interventions effectively support safe and efficient inland navigation. Based on this analysis, you will select the most suitable intervention measures to ensure that navigational criteria are met, and navigability is maintained. Finally, you will evaluate an extreme drought scenario to test the resilience and future proofing of the design.

1. Verify whether the selected interventions alter navigation patterns and accessibility (short-term effects).
2. Assess whether sedimentation rates may hinder accessibility (long-term effects).
3. Define a maintenance dredging strategy to ensure 100% navigability.
4. Evaluate the impact of an extreme drought scenario on navigation accessibility.

Tutorial 5 Small-scale design aspects - 1

Due to navigation requirements, the lowest water level in the main channel should not be influenced by the side channel. This is accomplished by making a weir in the side channel. In this and the next tutorial the outline design of the weir and required bed protection are designed. The hydraulic design conditions for the weir and channel were determined in Tutorial 2. Other functional requirements are obtained from other tutorials.

1. Discuss and determine (choose) the main dimensions and characteristics of the weir (crest level, slope angles, permeability, location in the channel).
2. Indicate the (two-dimensional, streamwise-vertical) flow field (including streamlines) that you would expect over this weir. Indicate the regions with increased turbulence.
3. Quantify the hydraulic attack on the bed (protection) downstream of the weir.
4. Determine a stable rock grading for the top layer.

Tutorial 6 Small-scale design aspects - 2

5. Determine a stable filter under the top layer: closed granular filter or geotextile filter.
6. Based on the expected scour downstream of the weir, determine the required length of the bed protection.
7. Draw the layer build-up of the bed protection.