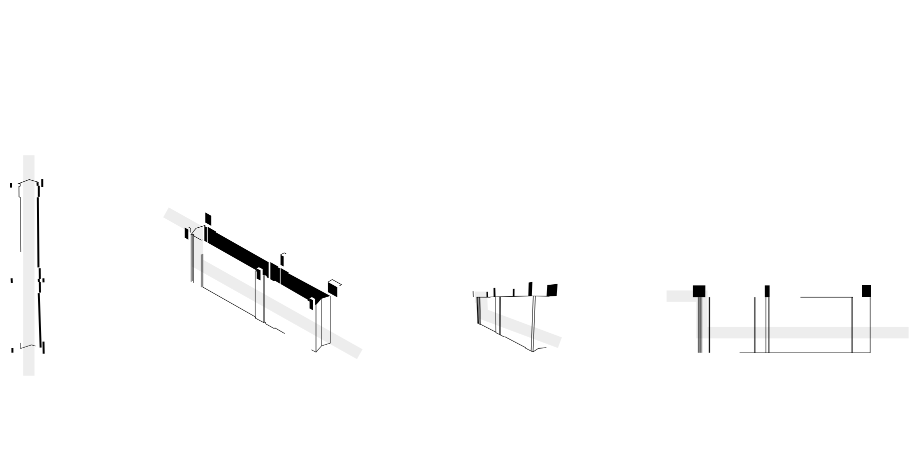
Perspectives on the **IJssel**



Perspectives on the IJssel

Widening solution space in riverine climate adaptation

Cas Goselink

MSc Architecture, Urbanism and Building Sciences

Urbanism Track Graduation Report

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Synopsis

The current approach in riverine climate adaptation strategies aims to accommodate all functionalities of rivers into one singular riverbed, but runs into the limitations of an integrated spatial system. The research shows that the different functionalities of rivers, i.e. the different riverine regimes, in synchronization will lead to a decline in performance of these separate regimes.

This thesis project *Perspectives on the IJssel* explores and illustrates an alternative future for the IJssel, in which an integral approach is paramount but with a methodology build on spatial decomposition rather than spatial integration. The project argues that spatial segregation in parallel systems offers solution space, which has to be seriously considered as a viable result of an integral approach.

Recommended readings:

Methodology:

Dorst, K. (2011). *The core of 'design thinking' and its application*. Design studies, 32(6), 521-53

Location:

Ziel, T. van der, Corporaal, A. (2021) *Atlas van de Ijssel.* Zwolle: Uitgeverij WBOOKS

Context:

Boersma, T., (ed.) (1995). *Nederland als kunstwerk: vijf eeuwen bouwen door ingenieurs*. Rotterdam: NAi Uitgevers.

Acknowledgements

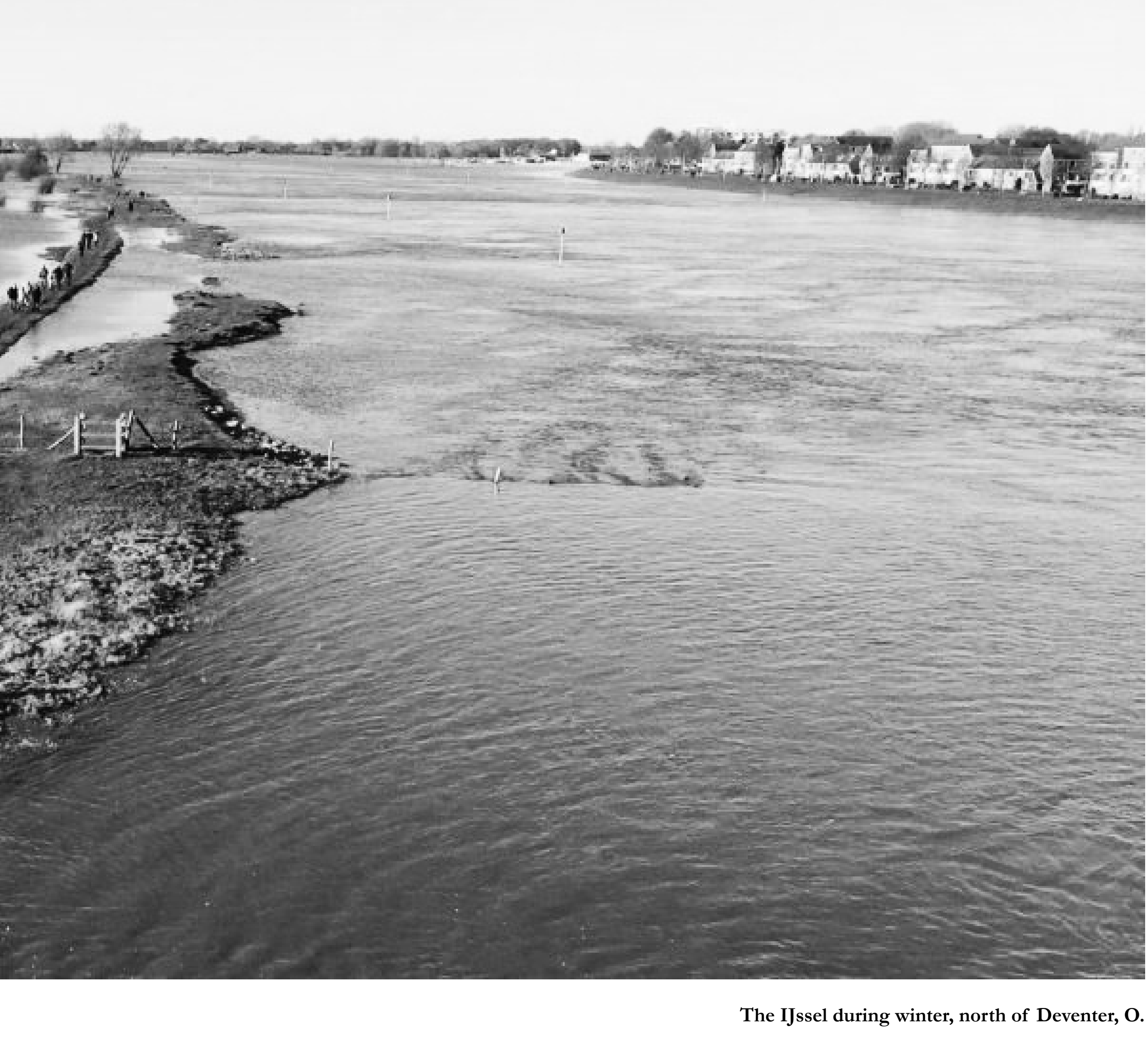
I would like to sincerely thank my main mentor Fransje Hooimeijer, who from the beginning of the thesis project has supported me during this sometimes trying year of the COVID-19 epidemic. Her understanding of the problem field in the Dutch context of engineered and produced landscapes has been a great aid to defining the thesis. Her know-how of methodologies and design instruments within inter- and multi-disciplinary challenges has truly shaped the project.

Also, I would like to thank my second and third mentors Denise Piccinini and Jos Timmermans, who with their extensive knowledge have greatly supported me through in depth discussions on what I was doing, what the purpose could really be and where I was going with the overall project. Their extensive knowledge, professional experience and most of all personal perspectives on the subject have supported me greatly and their influence cannot be underestimated.

Furthermore, I would like to extend my gratitude towards Kees-Jan Leuvenink (Waterschap Rijn & IJssel) and Roel Velner (Sweco) for their involvement and guidance in the Delta Futures Lab Rhine and IJssel project group, through which I have been able to get in contact with several very knowledgeable experts in their different professional fields, and get acquainted with fellow students from different faculties to exchange ideas. This has really helped me to develop and position my work within a larger context of contemporary projects.

The IJssel during summer near Cortenoever, Gld

Figure by Goselink (2021), adapted from: Foto Hissink



The IJssel during winter, north of Deventer, O.

Figure by Goselink (2021), adapted from: Indebuurt Deventer

Overlapping satellite image of the IJssel in both summer and winter near Zwolle, O.

Figure by Goselink (2021), adapted from: Google Maps

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I

Introduction
to the **IJssel**

1.1.1 Thesis Positioning

The project *Perspectives on the IJssel* is focused on the interface between water and water-related territories, located in a lowlands environment. This is aligned with the Transitional Territories studio of the Delta Urbanism Research Group at the Faculty of Architecture and the Built Environment, which focusses on the relation between natural environment, culture and (geo)politics, specifically in relation to marine and riverine territories. The studio provides a platform for interdisciplinary research into the territory under the changing climate regime. This has been combined with participation in the TU Delft Delta Futures Lab research group Rhine and IJssel, an interfaculty collaboration.

The role of urban planning and design in this specific cooperation with engineering and planning disciplines, is to provide a view on the spatial implications of interventions in the environment, posed by (geo) political regulations and infrastructural objects, while keeping liveability, performance and other societal demands in mind. Urbanism education at TU Delft is focussed on both combining knowledge from different disciplines into multiscale projects and proposals, and the embedding of temporal uncertainty in the project (Nijhuis et al. 2017).

As the discipline of urbanism is inherently focussed on spatial processes over time, this spatio-temporal dimension has been experienced to be one of the great assets of the urban designer within interdisciplinary teams research teams.

In relation to the overall MSc AUBS program provided by the Faculty of Architecture and the Built Environment, it is the object of architecture, urban design and spatial planning which physically constitutes the living environment, posed onto the territory and subjected to interior- and exterior forces of change. In the case of this specific project, it is the exterior force of the changing hydrological cycle, and the interior geopolitical force of the proposed modal shift and societal awareness concerning biodiversity and renaturalization. The relevance the project in the larger social, professional and scientific framework is threefold.

First, the problems caused by both extreme peak discharges, as well as droughts with extreme low discharge rates, have been increasing. The predictions show that this is only the beginning of a complete change in the hydrological cycle, encompassing both riverine discharge and hinterland precipitation patterns, and an adaptation strategy is therefore necessary.

Secondly, the literary review concluded that there is a gap in discourse concerning riverine climate adaptation strategies (see Appendix). The separate riverine regimes of flood control, drought management, navigation and eco-hydrology, all propose ideas and strategies related to their own specific needs and values. Integration of those increasingly opposing plans in discourse is not common, and due to the abstract and high scale level of the strategies the details of the plans are often not included in this stage.

It is paramount to visualize the plans, as the role of visualization within complex problem solving is aimed at both precisely defining and understanding the problems at hand, as in the communication between different actors and audiences (Rieber, 1994). Especially in the first stages of an abstract strategy or concept, visualization is important to discuss the viability of the posed solution spaces and identify key concepts and notions.

Thirdly, discourse concerning riverine strategies is often limited to the related practitioners and scholars. As can be seen with the publication of the plan by Baptist et al. (2019), a visualization can lead to a widely spread debate in a broad audience. This is why the project proposes a reconceptualization and visualizes this through the spatial and temporal scales, in order to try and captivate a larger audience, and show how a new view on a centuries old system might lead to the expansion of solution space.

1.1.2 Academic Aims

At the base of the thesis lies the assumption that an urbanist (and designerly) perspective on the reconceptualization of the spatial dimension of the water system can be a valuable addition to contemporary discourse concerning riverine climate adaptation strategies and water management structures. It can aid in widening solution space through research by design Currently, the system is managed by placing objects, after which the surrounding territory can be planned accordingly (Sijmons, 2002). By reversing this process, a spatial design with more positive externalities to society can be created, after which the management of the water system can be implemented. Especially focussing on the issue of drought, the spatial dimension of the surrounding territory has to be taken into account from the start.

As has become apparent during the theoretical research into the contemporary discourse regarding riverine climate adaptation strategies, there are gaps in the scales on which the plans are proposed, and an integrative approach containing different views is needed. This design proposal aims to provide an integrative strategy regarding the 4 identified spatial riverine regimes (Flood control, drought management, navigation and eco-hydrology) and show the impacts of the proposal on the object-, ensemble- and territorial scale. The idea of either integration or separation of the 4 riverine regimes is a guiding principle throughout the scales. In order to increase performance to society, it is paramount not to compromise when it comes to the separate needs of the regimes, and therefore the current state of the integral riverscape (all regimes in one system/flow path) is questioned. A parallel system might be better suited to adjust to site specific conditions, which would lead to a set of junctions between environment, infrastructure and waterscape. By elaborating on the territorial scale, and showing the implications on the architectural scale, the changes in the water management system become apparent and clearly visible for a larger audience. This way, discourse can be stimulated in more detail, involving a broader audience.

The urbanism thesis project aims per definition for the goals of spatial quality, robustness, aesthetics, diversity and relations between scales (Dorst & Duijvestein, 2004). This thesis project will go through the following three scales:

Territorial scale:
The strategy to adapt the riverine territory to the new hydrological cycle and climate regime (based on research into the expected flow rates and precipitation) will identify how the water system should be managed on the scale of the entire river. This will be a quite abstract level of strategizing, focussing mostly on the systemic functioning and less on the spatial conditions the strategy will engage with. This strategy will be mostly made up of diagrammatic drawings.

Ensemble scale:
The embedding of the more abstract overall strategy into the actual territorial conditions of

on the ensemble scale, where the superimposed strategy will be adapted to the conditions of soil, habitat typology, economic importance and urban developments. A special focus will be placed on the integration of the current geopolitical regime of the energy transition, trying to interact with this (invasive) spatial landscape typology. The representation of this scale will result in sections and transects, taken along the river to identify local conditions combined with the hinterland-relation of the river in a set of lateral trenches.

Object scale:
The lowest scale, bordering the architectural level, will show the spatial integration of the water management objects needed by the system to perform, in relation to the newly created territorial form. This will clearly show the implications for users, inhabitants and other actors in the riverine territory, in order to enhance the level of detail of discussion, and engage a broader audience within the decision making process concerning climate change adaptation strategies. Up till now, these have been on a large and abstract level, the object oriented small scale will provide an insight in the changes this will lead to for the local people involved. The visualization of the object scale will result in maps and sections, but mostly isometric spatial models and birds- and eye-level views.

Aims is also to provide a new perspective on the matter, an alternate way of identifying problems and opportunities, which might lead to a reconceptualization of possibilities in the anthropogenic riverscape.

1.1.3 Societal Relevance - the importance of widening solution space now

To this day, we have had several signals of the conditions to come, however a clear pathway forward is still non-existent. Therefore, now is the time to widen solution space and see the different approaches and results, in order to make sure all participants are working towards the same horizon, are on the same page, and do not act on the short term thereby limiting themselves on the long term.

At the same time, lead times can be expected to increase (as well as the time between T1 and T2) in case of a large uncertainty range, e.g. a wide spread in the predictions (Zevenbergen, 2021). As can be seen in the figure to the right, the depicted spread between the high- and low estimates of the Rhine discharge rates is quite large, therefore it is of the upmost importance to think about different types of adaptation measures. The large scale developments and short term interference has to be planned accordingly, while we are still ahead of the lead time.

As complexity and indecisiveness caused by a lack of overview and insight can extend lead times even more. Therefore, the aim of this project is to widen solution space in riverine climate adaptation, in order to provide an alternative solution that can be investigated to be either a viable or a nonviable alternative, which will either way help clear the picture.

Simultaneously, it will aim to put forward a methodology of understanding the complexity of the problem and solution space, which can be implemented to provide an overview of underlying problems.

The aim of the project is to use design as a tool to explore and visualize potential, in order to broaden the audience, thereby indirectly starting to increase societal awareness of different possibilities and creating new potential.
The propositions are made explicit through research by design, reducing possible problems which might occur between actors when conveying thoughts by differences in viewpoint and therefore interpretation.

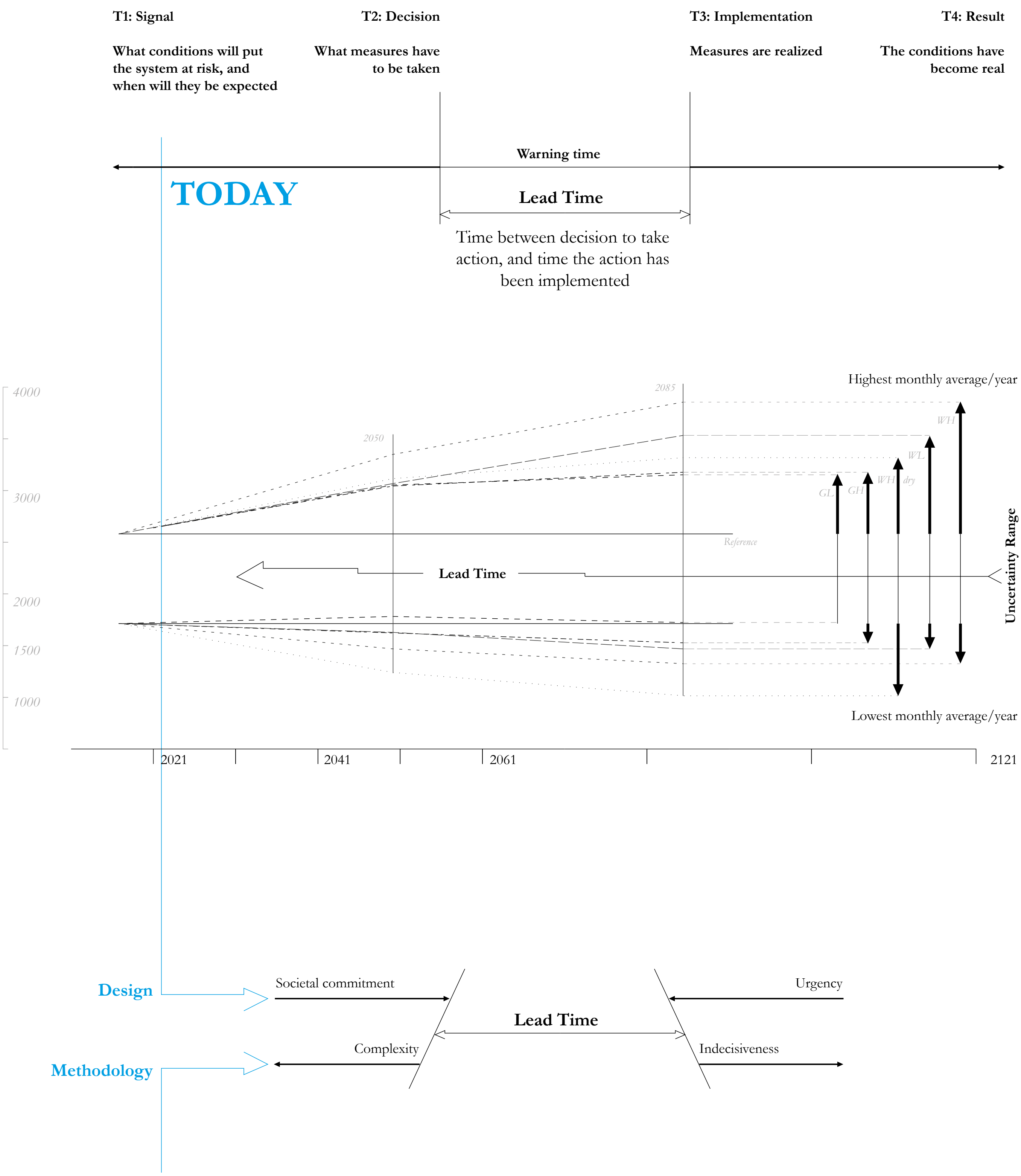
Secondly, the methodology based on separation and deconstruction of the anthropogenic riverine territory aims to create a deeper understanding of the complexity, oppositions and possible complementary aspects of the integral assignment in riverine climate adaptation strategies. This will aid in keeping the complexity manageable, which in turn will decrease lead times in the process.

Figure 1: Time horizon of adaptation measures in the planning proces

Figure by Goselink, 2021

Based on:

Zevenbergen, C. (2021, February 19th). Shifting Time Horizons (in Flood Risk Management) (PowerPoint). Retrieved on: 12-05-2021. Retrieved from: http://deltafutureslab.org/media/


T1: Signal
What conditions will put the system at risk, and when will they be expected
T2: Decision
What measures have to be taken
T3: Implementation
Measures are realized
T4: Result
The conditions have become real
Warning time
TODAY
Lead Time
Time between decision to take action, and time the action has been implemented
Highest monthly average/year
4000
3000
2000
1500
1000
2050
2085
WH
WL
GL
GH
WH
dry
Reference
Lead Time
Uncertainty Range
Lowest monthly average/year
2021
2041
2061
2121
Design
Methodology
Societal commitment
Complexity
Lead Time
Urgency
Indecisiveness

1.1.4 Methodology

The methodology adopted to deal with the complexity of the posed open-ended problem solving challenge is based upon the general problem solving equation as posed by Dorst (2011). The thesis project aims to show the importance and value of design approaches towards interdisciplinary, complex and open-ended problematic scenarios. The first step is to understand its working on an academic level, and value its fundamental difference to other professions and their ways of problem solving. In order to do so, the thesis will continuously adress the subsequent stages of the design thinking process, while simultaneously demonstrating its potential in the conducted design research and experiments.

Three main aspects of the methodology will be elaborated upon; the deliberate and conscious proceeding throughout the design thinking process, the base of spatial decomposition rather than spatial integration, and the use of both integrated (Dutch: integraal) and integrative (Dutch: geïntegreerd) design. The core practice in which design thinking is in growing demand, revolves around the capability for addressing open-ended challenges and complex, contemporary and integral problem fields (Dorst, 2011). Logic problem solving reasoning consists of three elements. The analytical reasoning is shown in the top of the scheme to the right. In these models (Induction and Deduction) either results can be predicted based on an object in relation to its behaviour, or results used to identify the working principle or behaviour of an object (Roozenburg & Eekels, 1995). For productive problem solving, the result is changed into an aspired value, which askes in conventional productive reasoning (engineering) for an object, a system or a service to be produced. This closed problem solving is fundamentally different from the design thinking approach, in which open problem solving demands the construction of both the problem and solution simultaneously: the Abduction – 2 method.

The core of design reasoning is the creation of frames as an implicit and inherent part of the design process. Especially in complex and integrative design assignments, the problematic scenario provides the designer with a central paradox consisting of conflicting statements (Dorst, 2006). This opposition of views, standpoints or requirements is the basis for understanding the situation, relating to both the aspired value and the working principle to solve the equation. Engaging the paradox is done by indirectly identifying the design assignment through themes related to the central paradox, thereby creating an understanding of the underlying phenomenon and potential solution space (van Manen, 1990). This step has been deliberately and extensively worked on in order to visualize this often implicit step within the design process, as it leads to the creation of new solution space and conceptual ideas.

Figure 2: The fundamentals of design reasoning

Figure by Goselink, 2021

Based on:

Dorst, K. (2006). Design problems and design paradoxes. Design Issues, 22 (3) pp. 4-17

Dorst, K. (2011). The core of 'design thinking' and its application. Design studies, 32(6), 521-532

	What Thing	*plus*	**How** Working principle	*leads to*	**Result** Observed	
Analytical Reasoning SCIENCES	**What** Thing		**How** Working principle		**Result** Observed	Deduction
	What Thing		**How** Working principle		**Result** Observed	Induction
Productive Reasoning ENGINEERING	**What** Thing		**How** Working principle		**Value** Aspired	Abduction - 1 - closed problem solving
Productive Reasoning DESIGN	**What** Thing		**How** Working principle	**Central Paradox**	**Value** Aspired	Abduction - 2 - open problem solving

In order to navigate the complex riverine constructs of space, time and socio-technological institutions, the methodology is based on spatial decomposition rather than spatial integration. This allows for the identification of dissonances between spatio-temporal processes and socio-technical regimes, which would be encountered in spatial integration. It simultaneously opens up to a deeper understanding of the design principles, and how these could be reassembled in the (urban) landscape. It amplifies and visualizes the internal opposition within the current status-quo. The process of decomposing and reassembling allows for the evaluation of current spatially integrated approaches, while lead times can be shortened by decomposing the territory and its regimes. This allows for the identification of interrelations and interdependencies between them, which then results in the possibility to rearrange and reassemble them, through which the current state of the territory can be questioned and alternatives can be proposed. It provides options to increase diversity in the discussion, aiming to create a wider base of alternative knowledge upon which decisive argumentation can be built. This will lead to an increase in societal commitment, and a decrease in indecisiveness.

The project encompasses both integrated and integrative design aspects. Integrated approaches towards complex problems have become the standard in riverine climate adaptation strategies, such as the Integrated River Management programme in the Netherlands (Deltaprogramma.nl, n.d.). Integrated design can be explained as the framing of the compatibility of multiple artefact frames (Visser, 2021). In other words, taking multiple services, processes, actors or factors into account when framing the design. This is, as can also be seen in the scheme to the right, also an inherent quality of the open-ended problem solving process (Roozenburg & Eekels, 1995). An integrated design approach however, does not imply an end result in which all factors contribute. It provides an insight in the compatibility between them, after which the choice for incorporation can be made. The integrative design approach is focussed strongly on the end result, looking for synergies among strategies and services through which reciprocal enhancement can be reached (USGSA, n.d.). The thesis project incorporates both the integrated and integrative design to ensure that the complexity of the problem scenario and underlying phenomenon is understood, and the design exercise aims to amplify potential conflicts in relation to the central paradox.

Figure 3: Framing of the internal paradox as key to widening solution space through design thinking

Figure by Goselink, 2021

Based on:

Visser, J. (2021, June 25th). Creating a New Perspective by Integrating Frames Through Design (PowerPoint). Retrieved on: 23-08-2021. Retrieved from: http://deltafutureslab.org/media/

USGSA (n.d.). Integrative Design Process. Retrieved on: 23-08-2021. https://sftool.gov/plan/261/integrative-design-process

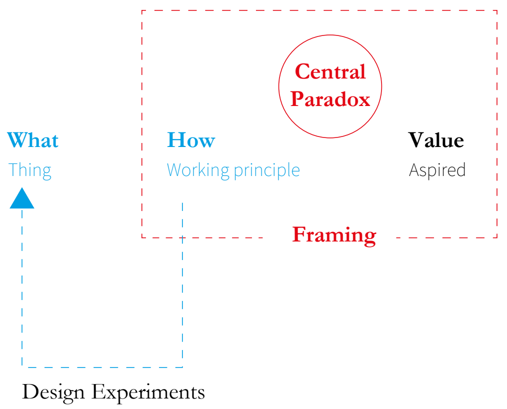
Dorst, K. (2006). Design problems and design paradoxes. Design Issues, 22 (3) pp. 4-17

Dorst, K. (2011). The core of 'design thinking' and its application. Design studies, 32(6), 521-532

Roozenburg, N. F. M., Eekels, J. (1995). Product design: Fundamentals and methods. Wiley, Chichester, England

Manen, M. van, (1990). Researching lived experience. The Althouse Press, Ontario, Canada

Productive Reasoning
DESIGN

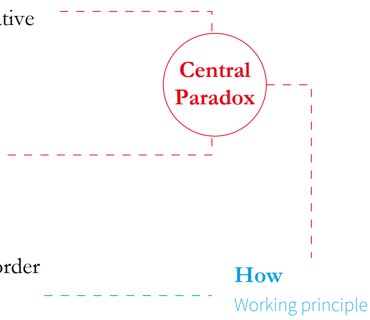


Abduction - 2 - open problem solving

How can the current spatial limitations of riverine territories, caused by the increasingly dynamic shifting hydrological cycle, be mitigated through integrative design?

How can the socio-technical regimes adapt to the shifting hydrological cycle through integrative design of the riverine landscape?

How can riverine territories and their socio-technical regimes synthesize, in order to increase performance output to society?



1.2.1 Location

The IJssel River is a Dutch branch of the Rhine delta system, flowing from the Rhine near Pannerden into the man-made IJsselmeer. The IJssel catchement therefore is part of the overall Rhine catchment, the largest catchment in the northern European Delta. Remarkable is the size of the catchment of the Rhine, which makes it highly susceptible for changes in the hydrological cycle due to climate change. As there is a decreasing amount of snowfall and melt in the Alps, the Rhine is becoming more and more dependent on rainfall in its catchment basin as primary base flow. This inherently means that, in the light of the changing climate and more extreme weather, this base flow is increasingly fluctuating. The IJssel receives a set amount of 1/9th of the total discharge of the Rhine, and will therefore also become increasingly instable with sudden fluctuations in the water level, predicted longer periods of water shortage or even drought, and high water levels threatening inhabitants in case of extreme precipitation.

As predicted changes in the discharge of the Rhine directly influence the flow of the IJssel, these predictions have been included in the research to illustrate the expected alterations.

Figure 4: Location of the IJssel catchment basin within the larger deltaic area

Figure by Goselink, 2021

Based on:

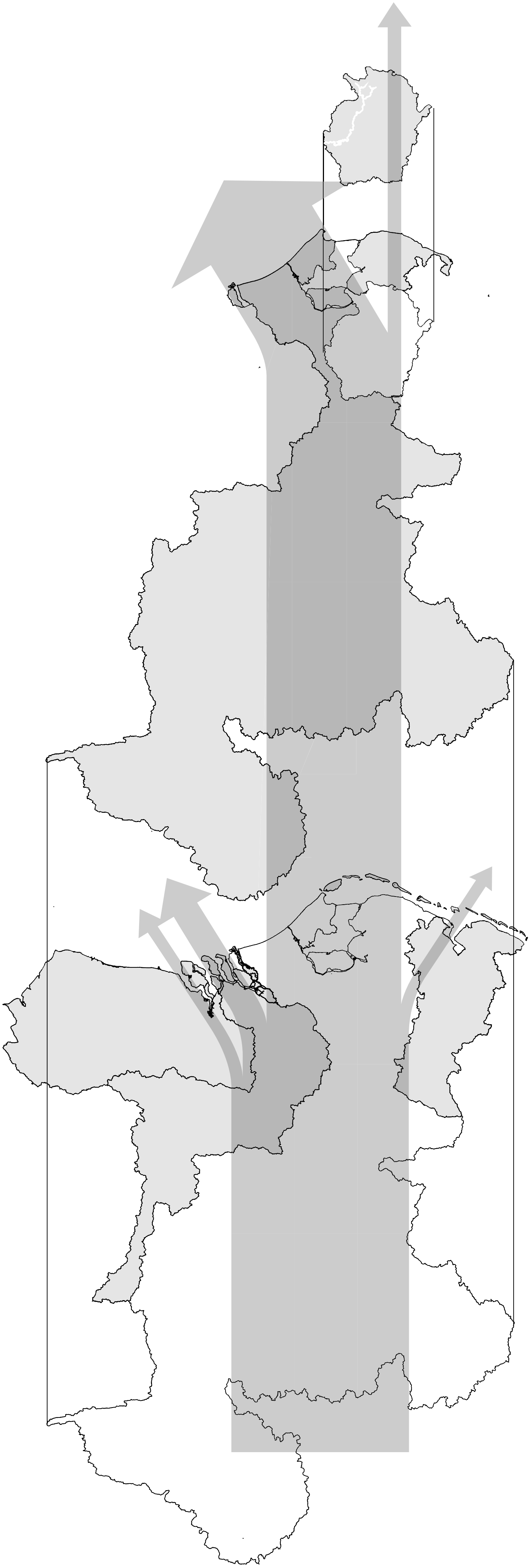
Baeyens, W., Van Eck, B., Lambert, C., Wollast, R., & Goeyens, L. (1998). General description of the Scheldt estuary. In Trace metals in the Westerschelde Estuary: A case-study of a polluted, partially anoxic estuary (pp. 1-14). Springer, Dordrecht.

De Wit, M. J. M., Peeters, H. A., Gastaud, P. H., Dewil, P., Maeghe, K., & Baumgart, J. (2007). Floods in the Meuse basin: Event descriptions and an international view on ongoing measures. International Journal of River Basin Management, 5(4), 279-292.

Kramer, K. J. M., & Duinker, J. C. (1993). The Rhine/Meuse Estuary. In Pollution of the North Sea (pp. 194-212). Springer, Berlin, Heidelberg.

Winterwerp, J. C. (2011). Fine sediment transport by tidal asymmetry in the high-concentrated Ems River: indications for a regime shift in response to channel deepening. Ocean Dynamics, 61(2), 203-215.

Wendland, F., Bogena, H., Goemann, H., Hake, J. F., Kreins, P., & Kunkel, R. (2005). Impact of nitrogen reduction measures on the nitrogen loads of the river Ems and Rhine (Germany). Physics and Chemistry of the Earth, Parts A/B/C, 30(8-10), 527-541.



IJssel Catchment

Catchment area:	11,000	km2
Annual average discharge::	300	m3/s
Low:	*210*	*m3/s*
High:	*1,150*	*m3/s*

Rhine Catchment

Catchment area:	185,000	km2
Average discharge::	2,200	m3/s
Low:	*980*	*m3/s*
High:	*9,400*	*m3/s*

Northwestern European Delta
Scheldt - Meuse - Rhine - Ems

Catchment area:	272,000	km2
Average discharge::	2,754	m3/s
Low:	*1,050*	*m3/s*
High:	*13,400*	*m3/s*

1.2.2 Problem Description

In recent years, mostly since the extreme drought in the Netherlands of 2018, the fragility of the Dutch river system has become apparent in common discourse as can be seen in the newspaper clippings to the right. The Rhine, which constitutes most of the Dutch delta system through its branches, is becoming increasingly influenced by climate change.

The riverscape has been continuously adapted to increase usability over the past centuries, focusing on riverine regimes of flood control and navigation (Sijmons, 2002).The premises has always been to maximize discharge capacity. In the face of a rapidly changing climate regime, the extreme pluvial events in catchment basins, alternated with periods of water shortage or even drought, form a real threat to the riverscape and its uses (Tol et al., 2003). In order to be able to maintain the intricate riverine systems, adaptation to the new climate regime and hydrological cycle is paramount. The water levels in the rivers will become highly dependent on the amount of precipitation in the catchment basin, and therefore discharge levels will fluctuate increasingly high and sudden (Attema et al., 2014).

The typical Dutch landscape, characterized by its austerity and functionality, has always been planned along the confines created by water management systems (Sijmons, 2002). When the Rhine is becoming a rain river, it could lead to the complete de-naturalization of the system in order to sustain our economic needs in relation to the EU Green Deal (Kraaijvanger & Lindeboom, 2019). The consideration of canalizing the Rhine has been put off until now, but might have to be seriously reconsidered. On the other hand, the new climatic reality would create possibilities to rethink the relation between human and natural systems, leading to a more nature-based approach towards managing water (Baptist et al., 2019). The IJssel, being a branch with a set discharge of 1/9th of the total flow of the Rhine, is especially interesting as it does not only support an international riverine transport system, but also plays an important role in the fresh water supply to the drought stricken north and east of the Netherlands and supplying the IJsselmeer fresh water storage.

This duality of the problem for the IJssel River basin adds to the stress the territory is about to experience, and underpins the importance to rethink the anthropogenic riverine water system and its territory.

Figure 5: News articles related to the new threat of drought, experienced throughout 2018, '19 and '20.

Figure by Goselink, 2021

Based on:

Kraaijenbrink, H., Lindeboom, P. (2019). De Rijn wordt een regenrivier, tijd voor stuwen en sluizen. Retrieved on: 07-11-2020. Retrieved From: https://www.nrc.nl/nieuws/2019/12/18/de-rijn-wordt-een-regenrivier-tijd-voor-stuwen-en-sluizen-a3984309

Reijnen Rutten, E. (2020). Wegzakkende IJssel dreigt onbevaarbaar te worden. Retrieved on: 07-11-2020. Retrieved from: https://www.destentor.nl/deventer/wegzakkende-ijssel-dreigt-onbevaarbaar-te-worden~a2cede30/

Wismans, L. (2020). Draaien aan de knop van de nationale regenton. Retrieved on: 06-11-2020. Retrieved from: https://www.nrc.nl/nieuws/2020/08/18/draaien-aan-de-knop-van-de-nationale-regenton-a4009091

Yang Yang, C. (2018). Opgesloten schippers mogen deventer haven verlaten. Retrieved on: 07-11-2020. Retrieved from: https://www.destentor.nl/deventer/opgesloten-schippers-mogen-deventer-haven-verlaten~aa1ff892/

O opinie

18 december 2019

De Rijn wordt een regenrivier, tijd voor stuwen en sluizen

Transport In Rijn en Waal zal de waterstand vaker laag zijn. Om Rotterdam bereikbaar te houden is nu actie nodig, schrijven *Peter Lindeboom* en *Henk Kraaijenbrink*.

Wegzakkende IJssel dreigt onbevaarbaar te worden

De IJssel en Waal dreigen in tijden van droogte onbevaarbaar te worden door het almaar verder wegzakken van de rivierbodem. Waar de aandacht lang vooral naar bescherming tegen hoog water ging, moet nu samen met buurlanden en binnenvaart werk gemaakt worden van het waterpeil in de rivier.

Eric Reijnen Rutten 24-01-20, 06:30 Laatste update: 09:05

Reportage

Draaien aan de knop van de nationale regenton

Periodes van droogte zullen vaker voorkomen. Nederland moet zich aanpassen. Aflevering 7 uit een serie: de stuwen, sluizen en kokers bij het IJsselmeer.

Laura Wismans 18 augustus 2020 Leestijd 3 minuten

Opgesloten schippers mogen Deventer haven verlaten

VIDEO De vijf schippers die 4,5 week geleden door de lage stand van de IJssel vast kwamen te liggen in Deventer, mogen vandaag de haven verlaten. Het eerste schip koos even voor 10.00 uur het ruime sop.

Yang Yang Chiu 06-09-18, 09:00 Laatste update: 16:59

1.2.3 Problem Operationalisation

In order to be able to pinpoint and address the problems identified within the problem field, the narrative has to be operationalized into concepts and themes which can be researched separately and in relation to one another. The primary research question to be answered during the research and design is:

How can *integrative design* of **riverine territories** with inclusion of **socio-technical regimes**, result in water management systems adapted to the **shifting hydrological cycle**, while *increasing performance* to society?

Integrated design (Id) is an approach, which is used in order to achieve the aim of increasing overall performance (P) of the water management system to society. The key concepts are riverine territories, the socio-technical regimes which inhabit the riverscape, and the external pressure of the shifting hydrological cycle.

A: Riverine Territories

The physical landscape encompassing both the riverbed and floodplains itself, as well as the connection to the hinterland surface- and subsurface aquatic and ecologic flow paths.

B: Socio-technical Regimes

The institutions inhabiting and influencing the space and functioning of the riverine landscape. Although historically navigation and flood control have dominated the riverine landscape, the equation has been extended in the past decades. The identified four primary regimes are; 1) Navigation, 2) Flood Control, 3) Drought Management and 4) Eco-hydrology.

C: Shifting hydrological cycle

Patterns of precipitation and riverine discharge, influenced by the changing climate. A projected increasingly dynamic cycle, in which precipitation shortages lead to elongated periods of meteorological drought in the hinterland during summer and fall, combined with lowering riverine base flows. Simultaneously, extreme precipitation events during winter and spring, accompanied by increasingly high river discharges.

Three secondary questions pair up the three previously mentioned concepts, in order to identify the interconnectivity between them. The conceptual framework to the right shows the interdependency. The riverine territories and socio-technical regimes are first separately researched in relation to the context of the shifting hydrological cycle, after which the territories and regimes are matched up to identify the possibilities to synthesize both, resulting in an increased performance output.

In order to make the design process explicit, the core practice of framing is often an implicit process for designers (Dorst, 2011). For this thesis, it has been consciously and deliberately carried out, and is explicitly divided into two parts accompanied by sub questions. This amplifies and highlights the importance of the stage within design thinking and researching, as a large part of the complete reasoning and finding of new solution spaces simultaneously with the framing of the problem (construct problem and solution simultaneously) takes place within this section.

[**A**]	[**B**]	[**C**]	[*Id*]	[*P*]
The territory including - but not limited to - the riverbed and floodplains, including hydrological and ecological corridors	Socio-technological and often partially environmental institutions functioning in direct relation to the river	Patterns of precipitation, riverine discharge and soil/atmospheric water pressure - which are shifting due to climate change	Approach towards the design process aiming at the synthesis of complementary systems in order to enhance one another	The output of the specific system to society in relation to economic, environmental and sustainability goals

How can the current spatial limitations of **riverine territories**, caused by the increasingly dynamic **shifting hydrological cycle**, be mitigated through *integrative design*?

[**A**] + [**C**] *in relation to* [*Id*]

How can the **socio-technical regimes** adapt to the **shifting hydrological cycle** through *integrative design* of the riverine landscape?

[**B**] + [**C**] *in relation to* [*Id*]

How can **riverine territories** and their **socio-technical regimes** synthesize, in order to *increase performance* output to society?

[**A**] + [**B**] *in relation to* [*P*]

DESIGN EXPERIMENT

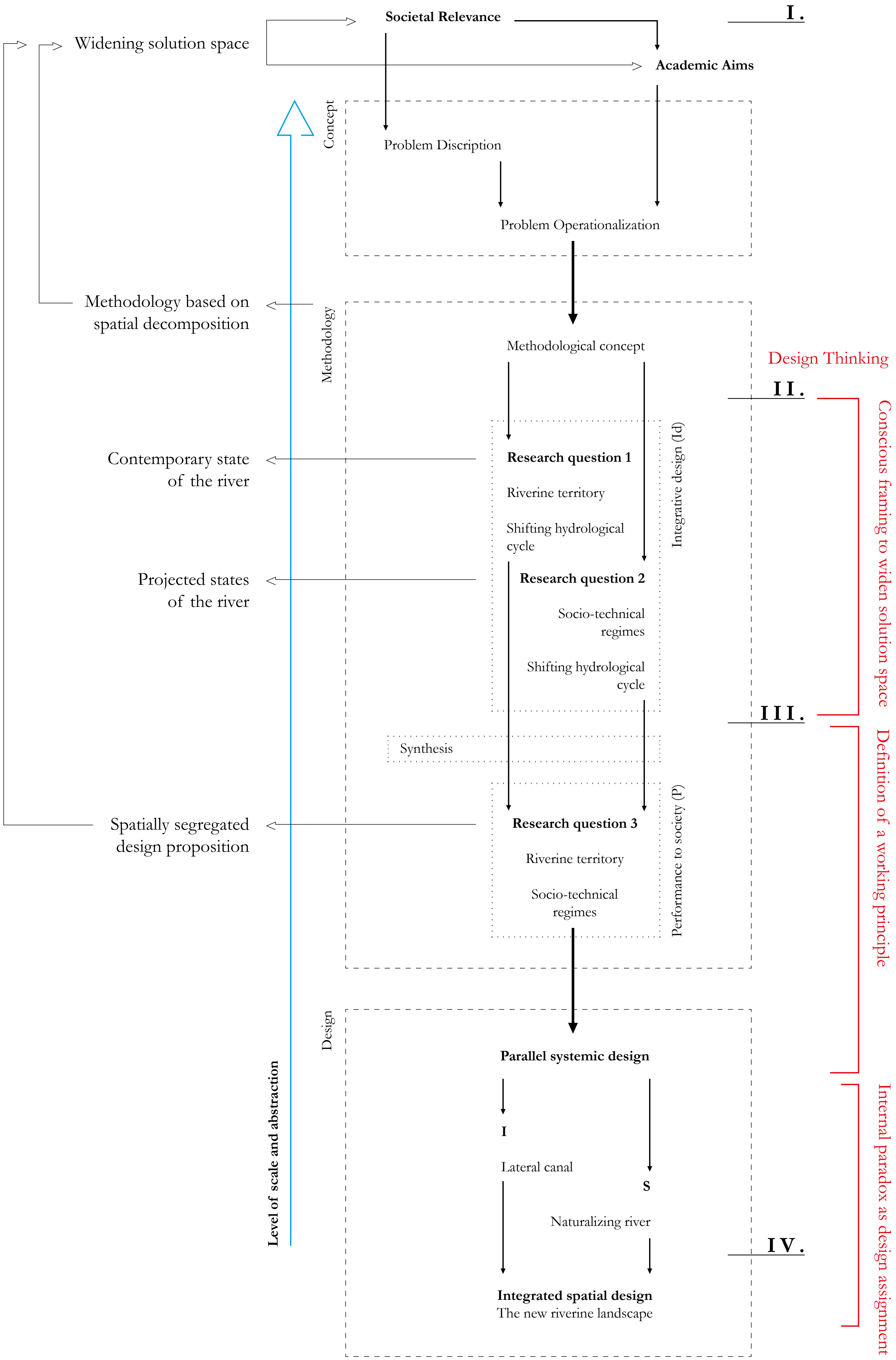
1.1.4 Thesis Guide

The aim of this thesis project is to widen solution space in riverine climate adaptation discourse. The report presents a methodology of spatial decomposition to understand the fundamental spatial characteristics of both the riverine territory and socio-technical regimes, bringing them together through a systemic process of parallelization and integration. The model to the right shows the structure of the report.

From the initial societal relevance and academic aims of the project, the problem description and operationalization in relation to the shifting hydrological cycle are defined. This provides the methodological structure of the Research by Design process, which will start in chapter II. The first two research questions will be investigated in light of the integrative design approach, and will simultaneously provide input for the third research question which will conceptualize upon the findings in relation to the performance of the landscape and socio-technical output in chapter III. The parallel complementary designs will eventually be projected onto a conflicted territory in the final, spatial design in chapter IV. In order to be able to discuss and evaluate this design, it is of vital importance to see it within the historic framework of adaptations to the riverscape, therefore a landscape biography has been composed. The evaluation of the design will also provide a combined evaluation on the proposed research methodology itself, which is also considered to be a vital result of the thesis project.

Figure 6: Methodological thesis framework

Figure by Goselink, 2021


Societal Relevance
Academic Aims
I.
Widening solution space
Concept
Problem Discription
Problem Operationalization
Methodology based on
spatial decomposition
Methodology
Methodological concept
Design Thinking
II.
Integrative design (Id)
Research question 1
Riverine territory
Shifting hydrological
cycle
Contemporary state
of the river
Research question 2
Socio-technical
regimes
Shifting hydrological
cycle
Projected states
of the river
Conscious framing to widen solution space
III.
Synthesis
Definition of a working principle
Performance to society (P)
Research question 3
Riverine territory
Socio-technical
regimes
Spatially segregated
design proposition
Design
Parallel systemic design
I
Lateral canal
S
Naturalizing river
IV.
Integrated spatial design
The new riverine landscape
Level of scale and abstraction
Internal paradox as design assignment

0 3 4

II

Separation from the IJssel

Or the conscious framing to adopt a viewpoint

2.1.1 Monograph Series

The monograph series aims to answer the first sub question: How can the current spatial limitations of riverine territories, caused by the increasingly dynamic shifting hydrological cycle, be mitigated through integrative design? The result of the research will be an understanding of the compositions, alterations and limitations of the anthropogenic riverscape, which will conclude in a design proposition. This proposition will form the base of the integrative design experiment.

Through the process of decomposition, abstraction and interpretation of single elementary narratives of the contemporary anthropogenic river, an understanding of the composed riverscape as an integral project emerges. The critical identification of the spatial principles of riverine territories consists of processes, taking place in the riverine space over a time scale.

The current state of the riverbed and floodplains is a manifestation of human interference in an underlying natural system. The successive cartographies on matter, topos, habitat and geopolitics identify the criticalities posed by objects of past interference in relation to projected fluvial changes, combined in spatio-temporal diagrams. The monographs series will subsequently research (See appendix for full work):

Matter: water and the anthropogenic riverscape

The only way to fully understand the system of the Dutch anthropogenic riverscape, is to identify the characteristic elements which are put in place to control the matter, and the anthropogenic remnants of rigidity binding fluidity in place.

Topos: fluidity through fixation

The dual processes of erosion and sedimentation taking place within the natural riverine flow regime, manifest the fluidity of riverine territories through the fixation of sediment, which is eliminated by interference in migrational patterns.

Habitat: competitive patterns

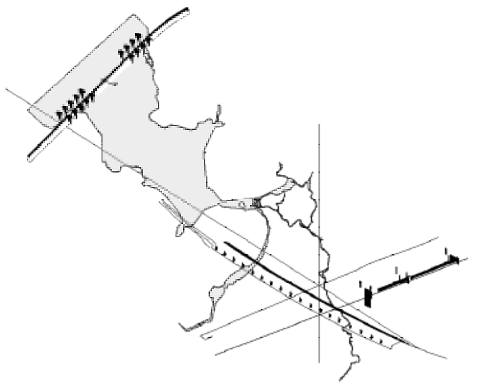
The pattern of human inhabitation has successively co-existed, dominated and virtually eliminated the natural habitat structures in place, competing with natural riverine flows, regimes and structures to ensure usage to the maximum human potential, leading to disconnectivity.

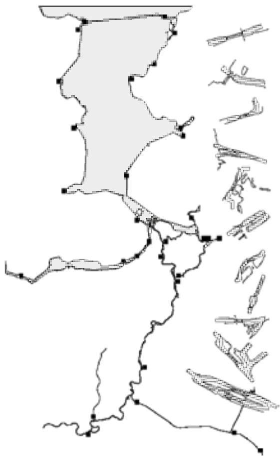
(geo)Politics: natural regimes and artificial territories through landscape proximity

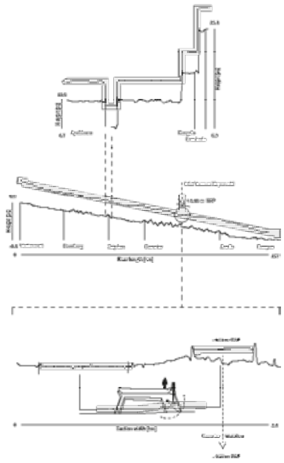
The Dutch land- and riverscapes are patchworks of disconnected and partially conflicting spatial representations of former geographical political paradigms and discourses, the temporality of which manifests itself through sequences and shifts.

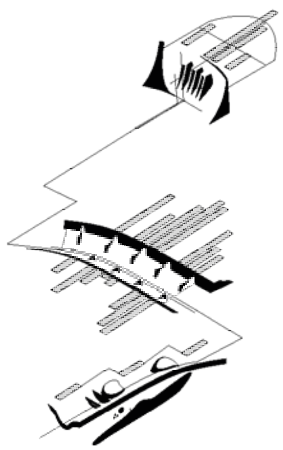
Figure 7: Overview of monographs on the concept, compositioin and alteration of the anthropogenic riverscape

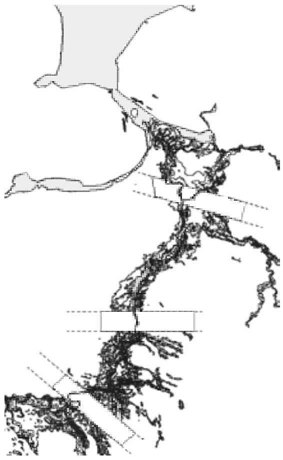
Figure by Goselink, 2021

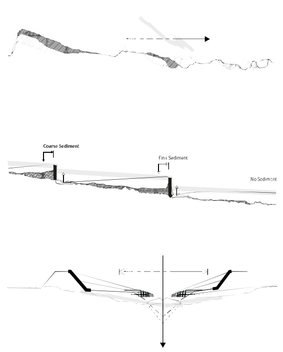


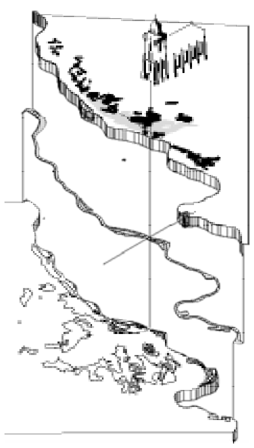


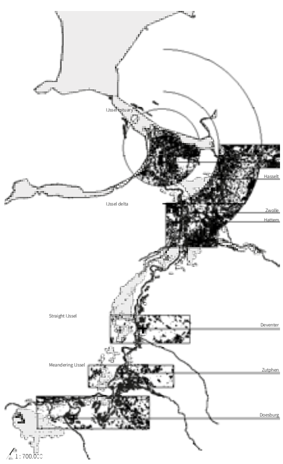


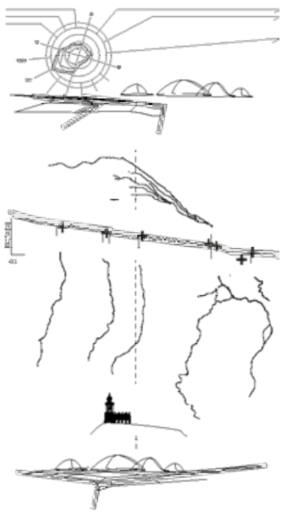


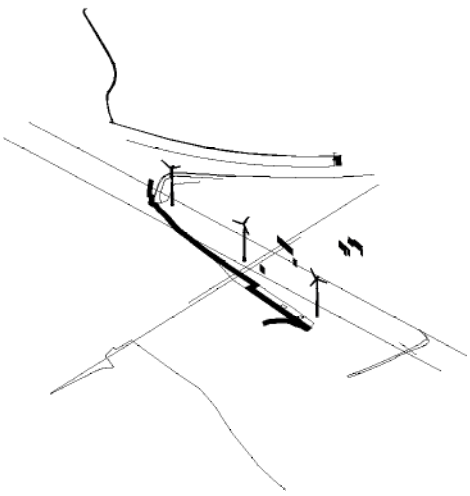


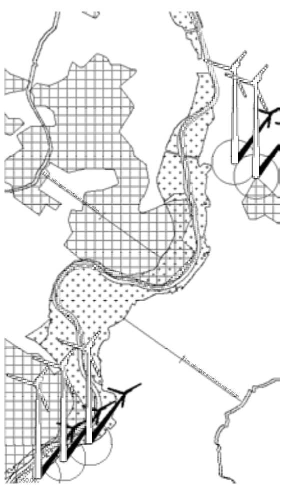

Coarse Sediment
Fine Sediment
No Sediment

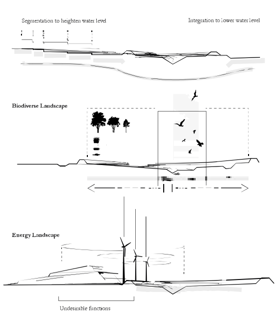



Deventer
Zutphen
Doesburg








Production Landscape
Segmentation to heighten water level
Integration to lower water level
Biodiverse Landscape
Energy Landscape
Undesirable functions

2.1.2 Matter - Properties of Water

As the Dutch river- and landscape has been continuously adapted to increase functionality over the past centuries, the delta can be described as an anthropogenic river system (Sijmons, 2002). Therefore, the only way to fully understand the system of the Dutch anthropogenic riverscape, is to identify the characteristic elements which are put in place to manage it. These remnants of rigidity portray the desire to control the fluidity inherently connected to the delta. The objects are necessary in order to manipulate the water table, ensuring both navigability across sloped terrain, and precise management of water levels for safety of the surrounding territory. Most of the objects were placed in the 1950s and '60s (HSSN, n.d.).

Next to the rigid infrastructural objects, the temporal dimension of the water system, the high water canal near Veessen - Wapenveld is depicted. This recently constructed weir will open its floodgates when the riverine water level reaches + 5.65 m NAP, after which a controlled flow of water will be stored in a neighbouring polder (De Ingenieur, 2017). The riverine water level at the site drops by 0.71 meters, however the effects are still being witnessed 17 kilometres downstream at Deventer.

The spatio-temporal diagram to the right shows the current (reference) discharge levels of the Rhine, along with the predictions for 2050 and 2085 (Attema et al., 2014). Due to the rapidly changing climate regime, the extreme pluvial events in catchment basins, alternated with periods of water shortage or even drought, form a real threat to the contemporary anthropogenic riverscape and its uses (Tol et al., 2003). In December, January and February, extreme peak discharges will have to be managed in order to ensure safety for all inhabitants. During the dry months of August, September and October, water levels will be too low for river navigation, and locks will be unable to function, depriving factories of their raw materials. In general, concluding on the objects of the anthropogenic riverscape, is the system too rigid to cope with climate change as it sits now.

Figure 8: Limitations of the anthropogenic riverscape in relation to the shifting hydrological cycle

Figure by Goselink, 2021

Based on:

AHN (n.d.). Actueel Hoogtebestand Nederland. Retrieved on: 30-11-2020. Retrieved from: https://ahn.arcgisonline.nl/ahnviewer/

Attema, J., Bakker, A., Beersma, J., Bessembinder, J., Boers, R., Brandsma, T., Hazeleger, W. (2014). KNMI'14: Climate change scenarios for the 21st century—A netherlands perspective. KNMI: De Bilt, The Netherlands.

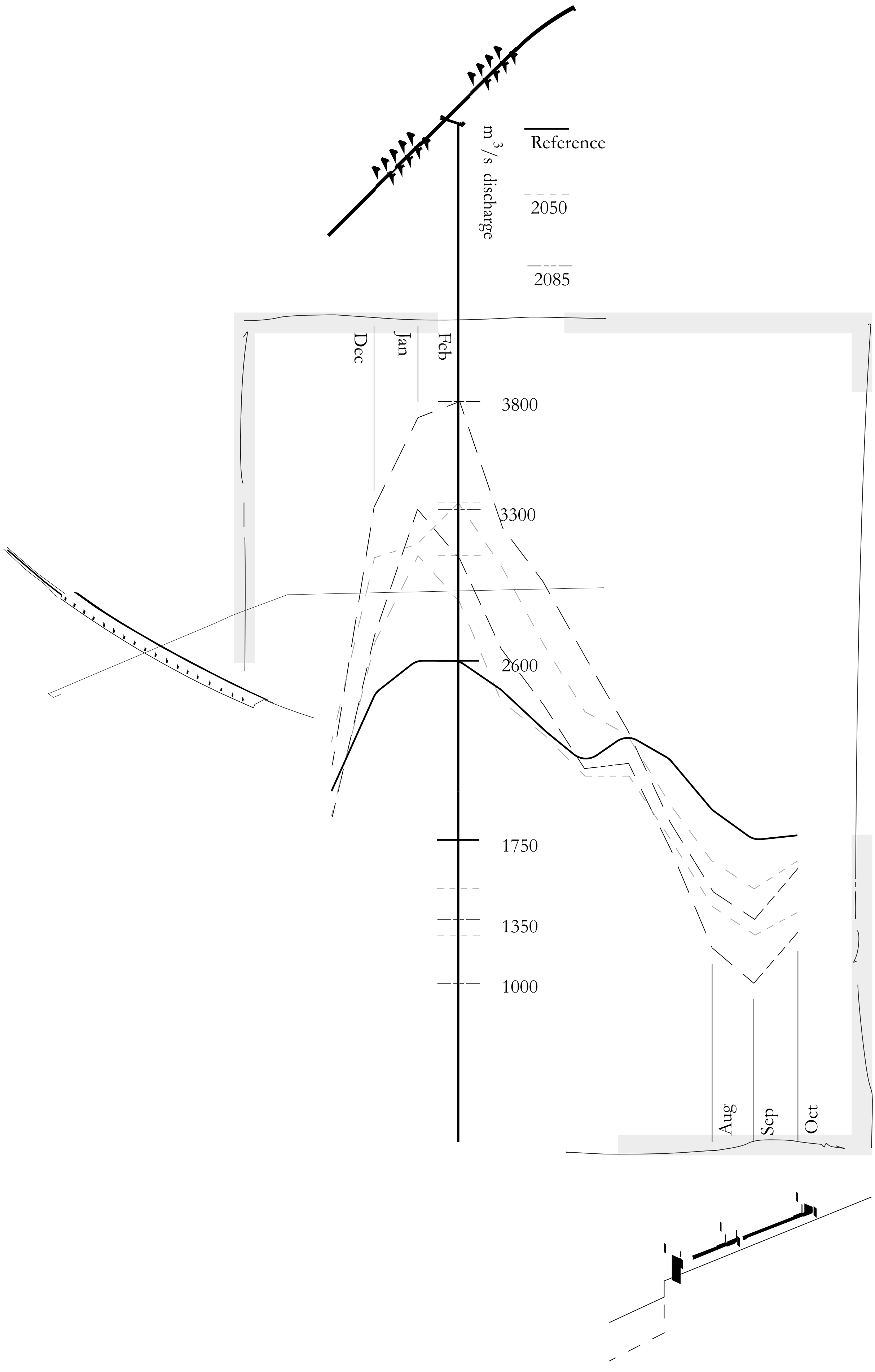
De Ingenieur (2017). Hoogwatergeul voor de IJssel. Retrieved on: 08-10-2020. Retrieved from: https://www.deingenieur.nl/artikel/hoogwatergeul-voor-de-ijssel

HSSN (n.d.). Historische Sluizen en Stuwen in Nederland. Retrieved on: 24-12-2020. Retrieved from: https://www.sluizenenstuwen.nl/geschiedenis_van_sluizen_en_stuwen.asp

Klijn, F (2020, November 20th). The development of the Rhine River's flood management: past, current and future issues (PowerPoint). Retrieved on: 26-11-2020. Retrieved from: http://deltafutureslab.org/media/

Sijmons, D. (2002). Landkaartmos en andere beschouwingen over landschap [Map moss and other contemplations on landscap]. Rotterdam: Uitgeverij 010.

Tol, R. S., Van Der Grijp, N., Olsthoorn, A. A., & Van Der Werff, P. E. (2003). Adapting to climate: a case study on riverine flood risks in the Netherlands. Risk Analysis: An International Journal, 23(3), 575-583.


m³/s discharge
Reference
2050
2085
Dec
Jan
Feb
3800
3300
2600
1750
1350
1000
Aug
Sep
Oct

2.1.3 Topos - Functioning of Water

The riverscape is composed of out of a set of geomorphological elements, created by the processes of terraforming and erasure over time. These dual processes manifest the fluidity of riverine territories through the fixation of their elements of movement, the particles of sand and clay. Amongst the most important terraforming elements are river dunes and fluvial deposits of clay in the floodplains. Erasure is characterized through the meander gully patterns and worn-down crevasse gullies (Geologische Dienst Nederland, 2020). In relation to the current river, the influence the IJssel used to have on the surrounding territory in its natural form exceeds its current streambed immensely.

Most sediment carried in the riverine system is moving downstream from its origins in the Swiss Alps. Due to the creation of weirs, locks and hydropower plants (mostly in Switzerland and Germany) the carrying capacity of sediment in the longitudinal direction is largely eliminated. Through the creation of straight rivers and hard embankments, lateral movement is limited. The addition of groins into the riverscape has further eliminated the terraforming and erasure processes, which combined with the normalisation has led to scouring of the riverbeds.

Through the continuous human interference in the riverine system, the dual processes of terraforming and erasure, or sedimentation and erosion, have effectively been eliminated. The spatio-temporal diagram to the right shows on the vertical axis the timeline of taking space from the rivers, the total amount which is taken from all rhine related streambeds in the Netherlands (Hooijer et al., 2002). Interesting is the recent example of the Room for the River project, which has started a reversed pattern. All in all, over two thirds of space was taken from the rivers in the past 170 years, an immense amount. The spatial characteristics of these practices are the straightened riverbanks, and dikes and rigid embankments alongside that. The straightjacketing has, in combination with the addition of groins to ensure a clear river channel to benefit navigation, lead to the continuous scouring of the riverbed, as is shown in the bottom of the diagram. Since 1901, the riverbed near Lobith, where the Rhine enters the Netherlands, scoured almost 2 meters. Firstly, this means more water is needed to connect the river to the floodplain level of the surrounding territory, causing a territorial disconnection. Secondly, the subsurface scouring has different rates in relation to the soil characteristics and possible underground infrastructure, leading to underwater levees and ponds hindering shipping during low water levels.

Figure 9: Limiting of lateral transmission and translation

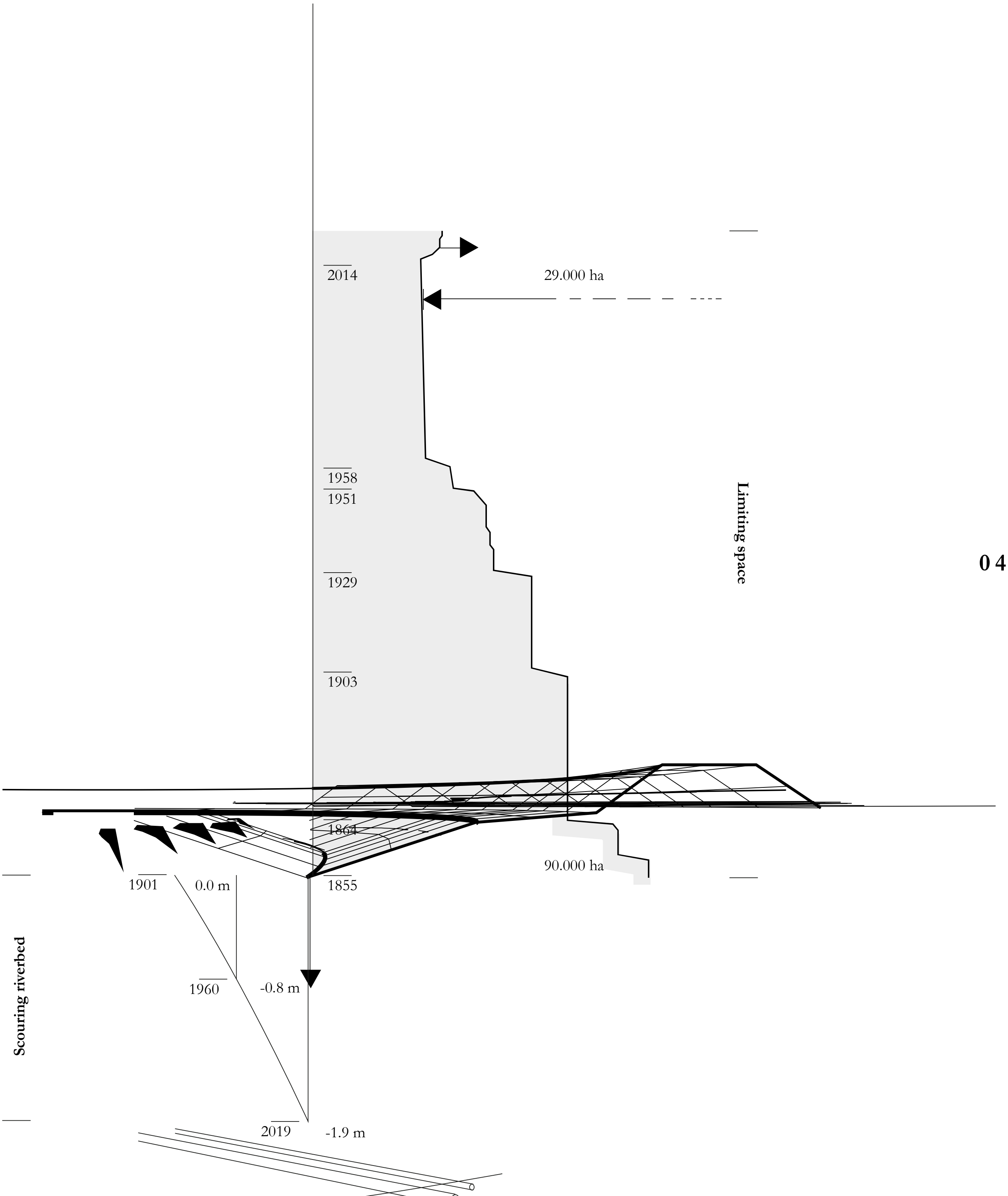
Figure by Goselink, 2021

Based on:

Geologische Dienst Nederland (2020). Geomorfologische Kaart Nederland. Retrieved on: 29-09-2020. Retrieved from: https://www.dinoloket.nl/modeldeliverylogic-web/rest/deliver/delivery/ad46ebaa-c595-45e2-b309-6def7148d680

Hooijer, A., Klijn, F., Kwadijk, J., & Pedroli, B. (2002). Towards sustainable flood risk management in the Rhine and Meuse River basins. Irma Sponge summary document.

Klijn, F (2020, November 20th). The development of the Rhine River's flood management: past, current and future issues (PowerPoint). Retrieved on: 26-11-2020. Retrieved from: http://deltafutureslab.org/media/



2014
29.000 ha
1958
1951
1929
1903
1864
1855
90.000 ha
Limiting space
1901
0.0 m
1960
-0.8 m
Scouring riverbed
2019
-1.9 m

2.1.4 Habitat - Assets of Water

Inhabitational patterns follow a clear construct. Deventer and Zutphen are amongst the oldest urban settlements of the Netherlands, located on the high river dunes to the east of the river, on junctions with tributary streambeds (Geologische Dienst Nederland, 2020).

The creation of the habitat diversity in the area happened through the interplay of soil, water and air. The meandering river with its parallel tributaries and floodplain to the west continuously deposited and exposed sand particles, after which they were blown onto the dunes on the eastern riverbank by the predominantly south-western winds. These river dunes and high sandy terraces then were built upon and strengthened with pavement and vegetation, creating solid raised foundations suitable for safe and long-term inhabitation close to the river. Through the process of inhabitation, the naturally opposing habitats were slowly bound in rigid structures, decreasing its natural free-flowing and dynamic character.

The resulting and ongoing competition for space in riverine environments can be characterized as a dynamic process, as the free flowing river migrates and changes the surrounding territory continuously. The spatio-temporal diagram to the right shows a fictional riverine flow regime with occasional flooding or peak discharge. The natural process of ecological regeneration after this disturbance event gradually reclaims its territory, followed by a continuous ecological cycle of succession of species, creating a high amount of habitat diversity along the river. After every disturbance event, depending on the severity of the flooding, and the specific site of the flooding, the process will (partially) start over.

The level of human inhabitation however does not reset and start over, as flooding leads to the creation of protective levees and embankments, creating a safe and liveable environment, rigid within the dynamics of the riverine territory. From the moment of inhabitation, human habitat takes over the dynamic natural character of the place, leading to monoculture and human-dominated territory instead of a cyclical, diverse and ever-changing riverscape.

The horizontal axis depicting the height of the terrain, shows how the human habitat moved from the safe and high grounds, into the low floodplains and riverbanks, increasing the need for ever growing dikes.

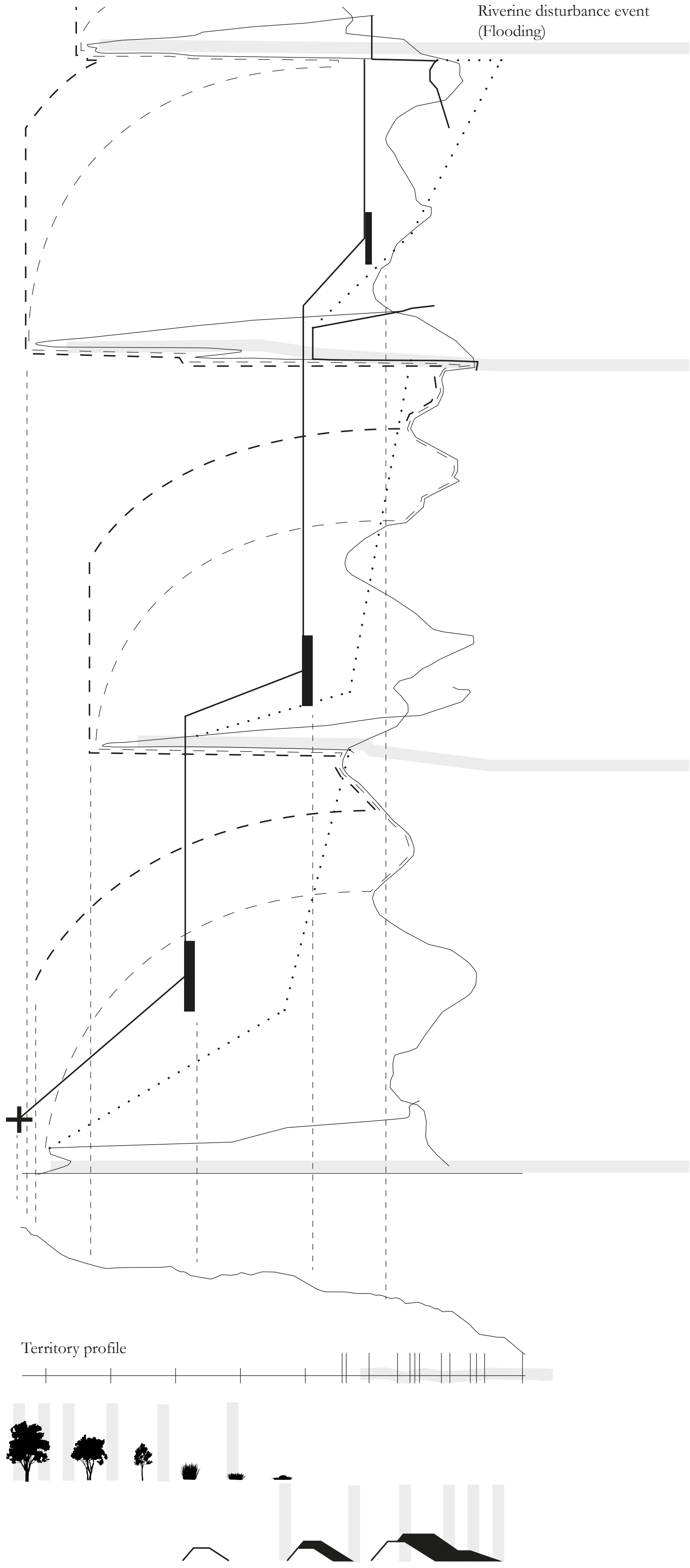
Figure 10: Cyclical competition for riverine habitat between Anthropogenic and natural processes

Figure by Goselink, 2021

Based on:

Geologische Dienst Nederland (2020). Geomorfologische Kaart Nederland. Retrieved on: 29-09-2020. Retrieved from: https://www.dinoloket.nl/modeldeliverylogic-web/rest/deliver/delivery/ad46ebaa-c595-45e2-b309-6def7148d680

Rijksdienst voor het Cultureel Erfgoed (n.d.) De opkomst van de stad: 1000 - 1500. Retrieved on: 24-12-2020. Retrieved from: https://www.landschapinnederland.nl/de-opkomst-van-de-stad-1000-%E2%80%93-1500-0


Riverine disturbance event
(Flooding)
Territory profile

2.1.5 Geopolitics - Representations of Water

The selected three geopolitical representations of production-, nature- and energy landscapes have resulted in specific cultural landscapes. In relation to the production landscape, three generations of re-allotment typologies are recognizable in the landscape. With the establishment of the Vogelrichtlijn in 1979 and the Habitatrichtlijn in 1992, which were combined into the Natura2000 protection areas, the trajectory of the river was appointed a nature zone (Vogelbescherming Nederland, n.d.).

Next to the patches of production landscape, bordering the ongoing natural landscape around the river, recently they are interfered by the upcoming energy landscapes of windmills and solar plants, adding a third generation to the patchwork of geopolitical representations. The spatio-temporal diagram to the right indicates the landscape proximity, i.e. a measurement of how close the current landscape is to the natural sub layer. It becomes clear that although the landscape became more and more detached in the mid-20th century, the nature landscape has brought it (partially) closer. What also becomes clear is the relation between the separate geopolitical representations, and the fact that they are dispersing into different directions when looking at the landscape proximity. An increasing gap is starting to appear between the natural landscapes for example, and the energy landscape.

Where the natural landscape is posing limits outwards across other representation fields, the energy landscape is doing the same in exactly the opposite direction, causing ridges and creases in of misalignment in the landscape flows. The physical interference of geopolitics, most directly visible in the production landscape re-allotment plots, shows the processes have mostly been executed throughout the second and third phases of re-allotments. The second generation (1954-1984) and later the current generation (1985-now) pay more attention to the existing pre-allotment structures, interfering on a smaller scale with more attention to existing landscape structures.

In general it can be said that all of the geopolitical representations in the riverine landscape interfere with the former and more natural network, however the politics are evolving from direct interference in the physical territory, towards regulation of use and behaviour of inhabitants in the territory.

Figure 11: Landscape proximity in relation to the spatial alterations over time

Figure by Goselink, 2021

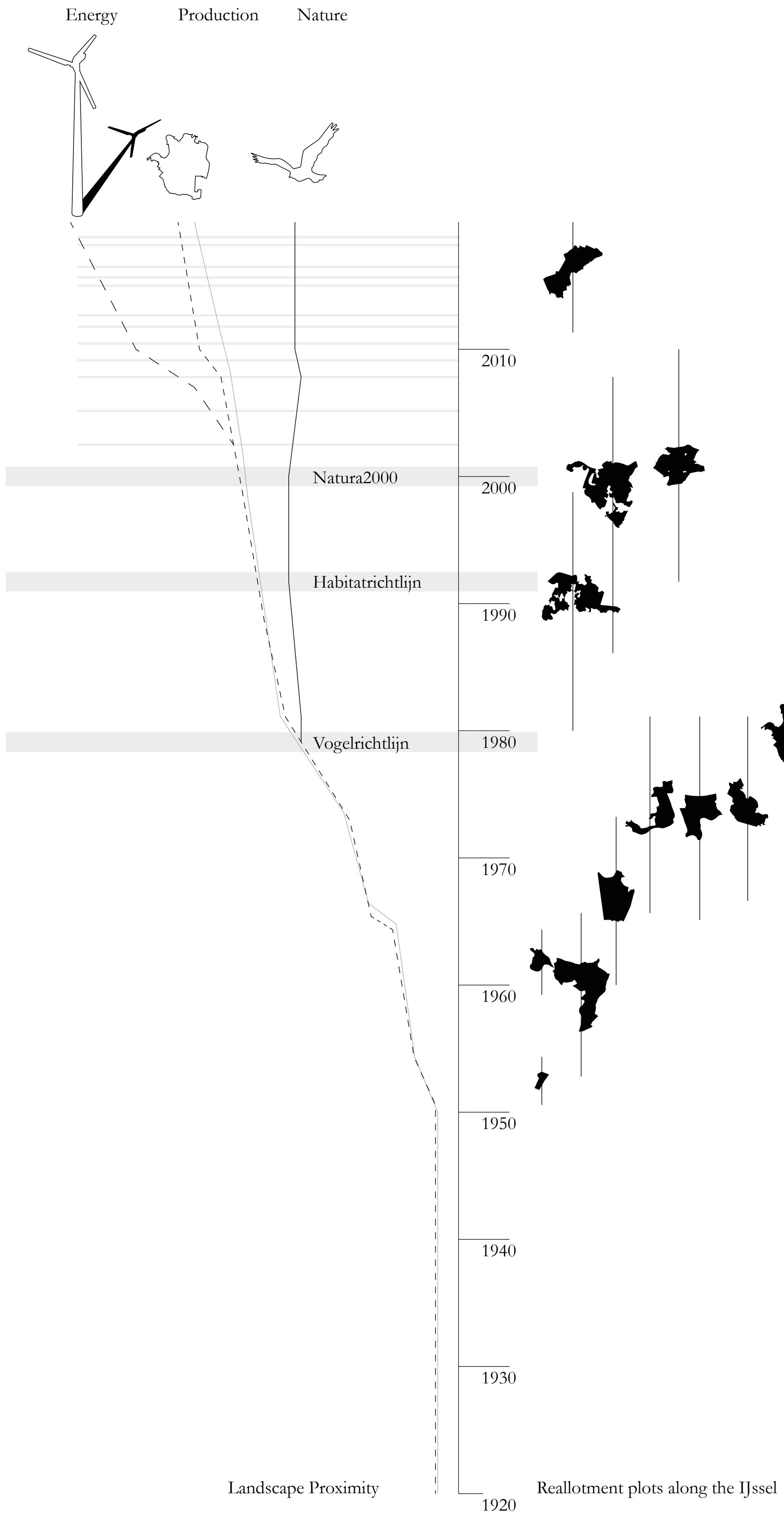
Based on:

European Environment Agency (2019). Natura 2000 End 2019 - Shapefile. Retrieved on: 27-10-2020. Retrieved from: https://www.eea.europa.eu/data-and-maps/data/natura-11/natura-2000-spatial-data/natura-2000-shapefile-1

Provincie Overijssel (2020). Ruilverkavelingslandschappen. Retrieved on: 26-10-2020. Retrieved from: https://services.geodataoverijssel.nl/viewer/layer/B73_Cultuur/B7_Ruilverkavelingslandschappen

Rijksdienst voor het Cultureel Erfgoed (2015). 20-eeuwse Landinrichtingsprojecten. Retrieved on: 27-10-2020. Retrieved from: http://rce.webgispublisher.nl/Viewer.aspx?map=Nederland_kavelland#

Vogelbescherming Nederland (n.d.) EU vogelrichtlijn en habitatrichtlijn. Retrieved on: 28-12-2020. Retrieved from: https://www.vogelbescherming.nl/bescherming/juridische-bescherming/wet-en-regelgeving/eu-vogelrichtlijn-en-habitatrichtlijn


Energy
Production
Nature
Natura2000
Habitatrichtlijn
Vogelrichtlijn
2010
2000
1990
1980
1970
1960
1950
1940
1930
1920
Landscape Proximity
Reallotment plots along the IJssel

2.1.6 Contemporary Riverscape

The contemporary anthropogenic riverscape has been highly adapted to the confines posed by the hydrological cycle it was reliant upon, and has been very successful in its performance. However, now that the context of the system is changing, e.g. the climate and through that the shift in the hydrological cycle, the rigidity of the systems leads to a fragility in the face of increasing riverine dynamics. The current spatial layout is therefore unsustainable, and a new approach has to be found.

In answer to the posed research question "How can the current spatial limitations of riverine territories, caused by the increasingly dynamic shifting hydrological cycle, be mitigated through integrative design?" it can be said that the rigidity of the system creates an inability to meet the demands posed by the increasing dynamicity and fluidity of the discharge regime. In other words, the perspective based on the projected changing hydrological cycle shows us two completely opposing systems; one rigid, one fluid.

A design solution might be found in the high level of scale and abstraction, adopted during the monographs' cartographic work. This allows for the conceptualizing of an integrated system on a high functional scale, which will work down into a parallel, complementary and synthesized system on the lower spatial scale levels. If the projection shows a space of a dual nature, the potentiality to actively promote and widen solution space as an alternative to the integrated riverbed, the potentiality lies in the deliberate expansion on the idea of parallelization. Therefore, the proposition based on the research is as follows; the rigid anthropogenic riverscape is unable to meet the fluidity demanded by the shifting hydrological cycle.

The answer to the research question is the following: the spatial limitations of the riverine territory can be mitigated by applying an integrative design on a high scale level, allowing for spatial segregation into a complementary set of systems on the lower scale. By extracting the rigid objects and relocating them, the river can be allowed to flow dynamically.

Research Question 1

How can the current spatial limitations of riverine territories, caused by the increasingly dynamic shifting hydrological cycle, be mitigated through integrative design?

Proposition

The rigid Dutch anthropogenic riverscape is unable to meet the fluidity demanded by the increasingly dynamic hydrological cycle

Conclusion

Spatial limitations of the riverine territory can be mitigated by applying an integrative design on a high scale level, allowing for spatial segregation into a complementary set of systems on the lower scale

2.2.1 Riverine Regimes

The riverine territory is inhabited by socio-technical regimes. These socio-technical institutions have placed themselves in the system, adapting to local conditions and opportunities. They also are the reason for many of the adaptations of the territory to increase usability and productivity. This iterative relationship will change due to the consequences of the shifting hydrological cycle. In order to fully understand how the regimes currently place spatial demands onto the river system, and how this can be projected to change in relation to climate change, they are investigated separately.

The main focus of research is the relation between the spatial demands of the river system and flow characteristics. The research will aim to answer the following research question: "How can the socio-technical regimes adapt to the changing hydrological cycle through integrative design of the riverine landscape?"

Navigation

Navigation has to become increasingly important due to the modal shift. Its main spatial dependency lies in the consistency of standardized fairway breadth and depth, which is threatened by increasing dynamics in riverine flow. Compartmentalization of free flowing waterways with hydraulic structures is needed to ensure year-round reliability.

Flood Control

The regime of flood control is characterized by its probabilistic measure of flood hazard, resulting in designed water- and discharge levels which are the basis of the safety structures. Free, uninterrupted flow is key, with a preferred reduction of hydraulic roughness over increasing available space to stay within the designed limits.

Eco-hydrology

Eco-hydrology is focussed on integrating hydrological and biological components of freshwater ecosystems, based on the ecological functions of flow characteristics in rivers and catchments. In order to connect to lateral habitats and longitudinal particle movements, a free, variable and most importantly uninterrupted flow is needed.

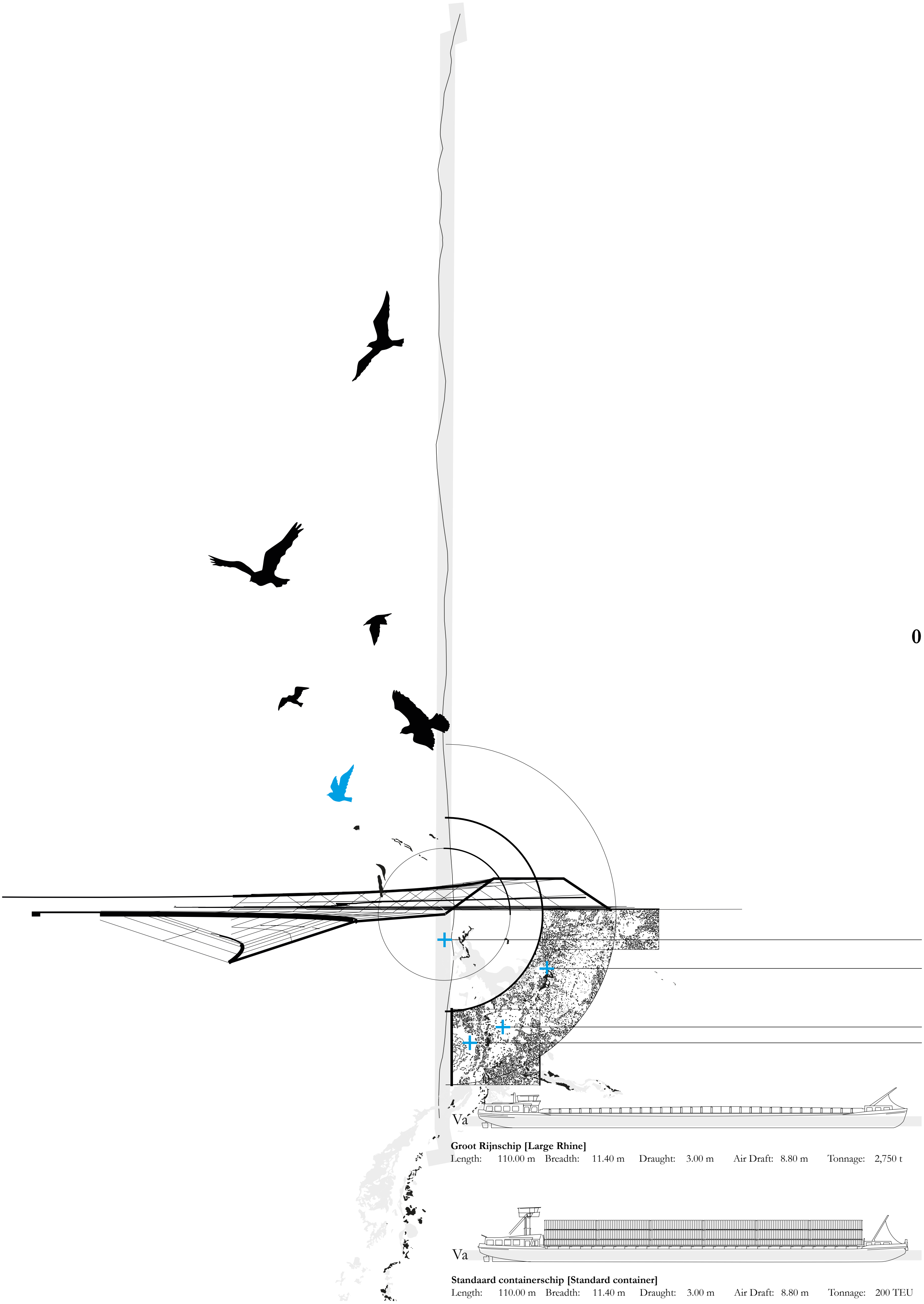
Drought Management

The Dutch water system is vulnerable to hydro-meteorological extremes. It is highly adapted to the rapid transmission of peak discharges, but unable to mitigate drought. Further compartmentalization of waterways and surface flows is needed to prevent the expedient discharge of water during periods of scarcity, while bifurcation of flows for retention and storage is needed to proactively manage reserves.

Figure 12: Complexity of combined regimes

Figure by Goselink, 2021

049


Va
Groot Rijnschip [Large Rhine]
Length: 110.00 m Breadth: 11.40 m Draught: 3.00 m Air Draft: 8.80 m Tonnage: 2,750 t
Va
Standaard containerschip [Standard container]
Length: 110.00 m Breadth: 11.40 m Draught: 3.00 m Air Draft: 8.80 m Tonnage: 200 TEU

2.2.2 Regime: Navigation

Navigation has, as has already been emphasized several times in this report, along with flood defence always been the most important regime within the riverine territory. Due to the large economic importance of inland waterway transport (IWT), year-round reliability of the system is key (Rijkswaterstaat, 2020). The drought of 2018 has been a wake-up call to many people, exemplifying the threat of the changing hydrological cycle for inland navigation (Reijnen Rutten, 2020).

The shallowest water depth in the IJssel was measured at 1.45m (van Hussen et al., 2019). International agreements state the minimum available depth should always be 2.80m, which was for the Upper-IJssel already lowered to 2.50m. Rijkswaterstaat already dredges the IJssel twice a year to ensure enough water depth. The meandering character of the IJssel makes it specifically difficult to navigate and maintain, especially in the face of increasingly low discharge rates (Rijkswaterstaat, 2020). During the summer of 2018, the price to get goods shipped went up in general 30%, while this would provide only 25% of the original capacity per ship. Total damages in the sector due to the drought are estimated to be between 140 and 345 million EUR (Hussen et al., 2019).

As transport temporarily had to be shifted to road based modalities, the reliability of IWT as sustainable modality in the future was started to get questioned. With both growing capacity per ship and absolute tonnage, the IJssel (which is already a difficult river to navigate) will become insufficient. Simultaneously, the EU has expressed a plan to shift transport from road to railroad and IWT. In order to reach the goal of increasing IWT capacity by 25% in 2030, and 50% in 2050, the system has to be expanded and its assets managed more efficiently (Hacksteiner & Rycquart, 2021).

In conclusion, the most important factor of IWT in the relation to climate change is the year-round reliability on the modality, based upon the available fairway breadth and depth. Free flowing rivers will not be able to provide this certainty, therefore the necessity and pressure to start planning the compartmentalization of inland waterways with weir- and lock structures is increasing in order to prepare the system for both the modal shift and the shifting hydrological cycle as was also stated by Kraaijenbrink & Lindeboom (2019).

Figure 13: The systemic functioning of the IJssel in the inland fairways network from a navigation perspective

Figure by Goselink, 2021

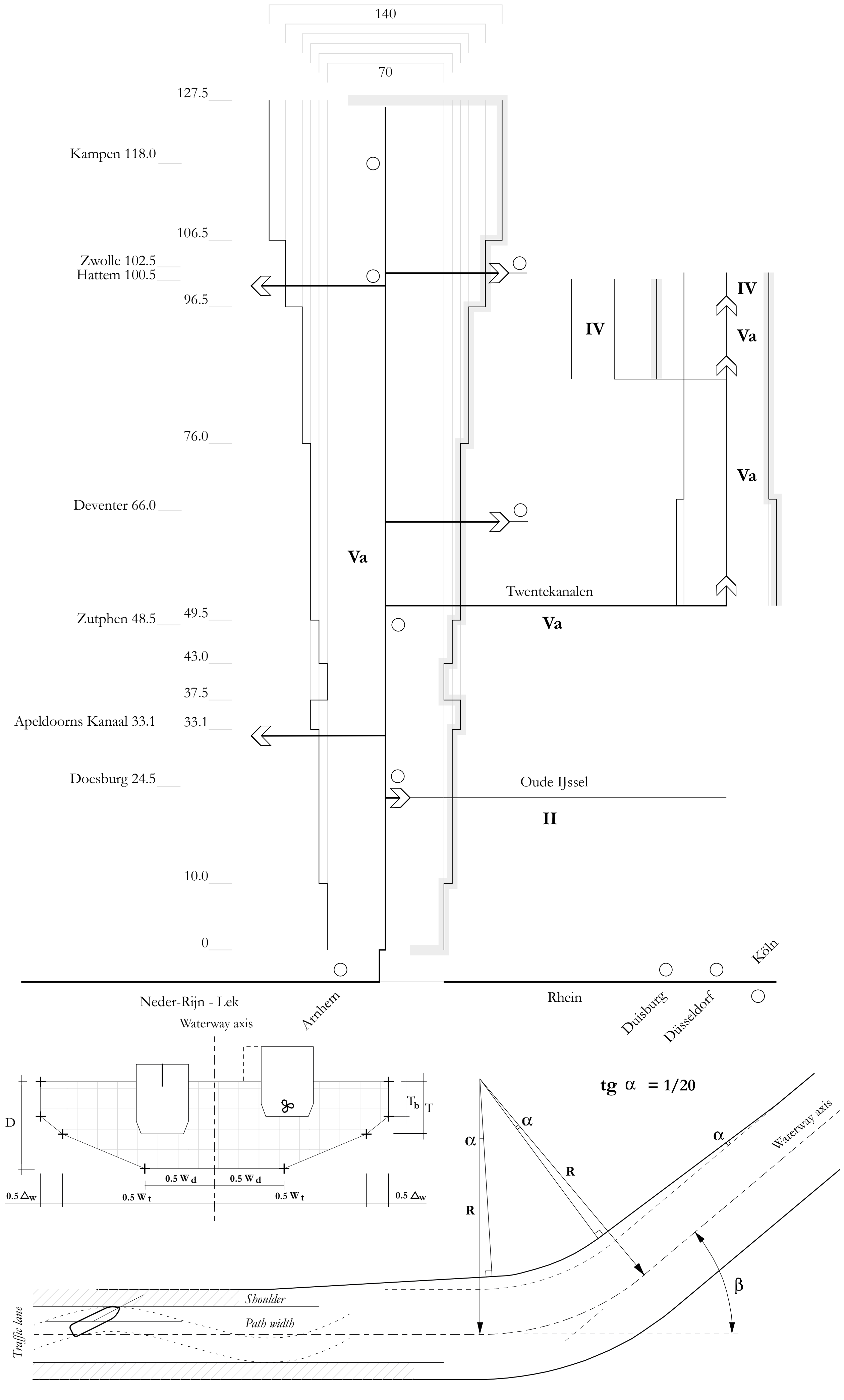
Main waterway —
Shipping lock complex
Allowed CEMT-class **Va**
Inland port city ○
Waterway width 140

Based on:

Bureau Voorlichting Binnenvart (s.d.) Scheepstypen. Retrieved on: 23-01-2021. Retrieved from: https://www.bureauvoorlichtingbinnenvaart.nl/over/basiskennis/vaarwegen#vaarwegen_nederland

European Conference of Ministers of Transport (June 12th, 1992). Resolution No. 92/2 on New Classification of Inland Waterways (PDF). Retrieved on: 03-03-2021. Retrieved from: https://www.itf-oecd.org/sites/default/files/docs/wat19922e.pdf

Koedijk, O. C. (red.) (2020). Richtlijnen Vaarwegen 2020. Rijswijk: Rijkswaterstaat Water, Verkeer en Leefomgeving



140
70
127.5
Kampen 118.0
106.5
Zwolle 102.5
Hattem 100.5
96.5
IV
IV
Va
Va
76.0
Deventer 66.0
Va
Twentekanalen
Zutphen 48.5
49.5
Va
43.0
37.5
Apeldoorns Kanaal 33.1
33.1
Doesburg 24.5
Oude IJssel
II
10.0
0
Köln
Neder-Rijn - Lek
Arnhem
Rhein
Duisburg
Düsseldorf
Waterway axis
D
T_b
T
0.5 W d
0.5 W d
0.5 Δw
0.5 W t
0.5 W t
0.5 Δw
tg α = 1/20
α
α
α
R
R
Waterway axis
β
Shoulder
Path width
Traffic lane

2.2.3 Regime: Flood control

In the Netherlands, flood protection structures are viewed through a set of flood safety levels based on the maximum return times which are acceptable, in relation to the probability of flooding (flood hazard) and the expected damages of flooding in an area (Brouwer & van Ek, 2004). Dike slope, width and height standards are based upon design water levels; the water level the dike has to be able to withstand. The designed water levels are related to a probabilistic occurence, corresponding to a protection level between 1/1.250 and 1/10.000 (van Stokkom et al., 2005).

The design water levels are related to design discharge rates, but measures can be taken separately to decrease water level, discharge rate of both (Jonkman et al., 2018).. According to Rijkswaterstaat (2017), vegetation and sedimentation are processes of deterioration of the Dutch Rivers, causing reduction of discharge capacity. The maintenance of riverbeds and floodplains between the dikes ensures a free flow and a quick discharge of river water (Brouwer & van Ek, 2004). Rijkswaterstaat acts as manager of the river (load), while waterboards are responsible for strengthening the dikes alongside the river. Next to minimizing risk due to reducing of flood hazard, another opportunity to reducing the value in the risk equation is reducing damages when flooded, e.g. giving more space to the river (Vis et al., 2003). Natural dynamics, resilience and flexibility of water systems have been regarded as potentially effective flood risk reduction means since the flooding of 1993 and 1995 along the Rhine and Meuse (Brouwer & van Ek, 2004). The Room for the River project is an example of this approach, as are the recently developed green rivers near Veessen-Wapenveld and Kampen.

The demands on the flood control infrastructures are changing due to increasingly stringent standards, increase in discharge volumes and current (and projected) increase in riverine use (Jonkman et al., 2018). In relation to flow characteristics, a quick, free flowing discharge within its designed level and discharge rate is eminent. Reducing hydraulic roughness of vegetation and sedimentation, or increasing space through 'green rivers' can aid in retaining the safety standards during the projected peak discharges.

Figure 14: The flood defence perspective on the IJssel, showing dike segments and prospected risk of damages

Figure by Goselink, 2021

Risk of damage; 10,000+ Eur/ha/yr

Risk of damage; 1,000 - 10,000 Eur/ha/yr

Risk of damage; 100 - 1,000 Eur/ha/yr

Territory in risk of flooding

Dike segment 53 - :

Segment devide

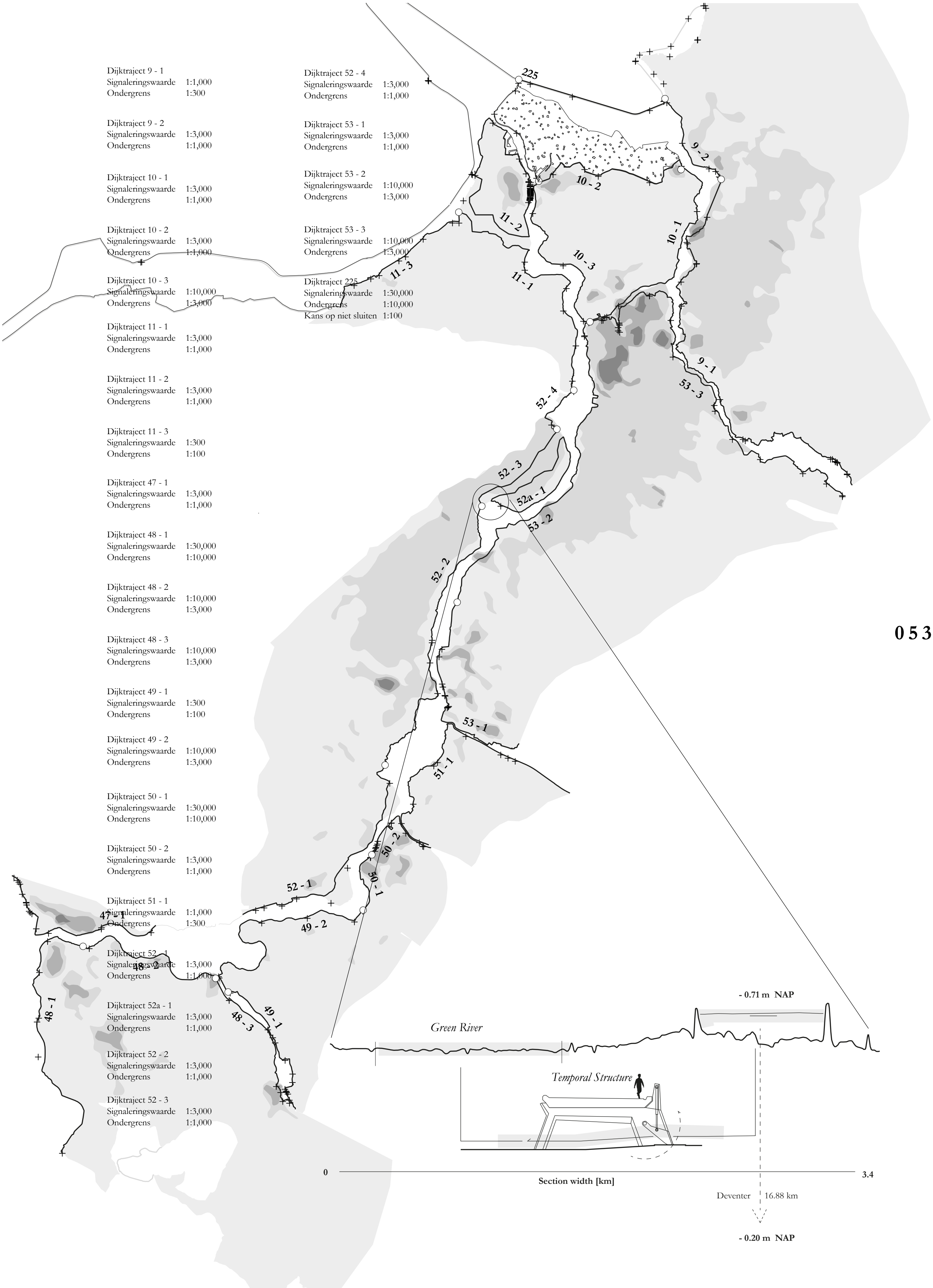
Flood safety engineering works

Outerdike hedgerows obstructing flow

Based on:

Helpdesk Water (n.d.) Nationaal Basisbestand Primaire Waterkeringen. Retrieved on: 16-03-2021. Retrieved from: https://waterveiligheidsportaal.nl/#/nss/nss/norm

Ministerie van Infrastructuur en Milieu (2017). Normering Waterveiligheid. Retrieved on: 16-03-2021. Retrieved from: https://www.infomil.nl/onderwerpen/lucht-water/handboek-water/thema-s/waterveiligheid-0/normering-primaire/


Dijktraject 9 - 1
Signaleringswaarde 1:1,000
Ondergrens 1:300
Dijktraject 9 - 2
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 10 - 1
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 10 - 2
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 10 - 3
Signaleringswaarde 1:10,000
Ondergrens 1:3,000
Dijktraject 11 - 1
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 11 - 2
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 11 - 3
Signaleringswaarde 1:300
Ondergrens 1:100
Dijktraject 47 - 1
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 48 - 1
Signaleringswaarde 1:30,000
Ondergrens 1:10,000
Dijktraject 48 - 2
Signaleringswaarde 1:10,000
Ondergrens 1:3,000
Dijktraject 48 - 3
Signaleringswaarde 1:10,000
Ondergrens 1:3,000
Dijktraject 49 - 1
Signaleringswaarde 1:300
Ondergrens 1:100
Dijktraject 49 - 2
Signaleringswaarde 1:10,000
Ondergrens 1:3,000
Dijktraject 50 - 1
Signaleringswaarde 1:30,000
Ondergrens 1:10,000
Dijktraject 50 - 2
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 51 - 1
Signaleringswaarde 1:1,000
Ondergrens 1:300
Dijktraject 52 - 1
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 52a - 1
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 52 - 2
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 52 - 3
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 52 - 4
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 53 - 1
Signaleringswaarde 1:3,000
Ondergrens 1:1,000
Dijktraject 53 - 2
Signaleringswaarde 1:10,000
Ondergrens 1:3,000
Dijktraject 53 - 3
Signaleringswaarde 1:10,000
Ondergrens 1:3,000
Dijktraject 225
Signaleringswaarde 1:30,000
Ondergrens 1:10,000
Kans op niet sluiten 1:100
225
9 - 1
9 - 2
10 - 1
10 - 2
10 - 3
11 - 1
11 - 2
11 - 3
47 - 1
48 - 1
48 - 2
48 - 3
49 - 1
49 - 2
50 - 1
50 - 2
51 - 1
52 - 1
52 - 2
52 - 3
52 - 4
52a - 1
53 - 1
53 - 2
53 - 3
- 0.71 m NAP
Green River
Temporal Structure
0
3.4
Section width [km]
Deventer 16.88 km
- 0.20 m NAP

053

2.2.4 Regime: Eco-hydrology

The regime of eco-hydrology is focussed on integrating hydrological and biological components of freshwater ecosystems to enhance and restore resilience against anthropogenic stressors (Zalewski et al., 1997). The scientific field of eco-hydrology has emerged in the 1990s, researching the impact of hydrology on ecosystems and vice versa (Hannah et al., 2004). It aims to asses and manage freshwater reserves and resources in a sustainable manner, based on the ecological functions of flow characteristics in rivers and catchments.

The inherent character of rivers as longitudinal ecological corridors is pressured by continued interruptions into the system by anthropogenic barriers, pressing the distribution of species due to the interference in reproductive, feeding and population patterns (Branco et al., 2014). The barriers change the hydrology through not only physical disconnection, but according to Cote et al., (2009) also alteration of flow velocity, water depth, thermal and discharge regimes and sediment transport while it should provide continuous exchanging of energy, organisms and matter (Ward & Stanford, 1995).

The physical fragmentation of habitat is a major anthropogenic factor in the decline of biodiversity, specifically within riverine aquatic ecosystems (Rolls et al., 2014). This interruption and pressure has, according to Branco et al. (2014), led to decreasing populations of over 50 % of the threatened fish species within Europe.

In order to increase habitat- and biodiversity, temporal variation in flow conditions has to be increased. The aquatic connection between the main streambed and temporary lateral habitats (like the floodplains) is of the upmost importance for migratory species. The interlinkages between river channel and floodplain are mainly driven by the frequency and magnitude of inundation (Fryirs, 2007). Habitat connectivity in riverine ecosystems is fundamental to the regulation of distribution and abundance of aquatic organisms (Schumm at al., 1984). The dynamic nature of rivers as spatially and temporally variable environments in which suitable habitats for diverse species are continuously isolated or connected through stream hydraulics, offers significant opportunities for the migration. Variation in flow pulses through anthropogenic barriers might mitigate the effect of smaller barriers on longitudinal connectivity, as the temporal overtopping of barriers reconnects flows (Rolls et al., 2014).

To increase habitat diversity and improve settling conditions for species, the variability of flow, access to lateral habitats and longitudinal sediment (and seed) movement have to be greatly improved. The related flow characteristics are based on the premise of free, variable and most importantly uninterrupted flow.

Figure 15: An eco-hydrological perspective on the IJssel, containing its tributary rivers and catchment basin territory

Figure by Goselink, 2021

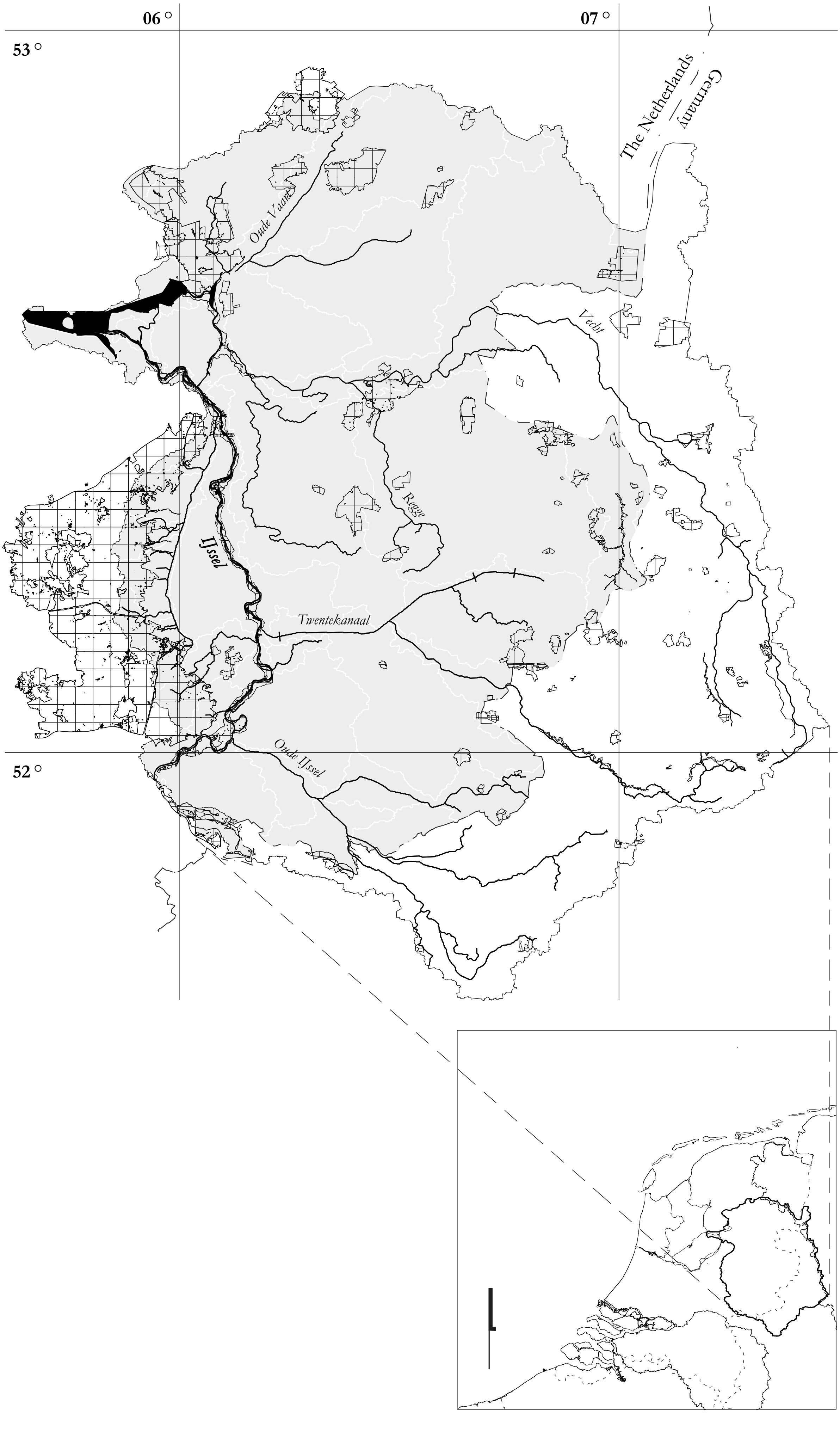
German IJssel catchment territory

Dutch IJssel catchment territory

Nature reserve

Sub-catchment devide

Waterway


06 °
07 °
53 °
52 °
The Netherlands
Germany
Oude Vaart
Vecht
Regge
IJssel
Twentekanaal
Oude IJssel

2.2.5 Regime: Drought management

The Dutch water management system has shown to be vulnerable to hydro-meteorological extremes, especially in relation to precipitation- and riverine discharge deficiencies (Veraart et al., 2010). Drought is the result of a precipitation deficiency combined with raised evaporation rates. Different types of drought (agricultural, hydrological, meteorological and socio-economic) can occur over several spatio-temporal scales (Wang et al., 2016). The term drought should therefore be used with caution.

The dry summer experienced in 2018 led through the hydrological cycle from a meteorological drought to depletion of soil moisture and a lowering of subsurface ground water. Both surface and subsurface fresh water reservoirs were influenced, leading to deficiencies affecting both natural processes and human activities (van Hussen et al., 2019).

The fresh water supply network depicted to the right shows a balanced and highly manageable system (Klijn et al., 2012). However, now the hydrological cycle is projected to increase periods of precipitation deficiency or drought as experienced in 2018, 2019 and 2020, the system has to be managed proactively to avoid uncontrolled output of fresh water, but rather divert, store and retain water when possible. Especially in the areas reliant solely on precipitation, of which the hinterland of the IJssel catchment is a large part, a radical change in functioning of the system is needed. The current water management system founded on the premises of discharge will be the basis of the new system, but the transition has to be made towards a robust system of conservation (Rijkswaterstaat, n.d.). The regime of drought management has to therefore be developed incorporating - but limited to - the fresh water supply regime.

In conclusion, it can be said that adaptation of existing - and overall increase of - infrastructure has to be implemented to be able to efficiently manage the available fresh water during precipitation shortages throughout the Netherlands. Diversion of high water during periods of excess, and the compartmentalization of free flowing rivers during shortages will lead to a more robust and resilient system.

Figure 16: A drought management perspective on the functioning of the IJssel within the larger Dutch context

Figure by Goselink, 2021

High grounds with supply during drought
Fresh water reserve
Supply by pipeline
Salt water intrucion
Throughput for quality standards
Throughput for groundwater replenishment
Weir and lock
Lock
Pumping station

Based on:

Klijn, F., Velzen, E. van, Maat, J. ter, Hunink, J. (2012) Zoetwatervoorziening in Nederland: aangescherpte landelijk knelpuntenvoorziening 21e eeuw. Deltares.

IJsselmeer
Fresh water reserve
12.6%
15.9%
71.3%
28.6%
Rhine
100.0 %

2.2.6 Regime Projections

In regards of the hypothesis of the sub question, the proposition put forward by the separated research into the different riverine regimes is clear. The spatial demands made in relation to the flow characteristics are projected to move simultaneously into two opposite directions: free, variable flow for flood control and eco-hydrology, and compartmentalised consistent flow for navigation and drought management.

In regards of the posed research question "How can the socio-technical regimes adapt to the changing hydrological cycle through integrative design of the riverine landscape?" the proposition has to be related to the integrative design assignment which results from the explorative exercise. The adaptation of the regimes to the hydrological cycle demands a further specialization of the territory in providing conditions in which the regime can thrive. In other words, the spatial demands of the regime are exposed and extrapolated in the face of an increasingly extreme environment.

The extrapolation projects a more stringent spatial demand onto the riverine landscape, through which the landscape has to be adapted and the regime gets embedded deeper in the overall functioning of the landscape.

The conclusion towards the posed research question is therefore that the increasingly opposing needs, as displayed per socio-technical regime, demand a higher level of adaptation of the riverine landscape to the regime. This results in growing incompatibility between the separate conflicting territorial claims.

A synthesis between spatial form and flow characteristics demanded by the separate regimes appears to be once more applicable on a larger scale of space and abstraction, where segregation of the actual space in time has to be considered as a viable solution to the posed problems.

The central paradox discovered through the framing process into the themes now appears clearly. The phenomenon underlying the problems caused by the shifting hydrological cycle are related to the question of control over the natural functioning of the river. Whereas we have found ourselves on a crossroads 150 years ago, when in the 1850sopposing views on the relationship of our society to the rivers were posed (van der Ziel & Corporaal, 2021). Either an uncontrollable entity which should and could not be controlled, against the engineering view that man would overcome natural systems and a normal river was considered to be a good river, now we see a similar opposition in the research. A question of control, in which we see how the current engineered system in unable to accommodate a new natural system, and simultaneously the regimes operating within the riverine territory are becoming increasingly opposites on the subject of free versus controlled flow. This is the central paradox underlying the superficial problems we encounter.

Research Question 2

How can the socio-technical regimes adapt to the changing hydrological cycle through integrative design of the riverine landscape?

Proposition

The separate regimes display increasingly opposing needs in relation to flow characteristics; in need of either compartmentalisation or uninterrupted flow

Conclusion

The opposing needs displayed by the regimes aim towards a deeper embedding into the riverscape, demanding more spatial alteration to fit their needs, resulting in incompatibility of the conflicting territory

III Parallelization along the IJssel

Or the definition of a working principle from the key thesis

3.1.1 Synthesis

The previous research questions have led to propositions showing both increasingly incompatible spaces, and increasingly incompatible trends within space. Both the riverine territory and the socio-technical regimes show are growing apart. A synthesis of the two previous propositions can lead to two possible outcomes; 1) a spatially integrated system based on the principles put forward by the 2 complementary systems, gained through a process of consensus seeking, or 2) a spatially segregated system in which the two opposing systems can maximize within their confines.

Now, the first option is what has historically been done, seeking consensus between all parties involved leading to a mediated optimal solution in which all actors have to accept a lower level of functioning to allow for compromises. This would lead to a decrease in performance of the separate regimes and riverine territory as a whole, decreasing further and further over time as the needs and demands become increasingly opposing. In order to maximize performance to society, the solution has to be found in a non-compromising synthesis, e.g. a spatially segregated system which functions as a whole in the integrative design on a higher level of scale and abstraction.

In conclusion, it is the performance output factor which demands an approach of parallelization in space. In answer to the research question 'How can the riverine territory and the socio-technical regimes synthesize, in order to increase the performance output to society?' it can be said that synthesis through spatial integration will not lead to an increase in performance output, however synthesis through spatial segregation is a promising approach. No consensus seeking, but rather parallelization of river management systems allows for performance increase in a changing climate.

Through this line of reasoning, the internal paradoxal relations in the riverine territory are amplified; the aspired value to both adapt to the shifting hydrological cycle, AND increase performance to society, is not possible within the current societal and political framework based on consensus seeking between all parties, as is derived from the integrated approach. In this framework, compromises are needed, resulting in decreasing performance for (at least) a portion of the outputs of the territory. Therefore, the paradox is expanding to encompassing not only the conflicting territory but also a paradoxal relationship between the parties involved in the decision making process.

The key thesis of the paradox and aspired values is the following: In order to both adapt to the shifting hydrological cycle and increase performance output to society, a single integrated river cannot suffice. Therefore, a spatial decomposition into a segregated parallel river system will both amplify and visualize the internal paradoxal relationships as discovered through the act of conscious framing, while it will be able to meet the demands of the aspired value.

Figure 17: Synthesizing in order to increase performance

Figure by Goselink, 2021

Based on:

Merriam-Webster. (n.d.). Synthesis. In Merriam-Webster.com dictionary. Retrieved on: 22-05-2021. Retrieved from: https://www.merriam-webster.com/dictionary/synthesis

Lexico.com (n.d.) Compromise. Retrieved on: 15-03-2021. Retrieved from: https://www.lexico.com/definition/compromise

Synthesis

• *Noun*

1.

the composition or combination of parts or elements so as to form a whole

2.

the combining of often diverse conceptions into a coherent whole

- Performace

+ Performace

Spatially integrated

Spatially segregated

Compromise

Noun •

1.

An agreement or settlement of a dispute that is reached by each side making concessions

2.

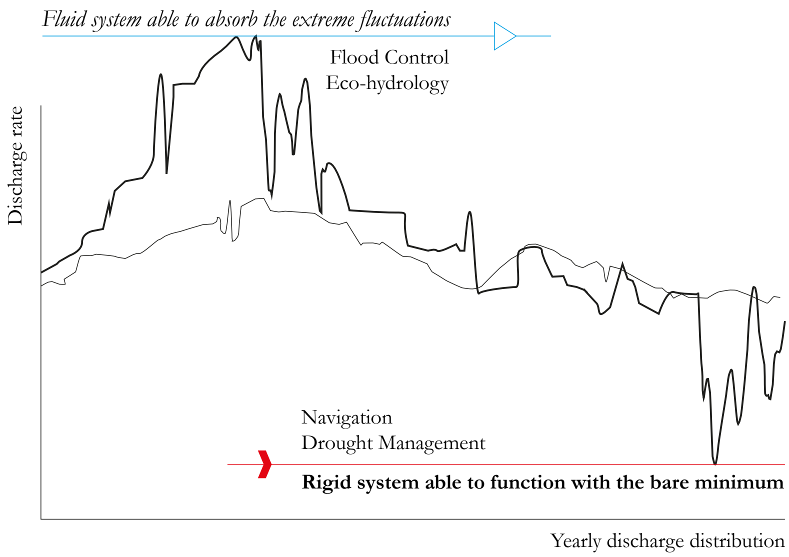
the expedient acceptance of standards that are lower than is desirable

Optimal solution for everyone involved, given the situation; resignation

Is this really how we should move forward ?

Fluid		Rigid
Uninterrupted	V	Compartmentalised
Variable		Consistent
Free		Controled

Optimization in parallelization



3.1.2 Retrospective: Canalisation *alongside* the IJssel

In the 18th century the IJssel, and other Dutch rivers, had to deal with regular flooding due to high discharges and ice blockages. At the time, there are two opposing types of engineers in the Netherlands. The first group is convinced that man cannot control and restrain nature, and said therefore that an engineered set of overflows to inundate agricultural lands during high river discharges is the best way to ensure safety. Eventually, even a complete longitudinal bypass canal is proposed in the 1830s to discharge the water of both the IJssel and the Nederrijn-Lek, with the motto "The complete reconceptualization of the Dutch rivers" (van der Ziel & Corporaal, 2021). The plans are not completed due to lack of funding and opposition of local inhabitants.

The following 19th century displays a period in Dutch history in which many canals were dug throughout the Netherlands, guided by the direct influence of King Willem I. In that period, the Apeldoorns Kanaal planned and built, initially to connect Apeldoorn to the system of riverine waterways throughout the Netherlands, bringing economic perspectives to the eastern Veluwe-region.

Next to this regional importance for the creation of the canal, the secondary function of the canal was of (inter)national importance: as a lateral bypass along the IJssel River. During high- and low water levels in the IJssel, the IJssel was extremely difficult to navigate. Either due to insufficient water depth during low discharge levels, or strong currents during high water. The canal was also 11 km shorter than the equivalent river trajectory of 66 km, although navigation was hindered by many bridges and locks.

Simultaneously, the IJssel was normalised several times from the second half of the 19th century onwards. Eventually, in 1928, the fairway within the riverbed was still too shallow, and could not be made any narrower any more to increase the depth. When the construction of the Twentekanalen was proposed, the river should therefore again be completely bypassed from Almen to the Rhine at Lobith. However, during construction of the canal from Enschede to Almen in the 1930s, plans rose to canalise the entire IJssel, after which the IJssel bypass to the east was not realised (Hoefsloot, 1983). This partially led to the disappointing economical revenue of the Twentekanalen, as the IJssel limited transport capacity to and from the canal to the Rhine in the mid-20th century (Heitling & Lensen, 1984).

After 1955, the shipping along the Apeldoorns canal declined due to the development of road transport and the increased channel depth of the IJssel due to increased dredging and normalisation processes. The continued normalisation of the river meant that drought became less of a problem in the well maintained and deepened shipping lane, while increasingly large vessels became big and heavy enough to conquer the powerful currents during high water levels.

3.1.3 Retrospective: Canalisation *of* the IJssel

The second group of engineers, opposing the ideas that man cannot restrain natural forces, gets the upper hand in debates from the mid-1850s onwards (van der Ziel & Corporaal, 2021). They firmly trusted in the capacity of the engineering discipline to manufacture the landscape to specification. The irregular, variable river is seen as abnormal. Normalisation to them was perfection, and several plans to completely canalise the IJssel were proposed.

In the river, several gullies lay next to one another within a very wide streambed, containing shallow streams. In 1850, normalisation of the river started on a large scale, in order to limit the width of the low water bed (which was almost everywhere along the river much too wide in relation to the available discharges), eliminating sand banks and islands splitting the river channels, and cutting through sharp corners (Hoefsloot, 1983). When the works had been completed in 1928, the shipping channel depth was still too shallow, even though further narrowing of the channel was impossible due to growing ship sizes.

During the mid-20th century, plans revolving around the complete canalisation of the IJssel were once again seriously researched, debated and considered. Originally, the canalisation of the IJssel was planned to improve river navigation on the IJssel itself and - by redirecting more water - the Neder-Rijn as well. This plan was reversed when research showed the dramatic decrease of water supply towards the IJsselmeer due to the projected system of locks and weirs, thereby endangering this fresh water buffer. This led to the canalisation of the Neder-Rijn instead of the IJssel (Rijkswaterstaat, 1977). The perspective from this moment one became to ensure fresh water supply to the IJsselmeer, while allowing for continued navigation on the IJssel.

The weirs in the Neder-Rijn now ensured a larger discharge rate on the IJssel, thereby controlling the navigability of the water level and fresh water availability. It was already noted that during dry summers, referring back to 1947 and 1949, even the canalisation of the Neder-Rijn would be unable to prevent the water levels in the IJssel from dropping to a point where shipping would become impossible (de Jong, 1965). This was predicted to be the first and foremost reason in the future that could lead to the canalisation of the IJssel, which was estimated to cost fl. 200 million (550 million euros today) (CBS, n.d.).

Other scenarios in which canalisation of the IJssel could be expected were mentioned in the 1965 report as well. It could be beneficial in order to:

> Redirect more water towards the fresh water reserves in the south of the Netherlands instead of the Ijsselmeer.

In order to redirect more water to a possible drought in the south of the Netherlands, the IJssel would be dammed. In order to still ensure shipping, the river would then have to be canalised.

> To protect the IJssel during extreme peak discharges of the Rijn.

This would lead to less pressure on the safety alongside the IJssel, which would save money on the continuous strengthening and heightening of dikes and water control infrastructure.

> To build a weir near the IJsselkop at Westervoort in order to protect the Ijsselmeer's fresh water in case of Rhine contamination with toxines,

More research into the canalisation of the IJssel was conducted after a toxic spill of heavy metals in the Rijn caused massive fish death in 1969. The Netherlands were confronted with a concrete threat of calamity in or along the river. The consequences for the IJsselmeer could have been disastrous if the toxin levels would exceed acceptable levels for too long, starving the north of the country of its fresh water reserves.

Logically, the idea was coined to create the possibility of temporary interfering in the fresh water feed. The consequence of that for the IJssel would be a complete water depletion after several days had passed, leading to irreversible and unacceptable damages (de Jong, 1965). Canalisation to control the water level would once again be the preferred measure.

Two other new initiatives were included in the considerations as well. First, the canalisation of the IJssel in order to increase navigability across the Waal River, which would be made possible by diverting a larger portion of the available Rhine discharge towards the Waal. Secondly, the project 'Water infiltration in the Veluwe' , would need to receive a permanent amount of 15 m3/sec., which was planned to be subtracted from the IJssel. A subtraction like this was deemed to be absolutely impossible in case the depth for shipping would not be guaranteed by canalisation (Rijkswaterstaat, 1977).

In 1977, it was expected that none of the afore mentioned reasons in itself would lead to the canalisation of the IJssel, although it was deemed quite plausible that a combination of those would be enough incentive to start the transformation.

3.1.4 Strategy: the Key Position

The parallel system based on the identified problems of the spatio-temporal riverine systems can be regarded as a thinking exercise aimed to widen solution space in riverine climate adaptation. It is not proposed to be 'the solution', but is regarded to be a viable alternative that might put the current Dutch practice into a different perspective. It is about the way in which the future can be conceived, and the way in which we choose to engage with it; in order to get from a compromising position towards a continuously optimizing and thriving deltaic society, large scale interventions are a realistic necessity.

In order to capitalize on the value of Research by Design, the essence of the project is aimed at both the designed methodology and spatial intervention on the smaller scale in order to visualize and translate the possibilities. The exact location of the trajectory is within the context of the project proposition not of major concern, as the aim is to use Research by Design as a method to investigate and identify the potential of the concept, rather than to propose a detailed plan.

Important is *how* the canal and river could be developed in light of the synthesis of space and socio-technical regimes, and *what* would possibly be encountered that could be integrated as collateral benefits.

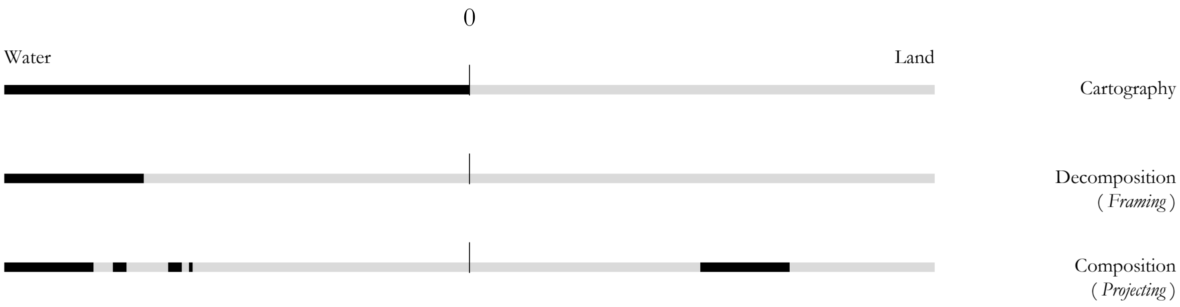
The strategy model to the right shows the parallel spatial system projected onto the territory. The lateral canal and naturalizing river are designed separately in the parallel system, as this allows for maximization and optimization of the regimes within their territories without compromises. The exercise will aid in showing both the full potential of the parallel system, as well as increasing the understanding of the underlying phenomenon as discovered in the framing.

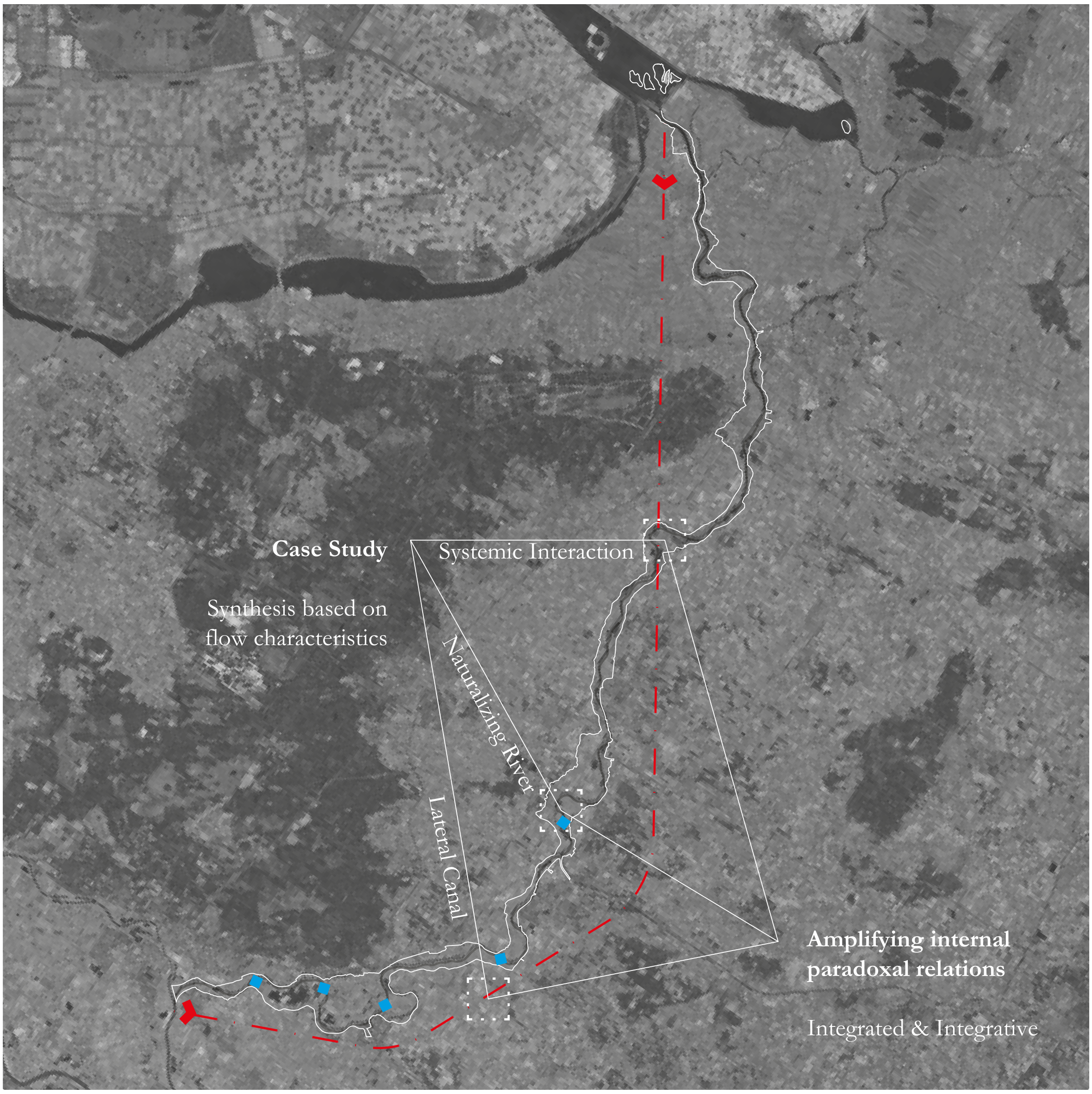
The approach of parallelization also brings forward a secondary benefit; throughout the process of segregated designing, the opportunity arises to adopt two separate viewpoints and visualization styles to increase the opposition and provide a detailed insight in the synthesis of ideologies as well. This will aid in the identification of criticalities and point of friction within integral river adaptation, allowing for the expedient understanding of the complexity of integrative practice in interdisciplinary projects.

In order to visualize the opposing and complementing values from the separated systems in relation to each other, the third design will show how the systems will intersect and interact. By visualizing this, the difficulties experienced in spatial integration will be made explicit through the act of designing. This final design will also consist of eye-level views, in order to show how the system engages with- and alters the surrounding riverine territory through experience of the landscape. Through movement, the complex rigid and dynamic composition can be understood best.

Figure 18: Strategic methodology and design model

Figure by Goselink, 2021


0
Water
Land
Cartography
Decomposition
(*Framing*)
Composition
(*Projecting*)

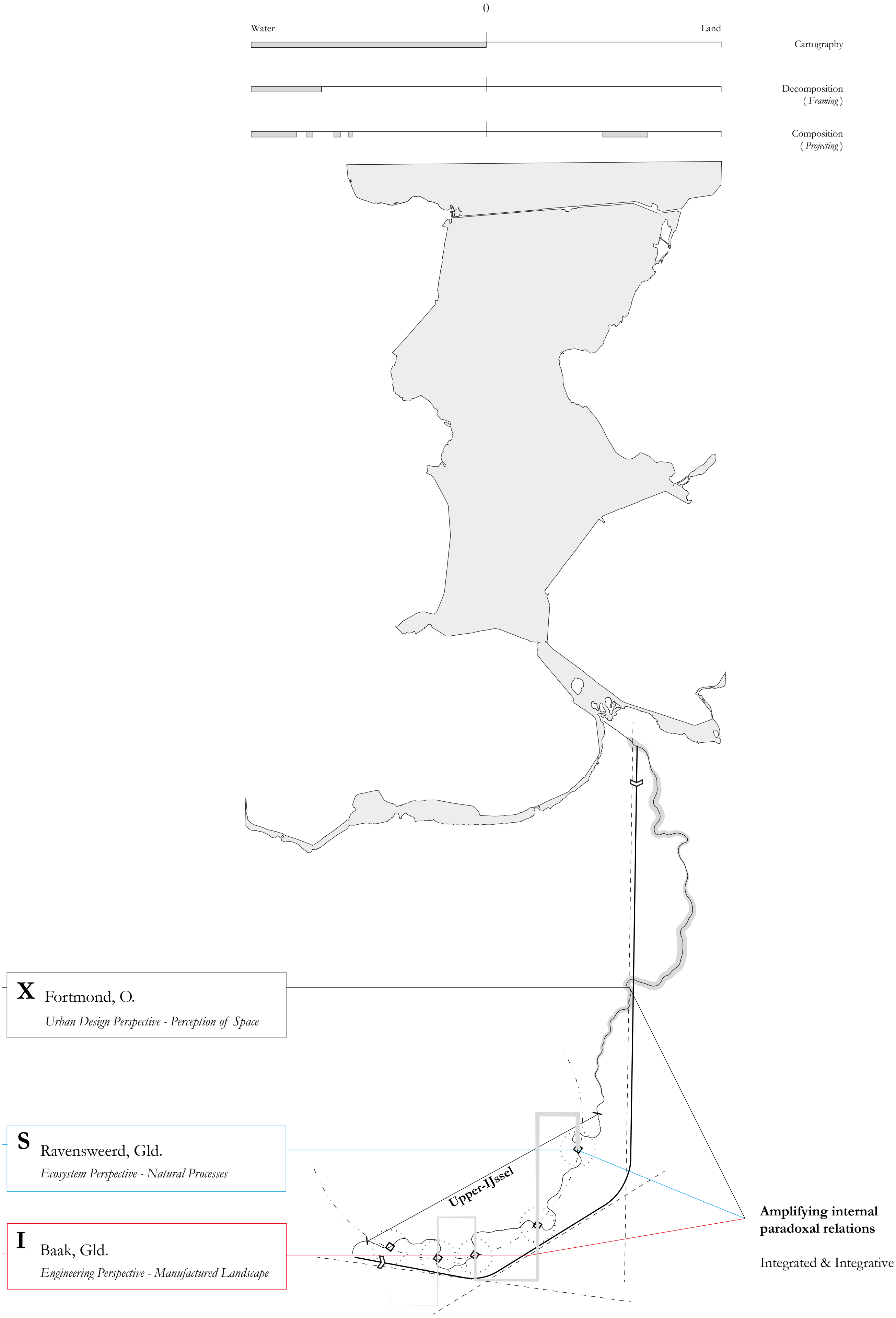

Case Study
Synthesis based on flow characteristics
Systemic Interaction
Naturalizing River
Lateral Canal
Amplifying internal paradoxal relations
Integrated & Integrative

070

In order for design practice to widen the solution space, it is imperative that it increases both the understanding of (a part of) the larger problem within its societal context, and provide a new perspective on possible ways of solving this issue. Therefore, to expand upon the key position provided by the framing phase of the design process, the strategy will be built on the premises that the two identified opposing systems should become separated systems next to one another, instead of integrated within each other. To amplify this scenario and increase in depth understanding of the complexity and paradoxal interrelationships, three design experiments or exercises are conducted. First the two separate systems will be specialized and within solely their needs and context (experiment I and S) after which they will be designed in an co-existence in the territory. In order to do so, the projected trajectory of the lateral canal bypassing the IJssel river, will be placed to intersect along its path, near Fortmond (O).

The design experiments aim to design separately in order to amplify and visualize (currently internal) oppositions, while the trajectory deliberately crosses at Fortmond (O) in order to discover the difficulties of the projected system. In design, you seek to solve not the average scenario, but investigate the extreme scenario in which most paradoxal relations are found and combined (Dorst, 2006). By aiming at synthesis and a reciprocal relationship between the separated parallel systems, integrative design is implemented alongside the in itself already integrated approach of conscious framing. In this exercise, design practice differs from problem solving in the engineering disciplines, where local context is deliberately isolated to be able to model and thoroughly solve a specific problem in a specific set scenario (Dorst, 2011).

The design location X at Fortmond is an expansion upon this typical design process, while the spatial decomposition in the two parallel design locations (I & S) functions as an addition to deepen the understanding of the underlying phenomenon of the core design paradox.



0
Water
Land
Cartography
Decomposition
(Framing)
Composition
(Projecting)
X Fortmond, O.
Urban Design Perspective - Perception of Space
S Ravensweerd, Gld.
Ecosystem Perspective - Natural Processes
I Baak, Gld.
Engineering Perspective - Manufactured Landscape
Upper-IJssel
Amplifying internal paradoxal relations
Integrated & Integrative

3.2.1 Design Experiment I: The Lateral IJssel Canal

The design experiment I shows the rigid spatial and functional principles of navigation, in combination with drought management. The conceptual design allows for a further specification of the system spatially, highlighting and emphasizing both its influence within the current integrated riverscape, as the potential future of the systems.

The two main findings of the design experiment are the potential to interfere in the underground draining capacity of the IJssel, which currently draws groundwater from the entire eastern part of the Netherlands (Reit et al., 1996). The second finding is the realisation that the canal is unable to directly be influenced by the tributary streams it intersects with, so in order to use the water as a supplement during shortages a secondary buffer system has to be designed along its trajectory. The experiment shows a greatly invasive design towards the current functioning (and natural substratum) of the territory, in order to enhance upon the concept of complete controllability of the system and region. Design experiment S will subsequently research what will happen to the river in case (mostly navigation) will be extracted from the territory.

With the sheet pile interference of the near subsurface flow, or shallow subsurface water transporting layer, the groundwater table in to the east of the canal can be controlled as the new buffer channel becomes the water body with either an infiltrating (high water level, low ground water table) or draining (high groundwater table, low water level) of the area.

This means that by heightening or lowering this table, the ground water level in the east of the Netherlands can be altered. This allows a proactive management of the fresh water resources towards the east, as pre-emptive heightening or lowering of the water table can buffer reservoir capacity in the subsurface ahead of dry and wet periods.

As the deeper subsurface flow still continues (30m below ground level and deeper), the area is still connected to the deep groundwater flow which puts it in contact with the water buffer of the Veluwe, which drains down towards the east (Anoniem, 1985). This will thereby increasing water in the area (Reit et al., 1996).

Figure 20: Design experiment I on a high scale level

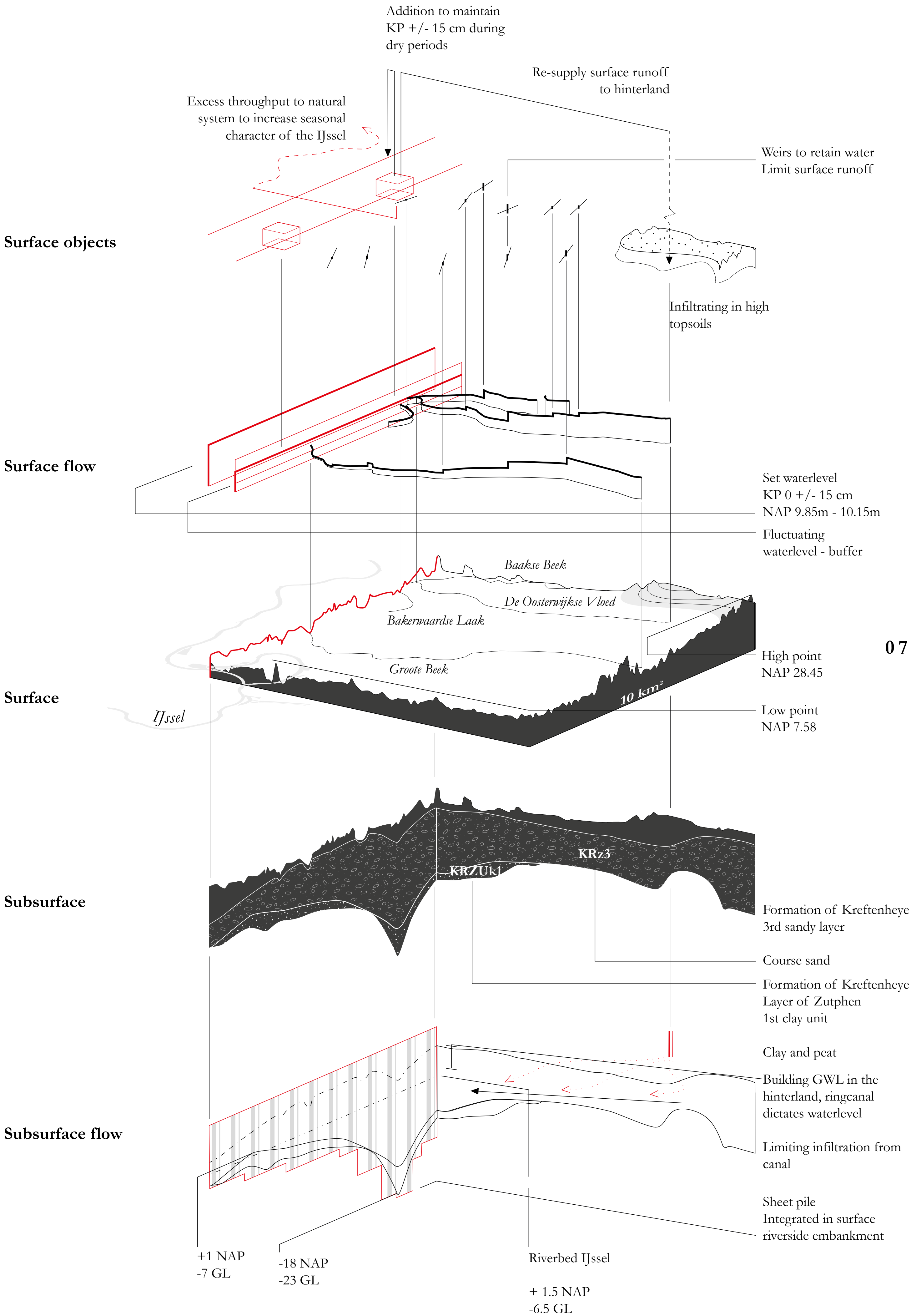
Figure by Goselink, 2021

Based on:

AHN (n.d.). Actueel Hoogtebestand Nederland. Retrieved on: 03-03-2021. Retrieved from: https://ahn.arcgisonline.nl/ahnviewer/

Anoniem (1985). Ontwerp primair grondwaterstandsmeetnet Gelderland. DGV-TNO, Rijkswaterstaat Directie Waterhuishouding en Waterbeweging, Provincie Gelderland Dienst Waterbeheer

DINOloket (n.d.) Ondergrondmodellen. Retrieved on: 03-03-2021. Retrieved from: https://www.dinoloket.nl/ondergrondmodellen


Addition to maintain KP +/- 15 cm during dry periods
Re-supply surface runoff to hinterland
Excess throughput to natural system to increase seasonal character of the IJssel
Weirs to retain water Limit surface runoff
Surface objects
Infiltrating in high topsoils
Surface flow
Set waterlevel KP 0 +/- 15 cm NAP 9.85m - 10.15m
Fluctuating waterlevel - buffer
Baakse Beek
De Oosterwijkse Vloed
Bakerwaardse Laak
Groote Beek
High point NAP 28.45
10 km²
Surface
IJssel
Low point NAP 7.58
KRZUk1
KRz3
Subsurface
Formation of Kreftenheye 3rd sandy layer
Course sand
Formation of Kreftenheye Layer of Zutphen 1st clay unit
Clay and peat
Building GWL in the hinterland, ringcanal dictates waterlevel
Subsurface flow
Limiting infiltration from canal
Sheet pile Integrated in surface riverside embankment
+1 NAP -7 GL
-18 NAP -23 GL
Riverbed IJssel
+ 1.5 NAP -6.5 GL

The water level of the shipping channel (KP) is, for this part of the trajectory, set at the same level (NAP) as the Twentekanalen to connect to this system. This means that the water level has to be maintained within 15 centimetres of the KP at 10 meters NAP (Rijkswaterstaat, 2014). The fluctuating water levels from tributary streams therefore have to be averaged and levelled before interacting with the lateral canal to ensure year-round stability of the water level as needed for the continuous inland waterway system (Rijkswaterstaat, 2020).

When designing the lateral canal in more detail on the lower (both abstract and physical) scale level, the context of the location becomes more important for the embedding of the system within the territory. The tributary streams intersecting the secondary channel have to be connected through weirs and sediment traps to prevent sedimentation and inflow of organic material. This process would decrease the buffer capacity and increase hydraulic resistance within the system (Rijkswaterstaat, 2017).

This results in a lateral canal at a set water level between locks for shipping, with a fluctuating buffer channel at the territorial level controlled with weirs. Embankments can be constructed from locally excavated soil to ensure circular soil management in the project. A note has to be made on the influence of the sheet pile intersection of the shallow subsurface water transporting layers. As the ground water level to the east can now be influenced directly, the territory between the lateral canal and the IJssel will be depleted of this water. It will be completely reliant on the water level of the IJssel, which means this will become increasingly instable (Attema et al., 2014).

This could be one of the most stringent arguments to change the proposed trajectory of the lateral canal if this measure is considered for application. This realisation shows that when the conceptual and abstract design proposal is formulated, it has to be continuously adapted when designing through the scales, as more detailed contextual information becomes of high importance for the succeeding of the plan.

Figure 21: Design experiment I on a low scale level

Figure by Goselink, 2021

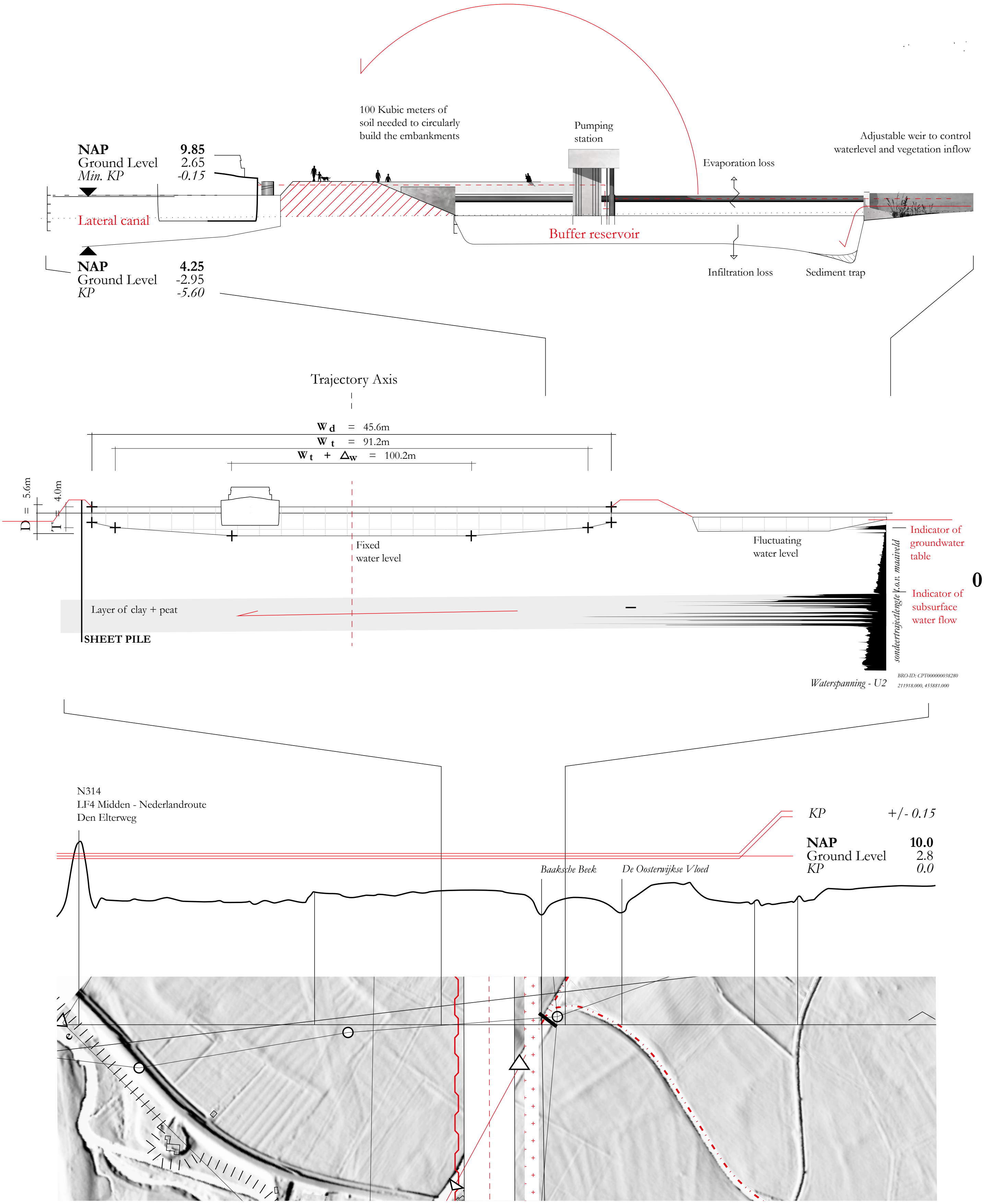
Based on:

AHN (n.d.). Actueel Hoogtebestand Nederland. Retrieved on: 04-03-2021. Retrieved from: https://ahn.arcgisonline.nl/ahnviewer/

DINOloket (n.d.) Geotechnisch sondeeronderzoek BRO. Retrieved on: 20-06-2021. Retrieved from: https://www.dinoloket.nl/ondergrondgegevens

Rijkswaterstaat (2014). Twentekanaal. Kijk op de ruimtelijke kwaliteit van kanalen. Retrieved on: 02-04-2021. Retrieved from: https://docplayer.nl/55730410-Twentekanaal-kijk-op-de-ruimtelijke-kwaliteit-van-kanalen.html

Koedijk, O. C. (red.) (2020). Richtlijnen Vaarwegen 2020. Rijswijk: Rijkswaterstaat Water, Verkeer en Leefomgeving


100 Kubic meters of
soil needed to circularly
build the embankments
Pumping
station
Adjustable weir to control
waterlevel and vegetation inflow
Evaporation loss
NAP 9.85
Ground Level 2.65
Min. KP -0.15
Lateral canal
Buffer reservoir
NAP 4.25
Ground Level -2.95
KP -5.60
Infiltration loss
Sediment trap
Trajectory Axis
W d = 45.6m
W t = 91.2m
W t + Δw = 100.2m
D = 5.6m
T = 4.0m
Fixed
water level
Fluctuating
water level
Indicator of
groundwater
table
Indicator of
subsurface
water flow
Layer of clay + peat
SHEET PILE
sondeertrajectlengte t.o.v. maaiveld
Waterspanning - U2
N314
LF4 Midden - Nederlandroute
Den Elterweg
KP +/- 0.15
NAP 10.0
Ground Level 2.8
KP 0.0
Baaksche Beek
De Oosterwijkse Vloed

3.2.2 Design Experiment S: The Renaturalizing Riverscape

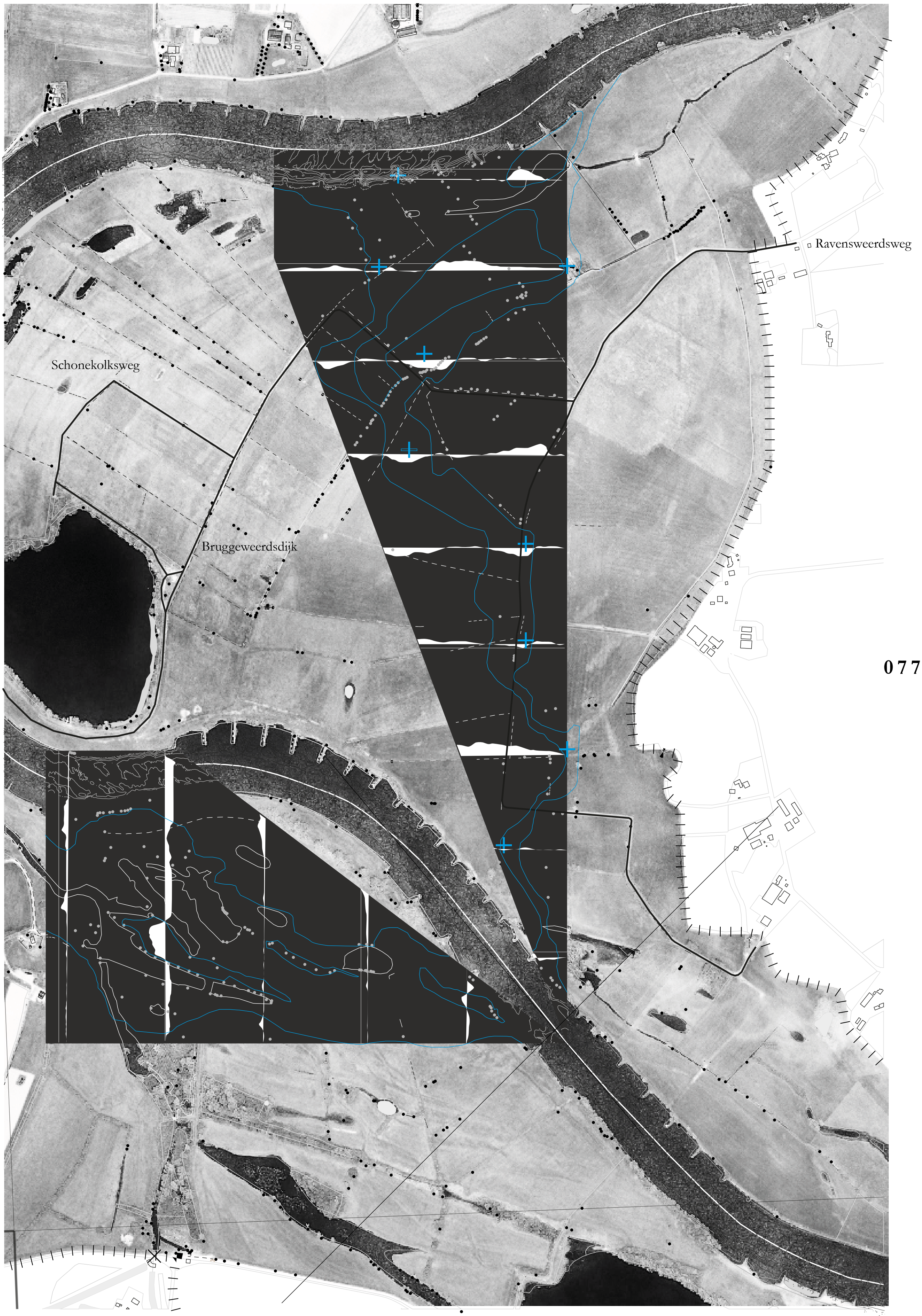
The IJssel has a strong meandering character, which leads to a (relatively) high level of sedimentation in sharp river bends (Rijkswaterstaat, 2020). Although the IJssel is dredged in general two times per year (so called 'hotspots' more often), seizing these activities will not lead to a drastic renaturalization of the river by itself. Sedimentation will occur in some bends and raise the mean riverbed depth, although the profile will not change drastically. Over the past centuries, especially since the firm believe in the engineered and manufactured landscape from the 1850s onward, a large amount of material went into the normalisation and straightjacketing of the river (van der Ziel & Corporaal, 2021). These elements posed an opposing force, subjecting the natural processes of the river. Now, the river will not be able to take over without interference to disrupt the status quo of the territory.

The proposition therefore is to force the river out of its current riverbed, so that is will once again start to sediment and erode within the floodplain areas, leading to a kick-start of the renaturalization effect. This opposing force, or object, will be placed within several large bends in the Upper-IJssel, where plenty of floodplain area can start the sedimentation and erosion processes without endangering flood protection structures. The available sediments will be deposited downstream, amplifying and speeding up the river rehabilitation (Florsheim et al., 2008). The proposition is to leave current objects in place, and to not alter and excavate the territory to a state that we identify to be natural, but let the river act on its own. The basalt blocks of the groins will be left in place, as remnants of past infrastructures. They will create a new habitat, leading to a specific bio diverse environment which is created on top of past human interference, not resembling a natural environment in itself. The force and weight needed to move the river from its contemporary context and equilibrium, shows the force that went into creating the current flow path over the past centuries. These anthropogenic anchors show the shifting view of the system, marking the beginning of a new era. The project proposes a certain visibility and tangibility of our influence, hence not trying to erase past measures.

The aspect of temporality is, in opposition with the canal projection, very important in this conceptual design. The design acts as an implement in order to start and initially guide a process, which will successively take place on its own afterwards. The creation of a certain habitat type is, as previously mentioned, dependent on micro-topographic circumstances, as well as on the amount of flow (Corenblit et al., 2009).

Figure 22: Renaturalizing the IJssel, now deplete of navigation purposes

Figure by Goselink, 2021



Voorster Beek

In the conceptual drawing to the right, the projected habitat is shown in the flow path confinements. The flow path is indicative of a rapid process of local erosion and sedimentation turning the shallow substrate layers upside down. There is the potential that seeds in the subsurface might rejuvenate once brought to the surface again.

After the initial rapid meandering (10-20 years), the flow path will start to settle and embed itself into the territory through backward erosion of the terraces next to the bed (Julien, 2010). From this moment on, succession of vegetation and animal species will start to occur on a larger scale, finalizing the newly created environment (Corenblit et al., 2009).

The aim is to obstruct the flow, thereby utilizing the force of the flow to identify and create its own flow path, dedicated to the contemporary flow regime and discharge rates of the IJssel. The large meander at the location is a reference to a past discharge rate, as the IJssel received a larger portion of the Rhine discharge between 1100 and 1424 AD (van der Ziel & Corporaal, 2021). This meander is now set in place, as it is not only strengthened with groins and embankments, but the river simply does not have the force to shape its flow path.

The new path finding of the river allows for the creation of a fitting and proportionally scaled riverine landscape, in which many different habitats are developed in rapid succession. This allows the system to both kick-start the sedimentation process further down river, and also create hotspots of habitat and species diversity spread throughout the riverine territory of the Upper-IJssel through the regulation of flux, system stability and energy transmission in the landscape (Jones et al., 1994).

The most important way in which the river can renaturalize itself is by sediment transport in which seeds and spores are carried, which will then spread and plant throughout the flow paths and floodplains (Dirks et al., 2014). The design concept is showing how from the point of interference in the current riverbed, a trajectory of flow can be identified. This flow path is characterized by micro-topographic elements in the floodplain areas, e.g. small gullies and meander ridges which will guide the flow through the lowest parts of the territory (Naeem & Wright, 2003). Secondly, the erodability of both the specific subsurface constructs of soil density, as well as the presence of vegetation types with complex or rigid root systems, containing the soil in place and therefore resisting (although temporarily) the erosion process (Coulthard, 2005).

The eroded material will aggregate within the existing bed downstream, in the Lower-IJssel area. The overall mean water levels will therefore slowly rise, leading eventually to an increasing need for space to accommodate the riverine territory.

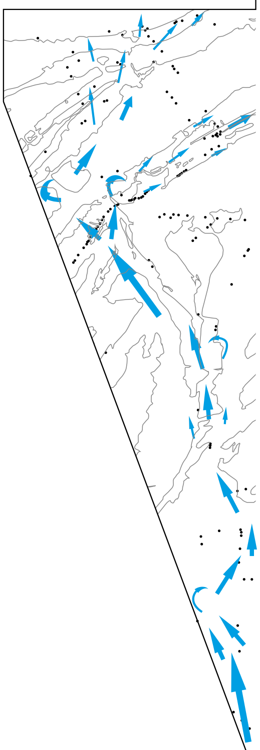
Figure 23: Temporal habitat creation and succession by erosion and sedimentation of the new bed

Figure by Goselink, 2021

1

Resistance landscape

Path finding
High grasses - reeds
Elimination of species unable to withstand



2

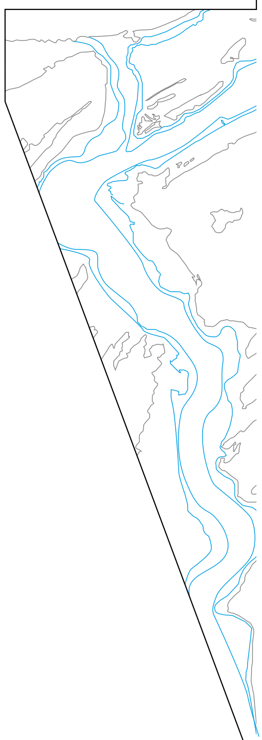
Translation landscape

Quick meandering
Sandbanks
High rate of change
Continuous rejuvenation

3

Embedded landscape

Backward erosion
Stabilizing and straightening bed
Succession of species



IV Interaction in the **IJssel**

Or the paradox as design assignment; amplifying internal opposition

4.1.1 Design Experiment X - Fortmond (O)

Fortmond is the name of the area and former brickworks in the inner bent of the IJssel between Den Nul and Veessen. The large meander is the tell-tale sign of a high discharge rate in the past. Between 1170 (Aelmere becoming Zuiderzee) and 1424 (consecutive St. Elizabethsvloeden) the IJssel was the shortest route from the Rhine towards the north sea. After 1424, a dramatic decline of flow through the IJssel started centuries of continuous sedimentation problems (van der Ziel & Corporaal, 2021).

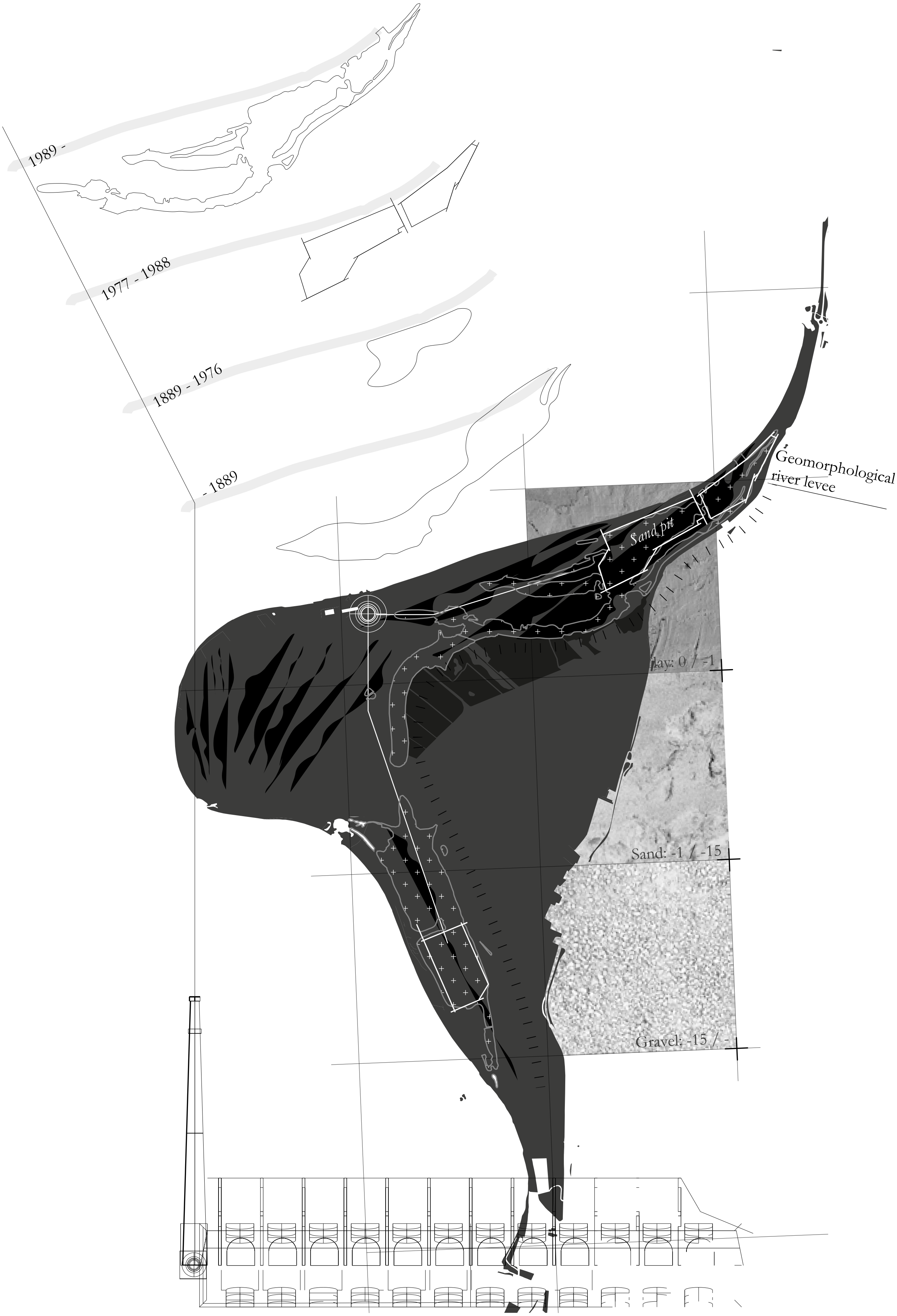
The carved riverbed was too large for the current Ijssel discharge rates, resulting in a braiding river prone to ice blockages and not suitable for shipping. Plans were made in the 1830s, favouring a central navigation channel and a spillway to prevent floodings (H. F. Fijnje, ca. 1830). This plan shows one of the earliest large scale plans integrating flood protection and navigation.
It was a direct consequence of consequetive floodings throughout the previous years caused by ice blockages during spring. It simultaneously instigates the engineering perspective of the constructed landscape, in which engineering will overcome the natural environment (Boersma, 1995).

The current riverscape is characterized by the towering chimney of the former brickworks facility, which has left its marks in the riverine territory through its excavation of the surface. After the production of bricks stopped, the pits were used to extract sand and gravel, leaving deep marks in the territory.

In 1989, the Duursche Waarden became one of the pilot projects of renaturalization in the Netherlands (Dirks et al., 2014).

Figure 24: Extractivist and renaturalized landscapes at Fortmond

Figure by Goselink, 2021


1989 -
1977 - 1988
1889 - 1976
- 1889
Geomorphological river levee
Sand pit
lay: 0 / -1
Sand: -1 / -15
Gravel: -15 / -

4.1.2 Spatial Characteristics and Accessibility

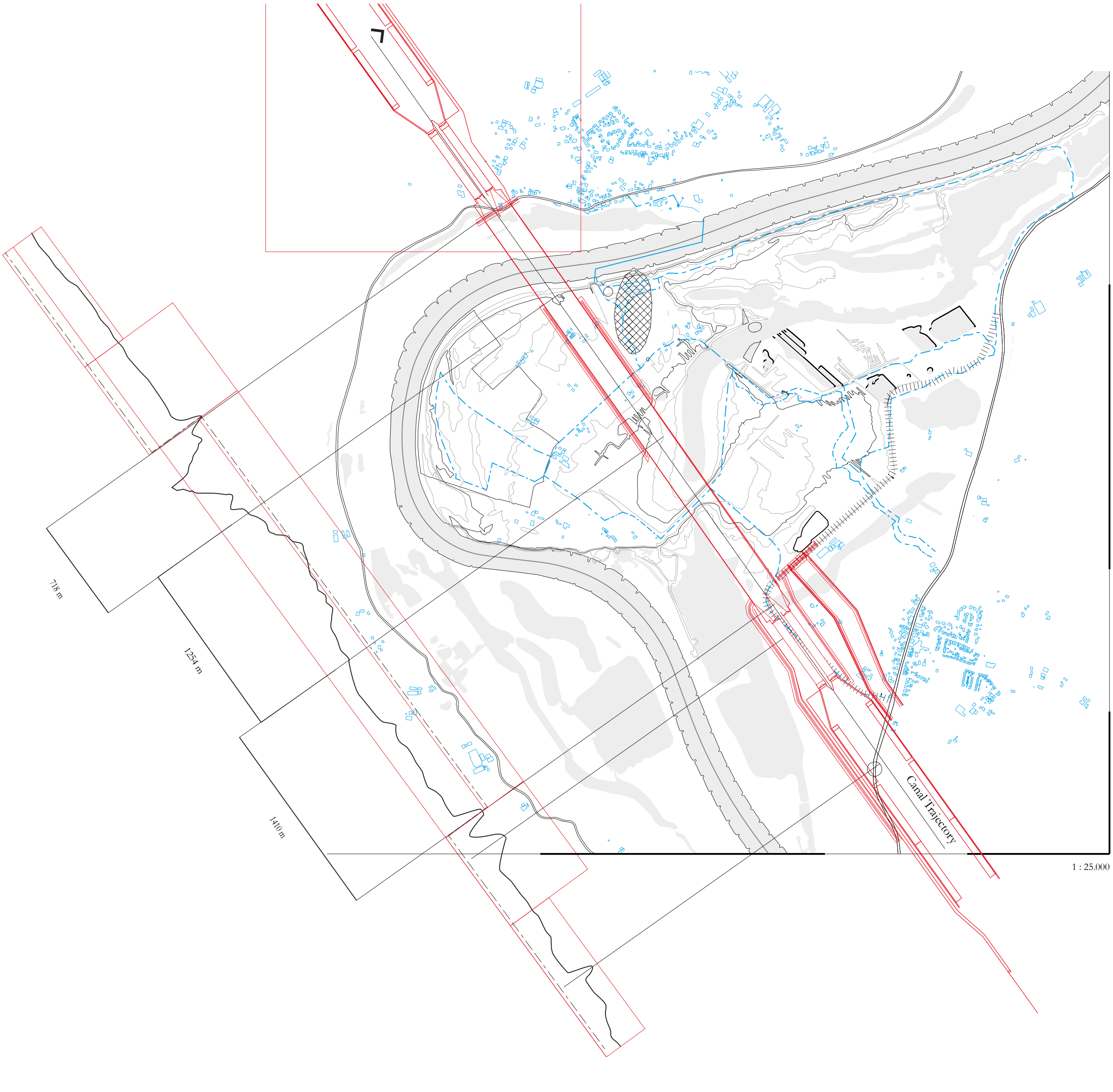
The map to the right shows the projected intersection of the lateral canal with the secondary buffer channel in the riverine territory of Fortmond. As the flow characteristics should be separated at a systemic level, two detailed design interventions will be produced on the lowes scale level. First, the connection of the secondary buffer channel at the territorial plane, which is used to show both the potential for synergy between the complementary parallel systems, as well as the highlighting of the difficulties and complexities experienced when this integration on the lowest scale level is achieved.

Secondly, the lateral shipping channel itself will be raised from the territory and juxtaposed to the IJssel, in order to emphasize and show the opposition between the systems in direct relation to one another. Simultaneously, it allows for the identification of potentialities in the space in which the both systems will interact.

The lateral shipping channel cannot be connected to the fluid riverscape directly, as the fluctuations and currents would undo the controllability of the system in itself on the large scale.

Figure 25: Projection

Figure by Goselink, 2021


718 m
1254 m
1410 m
Canal Trajectory
1 : 25.000

4.1.3 Systemic Connection

In design practice, proactive problem seeking in the direct confrontation of the paradox leads to the most interesting spatial challenges (Dorst, 2011). In this case it emphasizes the difficulties experienced when integrating flow characteristics and their spatial constraints. The secondary buffer system, as designed for the lateral shipping channel to absorb fluctuations from the intersected tributary streams, connects to the natural riverscape through an outlet at the Fortmond intersection.

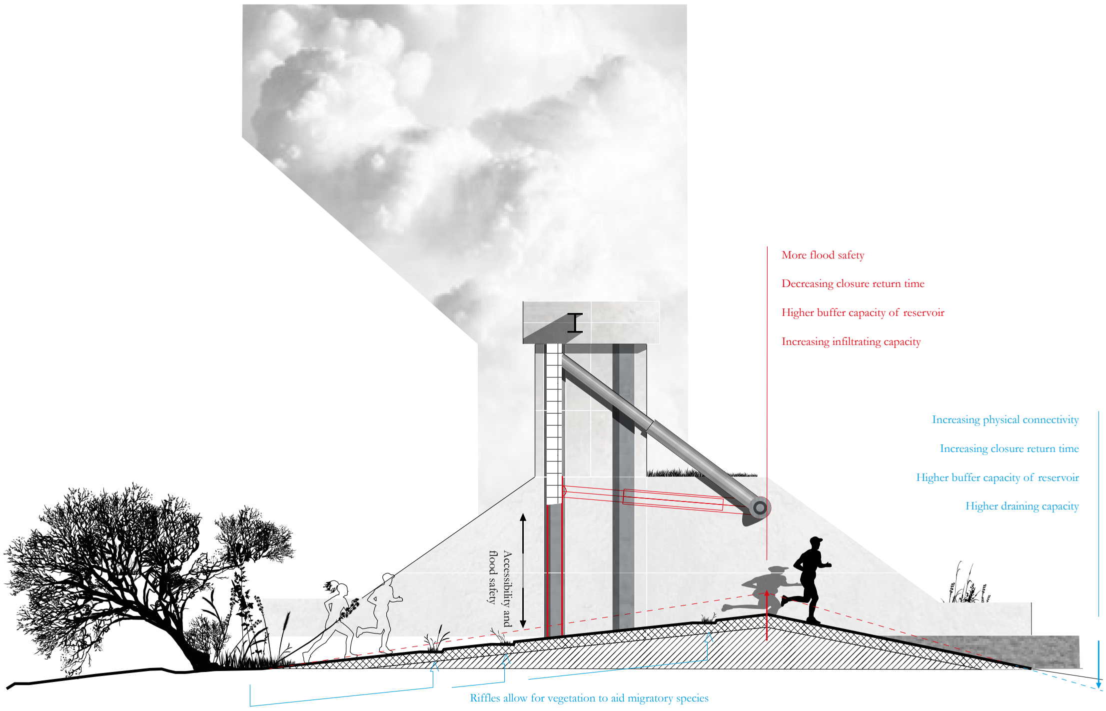
Although the two systemic functions based on flow characteristics are kept separately, the deliberate connecting of the two systems emphasizes the difficulties experienced when integrating both parallel systems and their spatial restraints. In order to achieve not only the integrated but also the integrative design, the possibilities of the secondary channel to function simultaneously for eco-hydrology and flood control are embedded in the design. The images to the right show lateral and longitudinal sections of the spillway design with red and blue elements representing the two parallel systems.

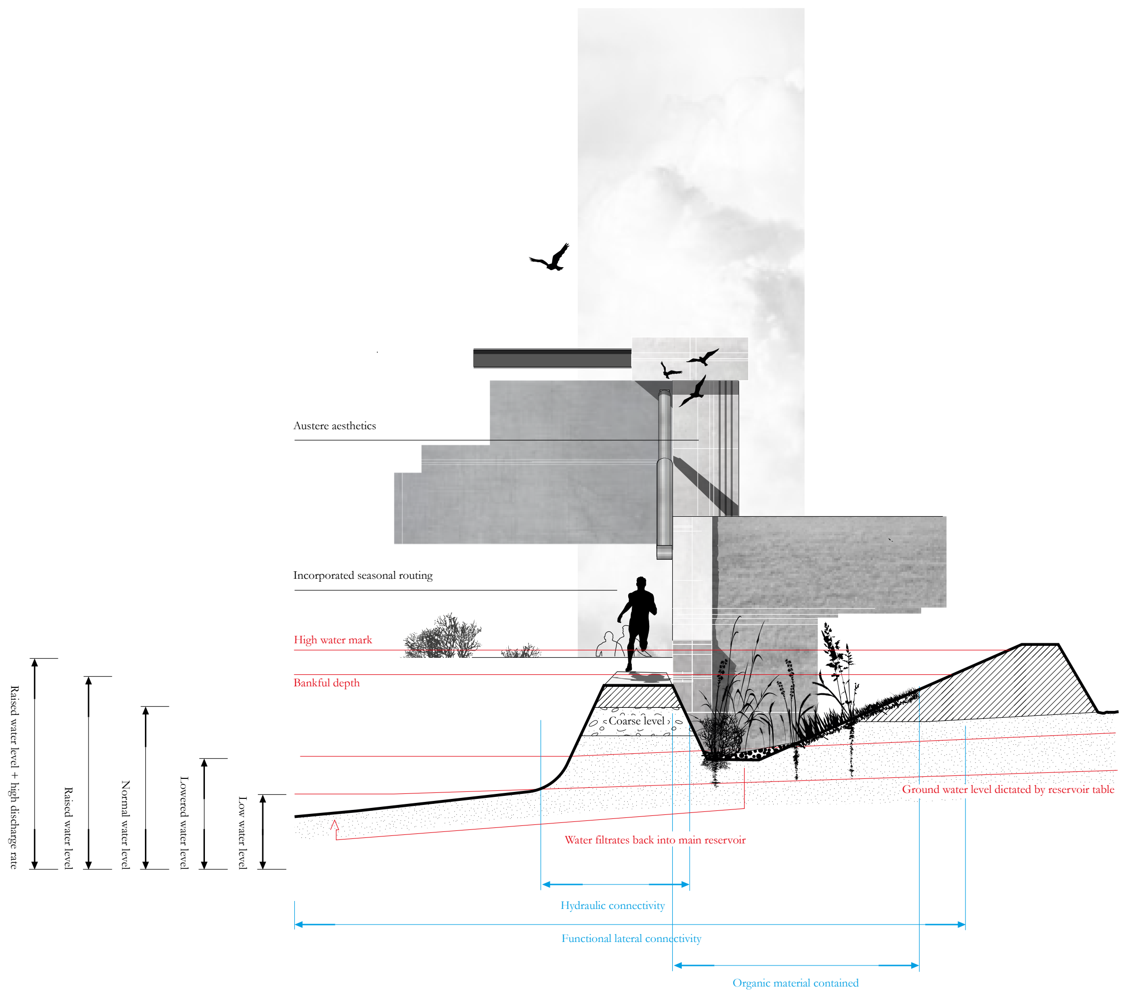
The buffer system can aid in temporarily discharging or storing large volumes of water in the riverine hinterland for proactive drought management. These buffer streams will have a temporal interlinkage with the river, through which it can aid in the abundance and distribution of aquatic organisms. Frequency and magnitude of connectivity drive and regulate species distribution. The anthropogenic barrier can be constructed as a spillway to suffice in the storing capabilities of the system, as temporal overtopping of barriers is enough to reconnect flows (Rolls et al., 2014). The structure now has to be designed for water levels which simultaneously maximize buffer capacity and allow for regular overtopping: two conflicting and opposing restraints demanding compromises.

To ensure free flow and maximal discharge capacity of the channel, regular maintenance to combat sedimentation and vegetation coverage will be needed (Brouwer & van Ek, 2004). For this purpose, sedimentation and vegetation are not allowed as they will cause deterioration of the channel and capacity (Rijkswaterstaat, 2017). For the habitat connectivity and in order to function as temporal habitat for diverse species, sediment transportation and vegetation are of the upmost importance (Schumm et al., 1984). In the design, these complementary but conflicting demands are met through an intricate system creating a secondary bank imitating a natural system, with a temporal physical connection in case of high water, but only allowing hydraulic (no physical) connection when the buffer volume decreases. An integrative design, combining the paradoxal demands, but inevitably based on compromising or immense complexity. It testifies to the conscious act of problem seeking in design practice, which leads to interesting design challenges and solutions.

Figure 26: Integrative design of the spillway at Fortmond

Figure by Goselink, 2021


More flood safety
Decreasing closure return time
Higher buffer capacity of reservoir
Increasing infiltrating capacity
Increasing physical connectivity
Increasing closure return time
Higher buffer capacity of reservoir
Higher draining capacity
Accessibility and flood safety
Riffles allow for vegetation to aid migratory species


Austere aesthetics
Incorporated seasonal routing
High water mark
Bankful depth
Coarse level
Raised water level + high discharge rate
Raised water level
Normal water level
Lowered water level
Low water level
Ground water level dictated by reservoir table
Water filtrates back into main reservoir
Hydraulic connectivity
Functional lateral connectivity
Organic material contained

The potential for including the urban experience and temporality within the structures in an early stage, allows for the experiencing of the new dynamic and non-dynamic environments more directly.

The design of the spillway shows that confronting the core paradox directly, as a part of the solution seeking process typical for designing, leads to interesting design assignments. However, it also leads to compromising of separate functionalities and the creation of an increasingly complex system of complementary solutions within the integrative design assignment.

Although there are potentialities for synthesizing of the two complementary parallel trajectories on a systemic level, it highlights how this will spatially inevitably lead to compromising and increasing complexity. In this, the design experiment allows for a critical view on this integrated practice adopted within the Dutch rivers.

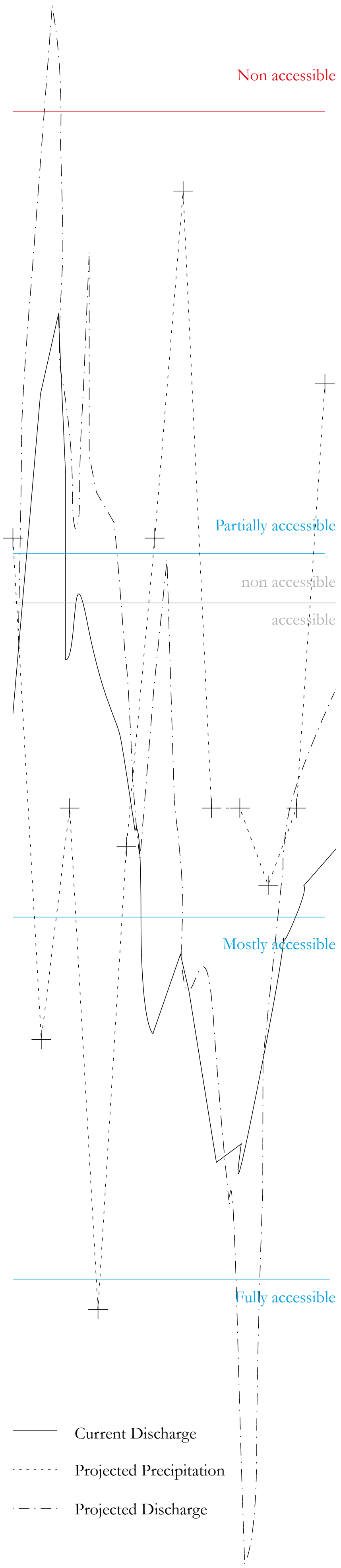
Figure 27:Urban temporality of the use and experience of the spillway and its connection between in- and outerdike area

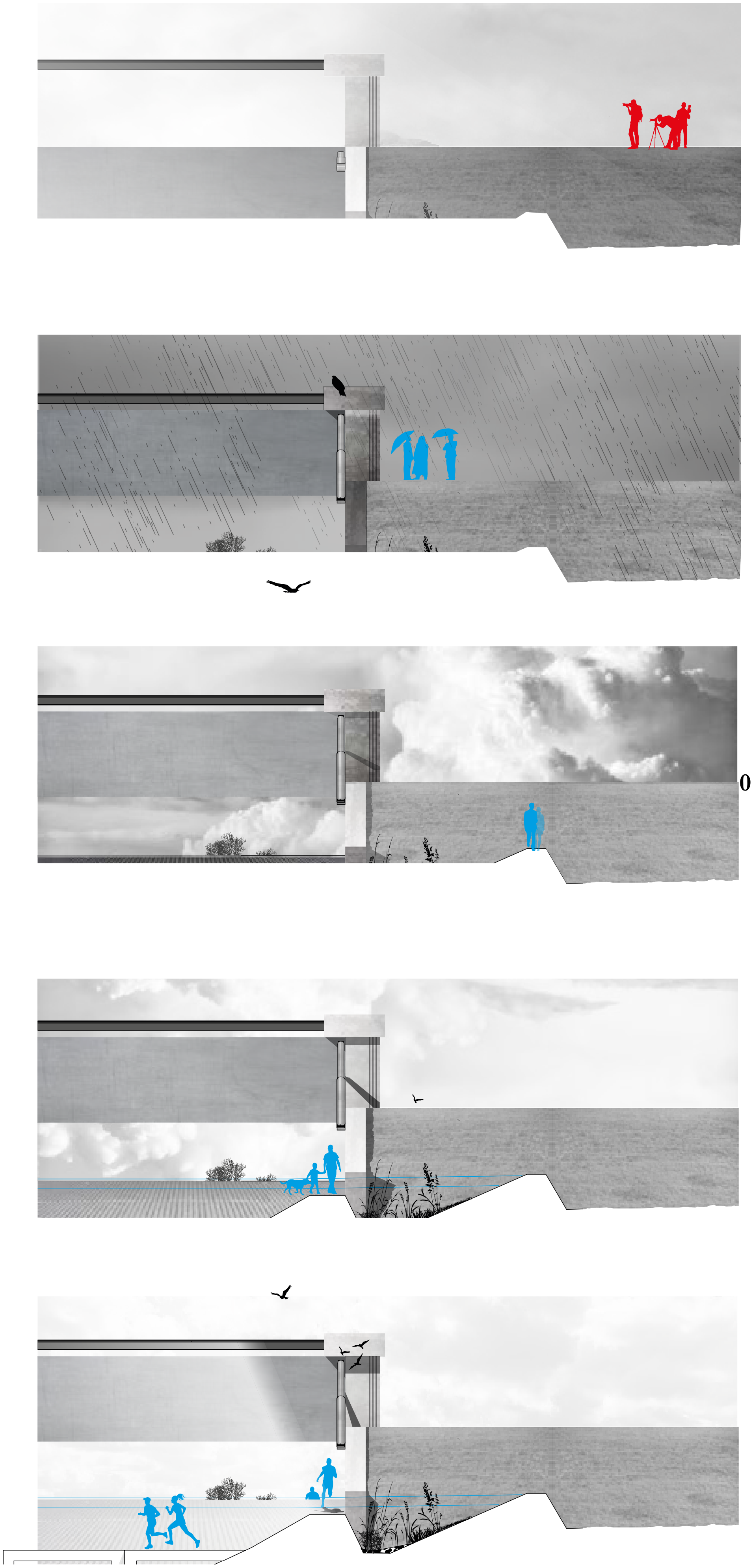
Figure by Goselink, 2021

Based on:

Attema, J., Bakker, A., Beersma, J., Bessembinder, J., Boers, R., Brandsma, T., Hazeleger, W. (2014). KNMI'14: Climate change scenarios for the 21st century—A netherlands perspective. KNMI: De Bilt, The Netherlands.

Meteoblue.com (n.d.) Climate in Deventer, NL. Retrieved on: 30-08-2021. Retrieved from: https://www.meteoblue.com/en/weather/historyclimate/climate-modelled/deventer_netherlands_2756987


Non accessible
Partially accessible
non accessible
accessible
Mostly accessible
Fully accessible
Current Discharge
Projected Precipitation
Projected Discharge



4.1.4 Systemic Interaction

In contradiction to the spillway design, the aqueduct is not an as much an integrative design, as the functional flow characteristics and spatial constraints are not interconnected, but they do interact. In this design, the parallel system interacts and reacts to one another, through which synthesis can be obtained.

In order for the raised shipping lane and its rigid constructs to effectively and most important positively interact with the natural stream and variable flow, not only stream hydrology is of importance. Underneath the structure, a fundamentally different habitat is created. In aquatic habitat creation the alteration of flow velocity, accompanied by water depth and thermal variability, makes up the most important components of the habitat typology (Cote et al., 2009). Combined with discharge of water and sediment transport, it provide the important continuous exchanging of energy, organisms and particle matter (Ward & Stanford, 1995).

As the dark space underneath the structure potentially provides shelter to a large diversity of small organisms and insects, the structure can expand upon this aspect by increasing variability in flow velocity through systems of riffles and height differences. This interacts with temperature, oxygen content in the water and moisture content in the air, providing suitable settling conditions for the aforementioned species.

By applying bio-receptive concrete to the facade of the structure, mosses and lichen are able to easily attach to the object. This creates a suitable set-up for biological content to grow upon the object without compromising the integrity of the object (Veeger et al., 2021). It highlights the potentiality of the rigid structure to provide an increasingly variable anthropogenic habitat, while constraints and consistency of the navigation fairways is enhanced and amplified through its extrusion from the territorial surface.

Figure 28: Design experiment of the systemic interaction between the systems

Figure by Goselink, 2021

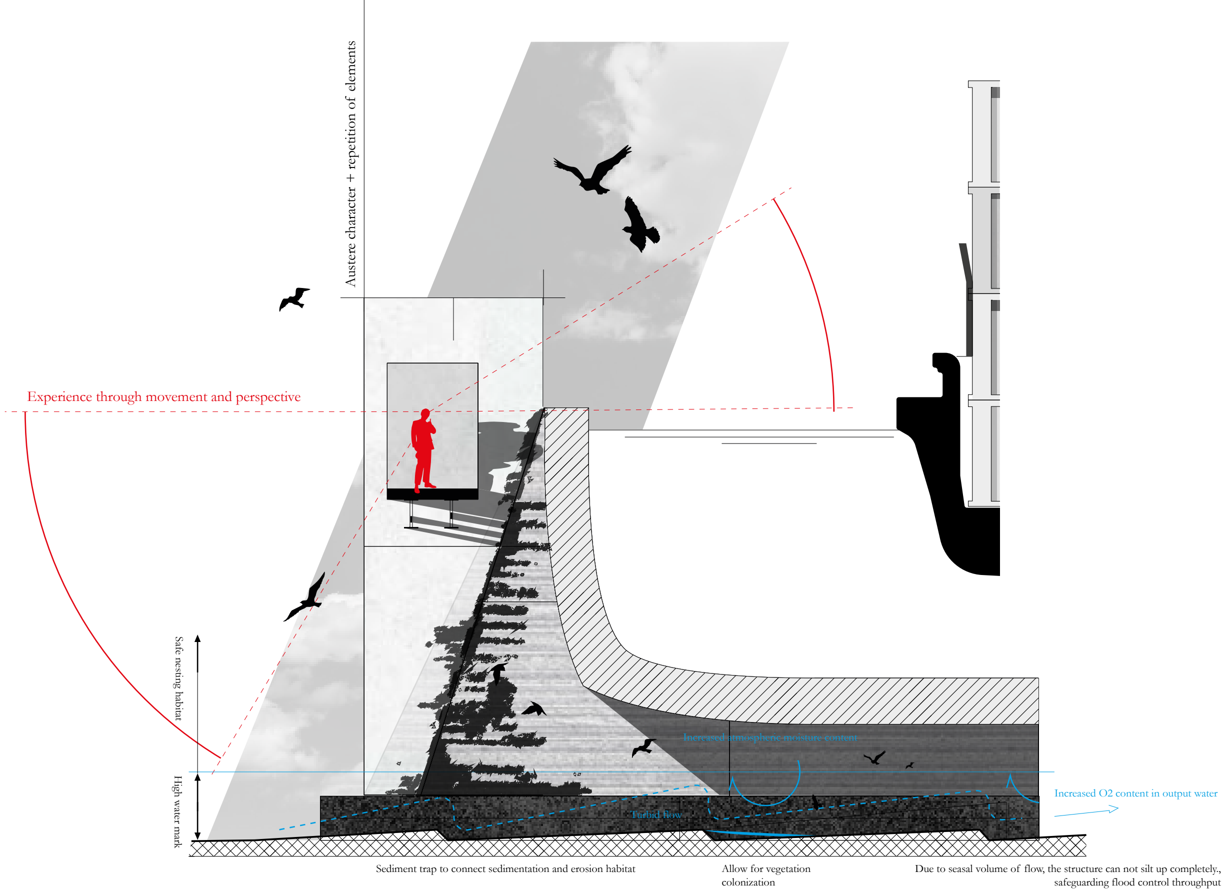
Based on:

Cote, D., Kehler, D. G., Bourne, C., & Wiersma, Y. F. (2009). A new measure of longitudinal connectivity for stream networks. Landscape Ecology, 24(1), 101-113.

Koedijk, O. C. (red.) (2020). Richtlijnen Vaarwegen 2020. Rijswijk: Rijkswaterstaat Water, Verkeer en Leefomgeving

Veeger, M., Prieto, A., & Ottelé, M. (2021). Exploring the Possibility of Using Bioreceptive Concrete in Building Façades. Journal of Facade Design and Engineering, 9(1), 73-85.

Ward, J.V. & Stanford, J.A. (1995) Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers, 11, 105–120.


Austere character + repetition of elements
Experience through movement and perspective
Safe nesting habitat
High water mark
Increased atmospheric moisture content
Turbid flow
Increased O2 content in output water
Sediment trap to connect sedimentation and erosion habitat
Allow for vegetation colonization
Due to seasal volume of flow, the structure can not silt up completely., safeguarding flood control throughput


250 X
Vb
Groot containerschip [Large container]
Length: 135.00 m Breadth: 17.00 m Draught: 3.50 m Air Draft: 8.80 m Tonnage: 500 TEU
CCG-97
Infrastructure
Habitat

As the design encompasses a deliberate interaction between infrastructure and natural processes, it is important to predict how this relation will shape the riverine territory. The processes of sedimentation, transport and erosion are directly related to the increase or decrease in flow velocity, influencing the capacity to carry larger or smaller sediment either as suspended matter or as bed load (Julien, 2010). In relation to the structure of the aqueduct, flow from the river will slow down in front of the structure (former sand pit underneath the structure on the map to the right) while it will increase velocity after passing through the structure when the water level is sufficiently high (above on the map to the right). This will create both a sedimentation and an erosion landscape alongside the structure.

Feedback mechanisms between habitat- and landform dynamics are under the influence of sediment transport and self-organisation of species within the landscape (Murray et al., 2008). Major ecological functions driving dynamicity of the riverine (aquatic) landscapes are the nutrient and water cycle, and the decomposition and creation of organic matter (Naeem & Wright, 2003). Biodiversity regulates flux, system stabilisation and the exchange of energy and material within the landscape (Jones et al., 1994).

Riparian vegetation largely controls the processes of erosion and deposition in fluvial zones. Pioneer species inhabiting new areas allow for vegetative succession and the accumulation of new sediments containing seeds and diasporas. Eventually woody structures will take over these islands and patches, which are of the upmost importance for the retention of organic material in case of large destructive events in the riverscape. It defines the regeneration on the larger timespan within the combined fluvial landform and habitat development (Corenblit et al., 2009).

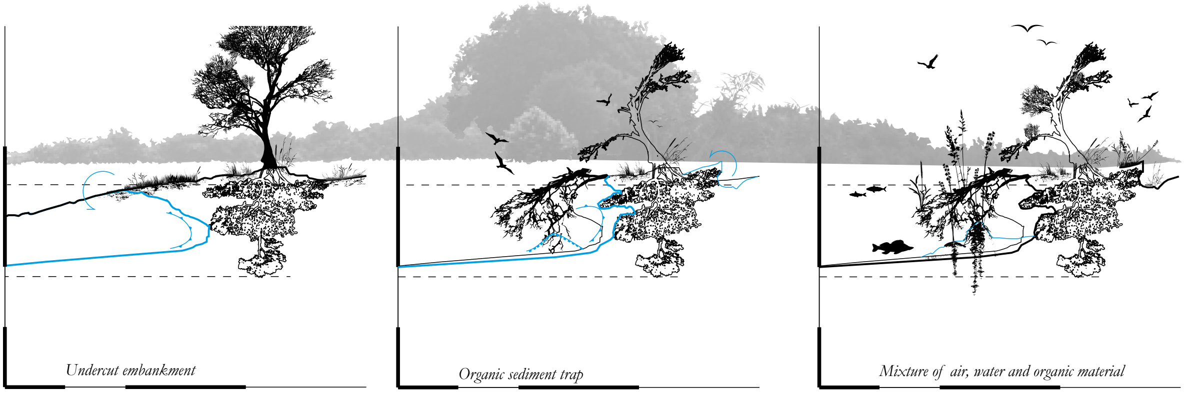
The erosion landscape is shaped through the geomorphological process of bed- and bank erosion, which is integral to the functioning of riverine ecosystems. It provides a crucial dynamic aquatic and riparian habitat for vegetation succession and regeneration (Florsheim et al., 2008). Bank erosion provides sediment downstream and modulates channel morphology, actively changes its bank structures and habitat, and contributes to large woody debris.

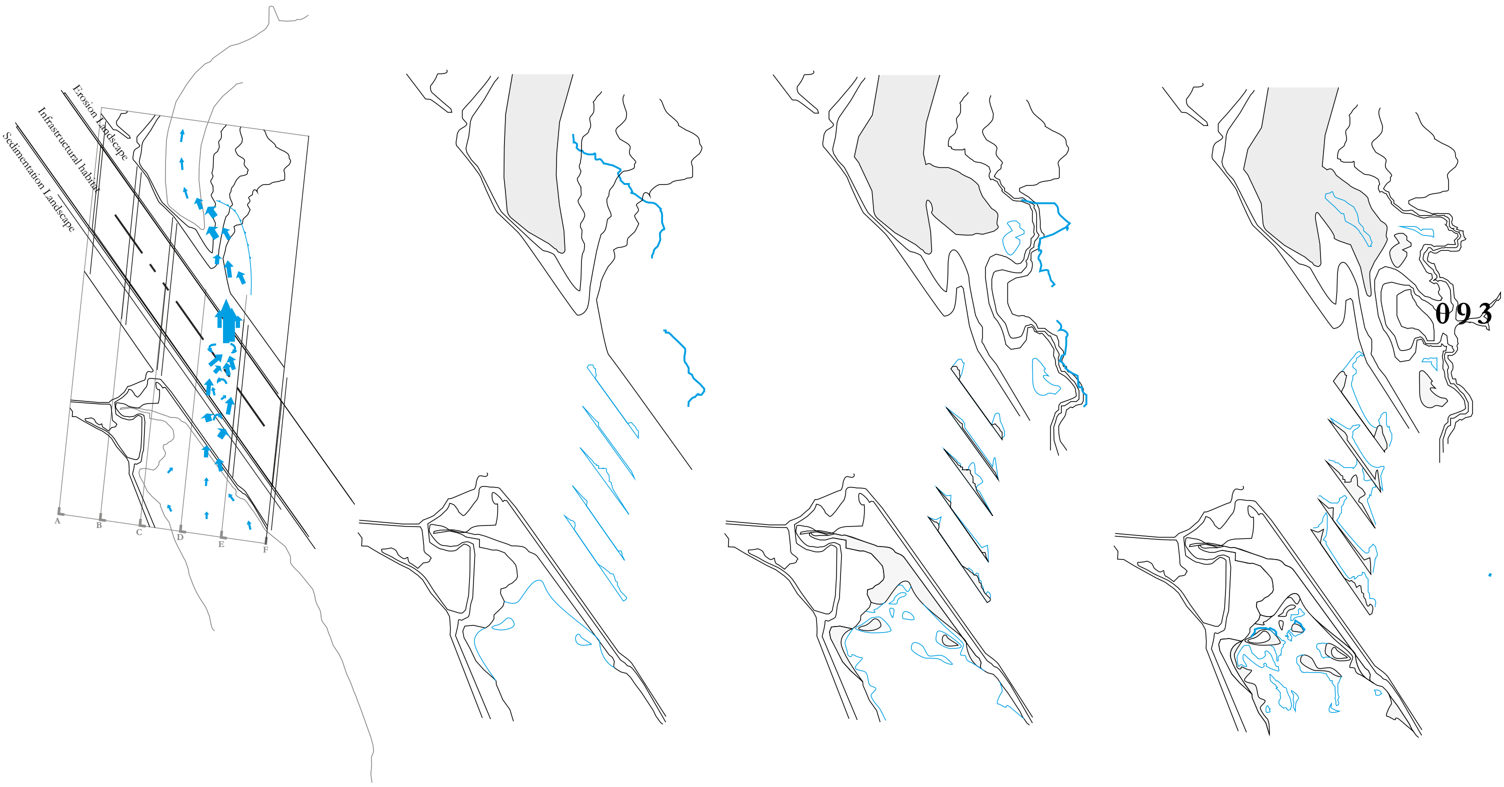
Large resistant vegetation (trees and shrubs) can alter the flow of a stream immensely, by resisting erosion and thereby forcing the river around into a braided pattern creating an island, or by degrading and providing large woody debris, which in turn slows down the near bank velocity and creates a trapping sediment (Coulthard, 2005). The riffles underneath the infrastructural object allow for patches of vegetation and sediment to accumulate, creating stepping stones between the two landscape typologies.

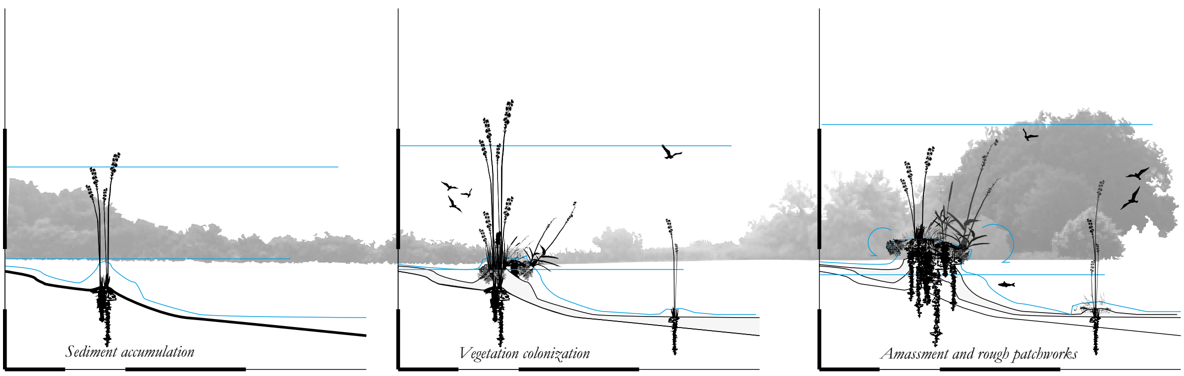
Figure 29: Sedimentation and erosion landscape typologies

Figure by Goselink, 2021

erosion landscape







sedimentation landscape

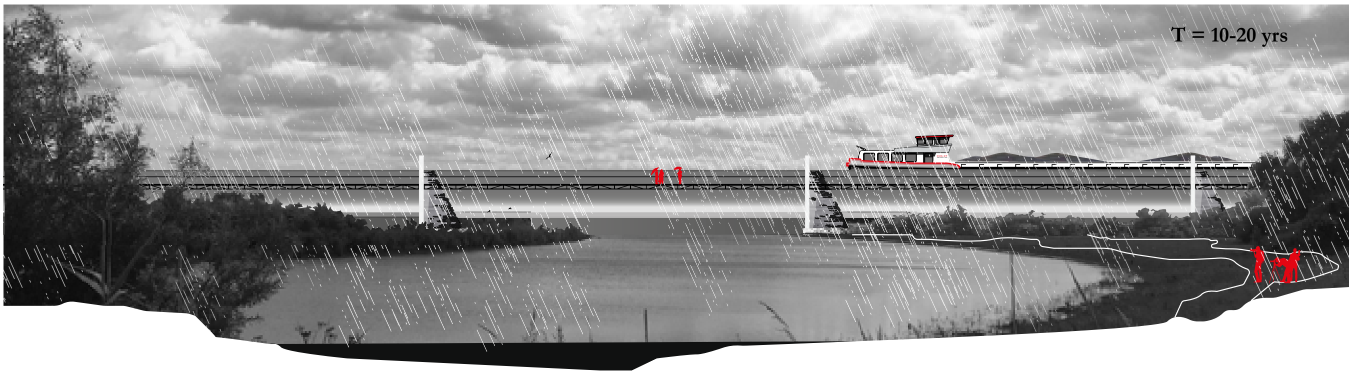
The image to the right visualizes and shows how the design emphasizes the internal paradox of the design assignment as identified through the conscious framing. By extruding the rigid principles from the riverine territory, juxtaposing the two systems based on flow characteristics within the riverine territory shows the increasingly opposing demands.

It is now easier to imagine the immense influence the practice of embedding this spatially restrictive principle within the Dutch riverine territory in relation to other functionalities of rivers. The extrusion and juxtaposition allows the river to renaturalize and absorb the effects of a shifting hydrological cycle, while the complementary parallel system is kept under complete control.

Figure 30: The extrucion and juxtaposition of the rigid over the fluid riverscape

Figure by Goselink, 2021


T = 0


T = 10-20 yrs

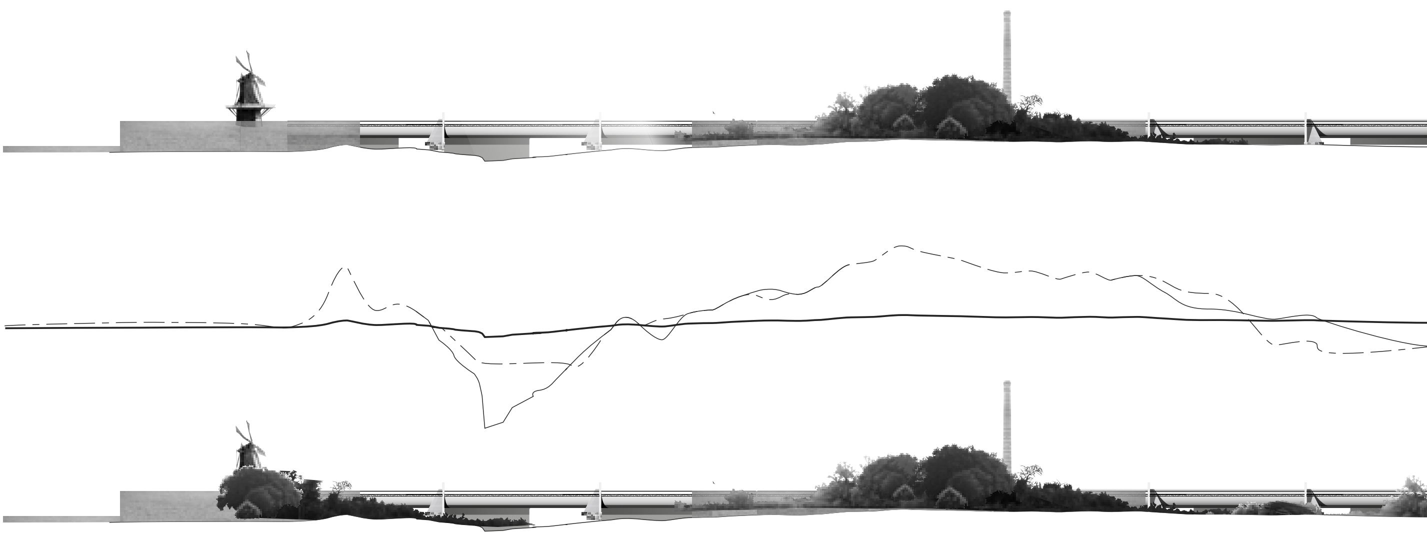

T = 30-40 yrs

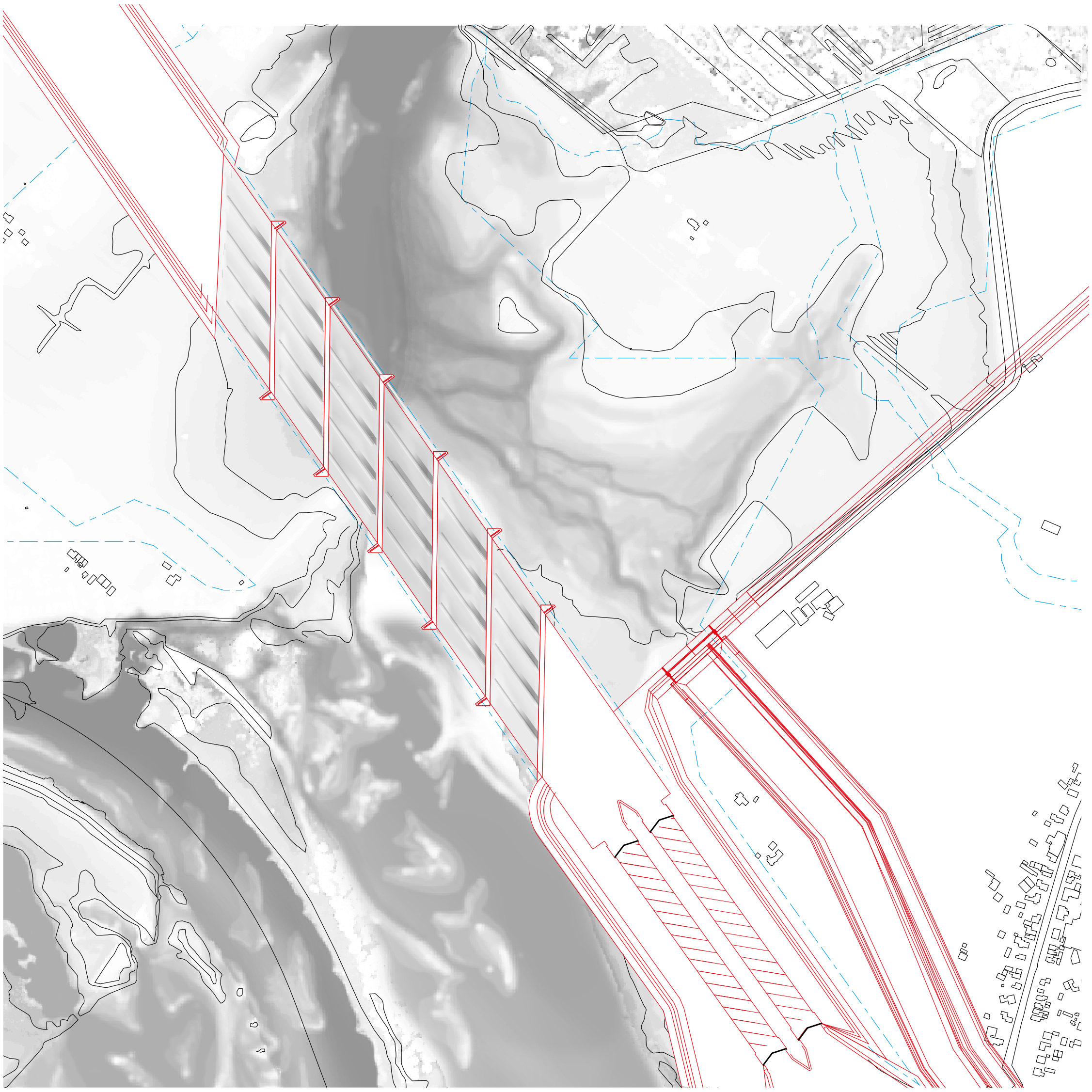
Figure 31: Potential of the design experiments at Fortmond (O)

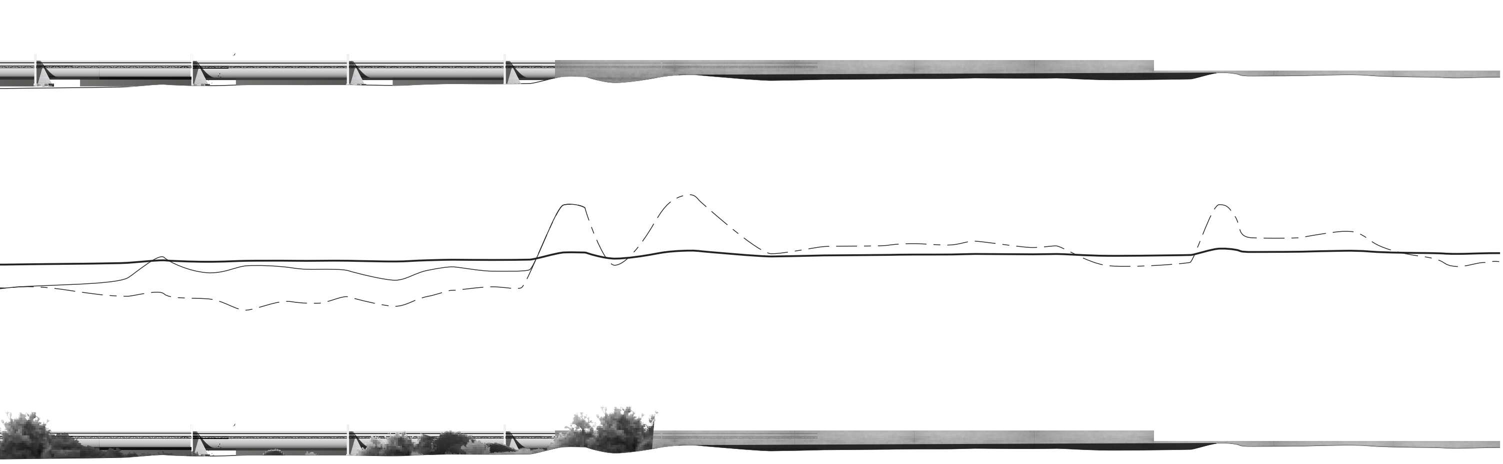
Figure by Goselink, 2021

Figure 32: Section of the design experiment on systemmic territorial synthesis

Figure by Goselink, 2021







V

Evaluation of the IJssel

5.1.1 Reflection

The limitations of decomposition and abstraction: posed by the designer and by the scale (physical context) at which the design process takes place. It is never fully deplete of a context, as the framing of the assignment and solution space is based upon findings and conceptualizations of the situation. However, the key potential to widen solution space is found in the combination of conscious framing and a high level of abstraction. When designing through the scales, limitations will occur posed by the physical surroundings in which the detailed design has to land, therefore the limitations posed to the level of abstraction will only be identified in the design process, validating the initial concept or iterating back to make alterations and start again.

The high level of abstraction, especially in the early stages of framing the paradox, really allows the designer to conceptualize the underlying phenomenon. Simultaneously, it allows for the construction of the solution space in combination with these phenomenon. This level of abstraction has no clear boundaries or limits, except for the ones the designer poses upon himself. Therefore, this abstraction is where most of the new solution space can be discovered and framed, and the concepts can be created.

When moving down through the levels of scale, the level of abstraction automatically moves down accordingly as more of the realistic context has to be taken into account and more detailed information becomes of importance for the solution seeking. Therefore, it limits itself gradually, leading to a more tempered and realistic exploration of the initial abstract concept.

In conclusion; yes there are limitation to the level of abstraction, but only the ones defined and adopted by the designer. When moving down the steps of physical scale, the level of abstraction decreases simultaneously because of the physical context in which the conceptual design eventually has to land on the small scale levels of the territory.

On the small scale level the territory poses universal problems to be solved. Difficulties found in the integration or interaction of systemic functions and conflicting spatial characteristics cannot be avoided and have to be faced head on. Therefore again, the high level of scale and abstraction adopted in the early stages of the design process are of importance to be able to come up with new perspectives on the matter.

Where the engineering disciplines are focussed primarily on problem solving within a clear context which can be modelled, design allows for the questioning of the experienced problem in itself. It asks whether another perspective on the matter still would experience the constructs as a problem, or rather a part of a solution. That is how design is aimed at the creation of multiple values for different artefact frames simultaneously, strongly related to the integrative design process.

In terms of transferability and scalability, the design approach is universal and is applied across the globe by designers. My addition of consciously abstracting the paradox and phenomenon initially, and placing extra attention when framing as it defines and limits the solution space twice during the process are of course applicable in all situations. The parallel riverscape as conceptualized might very well also be a possible solution in other contexts and situations, however both problem and solution were framed based upon research specifically done on the Ijssel River. Therefore, it is possible that a similar solution suffices in comparable situations, however it is likely that going through the design process and the possibilities it opens up, that a different and possibly complementary solution can and will be found.

The design thinking process is inherently integrated (Dutch: integraal) as the first step consists of the framing of an assignment from several viewpoints and constructs. The addition of deliberately aiming for an integrative design ensures not only an understanding of the different artefact frames, but the drive to synthesize them all within the design instead of compromising or deciding upon their value and the need for integration within the system.

Adaptation of the entire integrated river is obsolete from the viewpoint of increasing performance. The discovered underlying phenomenon is based on the internally paradoxal system which is starting to grow further apart due to the changing climatic context in which it is placed, therefore separation is needed and adaptation of the entire river has been found obsolete in a scenario leading up to increasing of all functionalities. This is how the design thinking has led to a reconceptualization of the river as a parallel system of complementary functionalities, thereby creating an integrative design on the higher scale levels.

5.1.2 Conclusion

How can *integrative design* of **riverine territories** with inclusion of **socio-technical regimes**, result in water management systems adapted to the **shifting hydrological cycle**, while *increasing performance* to society?

The design approach is fundamentally different from other problem solving reasoning, and is mainly through the act of framing and the simultaneous constructing of a core paradox and seeking the solution, able to discover new solution space. The integrative approach of synthesizing complementary systems instead of compromising between them, allows to both adapt and increase performance overall.

In conclusion; How can integrative design lead to adaptation AND increasing performance? By framing the problem and solution simultaneously on a high scale level leading to new solution space, which allows an integrative approach based on synthesis and performance increase through reciprocal relations instead of compromises decreasing output discovers new relations and potentials. That is the value of design in interdisciplinary assignments.

The key potential to discover new solution space is found in the all-important combination of both the conscious act of framing, which is typical for the design discipline according to Dorst (2011), and the adoption of a high level of abstraction to reconceptualise simultaneously what the underlying phenomenon of the core paradox are in relation to the solution. In this proactive process, new solution space can be found after which the design through the scales will pose limitations and boundaries which will test the initial concept and verify whether it needs alteration.

If the problem description and mission statements of the integral river are expanded, the space considered in which the solution should be realized has to be extended simultaneously, as only through separation of opposing systems an increase of functionality on all fronts can be realised.

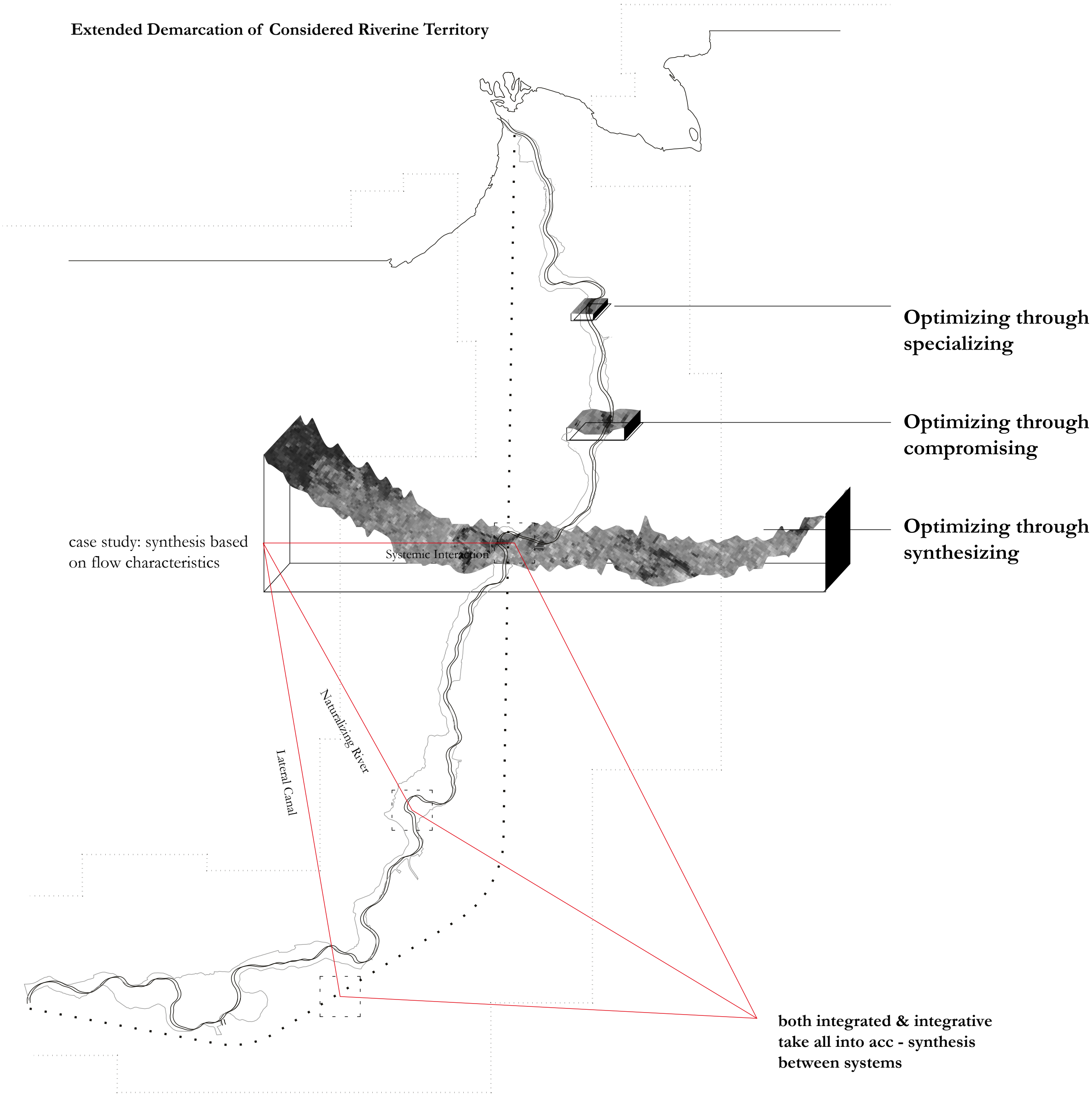
This is why the demarcation of what is considered to be the riverine territory is directly linked to the width of the themes which are allowed to be taken into account in the framing of the paradox, before the actual open-ended problem solving can actually start.

What is to be considered riverine territory defines both the width and extension during the framing leading up to the understanding of the central paradox of the design assignment. Simultaneously, it largely confines the solution space and thereby the possibilities on the “What” of the design thinking equation. It limits the solution space therefore twofold, and should be considered as the most important factor in the initial widening of solution space and possible futures.

Figure 33: Result of the design thinking methodology in riverine climate adaptation strategizing

Figure by Goselink, 2021

Extended Demarcation of Considered Riverine Territory



Productive Reasoning ENGINEERING

What	How	Value	
Thing	Working principle	Aspired	Abduction - 1 - closed problem solving

Productive Reasoning Design

Design thinking

What	How	Value	
Thing	Working principle	Aspired	Abduction - 2 - open problem solving

Frame

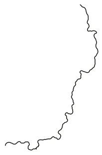
5.1.3 Two-fold Limitation of Territorial Demarcation

The experimental design concepts, aiming to emphasize opposition between the two systems and the approaches through which they are conceived, highlight the boundaries of the current practice of integral river management. Through the process of decomposition and parallelization of the riverine territory, the most stringent spatial demands of the separate socio-technical regimes have been identified, and translated into demands and principles which emphasize the character of the singular regimes. The synthesis of the regimes into two parallel and complementary systems within the larger integrative design framework is allowed by extending the demarcation of riverine territory. This opens up the possibility of spatial segregation rather than spatial integration within the singular riverbed, in order to optimize the performance of the system as a whole instead of compromising functionality on different scale levels. The methodology of decomposing and reassembling shows promising signs in relation to the evaluation of current spatially integrative practices, which can aid in widening solution space much needed in riverine climate adaptation strategies. If the problem description and mission statements of the integral river are expanded, the space considered in which the solution should be realized has to be extended simultaneously, as only through separation of opposing systems an increase of functionality on all fronts can be realised.

This is why the demarcation of what is considered to be the riverine territory is directly linked to the width of the themes which are allowed to be taken into account in the framing of the paradox, before the actual open-ended problem solving can start.

The process of obtaining spatial principles and designing spatial concepts in parallel allows for fast research into possible new avenues to approach riverine climate adaptation, illustrating the value of integrative research by design approaches to the traditional research within the interdisciplinary field. The freedom to explore conceptual alternatives outside of the current status-quo, in combination with the visual nature allowing for discussion and evaluation on a spatial level in the early stages of planning, results in rapid expansion of solution spaces. In conclusion, the thesis project Perspectives on the IJssel illustrates an alternative future for the IJssel, in which an integral approach is paramount, but with a methodology build on spatial decomposition rather than spatial integration. It questions the design methodologies currently applied in riverine climate adaptation, as an extended demarcation of riverine territories as well as a spatial understanding of the separated regimes allows for the widening of solution space. A parallel perspective to obtain an integral solution.

Figure 34: The variety of applicable scales on the IJssel
Figure by Goselink, 2021



IJssel Riverbed

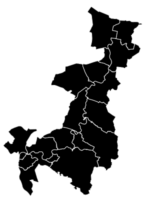
IJssel Outerdike Area

IJssel N2000 Area

IJssel Geomorphological Territory

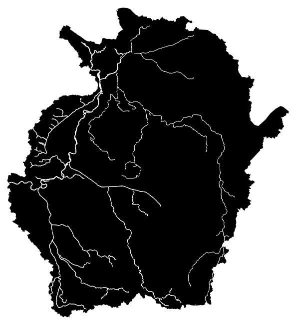
IJssel Flood Prone Territory

IJssel functional Tertiary Catchments

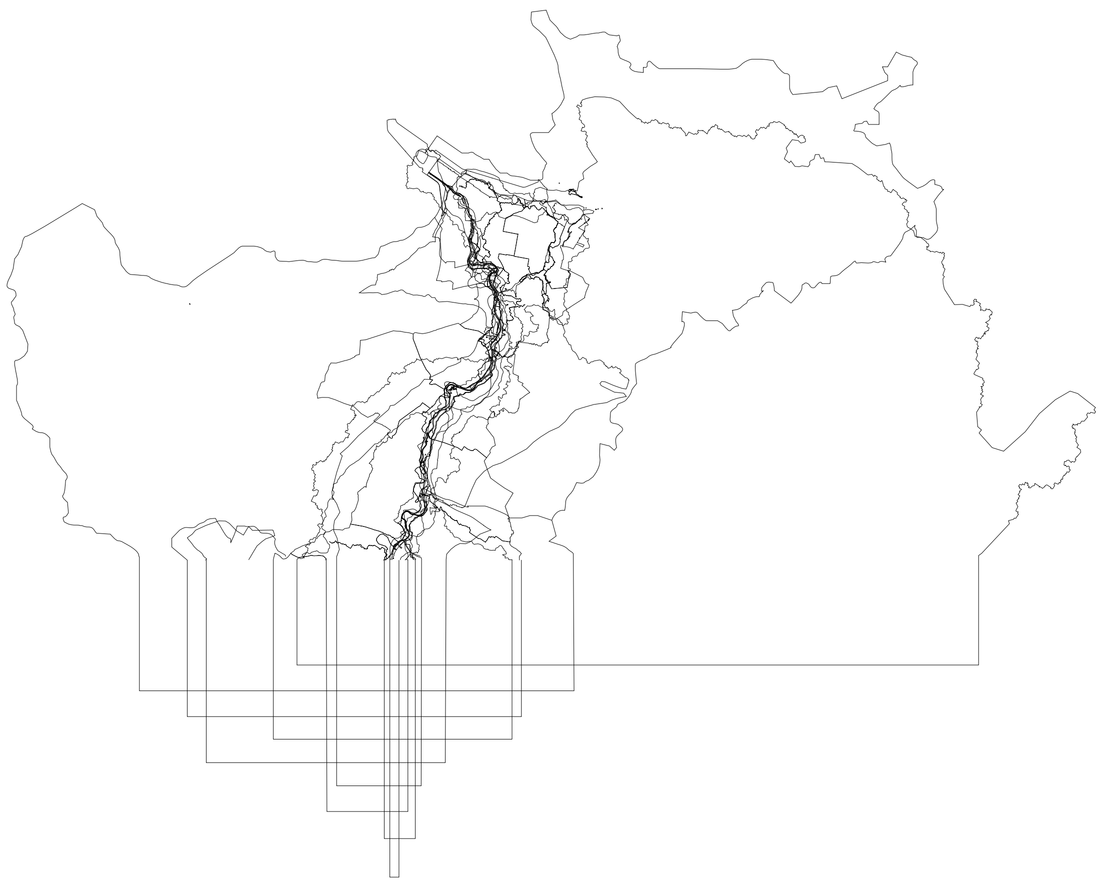


IJssel Municipalities

IJssel Waterboards



IJssel Catchment Basin



The advantages of the Research by Design methodology have been explained in the societal relevance of the project, there are disadvantages and limitations as well. The visual thinking of designers is developed during years of education, and translates into a specific spatial visualization language. This also entails that it can be observed to be foreign to other engineering disciplines which do not focus on the spatial dimension of interventions, but rather the actual numeric and systemic functioning. In order to convey the proposition to this audience, caution has to be taken to make sure the plans are paired with a technical language in talking and writing. This ensures the transferability of the project across scientific and professional fields, which would otherwise possibly be limited. It also poses difficulties, as ti is important to dive into the differentiating languages but it is also difficult to move back once the project moves in these directions. It demands flexibility, and regular reflections on where to move towards with the thesis.

I have tried to involve myself within this framework, amongst others by interacting with different actors within the professional field, adapting my language while presenting either for urbanism or an interdisciplinary (engineering) audience in the delta futures lab, and while writing for the delta links. For example, the use of the word functionalities instead of functions of rivers, of which the latter is more accustomed within the engineering disciplines. The first however, does portray a broader meaning of the functions of rivers next to only our projected functions for them from a user perspective, which can therefore also be used to emphasize the different viewpoints between professions.

As the IJssel is located within the Netherlands, large quantities of readily usable data are available. This creates an entirely new problem, in which the amount and level of detail available is a restricting factor in the design. The intricacy of the system and the large interdependencies between regimes make the reconceptualization of the overall spatial configuration extremely difficult, as it is easy to get lost in the limiting boundaries. The process of abstraction is used as a method within the Research by Design framework, in order to make the territory your own. Every cycle of interpretation, abstraction and visualization allows for personalisation of the subject by the designer, thereby continuously reducing complexity until the essence of spaces and systems is revealed. Limitation to this method is once again the transferability of the visualizations, as they are in general often more difficult to understand by people not involved in the spatial sciences.

The concept of co-creating knowledge has also been applied in the design process. By regularly discussing the projects propositions and concepts with experts from several fields of practice and scholars, the transferability has been continuously checked, and the input has led to the end result being a more interdisciplinary project.

In the larger scheme of the proposition, there is one inherently conflicting and opposing ethical element. The thesis aims to increase discourse concerning climate adaptation strategies by visualizing interventions and opening up debate. This is done in order to shorten lead times, but simultaneously to create awareness and increase involvement of the public in these large scale interventions. At the same time, the proposed intervention of a lateral canal, demands a strong top-down regulatory structure in order to be able to apply the intervention. In discourse regarding the large scale spatial interventions needed to adapt to the changing climate, a need for a ministry of spatial development is voiced regularly. This opposes the idea of small-scale local involvement in favour of top-down planning for the greater good of society.

The proposition of the project is strongly related to the overarching design studio Transitional Territories. The project is focused on the interface between water and water-related territories, located in a lowlands environment. This is aligned with the Transitional Territories studio, which focusses on the relation between natural environment, culture and politics, specifically in relation to marine and riverine territories. The studio provides a platform for interdisciplinary research into the territory and the changing climate regime. The role of urbanism in this cooperation with engineering and planning disciplines, is to provide a view on the spatial implications of interventions in the environment, posed by (geo) political regulations and infrastructural objects, while keeping liveability, performance and other societal demands in mind.

The particular focus of the studio on the contemporary anthropogenic environment is allows for the adoption of several different perspectives on the current state of matter and allows for a temporal scale within the project, projecting a time-sensitive interference within the territory. Especially in the Dutch context of integrated urbanism and landscape architecture, the highly adapted landscape cannot be dealt with without paying attention to the how and why of the current state.

In relation to the overall MSc AUBS program provided by the Faculty of Architecture and the Built Environment, it is the object of architecture, urban design and spatial planning which physically constitutes the living environment, posed onto the territory and subject to interior- and exterior forces of change. In the case of this specific project, it is the exterior force of the changing hydrological cycle, and the interior geopolitical force of the energy transition and EU Green Deal.

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Appendix

Monograph Series
Transitional Territories Studio Work

Pipeline, Waterway or Estuary?
Essay AR3U023 - Theories of Urbanism

Perspectives on the IJssel
An Urbanist Reconceptualisation of Integral Water Management in the Anthorpogenic Riverscape

Cas C. Goselink

Synopsis

The monograph series is the result of a proactive research into the chosen territories in relation to the thesis project. The process consists of consciously composing single elementary narratives, deliberately mapping through critical cartography, and concluding spatial characteristics in relation to a scale of time. The end result, a series of horizontal, vertical and spatio-temporal views on the subjects, creates a narrative that tells the story of the territory from the personal viewpoint of the designer.

Matter
Properties of water - objects
Water and the anthropogenic riverscape

The only way to fully understand the system of the Dutch anthropogenic riverscape, is to identify the characteristic elements which are put in place to control the matter, and the anthropogenic remnants of rigidity binding fluidity in place.

Topos
Functioning of water - elements
Fluidity through fixation: terraforming and erasure

The dual processes of erosion and sedimentation taking place within the natural riverine flow regime, manifest the fluidity of riverine territories through the fixation of sediment, which is eliminated by interference in migrational patterns.

Habitat
Assets of water - fields
Competitive Patterns

The pattern of human inhabitation has successively co-existed, dominated and virtually eliminated the natural habitat structures in place, competing with natural riverine flows, regimes and structures to ensure usage to the maximum human potential, leading to disconnectivity.

(geo)Politics
Representations of water - views
Natural Regimes, Artificial Territories: Landscape Proximity

The Dutch land- and riverscapes are patchworks of disconnected and partially conflicting spatial representations of former geographical political paradigms and discourses, the temporality of which manifests itself through sequences and shifts.

Matter
Catalogue

Territorial Objects of Water

01. Locks
Lateral connection of river navigation to canals and tributaries

02. Dams
Longitudinal disconnection

03. Weirs
Temporal connection / disconnection

04. Dikes
Lateral safety reinforcement

05. Embankments
Lateral streambed reinforcement

06.Quays
Hardened entrances of the river

07. Docks
Lateral connectivity of freight through harbors

08. Waterfronts
Relation between urbanisation and riverine system

09. Bridges
Lateral connection across riverine territory

10. Tunnels
Lateral connection across riverine territory

Matter Composition

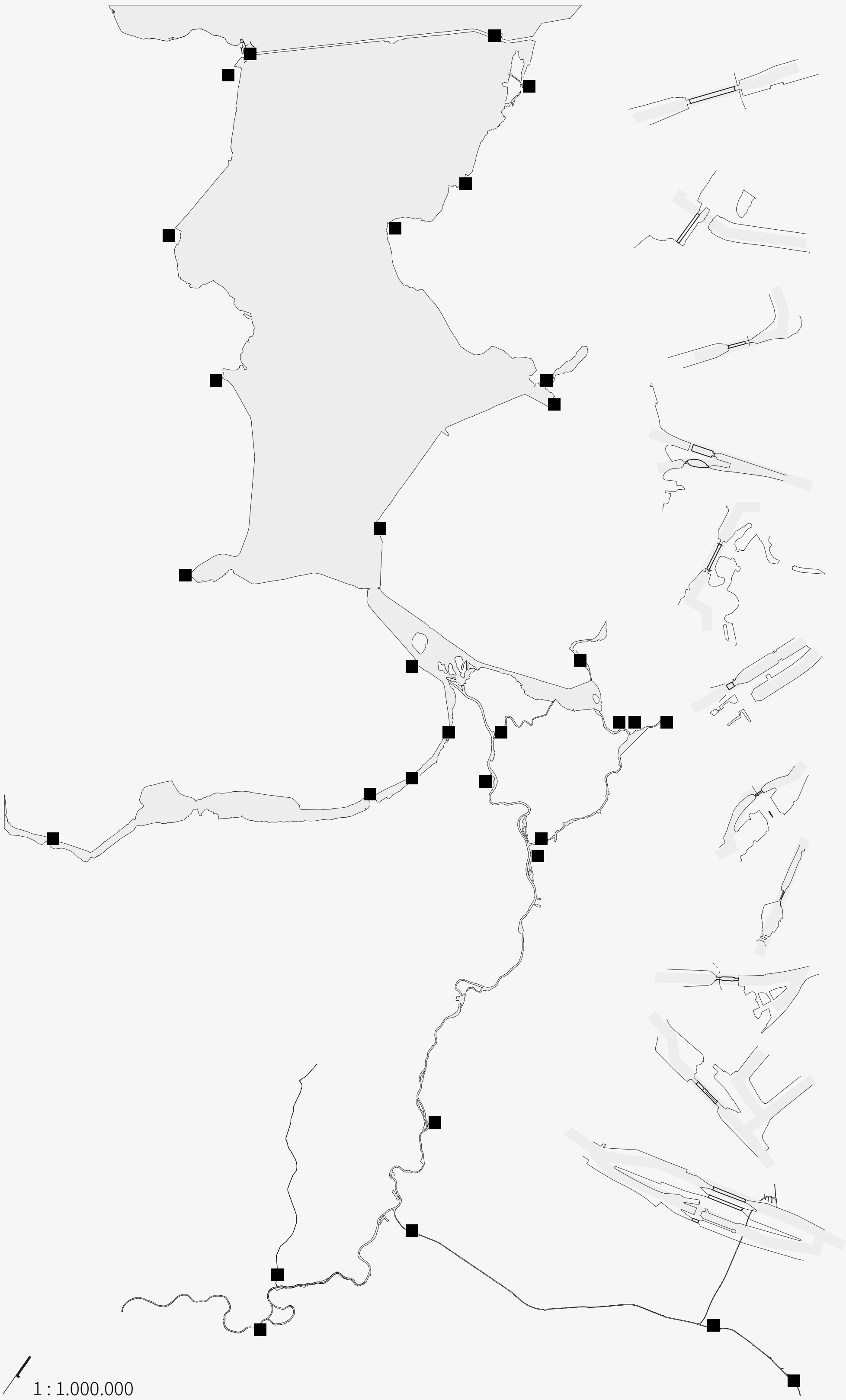


Figure 1: Location and composition of water management structures - Locks
Figure by Goselink, 2021

As the Dutch river- and landscape have been continuously adapted to increase functionality over the past centuries, the delta can be described as an anthropogenic river system (Sijmons, 2002). Therefore, the only way to fully understand the system of the Dutch anthropogenic riverscape, is to identify the characteristic elements which are put in place to manage it. These remnants of rigidity portray the desire to control the fluidity inherently connected to the delta. The map depicts the composition of locks along the IJssel river and estuary of the IJsselmeer. The objects are necessary in order to manipulate the water table, ensuring both navigability across sloped terrain, and precise management of water levels for safety of the surrounding territory. Most of the objects were placed in the 1950s and ‘60s (HSSN, n.d.). Although the basic spatial characteristics of the objects themselves are similar, the implementation into the water system and surrounding territory varies a lot.

Sijmons, D. (2002). Landkaartmos en andere beschouwingen over landschap [Map moss and other contemplations on landscap]. Rotterdam: Uitgeverij 010.

HSSN (n.d.). Historische Sluizen en Stuwen in Nederland. Retrieved on: 24-12-2020. Retrieved from: https://www.sluizenenstuwen.nl/geschiedenis_van_sluizen_en_stuwen.asp

Matter Alterations

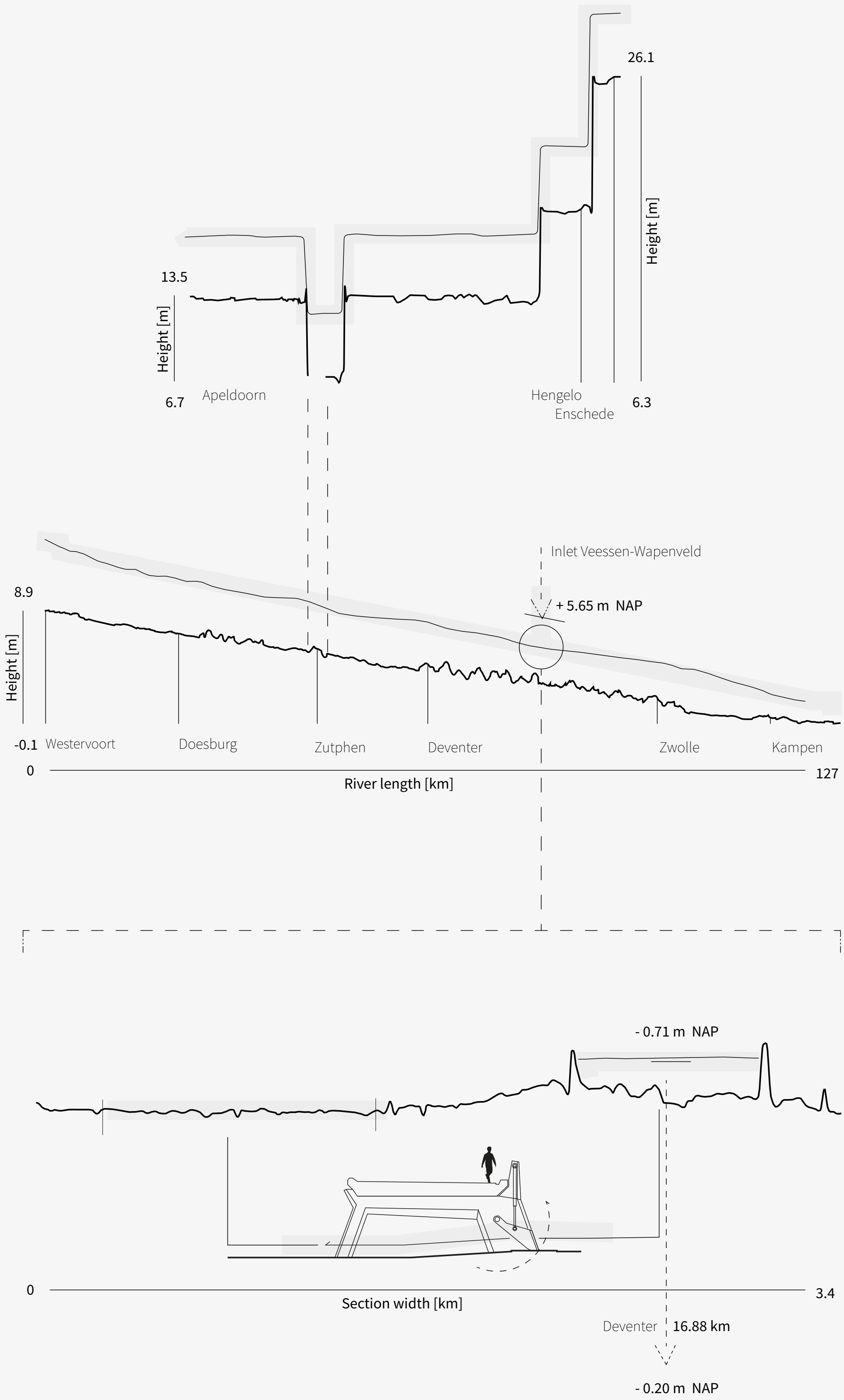


Figure 2: Anthropogenic alterations to the water system

Figure by Goselink, 2021

As the IJssel river flows through a valley, adaptation of the natural water system is necessary in order to connect to its hinterland. To both the west (Apeldoorn) and the east (Hengelo, Enschede), canals have been dug, complete with locks and weirs to manage the water levels uphill. Striking is the bridged height difference when comparing the lateral sections of the canals above, to the longitudinal river profile in the middle (AHN, n.d.). Interestingly, the water level indicator in the longitudinal section provides also clues on the spatial characteristics of the river, as every rise in the line indicates a narrow passage or bottleneck in the river, which holds up the free flow downstream (Klijn, 2020). These passages are mostly located next to riverine cities, created by bridges, harbour infrastructure or underground objects. The section below shows the temporal dimension of the water system, through the depiction of the high water canal near Veessen - Wapenveld. This recently constructed dam will open its floodgates when the riverine water level reaches + 5.65 m NAP, after which a controlled flow of water will be stored in a neighbouring polder (De Ingenieur, 2017). The riverine water level at the site drops by 0.71 meters, however the effects are still being witnessed 17 kilometres downstream at Deventer.

AHN (n.d.). Actueel Hoogtebestand Nederland. Retrieved on: 30-11-2020. Retrieved from: https://ahn.arcgisonline.nl/ahnviewer/

De Ingenieur (2017). Hoogwatergeul voor de IJssel. Retrieved on: 08-10-2020. Retrieved from: https://www.deingenieur.nl/artikel/hoogwatergeul-voor-de-ijssel

Klijn, F (2020, November 20th). The development of the Rhine River' s flood management: past, current and future issues (PowerPoint). Retrieved on: 26-11-2020. Retrieved from: http://deltafutureslab.org/media/

Matter
Limits

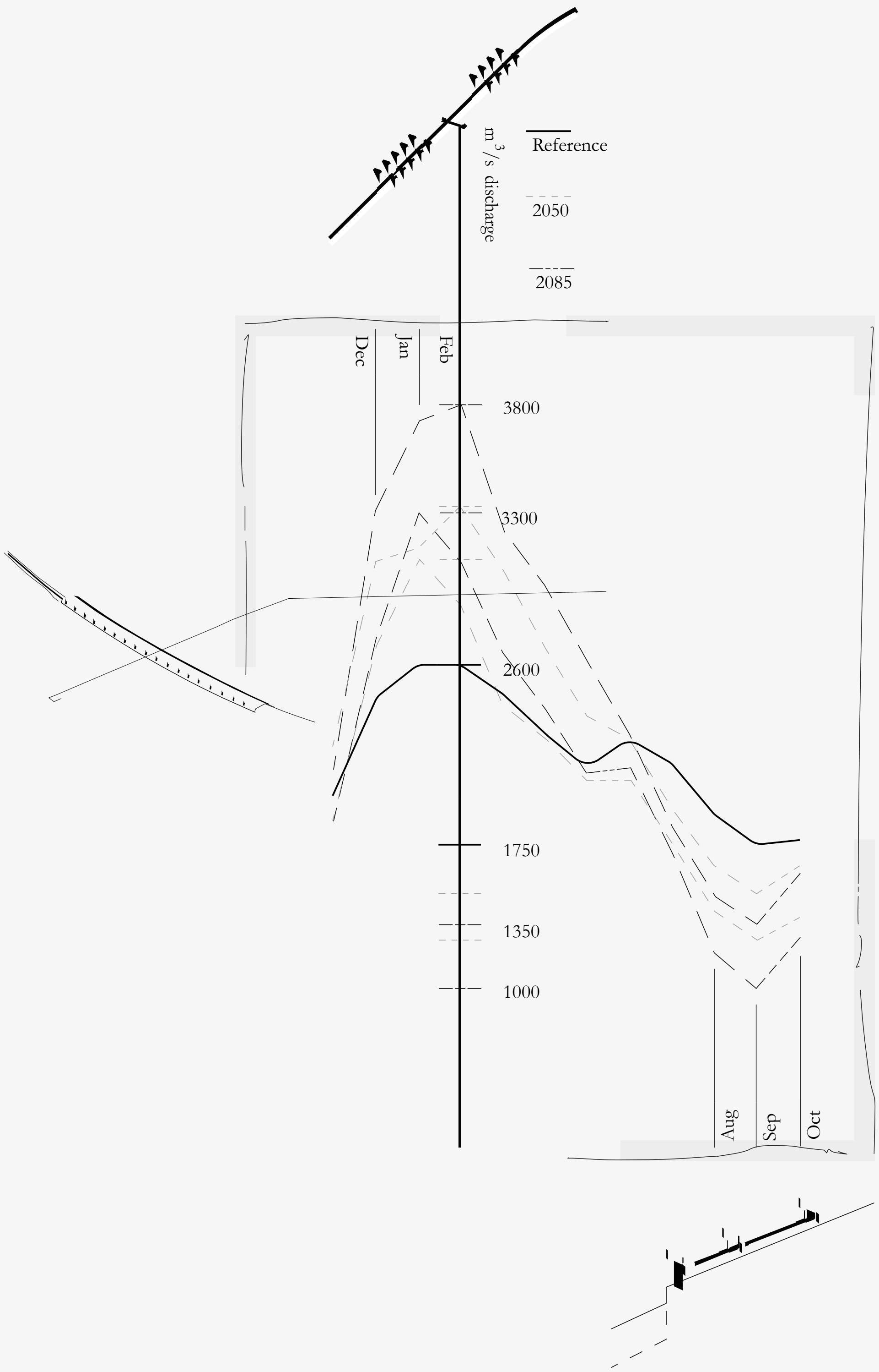


Figure 3: Limitations of the anthropogenic riverscape
Figure by Goselink, 2021

The spatio-temporal diagram to the left shows the current (reference) discharge levels of the IJssel*, along with the predictions for 2050 and 2085 (Attema et al., 2014). Due to the rapidly changing climate regime, the extreme pluvial events in catchment basins, alternated with periods of water shortage or even drought, form a real threat to the contemporary anthropogenic riverscape and its uses (Tol et al., 2003). In December, January and February, extreme peak discharges will have to be managed through the outlet of the IJssel estuary in the Closure Dam, which would have to be drastically adapted. At the same time, the temporal structure of the high water canal will be used more frequent over longer periods of time, raising the question whether a temporal structure is a sufficient solution. During the dry months of August, September and October, water levels will be too low for river navigation, and locks will be unable to function, depriving factories of their raw materials. In general, concluding on the objects of the anthropogenic riverscape, is the system too rigid to cope with climate change as it sits now.

*Based on the assumption that the discharge division stays at 1/9th of the Rhine discharge as set in Pannerden.

Attema, J., Bakker, A., Beersma, J., Bessembinder, J., Boers, R., Brandsma, T., Hazeleger, W. (2014). KNMI' 14: Climate change scenarios for the 21st century—A netherlands perspective. KNMI: De Bilt, The Netherlands.

Tol, R. S., Van Der Grijp, N., Olsthoorn, A. A., & Van Der Werff, P. E. (2003). Adapting to climate: a case study on riverine flood risks in the Netherlands. Risk Analysis: An International Journal, 23(3), 575-583.

Topos
Catalogue

Terraforming and Erasure

01. Sediment transport
Longitudinal carrying of sediment

02. Geomorphology of erosion
Geomorphological elements indication riverine erosion

03. Geomorphology of sedimentation
Geomorphological elements indication riverine sedimentation

04. Process of meandering
Lateral movement of rivers trough the territory

05. Process of normalisation
Anthropogenic process of lateral control

06. Streambed connectivity
Longitudinal connection of flowpaths through different-water levels

07. Sedimented soil
Soil characteristics created by sedimentation

08. Eroded soil
Soil characteristics created by erosion

09. Sand extraction
Riverine industrial processes

10. Sand replenishment
Riverine protection practices

Topos Composition

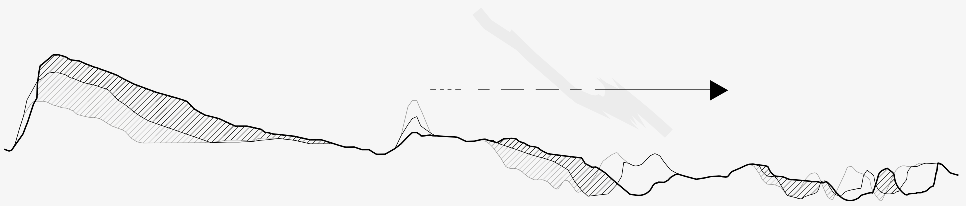
Figure 4: Traces of riverine erasure and terraforming

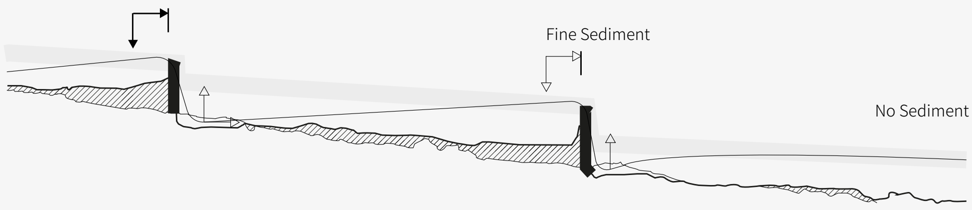
Figure by Goselink, 2021

The riverscape is composed of out of a set of geomorphological elements, created by the processes of terraforming and erasure over time. These dual processes manifest the fluidity of riverine territories through the fixation of their elements of movement, the particles of sand and clay. The composition map shows the geomorphological characteristics related to the migrational patterns of the IJssel. Amongst the most important terraforming elements are river dunes and fluvial deposits of clay in the floodplains. Erasure is characterized through the meander gully patterns and worn-down crevasse gullies (Geologische Dienst Nederland, 2020). In relation to the current river, as can be seen in the 'cut-outs', the influence the IJssel used to have on the surrounding territory in its natural form exceeds its current streambed immensely. Many spatial elements of the riverine patterns are still visible in the landscape today.

Geologische Dienst Nederland (2020). Geomorfologische Kaart Nederland. Retrieved on: 29-09-2020. Retrieved from: https://www.dinoloket.nl/modeldeliverylogic-web/rest/deliver/delivery/ad46ebaa-c595-45e2-b309-6def7148d680

Topos
Alterations





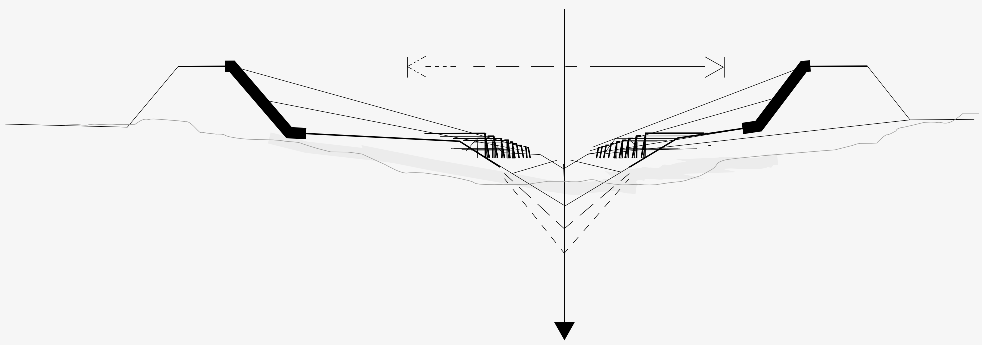


Figure 5: Natural migration and alteration by anthropogenic interference

Figure by Goselink, 2021

As is explained in the composition, a natural river system migrates laterally through the territory. The section above shows this movement over time, in which sediment on the outside bend of the meandering river is eroded, while new land is formed on the inside. The exposed material is blown onto river dunes by the west by south-western winds, creating an ever changing riverscape. Most sediment carried in the riverine system is moving downstream from its origins in the Swiss Alps. Due to the creation of weirs, locks and hydropower plants (mostly in Switzerland and Germany) the carrying capacity of sediment in the longitudinal direction is largely eliminated. On the temporal scale, the section below, the process of normalisation and straightjacketing is shown. Through the creation of straight rivers and hard embankments, lateral movement is limited. The addition of groins into the riverscape has further eliminated the terraforming and erasure processes, which combined with the normalisation has led to scouring of the riverbeds.

Klijn, F (2020, November 20th). The development of the Rhine River’ s flood management: past, current and future issues (PowerPoint). Retrieved on: 26-11-2020. Retrieved from: http://deltafutureslab.org/media/

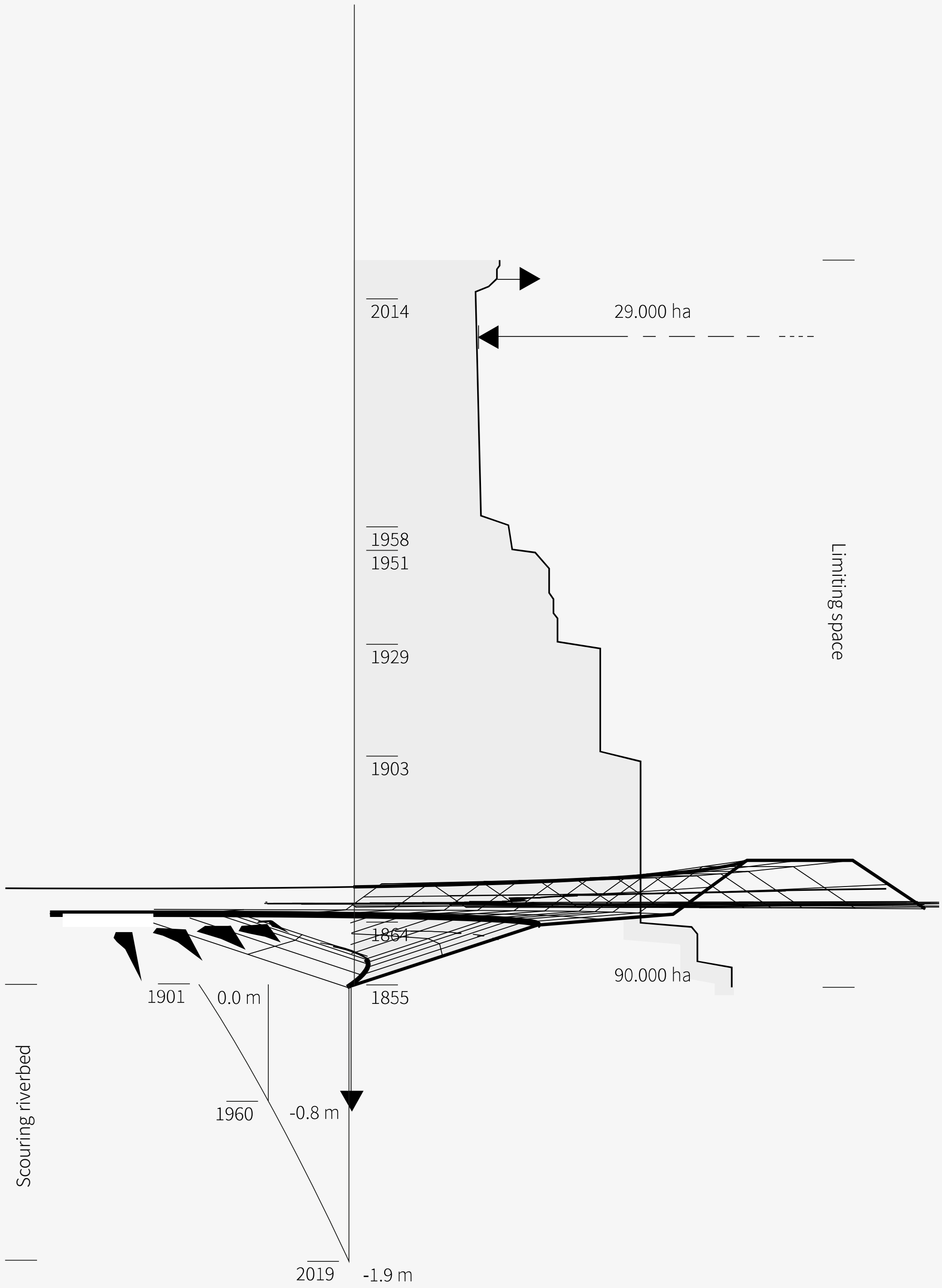


Figure 6: Limitations to the anthropogenic riverscape
Figure by Goselink, 2021

Through the continuous human interference in the riverine system, the dual processes of terraforming and erasure, or sedimentation and erosion, have effectively been eliminated. The spatio-temporal diagram to the left shows on the vertical axis the timeline of taking space from the rivers, the total amount which is taken from all rhine related streambeds in the Netherlands (Hooijer et al., 2002). Interesting is the recent example of the Room for the River project, which has started a reversed pattern. All in all, over two thirds of space was taken from the rivers in the past 170 years, an immense amount. The spatial characteristics of these practices are the straightened riverbanks, and dikes and rigid embankments alongside that. The straightjacketing has, in combination with the addition of groins to ensure a clear river channel to benefit navigation, lead to the continuous scouring of the riverbed, as is shown in the bottom of the diagram. Since 1901, the riverbed near Lobith, where the Rhine enters the Netherlands, scoured almost 2 meters. Firstly, this means more water is needed to connect the river to the floodplain level of the surrounding territory, causing a territorial disconnection. Secondly, the subsurface scouring has different rates in relation to the soil characteristics and possible underground infrastructure, leading to underwater levees and ponds hindering shipping during low water levels.

Hooijer, A., Klijn, F., Kwadijk, J., & Pedroli, B. (2002). Towards sustainable flood risk management in the Rhine and Meuse River basins. Irma Sponge summary document.

Habitat Catalogue

Competition

01. Patterns of human inhabitation
Development of human settlements along flowpaths

02. Terrain
Physical characteristics of territory

03. Ecological succession
Cyclical process of regeneration and succesion

04. Habitat diversity
Amount of different habitat typologies

05. Water availability
Baseline condition for specified habitat creation

06. Habitat connectivity
inter-connectivity of diverse habitats

07. Vegetational patterns
Collection of vegetative pattern typologies

08. Species diversity
Amount of different species typologies

09.Carrying capacity
Suitability to place functions

Habitat Composition

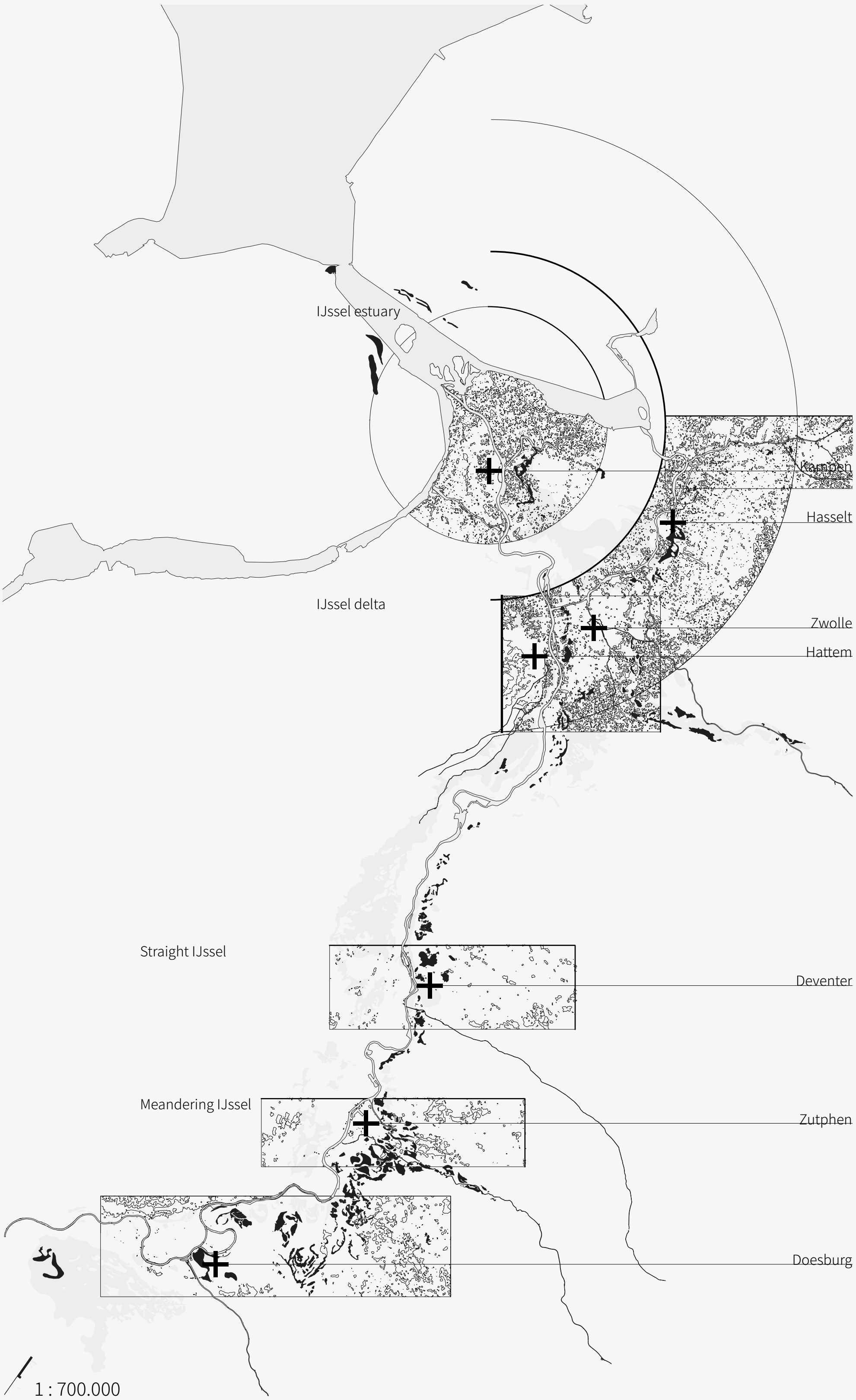


Figure 7: Habitat and patterns of inhabitation

Figure by Goselink, 2021

Inhabitational patterns follow a clear construct. Deventer and Zutphen are amongst the oldest urban settlements of the Netherlands, located on the high river dunes to the east of the river, on junctions with tributary streambeds (Geologische Dienst Nederland, 2020). Navigability and transport capacity of the waterways were most important factors for the location (Rijksdienst voor het Cultureel Erfgoed, n.d.). The other cities along the IJssel trajectory were later developed, and became part of the Hanseatic trade alliance.

- Water
- River dune
- Floodplain
- Height line

Geologische Dienst Nederland (2020). Geomorfologische Kaart Nederland. Retrieved on: 29-09-2020. Retrieved from: https://www.dinoloket.nl/modeldeliverylogic-web/rest/deliver/delivery/ad46ebaa-c595-45e2-b309-6def7148d680

Rijksdienst voor het Cultureel Erfgoed (n.d.) De opkomst van de stad: 1000 - 1500. Retrieved on: 24-12-2020. Retrieved from: https://www.landschapinnederland.nl/de-opkomst-van-de-stad-1000-%E2%80%93-1500-0

Habitat Alterations

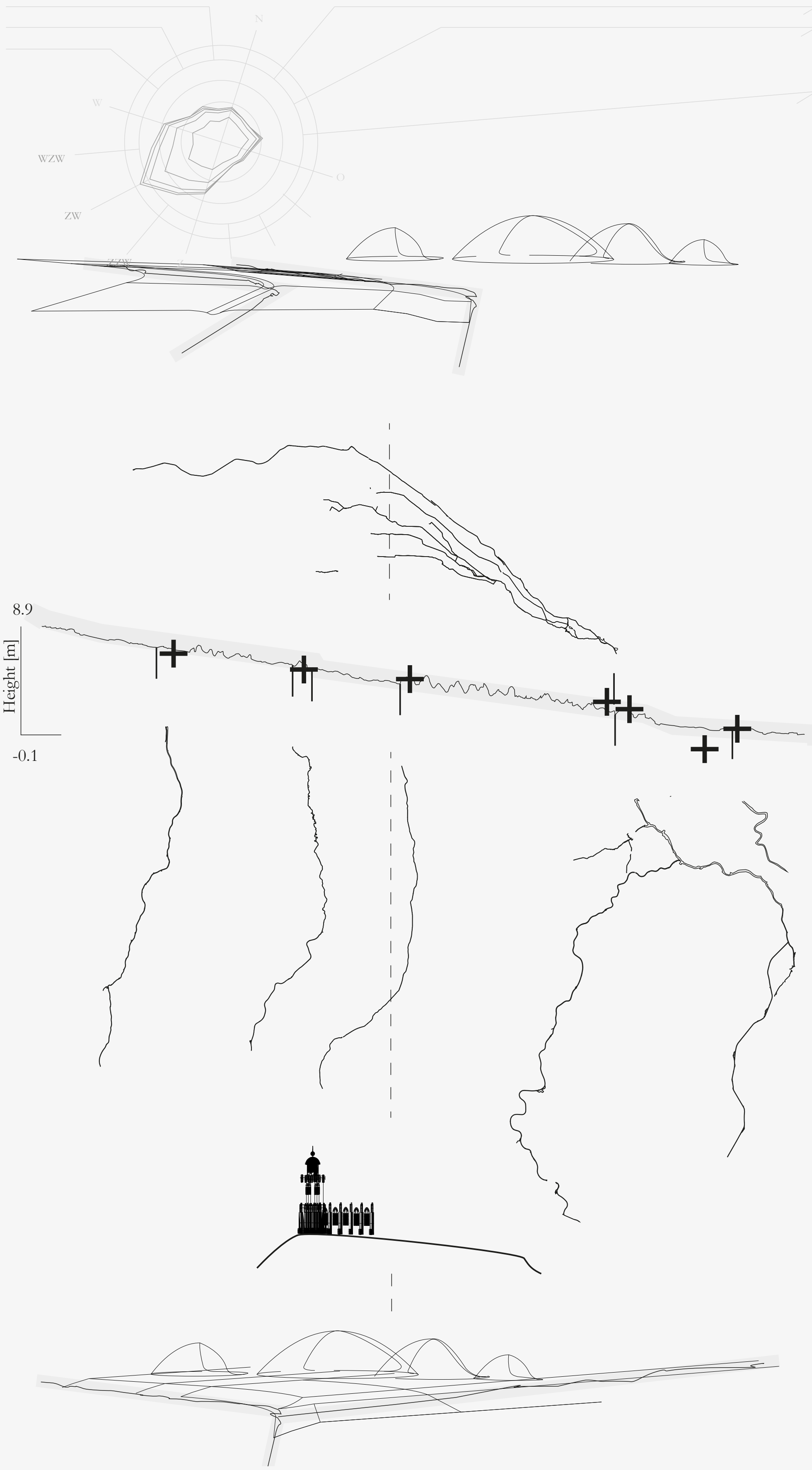


Figure 8: Habitat development
Figure by Goselink, 2021

The longitudinal section to the left shows the relation to the tributaries and cities along its flow path, with a perpendicular pattern in the east (underneath), and a parallel pattern to the west (above). This strongly relates to the topography as was discussed in the previous paragraph on Topos, with the parallel flow paths along the river in the floodplains, and the perpendicular tributaries through the river dunes. The creation of the habitat diversity in the area happened through the interplay of soil, water and air. The meandering river with its parallel tributaries and floodplain to the west continuously deposited and exposed sand particles, after which they were blown onto the dunes on the eastern riverbank by the predominantly south-western winds. These river dunes and high sandy terraces then were built upon and strengthened with pavement and vegetation, creating solid raised foundations suitable for safe and long-term inhabitation close to the river. Through the process of inhabitation, the naturally opposing habitats were slowly bound in rigid structures, decreasing its natural free-flowing and dynamic character.

Habitat Limits

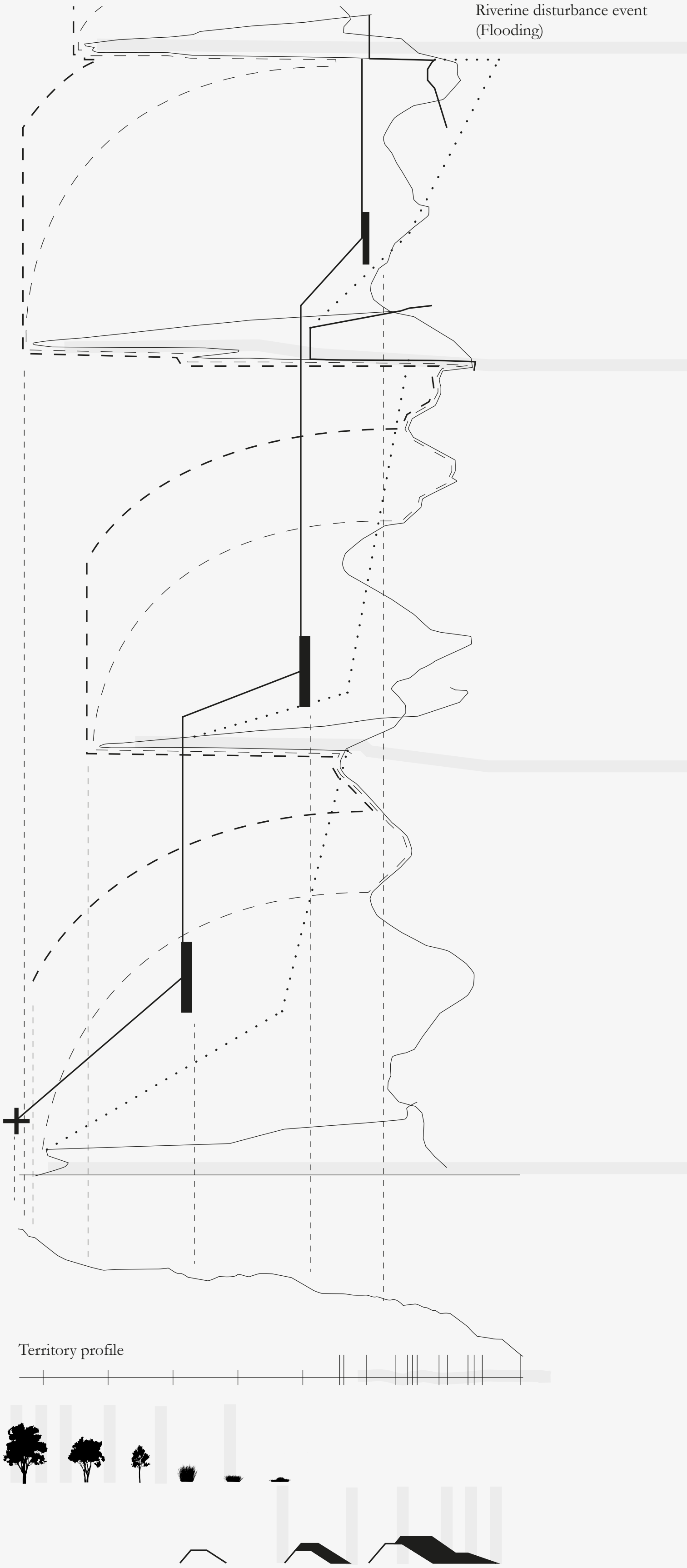


Figure 9: Cyclical competition for riverine habitat between human and natural processes.
Figure by Goselink, 2021

Competition for space in riverine environments can be characterized as a dynamic process, as the free flowing river migrates and changes the surrounding territory continuously. The spatio-temporal diagram to the left shows a fictional riverine flow regime with occasional flooding or peak discharge. The natural process of ecological regeneration after this disturbance event gradually reclaims its territory, followed by a continuous ecological cycle of succession of species, creating a high amount of habitat diversity along the river. After every disturbance event, depending on the severity of the flooding, and the specific site of the flooding, the process will (partially) start over. The level of human inhabitation however does not reset and start over, as flooding leads to the creation of protective levees and embankments, creating a safe and liveable environment, rigid within the dynamics of the riverine territory. From the moment of inhabitation, human habitat takes over the dynamic natural character of the place, leading to monoculture and human-dominated territory instead of a cyclical, diverse and ever-changing riverscape. The horizontal axis depicting the height of the terrain, shows how the human habitat moved from the safe and high grounds, into the low floodplains and riverbanks, increasing the need for ever growing dikes.

(geo)Politics Catalogue

Climate regime

01. Reallotment practices
20th century artificial production landscapes

02. Nature 2000
EU agreement on natural habitat interconnectivity

03. Paris Agreement
Energy transition and lareg scale energy landscapes

04.Green Deal
Transition of road-based transport to water and rail

05. Nitrogen emission limitations
Spatial distribution of companies

06.CO2 emission limitations
Spatial distribution of companies

07.Groundwater resource limitations
Limitations to use in relation to underground fresh water resources

(geo)Politics Composition

Figure 10: Overlaying of geopolitical representations in the landscape
Figure by Goselink, 2021

The selected three geopolitical representations of production-, nature- and energy landscape have been overlayed on the composition map. The geopolitical regimes have resulted in specific cultural landscapes. In relation to the production landscape, three generations of reallotment typologies are recognizable in the landscape. Through the years, more attention has been paid to the 'original' cultural landscape, thereby decreasing the distance taken from the natural landscape (Rijksdienst voor het Cultureel Erfgoed, 2015). With the establishment of the Vogelrichtlijn in 1979 and the Habitatrichtlijn in 1992, which were combined into the Natura2000 protection areas, the trajectory of the river was appointed a nature zone (Vogelbescherming Nederland, n.d.). this natural landscape however also influences the surrounding territories, as for example farmers are being bought out within a 3 km radius due to nitrogen emissions which might hurt the natural environemtn. Next to the pathces of production landscape, bordering the ongoing natural landscape arround the river, recently they are interfered by the upcoming energy landscapes of windmills and solar plants, adding a third generation to the patchwork of of geopolitical representations.

European Environment Agency (2019). Natura 2000 End 2019 - Shapefile. Retrieved on: 27-10-2020. Retrieved from: https://www.eea.europa.eu/data-and-maps/data/natura-11/natura-2000-spatial-data/natura-2000-shapefile-1

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(geo)Politics
Alterations

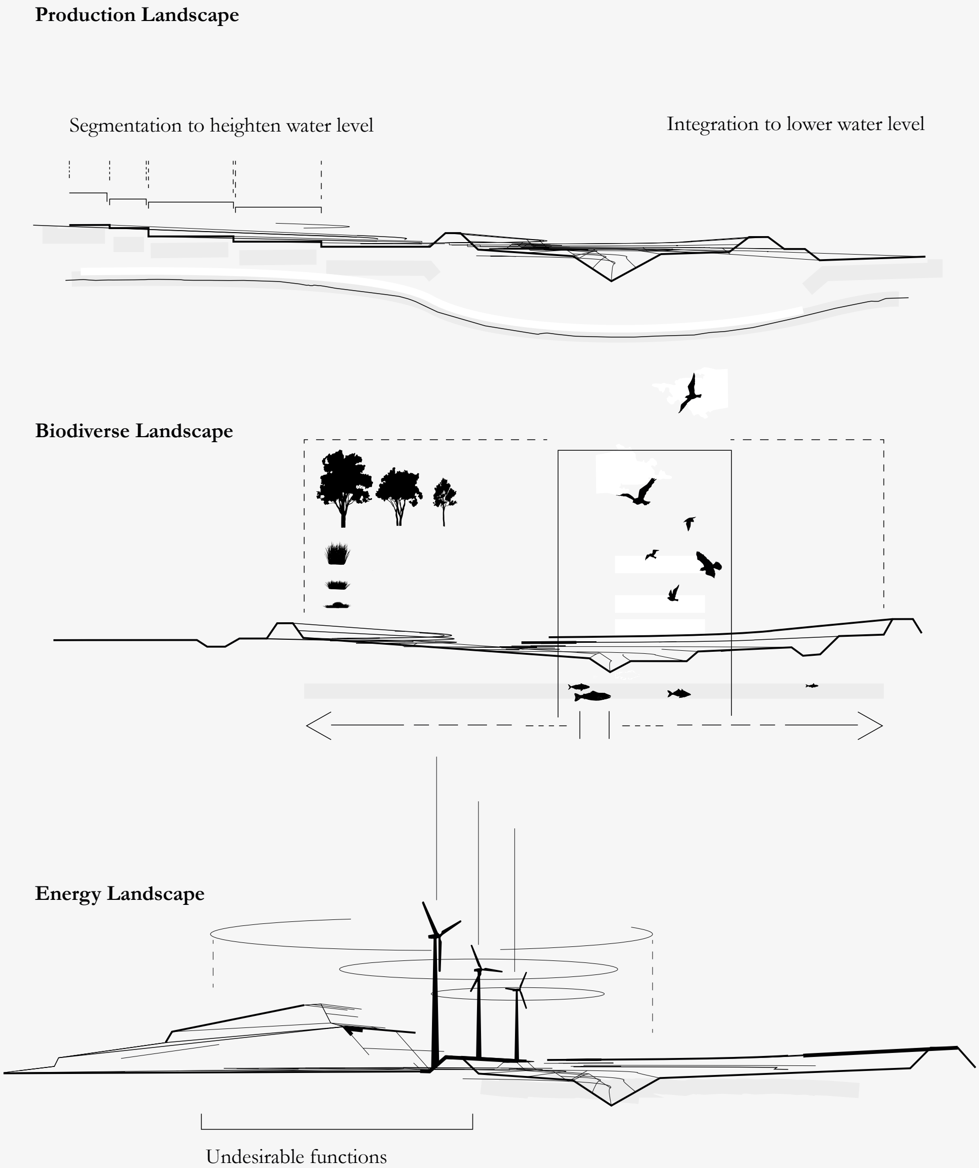

Figure 11: Altering of the landscape through different geopolitical regimes

Figure by Goselink, 2021

The alterations posed by the geopolitical views on the riverscape have been made visible in the sections to the left. First, the production landscape of reallotments, shows mainly interference in the existing network of waterways and ditches.
In order to maximize productivity, an optimal groundwaterlevel has to be determined and maintanied. For higher grounds with predominately dry sandy soils, this has lead to a segmentation of the former water network, in order to regulate waterlevels across different heights. For the lower meadows, located in former floodplains on clay, integration of smaller networks has been established, in order to extract water.
The bio-diverse landscape, or nature landscape, is set by regulations mostly, limiting interference in these areas and therefore preserving (and sometimes building) a network of calm areas for wildlife. Although this geopolitical view is less focussed on alterations in the physical landscape, it poses limitations to use of the neighboring territory for miles through legislation. The upcoming energy landscape is mostly placed in locations that are 1) suitable in relation to wind and sun, but first and foremost located in 2) areas where they do not interfere with inhabitants of the built environment. This can be recognized by the relation to other 'locally unwanted' uses such as landfills. In general it can be said that all of the geopolitical representations in the riverine landscapeinterfere with the former and more natural network, however the politics are evolving from direct interference in the physical territory, towards regulation of use and behaviour of inhabitants in the territory.

(geo)Politics
Limits

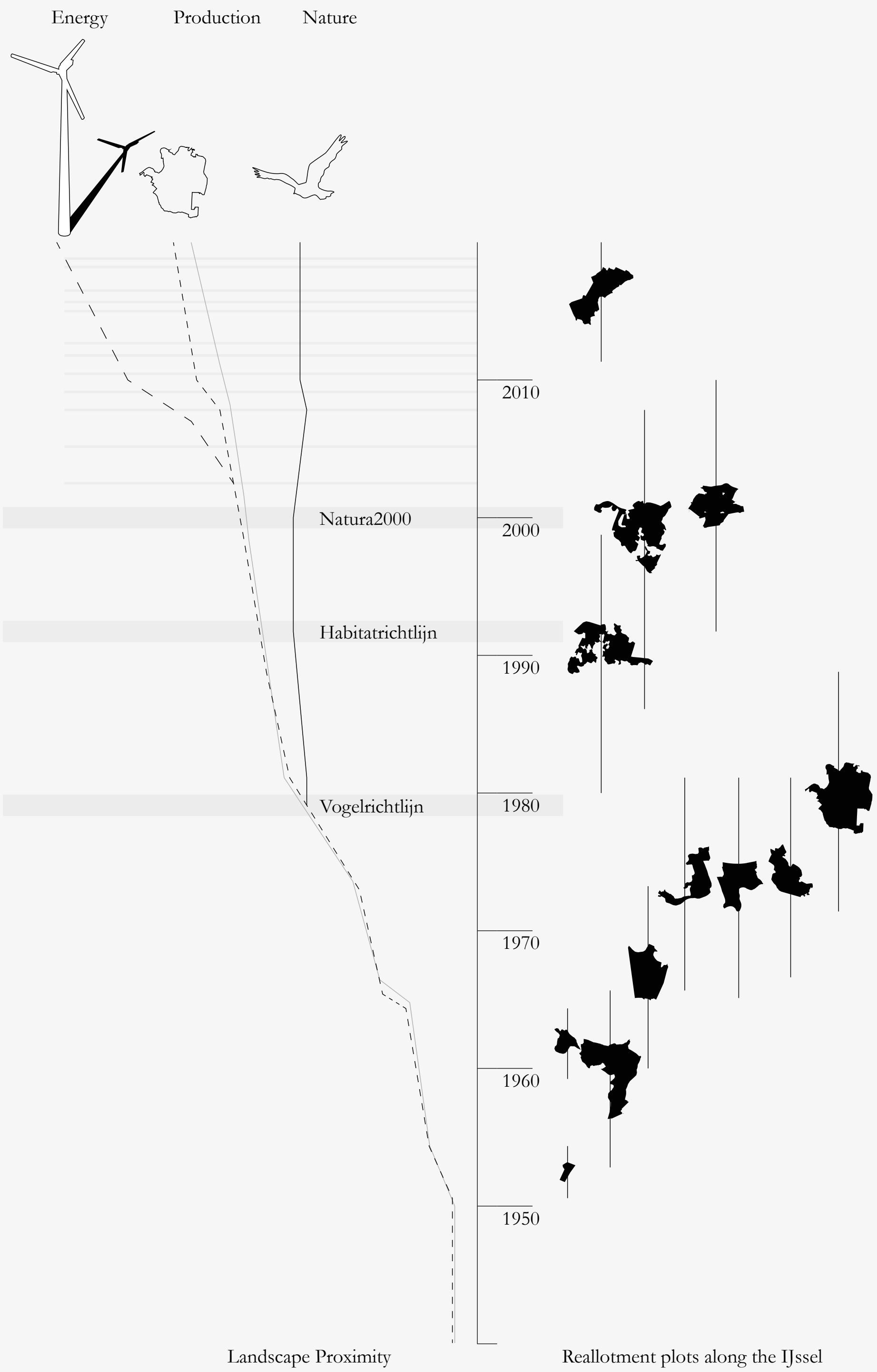

Figure 12: Landscape proximity in relation to spatial alterations over time
Figure by Goselink, 2021

The spatio-temporal diagram to the left indicates the landscape proximity, i.e. a measurement of how close the current landscape is to the natural sublayer. It becomes clear that although the landscape became more and more detached in the mid 20th century, the nature landscape has brought it (partially) closer. What also becomes clear is the relation between the seperate geopolitical representations, ant the fact that they are dispersing into different directions when loking at the landscape proximity. n increasing gap is starting to appear between the natural landscape for example, and the energy landscape. Where the enatural landscape is posing limits outwards across other representation fields, the energy landscape is doing the same in exactly the opposite direction, causing ridges and creasses in of disallignment in the landscape flows. The physical interference of geopolitics, most directly visible in the production landscape reallignment plots, shows the processes have mostly been executed throughout the second and third phases of reallotments. the second generation (195401984) and later the curent generation (1985-now) pay more attention to the existing pre-allogment structures, interfering on a smaller scale with more attention to existing landscape structures.

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Pipeline, Waterway or Estuary?

Characterizing contemporary discourse on riverine climate adaptation strategies in the Netherlands, based on the Dutch Layers Approach

AR3U023 Theories of Urbanism
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Abstract

This research paper is related to the urbanism master thesis *Perspectives on the IJssel*, and aims to provide a frame of reference concerning existing plans and strategies regarding riverine climate adaptation in the Netherlands.

In order to be able to review the material in relation to the Dutch context of spatial design, water management strategies and local climate change impact, the Dutch Layers Approach will be used. This approach has been influential in spatial planning processes since 1998, and will therefore be used as a method to review plans made in the same period, within the same context. It is concluded that proposals or either integral approaches, combining the biotic and abiotic environments to achieve a reciprocal and positive relationship, or focus mainly on the substratum layer with a high level of abstraction, in which the water management system is almost decoupled from the environment. In between those opposite archetypes, there is a third archetypical approach focusing on the usability of the system, and thereby the spatial layout of the riverine system in a limited manner.

Keywords: river, climate change adaptation, spatial planning, Dutch Layers Approach, Netherlands

1. Introduction

The Dutch have a long tradition of adapting the water system in order to create a safe, livable and productive landscape (Sijmons, 2002). Now, in times of climate change, the delta is faced with unprecedented challenges. The changing climate regime will affect the flow regimes of the rivers by increasing frequency and flow rate of peak discharges due to extreme pluvial events in the catchment basins. Simultaneously, water shortages and extreme low base flows lead to periods of drought (Kraaijenbrink & Lindeboom, 2018). Many plans, ideas and strategies have been, and are being developed, concerning these issues from the standpoint of inland shipping, water safety, fresh water supply and biodiversity. However, there is a gap in knowledge when it comes to the extent of the spectrum of plans, and a coherent overview of different archetypical approaches is missing. The large wealth of plans largely consists out of one-sided perspectives. Separate agendas related to the riverine landscape in the Dutch context propose their plans and interests, without compiling a clear overview of all separate demands of the system, especially in relation to the uncertainty of a changing climate regime. This essay will provide an overview of riverine climate adaptation strategies, which will be distilled into a set of archetypical approaches to the problem, in order to provide both an insight in the complex system, and to be able to position the thesis project in contemporary discourse.

In order to be able to come to a conclusive answer to the proposition, a main research question will be answered:

What are archetypical approaches in riverine climate adaptation strategies in the Netherlands?

In order to provide a clear overview of the broad spectrum of ideas and plans in the contemporary discourse concerning riverine climate change adaptation strategies in the Netherlands, an assessment framework is needed. The Dutch Layers Approach has been leading in the spatial planning process since the beginning of the 21st century (van Schaik & Klaasen, 2011). This approach will be operationalized to compare the vocal points of the plans. Sub-question 1 will provide an insight in the Dutch Layers Approach, both conceptions and misconceptions: *What is the Dutch Layers Approach?*

After having gained this insight, the discourse regarding the riverine development strategies will be identified, using the following second sub-question: *What are contemporary proposals in riverine climate change adaptation discourse?*

After having completed this research, the last sub-question will be answered in the results (chapter 3), and combine both previous questions: *How can the contemporary proposals be analyzed in relation to the approach?*

The conclusion of the above mentioned questions will lead to the answer to the main research question, and provide an overview of contemporary research, subdivided in archetypical approaches. Chapter 2 consists of the initial research into both the Dutch Layers Approach and the scope of contemporary discourse concerned with riverine climate adaptation strategies in the Dutch context. The third chapter combines the approach with the selected spatial planning proposals, after which the concluding fourth chapter defines the archetypes.

2. Research

2.1 The Dutch Layers Approach

Traditionally, Dutch spatial planning strategies have been dominated by utility. All elements within the typical Dutch landscape have, or had, a function or historical cause. Whether the elements fulfil their purpose in order to sustain the water system, agricultural production machine, or defensive systems of inundation. Functionality, and inherently a certain anonymity and austerity, depict the Netherlands being a country founded on utility and necessity (Sijmons, 2002). Next to these core principles of Dutch spatial planning practice, the landscapes were, throughout different geopolitical paradigms, always related to secondary or 'softer' goals. In general, spatial development can be characterized as focussed on prioritizing functionality and zoning by necessity.

The Dutch Layer Approach consist of three layers, which constitute of a specific level of priority and rate of change (Hoog et. al., 1998). Layer one, the substratum, is the fundament and most important of the layers. It is the layer of water management, the regulation of both land and water concerning the primary condition of existence in the Netherlands. Decisions made in these layer have top priority, for example the dealing with sea level rise, river discharge and the irrigation systems. Layer two, the network layer, consists of infrastructural elements and processes. Road-, water- and railways, infrastructural nodes like harbours, stations and airfields. These large scale planning decisions are relevant on the primary decisions made in layer one, while they are highly influential on the sequential third layer. This third layer of occupational patterns consists of, amongst others, the development of housing, industry, and agriculture (Sijmons, 2002).

2.2 Misconceptions of the Dutch Layers Approach

It is paramount to also review misconceptions regarding the approach, in order to review its applicability in the current context, and the essence of what the model implies. The Layers Approach is based on the assumption that the layers establish conditions for each following layer in a hierarchical relationship. The substratum layer has the longest rate of change, and provides the conditions for the infrastructure network, which in turn establishes the conditions for the occupational pattern (Hoog et. al., 1998).

Priemus (2004; 2007) argues that, although the substratum often indeed is a given circumstance, its low ability to change is an oversimplification. The levelling, raising, inundation and reclamation of land can raise its potential and therefore is not necessarily a guiding set condition with a low rate of change. The same applies for infrastructural networks (also including IT infrastructure) which might have a lower change of rate, due to the billions of euros related to the investments, maintenance and high costs of change. Simultaneously, the creation of a logistics hub might drastically alter infrastructural patterns within years. The final layer of occupational patterns is seen to be most flexible, although urban centres are usually built up over centuries, with its core patterns surviving several centuries (Priemus, 2007). According to this, the Dutch Layers Approach should allow for interrelationships between layers instead of proposing a purely hierarchical model.

Sijmons (2002) had already mentioned that it is not negligence towards interrelationships between the layers, but about the opportunity to add a hierarchy in the planning process, allowing for making choices and prioritizations easier. Also, there is a question of scales embedded in the system, as Sijmons explains the model will not be very useful on municipality level, as they mostly relate to the occupation layer, not the large infrastructure of basic water management system of the Netherlands (Hoog et. al., 1998; Sijmons, 2002).

Another misconception relates to the temporality of the approach in itself. The approach is said to be a contemporary model and paradigm, not an integral approach that will be applicable in relation to future challenges (van Schaik & Klaasen, 2011). This was already said by Sijmons in 2002, where he stated that the Dutch Layers Approach is not meant to be a rigid structure, which should guide all developments, but that it clearly is a method which could aid in prioritization of problems regarding spatial planning processes in the first decade of the 21st century (Sijmons, 2002).

2.3 Contemporary discourse on riverine development strategies

In current discourse, many plans and strategies on how to deal with the upcoming climate regime changes in regard to rivers are circulated. In order to be able to research the paradigms behind the plans, a broad scope of sources has been identified as important. Next to visions and strategies presented by well-established spatial planning and design practitioners, opinionated articles published in well-known national newspapers are considered part of the discourse as well, provided that they are written by either scientists or professionals from related fields. By integrating multiple types of plans coming from people speaking in different capacities, a wide range of contemporary discourse has been included.

According to Priemus (2007) planners have had a bias towards the layer of occupation, thereby neglecting the underlying networks of infrastructure and substratum. In order to ensure comparability between the various stages of completeness or detail in the plans, the Dutch Layer Approach is operationalized as method to identify statements on several key features of the spatial planning process and design. In this essay, six plans will be included in the overview in order to be able to go in enough depth to give a conclusive statement about the interrelationships between them. The plans are all related to the Dutch riverine areas, all produced after the year 2000, relate to the effects of climate change, and are produced from different perspectives and capacities:

The project *A nature-based future for the Netherlands in 2120,* proposed by Baptist et. al. (2019), from the capacity of a multi-disciplinary team of professionals and scientists. Secondly, *Ruimte voor Levende Rivieren: want levende rivieren geven ruimte [Room for Living Rivers: because living rivers give room]* proposed by Beekers et. al. (2018). Posed as a possible future scenario after the finishing of the well-known Room for the River plan by several institutions. Third, the *Landelijk inrichtingsvoorstel voor waterveiligheid, zoetwatervoorziening en estuariene dynamiek, [National layout proposal for water safety, fresh water supply and estuarine dynamics]* proposed by Borm & Huijgens as an elaboration on the Plan Beaufort and Water Highway Waal (Borm, 2010).

The fourth proposed plan is *De Nieuwe Hollandse Zeelinie: een grote sprong voorwaarts naar een strategische kustuitbreiding [The New Dutch Seadefense: a big leap forward to a strategic shoreline expansion]* by Bos (2001), which mostly relates to the future of shoreline protection, but also relates the problem of river discharges to this proposition. The fifth idea is an opinionated article in NRC.nl, a widely read national newspaper, posed in the capacity of retired civil engineer and social geographer (2019). *De Rijn wordt een regenrivier, tijd voor stuwen en sluizen [The Rhine is becoming a rain river, time for weirs and locks]*. The last proposition is also related to the Water Highway Waal plan, a continuation into a spatial plan as posed by Adriaan Geuze in cooperation with TNO (Schreuder, 2007): *Flipperen met het water uit de Rijn [Playing pinball with the water from the Rhine].*

3. Results

3.1 Application of the Dutch Layers Approach as methodology to analyze riverine climate adaptation strategies

The Dutch Layers Approach will be used to describe the key features of the plans identified in section 2.3. Per layer, the different plans will be discussed and approaches related to one another.

Substratum layer:

With the concepts of utility and austerity in the Dutch landscape in mind, in general the substratum layer dictated most of the spatial landscape features. In current discourse, there are several ideas about the prioritizing of the system, and how to organize the system to be able to adapt to the changing climate conditions. The plan proposed by Borm (2010), the *National layout proposal for water safety, fresh water supply and estuarine dynamics*, prioritizes the safety from increasingly extreme river discharge rates. It proposes a continuation of engineering the system by building two main primary embankment rings around the west of the country, in between which the bulk of river discharge will be transported out to sea. During regular flow rates, the water will be divided over the current rivers to maintain the current estuarine dynamics (Borm, 2010). This idea of further engineering the functioning of the rivers is a continuation of the Watersnelweg Waal [Water highway Waal] idea. Also in this plan, the substratum layer is built up around the idea of a large-scale mechanism near the village of Pannerden, where the water will be divided over the several riverine systems to ensure safety. This plan was later drawn by Adriaan Geuze, in cooperation with TNO, in which the river system was assigned more space, in order to be able to cope with the amounts of water (Schreuder, 2007). The rerouting of rivers is also an elementary concept in the *New Dutch Sea Defense*. Due to the need for large scale shoreline reinforcements, the rivers are forced to find another way to the sea (Bos, 2001). They are rerouted along the southern and eastern borders of the Netherlands, giving them more space for flexibility and a free flowpath within the hilly landscapes (Geurts, n.d.). A more engineered solution is posed by Kraaijenbrink and Lindeboom (2019) who, based on the navigability problems posed by both extreme high- and low discharge rates, propose to normalize the rivers completely and maintain water levels through the addition of weirs and locks. From their joint perspective of civil engineering and social geography, they emphasize that the duration of these projects is very long, and therefore should be started immediately.

In contrast, plans are also being based on the premises of re-naturalization and nature-based solutions. In *A nature based future for the Netherlands in 2120* an interdisciplinary team of professionals proposed a more natural approach to dealing with climate change instead of increasing the amount of infrastructure (Baptist et. al., 2019). Based on local conditions of soil typology, elevation and water retention capacity, priority on the substratum level is given to allowing the natural system to run its course, therefore giving more space to the riverine areas (Baptist et. al., 2019). More space for natural rivers is also proposed by Beekers et. al. (2018), in *Room for living rivers.* Main vocal point is that spatial quality and water safety should go hand in hand. It proposes an integral approach to combine navigation, water safety, water retention, spatial quality and biodiversity within a natural system.

Networks layer:

In the plan by Borm & Huijgens, the infrastructural network consist of the two large embankment rings, and the nodes which connect and cross them. The network is serving the purpose of water management in the substratum layer, utilized to keep the system functioning safely (Borm, 2010). Also in the ideas posed by Kraaijenbrink and Lindeboom (2019) and Geuze (Schreuder, 2007), engineering and water management structures make up the infrastructural network and pattern. Integration of multiple levels and dimensions of infrastructural networks was attained in the Netherlands 2120 vision, composing the networks layer out of raised infrastructural elements and networks, thereby not interfering in the soft natural networks and processes on the ground plane (Baptist et. al., 2019). If possible, hard infrastructure is replaced by soft infrastructure, integrating man-made and nature-based solutions. Bos (2001) also proposes a more natural riverine landscape, although completely man-made by rerouting the Rhine and Meuse rivers along the national borders. He proposed that these hilly landscapes should house the rivers in a more naturally enclosed flow path, so there is no need to build massive embankment systems. Infrastructure can therefore be downscaled (Bos, 2001). Soft infrastructure is also the core of Beekers et. al. (2018), using natural processes and landscape structures to perform as infrastructure, providing society with ecosystem services.

Occupational patterns layer:

Not all selected plans, ideas and strategies state how the integration of the occupation layer is conceived. Especially the ideas proposing an increase of hard infrastructure and engineering (Borm, 2010; Kraaijenbrink & Lindeboom, 2019), are mainly focussing on the water management system of riverine areas as a stand-alone object. Geuze and TNO have integrated the retreat of occupation layers along the riverine trajectories in order to make more (and much needed) space for high discharge capacities. Bos (2001) focusses mostly on shoreline defence and new developments along the newly created shorefront, not in relation to his statements about the rivers. Baptist et. al., (2019) have added the occupational layer in the framework and baseline conditions created by the substratum and networks layers. Human inhabitation is increased along the major embankment systems, providing safe living conditions on high grounds, and floating communities of proposed in the riverine floodplains (Baptist et. al., 2019). Spatial planning is guided by the availability of fresh water, relocating it to places that will become neither too wet, nor too dry. Its mission statement is that only through optimal biodiversity in the environment, a society can fundamentally thrive. The main objective is thereby set on creating positive externalities for society through the substratum and networks layers. In the *Room for living rivers* plan, occupational patterns are not specifically mentioned, but the focus is placed on the positive externalities a more natural river system can have for inhabitants of riparian areas (Beekers et. al., 2018).

3.2 Principles within the propositions

Now the different plans have been analyzed on their statements relating to the three layers of the Dutch Layers Approach, the principles have been combined into a coherent overview of the matter. The following scheme shows the core propositions with their statements categorized per layer. In the top, the implied levels of scale and rate of changed, as mentioned by Sijmons (2002), have been added to enhance clarity and distinction in regards to the spatial implications of the proposed interventions.

	High — Scale — Low		
	Low — Rate of change — High		
PROPOSAL	**SUBSTRATUM**	**NETWORK**	**OCCUPATIONAL PATTERN**
National layout proposal for water safety, fresh water supply and estuarine dynamics (Borm, 2010)	Engineering two major embankment rings in between which most river discharge will be guided during peak discharges to ensure safety	-	-
Watersnelweg Waal (Schreuder, 2007)	Engineering a large scale water dividing mechanism to steer water to ensure safety	-	Retreat along riverine trajectories
New Dutch Sea Defence (Bos, 2001)	Rerouting water to flow more naturally along the national borders	Naturally enclosed flow path to ensure downscaling of water management structures while maintaining uses	No statements related to riverine areas
Rhine as a rain river: add locks and weirs (Kraaijenbrink & Lindeboom, 2019)	Engineering locks and weirs to control water levels during high- and low discharge rates to ensure navigability	Increasing water management infrastructures, nodes improving connection of economic activity to rivers	-
A nature-based future for the Netherlands in 2120 (Baptist et. al., 2019)	Nature based solutions to ensure water safety, availability and biodiversity	Infrastructural networks raised to not interfere with natural processes, hard water management structures mostly replaced by soft measures	Increasing habitation along major embankments, floating communities in floodplains, inhabitation guided by water availability,
Room for living rivers (Beekers et. al., 2018)	Natural river landscape to ensure water safety, availability, biodiversity and spatial quality	Hard water management structures mostly replaced by soft measures, infrastructure downscaled	Inhabitation guided by positive externalities of bio-diverse system (ecosystem services)

Figure 1: Contemporary proposals regarding riverine climate adaptation strategies in relation to the framework of the Dutch Layers Approach. Figure by author.

It becomes clear that in relation to the occupational pattern layer, most plans do not integrate this development on the small scale with a high rate of change in the ideas. The propositions related to nature-based solutions and a more natural environments specify most what will happen on the smaller scale, in relation to the positive externalities the proposed measures will have for both natural and human environment. These plans propose integral approaches, combining the biotic and abiotic environments to achieve a reciprocal and positive relationship.

In regards of the substratum and network layers, the two propositions by Borm & Huijgens (Borm, 2010) and Geuze (Schreuder, 2007) focus mainly on the substratum layer with a high level of abstraction. The water management system is almost decoupled from the environment, focusing on riverine discharge rates and the needed space to achieve these rates. The ideas posed by Bos (2001) and Kraaijenbrink and Lindeboom (2019) focus on the usability of the system, and thereby the spatial layout of the riverine environments. Although the approaches proposed are almost opposites, either increasing infrastructure or downscaling it, the plans find themselves in between the decoupled system approach, and the integrated environment approach.

4. Conclusion

After having defined the width of contemporary discourse concerning riverine climate adaptation strategies in the Netherlands, and relating these proposals to the Dutch Layer Approach, the conclusions can be drawn in regards to the sub-questions as posed in the introductory chapter.

In relation to the first sub-question *"What is the Dutch Layers Approach?"* it can be said that the approach is a planning tool, which can aid in the decision making process by constituting three layers of consecutive rates of change, scales and priority levels. Layer 1 consits of the substratum; water management and engineering related to the primary conditions of living in a delta. Layer 2 is made up out of infrastructural networks and processes like road-, water- and railway transport structures and nodes. Layer three houses the occupational patterns of society. The approach is based on the assumption that every layer establishes baseline conditions for the following layer to be adapted to, in a hierarchical model.

Regarding the second sub-question *"What are contemporary proposals in riverine climate change adaptation discourse?"* it can be concluded that there is a large wealth of plans being currently debated and circulated both within and outside of the scientific and professional field. Six plans have been identified to include in this research, in order to be able to go in sufficient depth within the limits and constraints of this essay. The included proposals are:

> *A nature-based future for the Netherlands in 2120.*
> (Baptist et. al., 2019)
>
> *Ruimte voor Levende Rivieren: want levende rivieren geven ruimte [Room for Living Rivers: because living rivers give room]*
> (Beekers et. al., 2018)
>
> *Landelijk inrichtingsvoorstel voor waterveiligheid, zoetwatervoorziening en estuariene dynamiek, [National layout proposal for water safety, fresh water supply and estuarine dynamics]*
> (Borm, 2010)
>
> *De Nieuwe Hollandse Zeelinie: een grote sprong voorwaarts naar een strategische kustuitbreiding [The New Dutch Seadefense: a big leap forward to a strategic shoreline expansion]*
> (Bos, 2001)
>
> *De Rijn wordt een regenrivier, tijd voor stuwen en sluizen [The Rhine is becoming a rain river, time for weirs and locks]*
> (Kraaijenbrink & Lindeboom, 2019)
>
> *Flipperen met het water uit de Rijn [Playing pinball with the water from the Rhine]*
> (Schreuder, 2007)

Now the previous sub-questions have been answered, the third and final sub-question relates the previous two: *"How can the contemporary proposals be analyzed in relation to the approach?"*.With the Dutch Layers Approach as a method to review the proposals, it constitutes a framework to identify different features within the seperate plans, and conclusively align them in order to see how the plans relate to each other. Figure 1, as shown in section 3.2, shows how the approach is operationalized and applied to the chosen spatial planning proposals.

This leads to the final conclusion on the main research question: *"What are the archetypical approaches in riverine climate adaptation strategies in the Netherlands?"*

Three archetypical approaches to riverine climate adaptation strategies within the Dutch context have been identified.

- 'Pipeline-archetype'. The river is viewed upon and treated as a systemic function in the substratum layer, which has to be able to cope with set amounts of discharges and flow rates. The river system is decoupled from the environment. These plans are of high abstraction and large scale.
- 'Waterway-archetype', which relates to the rivers as being part of a large infrastructural network, relating to riverine uses and therefore dimensions. The rivers have a function, and should therefore be adapted to be able to fulfill this in regards to the changing climate regime.
- 'Estuary-archetype', related most to the occupational layer of the Dutch Layers Approach, integrating large and small scale interventions. It proposes a more natural environments in reciprocal relation with human inhabitation.

This structure can aid in providing an overview of all the different ideas regarding the subject, as was identified to be the knowledge gap. The archetypes are an abstract representation of different typologies of measures and interventions in the riverine water system, with a certain scale, temporal and spatial dimension. Therefore, the structure can be used to position the joint thesis proposal in relation to the existing body of knowledge and research.

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