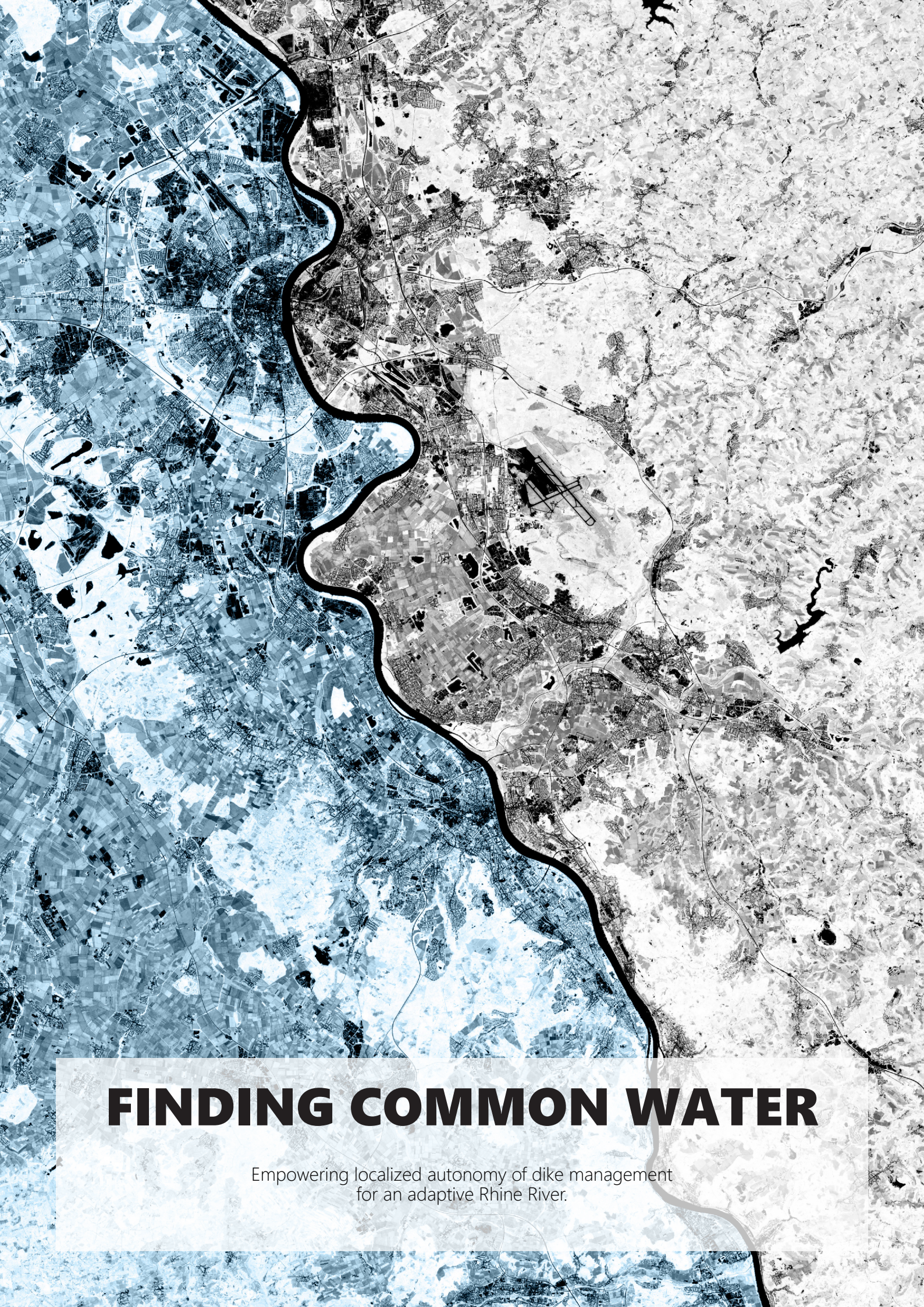


FINDING COMMON WATER

Empowering localized autonomy of dike management
for an adaptive Rhine River.

Colophon

Finding Common Water
Empowering localized autonomy of dike management for an adaptive Rhine River.

Thesis Report:
Jens Berkien
MSc Urbanism, Department of Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology

Graduation Course:
AR3U115 Graduation Lab Urbanism Studio - Planning Complex Cities.

First Mentor:
Verena Balz (Spatial Planning and Strategy) (TU Delft)

Second Mentor:
Kristel Aalbers (Environmental Technology & Design) (TU Delft)

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Introduction

From the first commission of the Rhine River: the Central Commission for the Navigation of the Rhine introduced in 1815 at the Conference of Vienna by Napoleon as the first ever free economic zone in the world, the Rhine has been characterized as one of the most monitored river basins in the world. The Rhine facilitates fresh water for the hydropower stations of Switzerland and France, the Industries of the Ruhr, the greenhouses of the Netherlands and not to forget: 60 million residents in one of the most urbanized regions of Europe. Humans have had 100% control over the Rhine since 1815, planning against the natural forces of the water system by channeling most of the river. After large floods of the previous decades alongside the Rhine river (Redeker, 2012), man has started to understand the geological system of the water. With programs like the Room of the River in the Netherlands, a paradigm shift has taken place to allocate space to the rivers. Although these new initiatives have increased resistance of the water system, changes in water and particularly drought management still need to take spatial form. Therefore potentially crippling the distribution of quality and efficient streams of water throughout the basin. Increasing urbanization rates in the large cities of Europe put pressures on the large cities of the Rhine river like Köln, Frankfurt, the Randstad, and other Ruhr cities. The increasing pressure of growing cities along the Rhine river in combination with the uncertainty of a stable water distribution provides new challenges for European national, sub-national and local authorities to find new ways to mitigate flood and drought risks.

Abstract

The Rhine River distributes water to more than 60 million residents, vital industries, and important agricultural sites across a total of eight countries. However, due to climate change, the availability of water resources has become increasingly dependent on seasonal supply and internal distribution (UNESCO, 2009). Moreover, extended periods of high river flow have the potential to pose threats to the urbanized regions along the Rhine (IKSR, 2011; Rottler et al., 2021; Stahl et al., 2022). In light of these developments, questions arise concerning the rights to use and manage the water. Simultaneously, water governance along the Rhine remains weak, with limited coordination between nation-states, sectors, and other relevant stakeholders, resulting in minimal influence at the local level (Rietveld et al., 2013; Akamami, 2016; Moodie, et al., 2022). Against this backdrop, this project focuses on the spatial element of the "dike" as a mechanism to control water flows and simultaneously restore the lost connection between local stakeholders and the Rhine.

The project, titled "Finding Common Water," employs the new governance principle of Active Subsidiarity to prioritize local and regional autonomy in water management and identify issues that can only be addressed at higher levels of governance. Its goal is to investigate the potential for delegating the decision-making process of dike management to local levels of society. By enabling self-organizing capacity at lower levels of government, independent stakeholder systems can be synchronized to support adaptive water governance and localized protection.

The methodology of the project comprises several components. It includes literature review studies to enhance understanding of changes in governmental schemes in the transition to adaptive water governance. Additionally, a socio-spatial analysis is conducted on the Rhine River to assess current conditions related to drought, water discharge trends, water usage, and water management. To assign water management to local levels of society, the areas surrounding the Rhine are viewed as Hydro-Social Territories. These territories are based on the mutual relationship between "water" and social, political, economic, cultural, and biophysical systems at a particular scale.

Drawing from the Dutch water management, a roadmap is created, following the principles of Active Subsidiarity toward localized dike autonomy. This roadmap empowers local stakeholder groups to evaluate their capacity to self-organize their relationship with the river through the spatial element of the dike. An assessment of indicators is made to evaluate the potential for localized dike autonomy. This is divided into four main subcategories: The Authoritative Region, The Dike, The Suitability Conditions, and The River Dynamics. By creating a calculation formula for these four main subcategories, potential locations along the Rhine suitable for localized dike autonomy can be identified. Finally, a test case is utilized to demonstrate the potential spatial outcomes of local dike autonomy.. Finally, a testcase is used to show the possible spatial outcomes of local dike autonomy.

Key Words: Localized Dike Autonomy, Active Subsidiarity, Hydro-Social Territory, Self-Organization, Water Management, Rhine River.

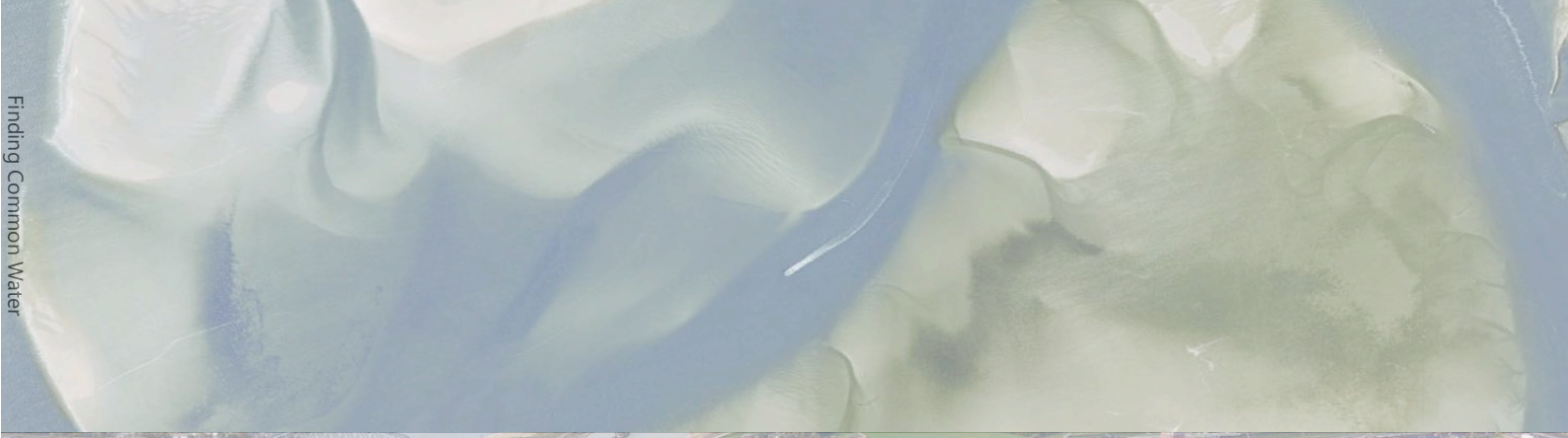










Figure 1: Overview of the various landscapes of the Rhine River Basin focussed on flood and drought impacts. From top to bottom: Delta region of Friesland (NL), Room of the River program Nijmegen (NL), Drought bottleneck Koblenz (DE), Water basin for energy production (CH), Melting glaciers (CH).

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List of Abbreviations

BGR:	Federal Institute for Geosciences and Natural Resources (DE)
CCNR:	Central Commission for the Navigation of the Rhine
CHR:	International Commission for the of the Rhine basin
EEA:	European Environmental Agency
EDGI:	European Geological Data Infrastructure
ESPON:	European Observation Network for Territorial Development and Cohesion
EU:	European Union
IKSR:	International Commission for the Protection of the Rhine
OECD:	Organisation for Economic Co-operation and Development
RoR:	Room of the River Program
ECR:	European Committee of the Regions
BAFG:	Federal Institute for Hydrology (DE)
CTCN:	UN Climate Technology Centre & Network
HST:	Hydro-Social Territories
GRDC:	Global Runoff Data Centre
GEMStat:	Global Freshwater Quality Database
HWBP:	Hoogwaterbeschermingsprogramma
UN:	United Nations

Difference between Water & Dike Management

As this project relates to both water and dike management, both concepts are used throughout this report. As dike management in almost every country, apart from the Netherlands, is an integral part of water management or infrastructural management, both concepts are used to express the same sector. To clarify the difference between the two concepts, below the main meaning is mentioned.

**Water Management:* Water management is based around the activities to manage the surface and groundwater. This relates to the treatment and transport of drinking water, wastewater and industrial water. Therefore it addresses the urban water cycle. Large components of water management are related to controlling the quantity and quality of water used and distributed by man. The spatial element of the dike is used as a civil engineering mechanisms to control these water flows.

**Dike Management:* Dike management is based around the activities that make sure the current dike infrastructure is maintained. This relates to keeping the technical stability and structure of the dike intact by the monitoring and the civil engineering maintenance that is conducted. Therefore it primarily focusses on the maintenance and construction of infrastructure to make sure regulations of water management can be implemented.

Explanation of the main Concepts

**Self-Organizing Capacity:* The capacity of a stakeholder group to organize itself spontaneously, without the need for a central authority and control. The capacity relates to the ability of the stakeholders to adapt, make free decisions and regulate their own activities, based on the interactions and relationships between the stakeholders.

**Localized Dike Autonomy:* The ability of local stakeholder groups to freely define, design, construct and maintain their own dike without any intervention by central authorities. Hereby, the focus of dike management is placed once again to the direct users of the dike and the river (Redeker, 2012; Lola Landscape Architects, 2014).

**Hydro-Social Territory (HST):* The spatial territory that emerges between autonomous localized stakeholder groups based on the translation of spatial layers, each indicating a different relationship between people and water. While the central notion of the Hydro-Social territory is not fixed, this roadmap follows the translation of newly defined territories based on chosen spatial layers of geological, water, and administrative characteristics. In this roadmap, the term is used to describe the Design Locations where the roadmap is implemented.

**Dike:* The dike is considered to be a spatial element that divides the water from the surrounding land with a primarily protective function. As conditions change, so does the meaning of the dike. Therefore, this report defines the dike as a transitional spatial element between the river and the surrounding landscape that depends on the availability of resources provided by the river, thus establishing a new relationship of connection rather than division.



Figure 2: Drought in the Rhine River (Sky News, 2022)

01

Contextualize the Problem

1.1 Rhine River Basin

Context
The Rhine River Basin

1.2 The Anthropocene

The Climage Change Epoch
Economic Growth vs Natural Values

1.3 Climate Change Effects of Drought

Effects on the Hydrological System
Effects on the Human Systems

1.4 Fragmenation of the European Union

The Need for a European Union
Dominant National Authorities
Cultural Differences in Spatial Planning
Institutional Thickness
Lack of Territorial Implementation
The gap between Europe and its Citizens

A Change in Dike Management

1.1

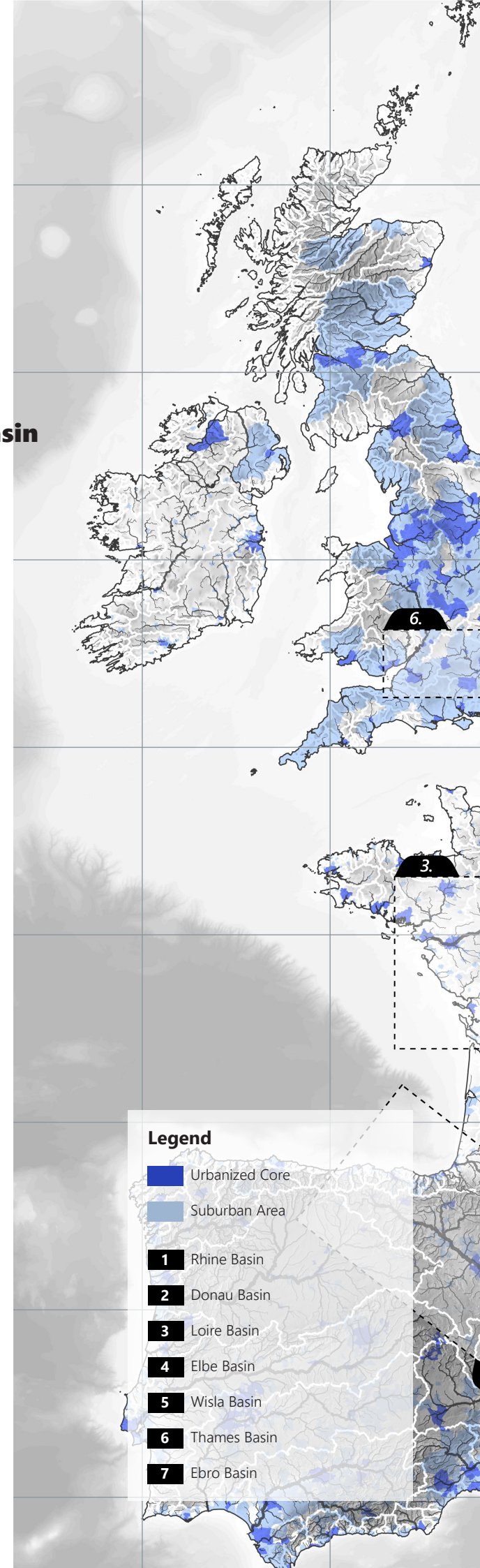
Rhine River Basin

Context

A river basin is an area of land where all the water that drains into rivers, streams, and other bodies of water within it, eventually flows into a larger body of water. There are thousands of river basins around the world, each with its unique characteristics and features.

The Rhine river Basin is located on the continent of Europe and passes through 8 countries. From the source in the Alps to the North Sea near the port of Rotterdam: Switzerland, Liechtenstein, Austria, France, Germany, Luxemburg, Belgium, and the Netherlands. The Rhine river Basin is considered to be one of the most urbanized river basins in the world, housing more than 60 million residents.





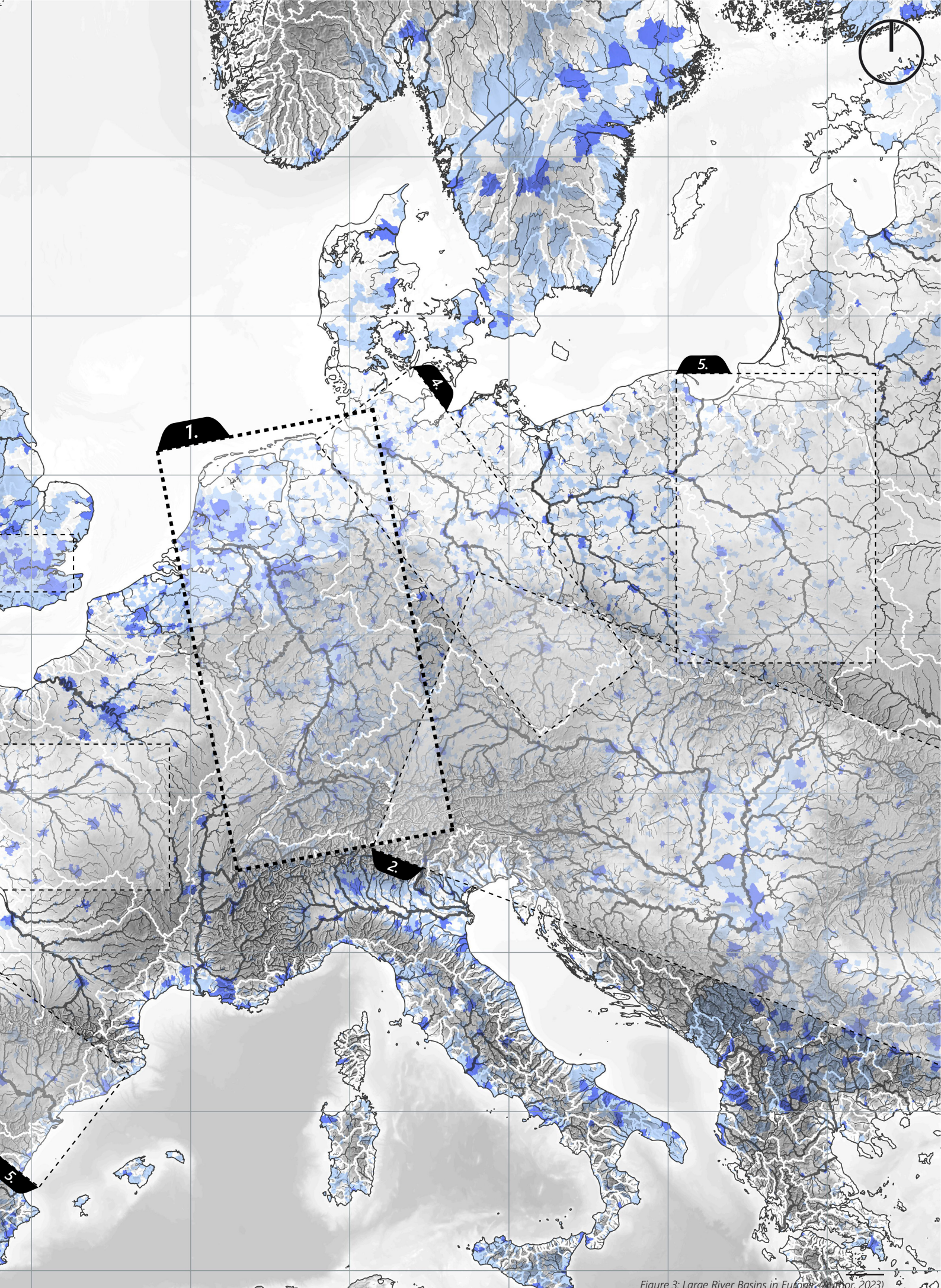


Figure 3: Large River Basins in Europe (Author, 2023)

The Rhine River Basin

The Rhine River Basin is one of the most important and heavily used river basins in Europe. The Rhine is the source of drinking water, irrigation, energy, and transportation for millions of people. The Rhine River is the longest in Europe, and its basin covers an area of approximately 170,000 square kilometers (Wantzen, et al. 2009). The Rhine River Basin has a rich history, culture, and economy, making it an important region for both Europe and the world.

The Rhine River is formed by the confluence of the Vorderrhein and Hinterrhein rivers in the Swiss Alps, and it flows through several major cities, including Basel, Strasbourg, and Rotterdam, before emptying into the North Sea. Along its course, the Rhine River is joined by several major tributaries, including the Aare, Moselle, Meuse, and Main rivers.

The Basin is also an important economic region, with a strong industrial and agricultural base. The Rhine River is a major transportation route for goods, including coal, chemicals, and agricultural products. The river also supports a wide range of industries, including manufacturing, energy production, but also tourism. The basin has had an eventful history housing many historic towns, castles, and other cultural sites that attract millions of tourists each year.

The Rhine River Basin is also an important region for environmental conservation and is home to several important wetlands, including the delta of the Rhine, Meuse, and Scheldt rivers, which are important breeding and feeding grounds for waterfowl and other wildlife. Since the last major environmental disaster of the Sandoz chemical spill in 1986, the Rhine authorities managed to revitalize parts of the old ecosystem, leading to the reintroduction of the Rhine Salmon in its waters (IKSR, 2020).

Despite its importance, the Rhine River Basin is facing several challenges. The river has been heavily modified for navigation and hydroelectric power, and its water quality has been affected by pollution and the introduction of non-native species. Climate change is also affecting the Rhine River Basin, with increasing frequency of droughts and floods, which can harm ecosystems and damage vital infrastructure.



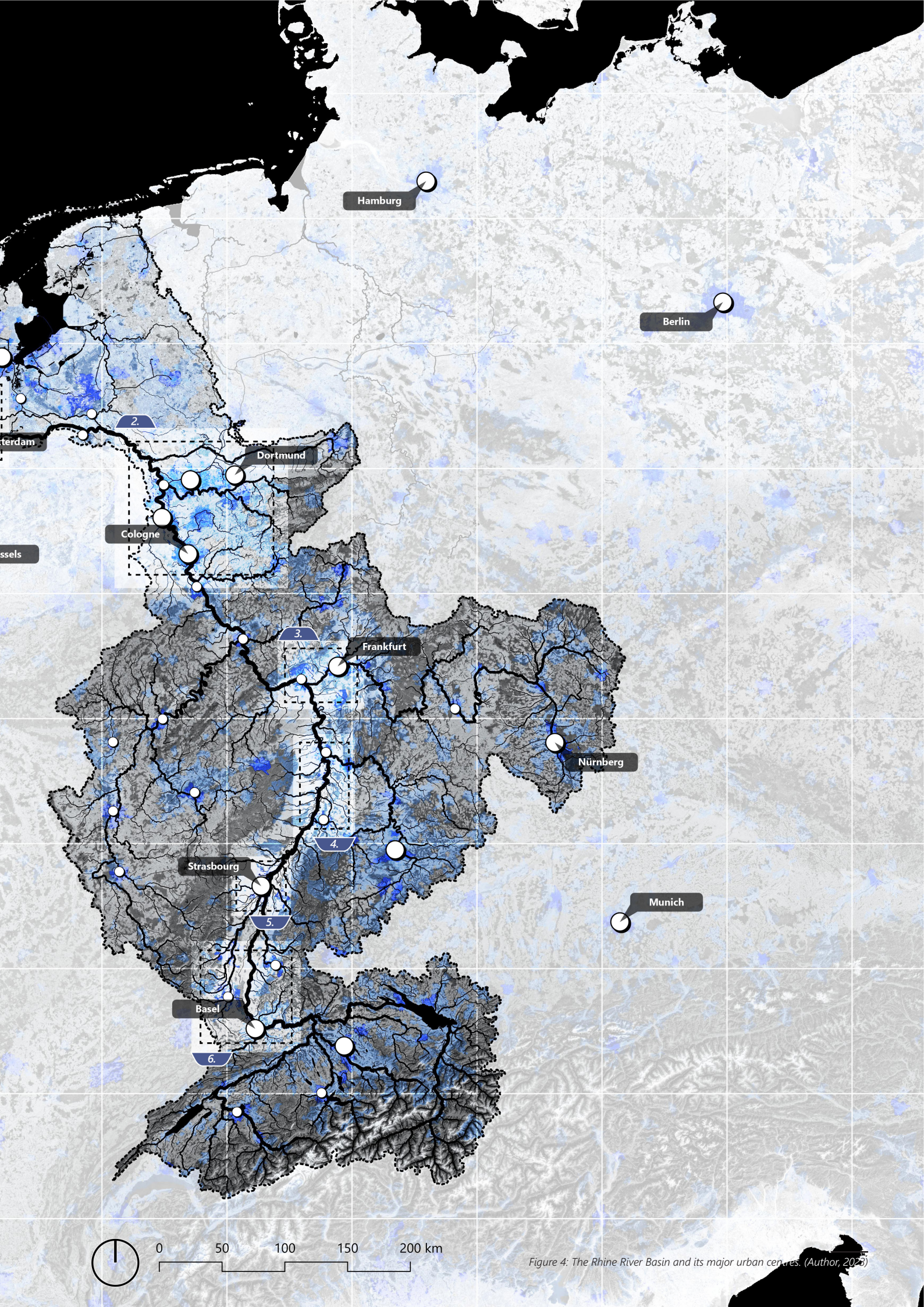


Figure 4: The Rhine River Basin and its major urban centres. (Author, 2023)

1.2

The Anthropocene

The Climate Change Epoch

Since the Industrial Revolution of the 18th century, natural resources have been used to facilitate the needs of an ever-fast-growing economy and society. Due to the greed of humans, we have encountered the Anthropogenic age. The term was first introduced by Paul Crutzen and Eugene Stoermer in 2000. The Anthropocene is a proposed geological epoch that marks the significant impact of human activity on the Earth's ecosystems (Crutzen & Stoermer, 2000). The Anthropocene is characterized by several distinct changes to the Earth's systems, including global warming, ocean acidification, and the loss of biodiversity. It highlights the fact that human activities have dominated the natural systems and that we need to take responsibility for the impact we are having on these systems.

This means recognizing the need for sustainable development and taking steps to reduce our impact on the environment, such as reducing carbon emissions and protecting biodiversity and our vital natural resources. As the effects of the Anthropocene are beginning to become more apparent in the Western world of America and Europe, the underlying natural systems have been starting to show their scars. Over-extraction has led to pollution of drinking water resources, soil degradation, the demise of protected flora and fauna, and massive refugee flows.

Only there remains a thorn in sight when considering the scale of time. As the Western world is still connected to a mindset of growth, therefore, accelerating urban processes, the natural systems work on a different schedule. As urbanization processes rely more and more on fast processes to keep on reaching the peak appropriation, natural systems will be exhausted further and because the natural systems need more time to recover, the exhausting of natural resources is starting to increase societal problems related to the fair distribution of resources.



Figure 5: Anthropocene of the Rhine: Coal mine Germany (Burtynsky, E., 2015), Fish deaths Oder River (EPA-EFE, 2022), Rhine drought in the Netherlands (ANP, 2019) & Alpine glacier melt (CNN, 2019).

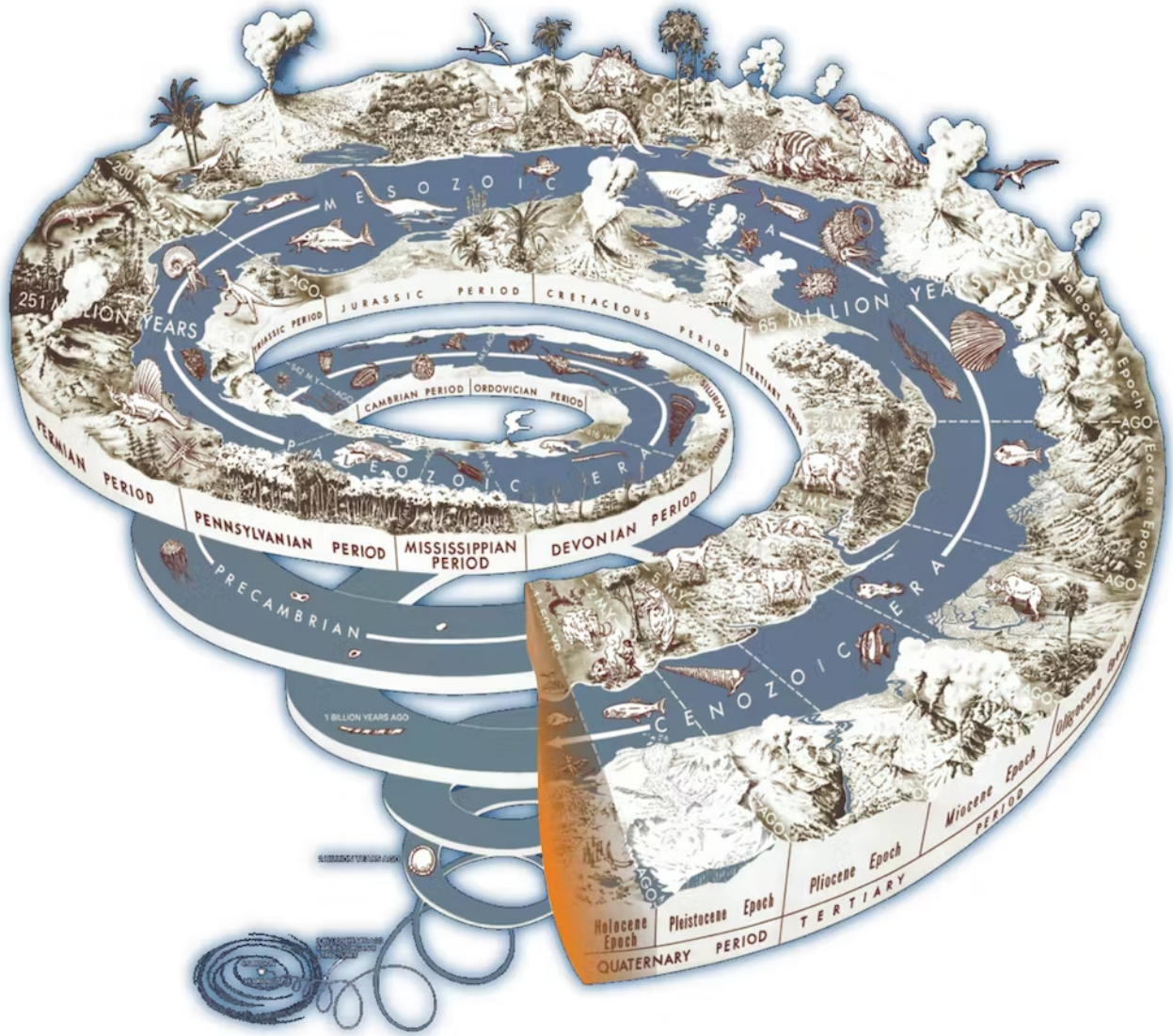
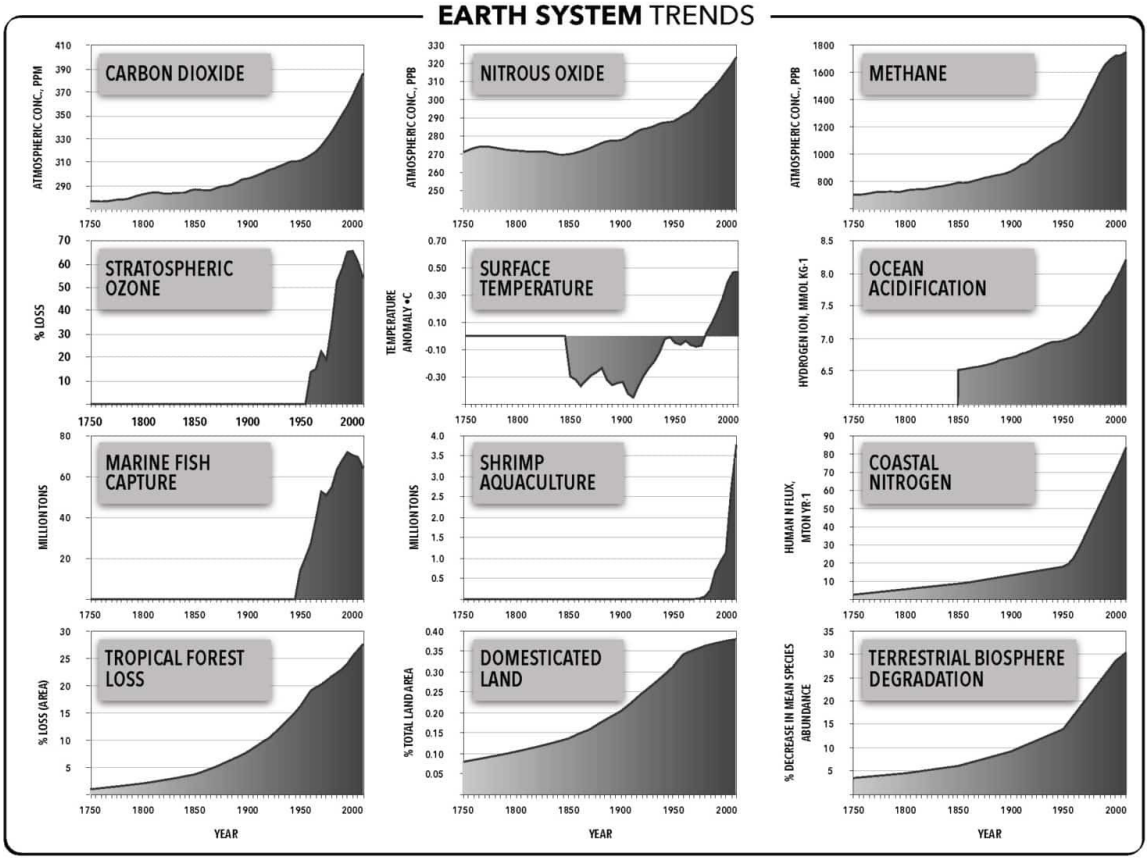


Figure 6: Timeline of the Earth towards the Anthropocene. (USGS/Wikimedia Commons, 2016)







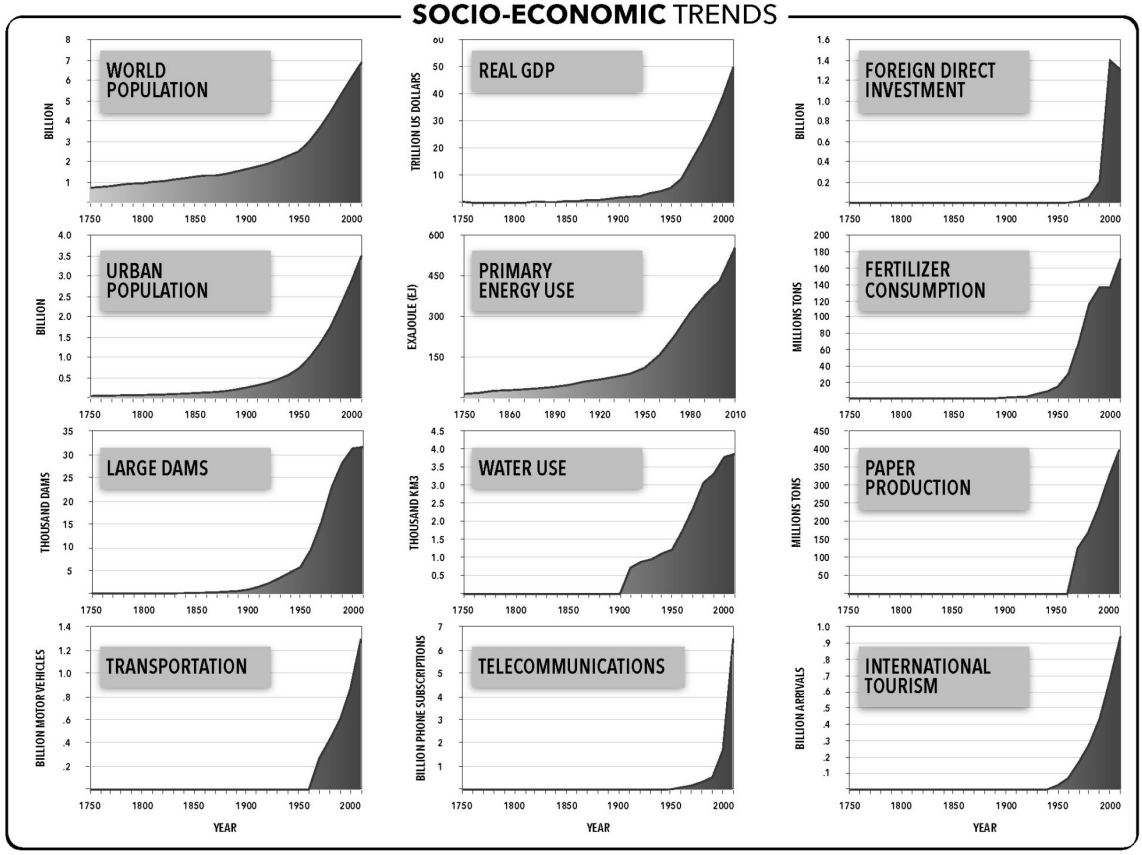


Figure 7: Earth System Trends & Socio-Economic Trends in the Anthropocene. (Jamil Jonna, 2015; based on Steffen et al., 2015: The Trajectory of the Anthropocene: The Great Acceleration)

Economic Growth vs Natural Values

As of late, the idea surrounding the understanding of the river systems has changed in Western Europe, from a concrete protective attitude to working with the natural system (Rijke et al., 2012). This change in awareness seems hopeful, but can also be considered as pretentious as the Rhine River is still one of the most controlled and monitored rivers in the world, mainly putting the focal point on its economic importance rather than its natural importance. Everybody experiences the level of change considering the Anthropocene differently, therefore amplifying the need for careful consideration of the relationship between levels of society with the human and natural systems. Therefore spatial planners and designers need to understand the various relations people have with human and natural systems and show the spatial relations between these human and natural systems. In the sense of the Rhine River Basin, the relation between the water-intensive industries with the underlying hydrological conditions of the soil creates a spatial understanding of places for water storage.

The first damming initiatives by Johann Gottfried Tulla in the Upper Rhine region in the 1850s kickstarted a new economic framework for the urbanization process that led to the creation of world cores of the Port of Rotterdam and the Ruhr industrialized areas, which are part of the global trade networks. The current global impacts of climate change and the unsustainable practices of the Rhine river industries, ask for a new configuration about the meaning of the operational landscapes of the Rhine river in this global network. When looking at the protection measurements (dike system) to provide this network, holes are starting to appear in this overall apparatus of the riverine trade. Particularly border crossings between the Rhine nations appear to disconnect the protection of the urbanization processes. As urbanization processes and the accompanying agglomeration have grown over the years, the understanding of transboundary collaboration remains a thorn in sight of these processes but can facilitate the change necessary within urbanization processes of the evolution of land uses as the natural systems change the game of the competition of space.

A means for large industrial practices and systems to gain a foothold in society always relates to a new exploration of new frontiers of the abstraction of natural resources. Although Europe can nowadays be seen as a completely urbanized landscape where everything looks controlled, the underlying natural systems have been starting to show their scars within the new paradigm of the Anthropocene. Large EU-funded cross-border collaborations surrounding the Rhine River have been introducing new biodiversity corridors bringing the salmon back into the river but this is only a small step into the revitalization of the Rhine River natural systems (IKSR, 2020). Facilitating space for natural systems is the only way for these systems to gain a foothold again.

The fluvial Anthropocene of the Rhine river Basin will have major impacts on the existing human and natural systems.

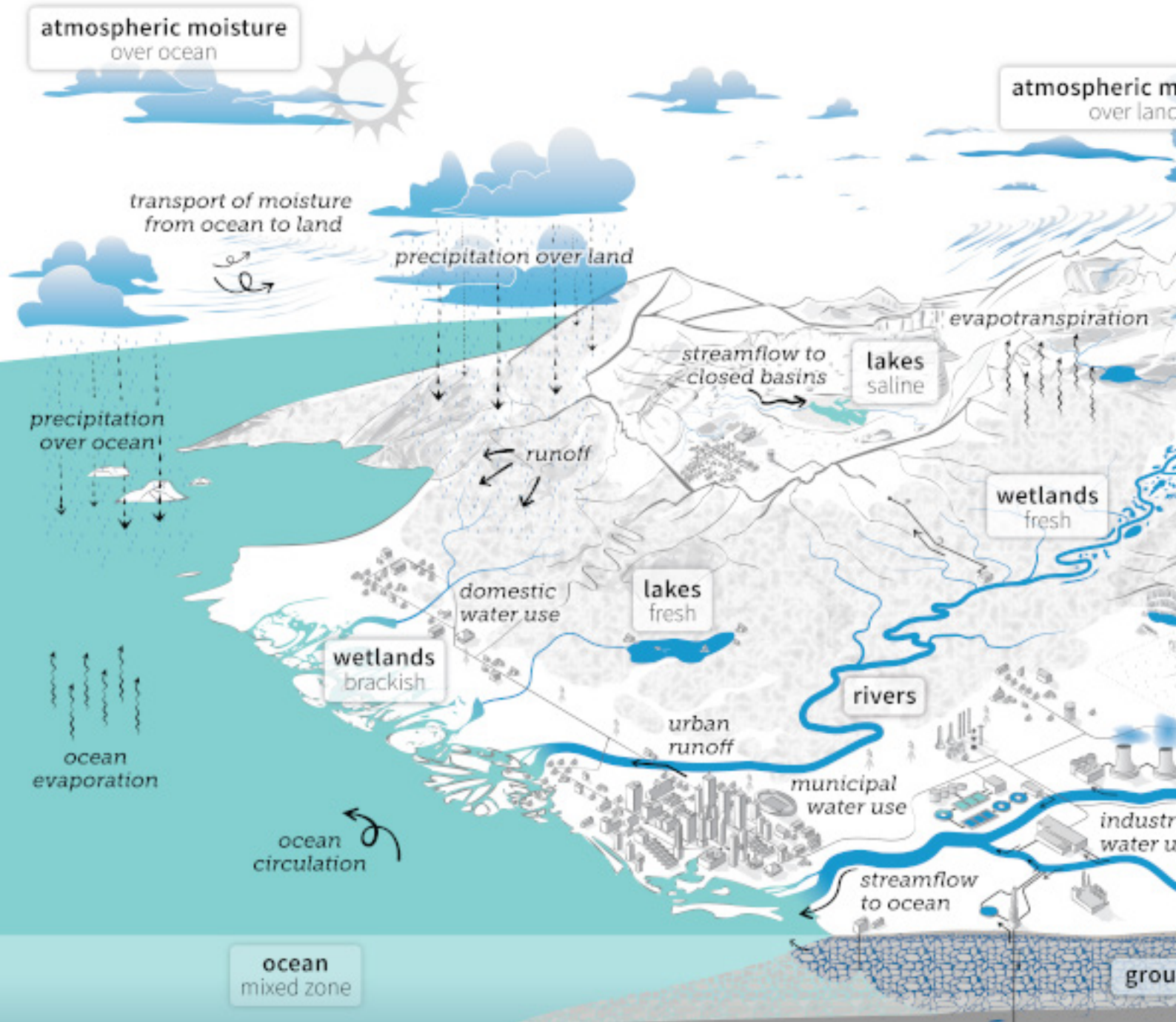


Figure 8: The 'Fluvial' Anthropocene. (Lukas Werther, Natasha Mehler, Gerrit Jasper Scheck & Christoph Zielhofer, 2021)

1.3

Climate Change
Effects of Drought

Natural Systems in the
Rhine River Basin



Effects on Hydrological Systems

The natural hydrological systems are the underlying foundation of society as we know it today. Due to climate change, humans will encounter more periods of intense rainfall and drought spells causing the drying and sealing of soils. This leads to the soils having less capacity to store water in their groundwater basins, less capacity to grow crops, and less available water for industrial, public sectors, and ecosystem services. The alteration of the climate has major impacts on the water cycle in general as increasing fluctuations of precipitation and discharges will lead to increasing patterns of erosion and sedimentation, endangering the survival of riverbanks and altering the flow of rivers. Besides the fact that due to climate change, glaciers will decrease in size leading to further climate disasters in the near future, research has shown a permanent decrease in freshwater resources in Europe after 2070 (IKSR, 2011). As these glacial rivers provide fresh water for the whole year, the source of drinking water will become dependent on precipitation. As climate change will alter weather phenomena in the Rhine basin, systems dependent on the Rhine water to survive will have to deal with increasing periods of intense droughts and decreasing availability of water resources. Increasing fluctuations of rainfall and drought spells also have major impacts on the current landscapes as predominantly polder regions for example that sustain due to a stable water level will encounter increasing patterns of subsidence as water has to be pumped and/or abstracted from rivers and surface water bodies. All these challenges and effects on the natural systems amplify the need for a revitalization of these systems as they can retain the vital resources humans need to survive.

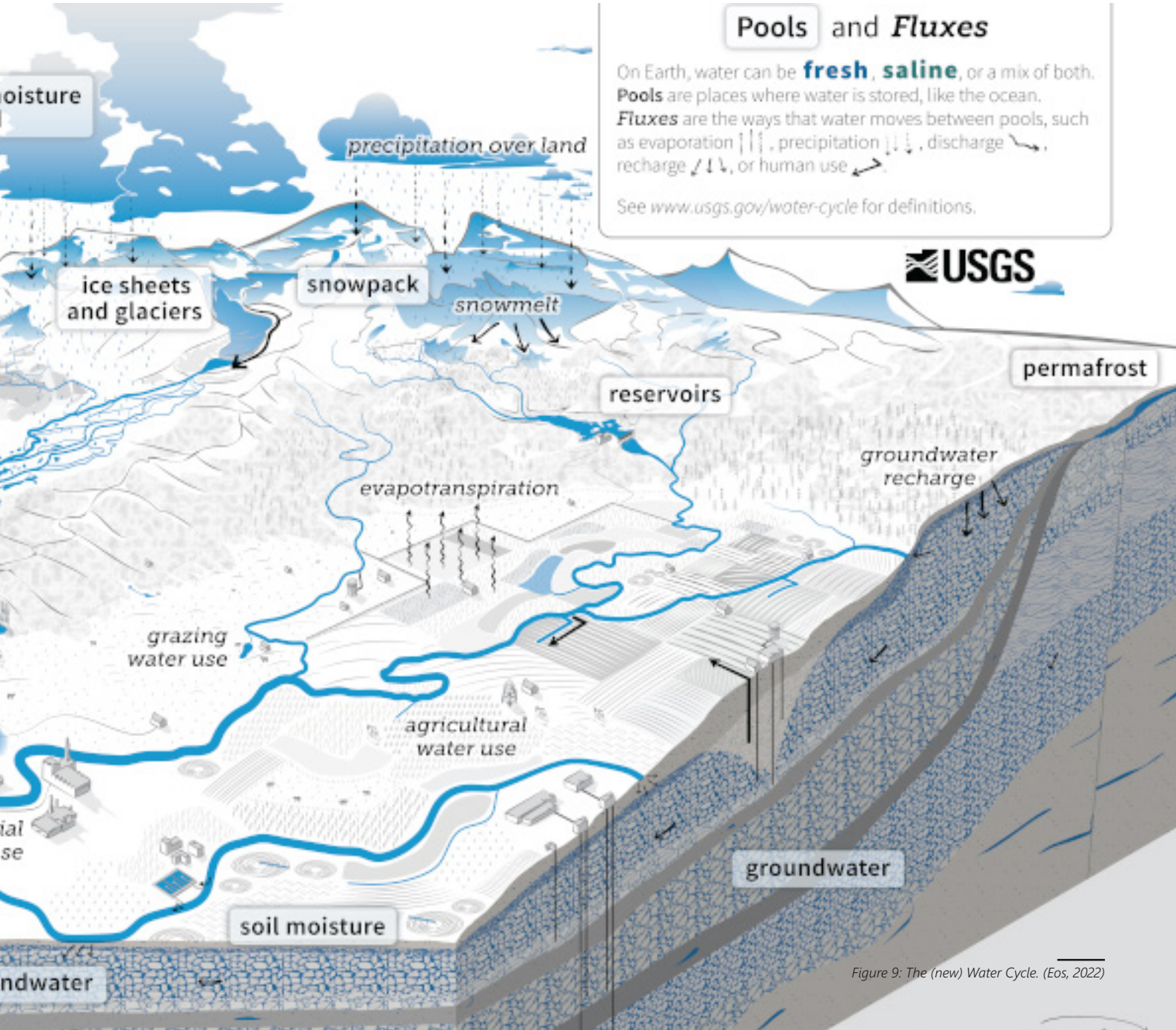
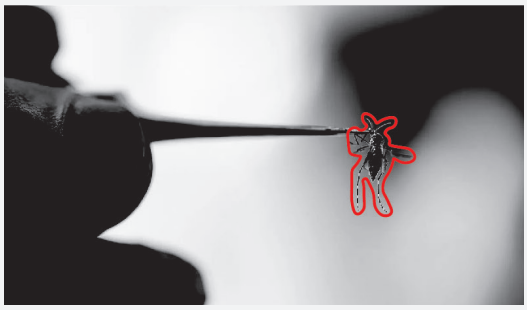


Figure 9: The (new) Water Cycle. (Eos, 2022)



Increase of diseases



Increasing sensitiviy of forrest fires



Unpredictability of flash floods



Decrease in future water quality



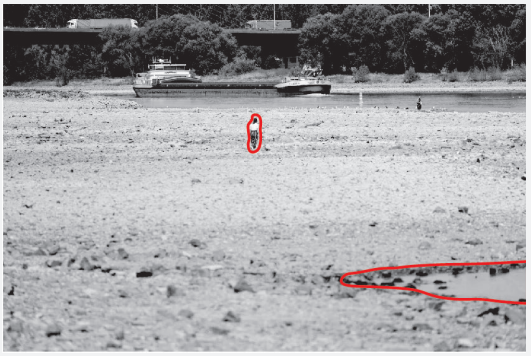
Increasing danger of subsidence & erosion



Loss of biodiversity



Drying out and sealing of topsoil



Dyring out and sealing of river beds

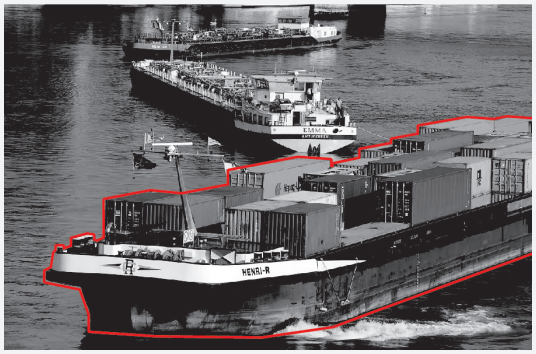
Figure 10: Effects of increasing periods of Drought on the Natural and Hydrological Systems. (Author, 2022)

Effects on Human Systems

Besides the fact that ecosystem services and the natural water systems will alter due to decreasing availabilities of water resources, these alterations also have major impacts on the human systems that have built our economic, urban, industrial, and agricultural cores. Due to the geological formations of the Rhine, Germanic industries have benefited from the abundance of raw materials like coal, oil, and natural gas. As these industries run on the usage of water as the primary cooling, production, and manufacturing resource, the decrease in available water resources will hamper industrial production and riverine transportation. As 50% of all European inland shipping is facilitated by the Rhine River (IKSR, 2020), which rely on a particular water level to facilitate the need of the Rhine industries and urban centers, a decrease in water level as recently was the case in Kaub in 2022, will further hamper the industrial character of the Rhine.

As part of the energy transition in Europe, more attention is given to alternative sources of sustainable energy resources. As water is a sustainable resource, hydropower stations will have an important role in facilitating that transition. In the increasing periods of drought, these hydropower stations become barriers to sustaining enough freshwater resources for downstream regions.

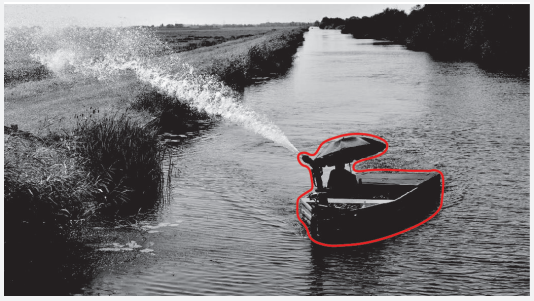
Besides the industrial claim on the water of the Rhine River, 60 million residents and vital agricultural regions of the lower lands of the Netherlands, Germany, and the Rhine Gorge, are also dependent on the resources of Rhine water to survive. Besides sustaining the basic human right to have access to fresh water, droughts have major impacts on the decay of vital infrastructures like dikes and levees, endangering large parts of the urban regions during seasonal periods of high water. To sustain the level of water for the use of production, drinking water, and energy production, increasing locations of water abstraction of groundwater bodies will be needed. Over-abstraction of ground and surface water bodies will have major impacts on biodiversity and water quality of rivers but also of groundwater basins themselves. And whereas rivers could be cleaned, groundwater basins cannot. As ground and surface water bodies are connected within the hydrological system, over-abstraction of groundwater aquifers directly influences levels of surface water and rivers.



Delays and decrease inland shipping



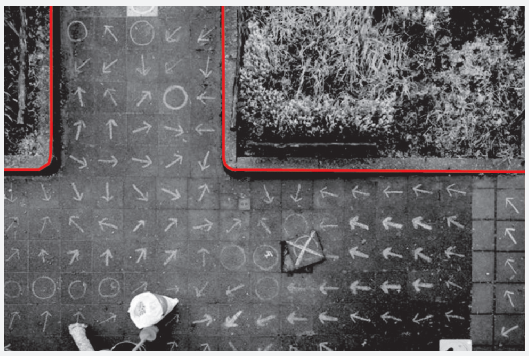
Loss of agricultural lands



Protection to preserve polders



Protection of Dyke systems



Change of waterflow due to land sealing



Decay of industrial practices



Loss of unique 'Rhine' practices



Changing intensity of river flow

Figure 11: Effects of increasing periods of Drought on the Human Systems. (Author, 2022)



Figure 12: Rhine River Cologne, August 2021 & August 2022. (ESA, 2022)

The European Union



Figure 13: The European Union. (European Commission, 2020)

1.4

Fragmenation in the European Union

The Need for a European Union

All these effects of the changing hydrological cycle and system will have major implications on the natural and human systems of the Rhine in sustaining fresh water. But as these vital resources will decrease in the future, the claim on the usage of the water will need collaborative action for the fair distribution of the water among the claims of stakeholders. As the Rhine river and its tributaries flow through 8 countries of which 6 are part of the European Union, collaborative action is dealing with transnational relations. The introduction of the European Green Deal and the Sustainability Development Goals try to facilitate the future sustainable development of the European continent. As the European Green Deal, is a bounding policy document, European nations have to follow the rules and ambitions set by the European Commission. As water can be traced to every single ambition of the European Green Deal (NWP, 2021), for example, in creating sustainable farming, circular economies, and smart mobility, collaborative actions between the Rhine River nations are necessary.

Dominant National Authorities

The Rhine River basin management organizations of the IKSR, CCHR, and CHR facilitate the combination of cross-border collaboration between nations. The representatives in these arrangements consist of independent officials therefore forming a neutral block between national agendas and regional and local authorities. However, due to the high interest in the economic development of the large nations states of the Rhine, the authority of these organizations can be questioned. Therefore the details of current spatial implementations are left to the nation-states themselves (Purkarthofer, et al, 2022). This allows for national authorities to form blockages between European regional policy and regional and local levels of government. With the occurrence of various consequences related to climate change directed at these nation-states states, the distribution of transboundary water resources clashes with the national agendas primarily focused on the economic character of the Rhine. Governance of common goods is therefore difficult. As climate change can be described as a wicked problem and borderless, the need for integral collaboration of nation-states, provinces, waterboards, private companies, and residents is crucial. Therefore an understanding of the planning cultures of these nation-states related to sectoral policies, adaptive planning, and citizen engagement is needed to be able to find solutions that create the minimum amount of negative externalities.

As water resources are considered a shared public good (Van den Berge, et al., (2021), developing water responsibility at the lower levels of society can provoke a transition toward sustainable water management (Akamani, 2016). Although the water management sector is considered to be too technical for common residents to understand, programs in the Netherlands showed the possibilities of integrating the voice of residents in the decision-making process (Klijn et al., 2012; De Bruijn et al., 2015). As the Rhine River is considered a transboundary region, it calls for coordination from the European Union to facilitate transnational collaboration but primarily empower regional and local authorities in the decision-making process as these authoritative scales are where the knowledge is found. Dominant uncoordinated national agendas on water management and the lack of support from EU governance to regional and local levels

of society, increase European fragmentation over its vital resources.

Cultural Differences in Spatial Planning

As the Rhine River Basin is located in different countries, EU and non-EU, all have completely different historical and cultural backgrounds that shaped the current spatial planning practices of the nations. Whereas developments in Germany have always been related to decentralization, its neighboring country the Netherlands has shown patterns of centralization (ESPON, 2018; Nadin, et al., 2020). Besides developments of re- and/or descaling in spatial planning, these countries also have different competencies regarding policy integration, planning adaptiveness, and citizen integration (Nadin, et al., 2020). These planning cultures are the foundation of how water management arrangements are organized, where transnational water management has to deal with several scales of authority, leading to unbalanced power relations between national, regional, and local governments.

Since the Napoleonic age, the Rhine River has been functioning as a free zone, leading to the formation of the IKSR, CHR, CCR, and recently the EGTC that resigns in over the Rhine today. These transnational organizations increase the possibility of transnational collaboration between levels of authority. Although the Rhine River is been considered a leading figure in integrated water management (EEA, 2021), the collaboration between the nations is still very complicated and often results in miscommunication and delays in decision-making processes (Klijn & Wagenaar, 2018).

The same story can be told about the differences in water management along the nations of the Rhine. Nations like the Netherlands have established a reputation when it comes to managing the flows and streams of water to protect its citizens. Although some say that this has led to allowing waterboards with too much power in water management (Teisman & Edelenbos, 2011), the available knowledge is only considered to be allocated in the Dutch contexts as the culture of water management in neighboring nations lacks the capacity for the integration of the Dutch models. This reflects yet again the cultural difference in spatial planning management in these nations, making it difficult for water authorities in the Netherlands to collaborate with its German colleagues as the internal nature does not allow for direct collaboration (Panten, et al., 2018), only facilitating the possibilities for the exchange of knowledge. This is reflected in the fact that the Rhine River is one of the most controlled rivers in the world. Each nation is responsible for its part. But when considering climate change effects on the availability of water resources, more direct collaboration between water authorities might be needed.

Institutional Thickness

To be able to bridge the gap between European spatial planning and its citizens, the need for the empowerment of sub-national levels of governance and framing of the involvement of local stakeholders and citizens is vital (Moodie et al., 2022). As regional and local authorities are often closer to their citizens (European Commission, 2018a), delegation of the decision-making process should be facilitated to these authoritative scales. Existing programs, like the Territorial Agenda, European Cohesion policies, and Interreg programs European governmental bodies like the European Committee of Regions already try to increase regional and local empowerment of governments. Only, what all these programs/committees and collaborative partnerships do is increase the thickness of institutional legislation. As these soft planning mechanisms increase the collaboration across administrative borders, they fail to facilitate territorial strategies (Moodie, et al., 2022), lower levels of governments so desperately need to translate EU legislation to local law.

Due to this institutional thickness, civil organizations are often excluded from decision-making processes therefore helping further establish the gap between the EU and its citizens. According to Moodie, Salenius, and Meijer (2022), the key lies in the clear distinction of territories. With a clear understanding of the involved regions in strategies, the sharing and transparency of the strategies will automatically increase. As sub-national levels of governance have been restricted by EU and national level actors, the loss of integration with local levels of society has been growing in recent years. The result can be seen in increasing EU skepticism and EU fragmentation with the rise of the extreme left and right political blocks (Moodie et al., 2022).



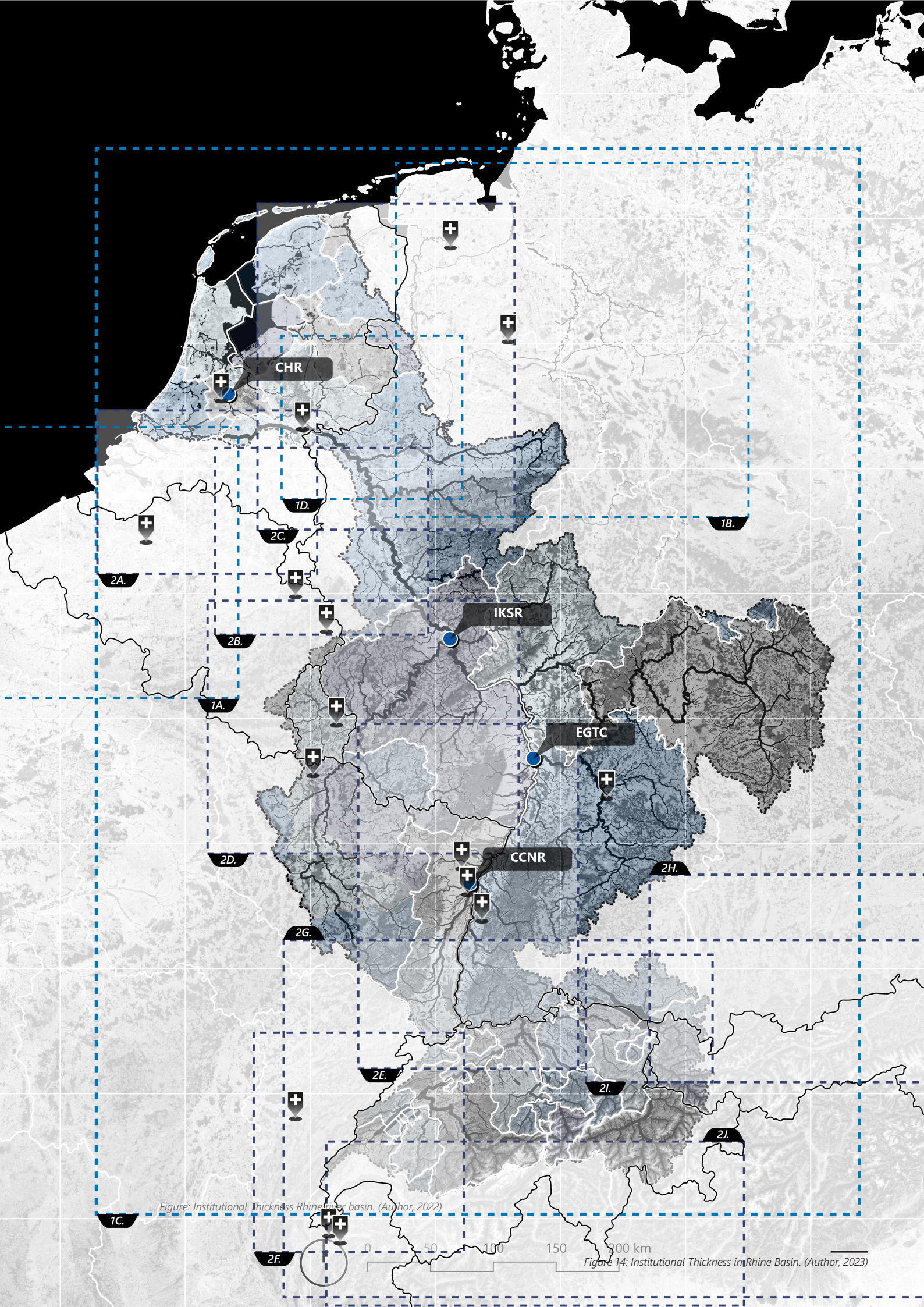


Figure: Institutional Thickness Rhine river basin. (Author, 2022)

Figure 14: Institutional Thickness in Rhine Basin. (Author, 2023)

Lack of Terriotorial Implementation

The European Union has been dealing with increasing patterns of fragmentation. Brexit, undemocratic stances by Poland & Hungary, and the rise of populism all have been hampering the relations between nations, but most importantly between the European Union and its citizens. The large focus on soft planning in European Governance has created unclear visions, rules, and legislation that can be interpreted differently by its member states, leading to further fragmentation in EU politics. The global challenges of today call for the integration of clear territorial strategies (Wanzenbrock, 2020; Purkarthofer, et al., 2021; Moodie, et al., 2022). The call for a clear understanding of policy implementation by nation-states and collaborative programs surrounding the Rhine River calls for new governance arrangements that allow for the integration of all its stakeholders.

The gap between Europe and its Citizens

According to many scholars, local conditions should be the leading voice in decision-making, as they supply the local and regional knowledge needed for the democratic legitimacy of legislation (Moodie et al., 2022). Next to the fact that communication between neighboring countries can often be seen as difficult (Klijn, & Wagenaar, 2018), the integration of citizen-led organizations within European politics is also a huge problem (Moodie, et al., 2022). As these citizen-led organizations have a cultural connection to the Rhine River Basin, they often have more in common with other citizen organizations in other countries than with their local governments (Panten, et al., 2018). Besides the fact that citizen organizations and sectoral ambitions have been overlooked by European politics, the distinction between citizen and stakeholder in EU policy is considered weak. Therefore the policies often address the wrong person or no persons whatsoever. Current spatial planning practices focus on large vision-making processes at the start of the initiation process between national and European politics. However, the integration of citizen engagement in the early stages of the process can provide additional legitimacy to complement later impact assessments on the local contexts (European Commission, 2018a; Moodie et al., 2022).

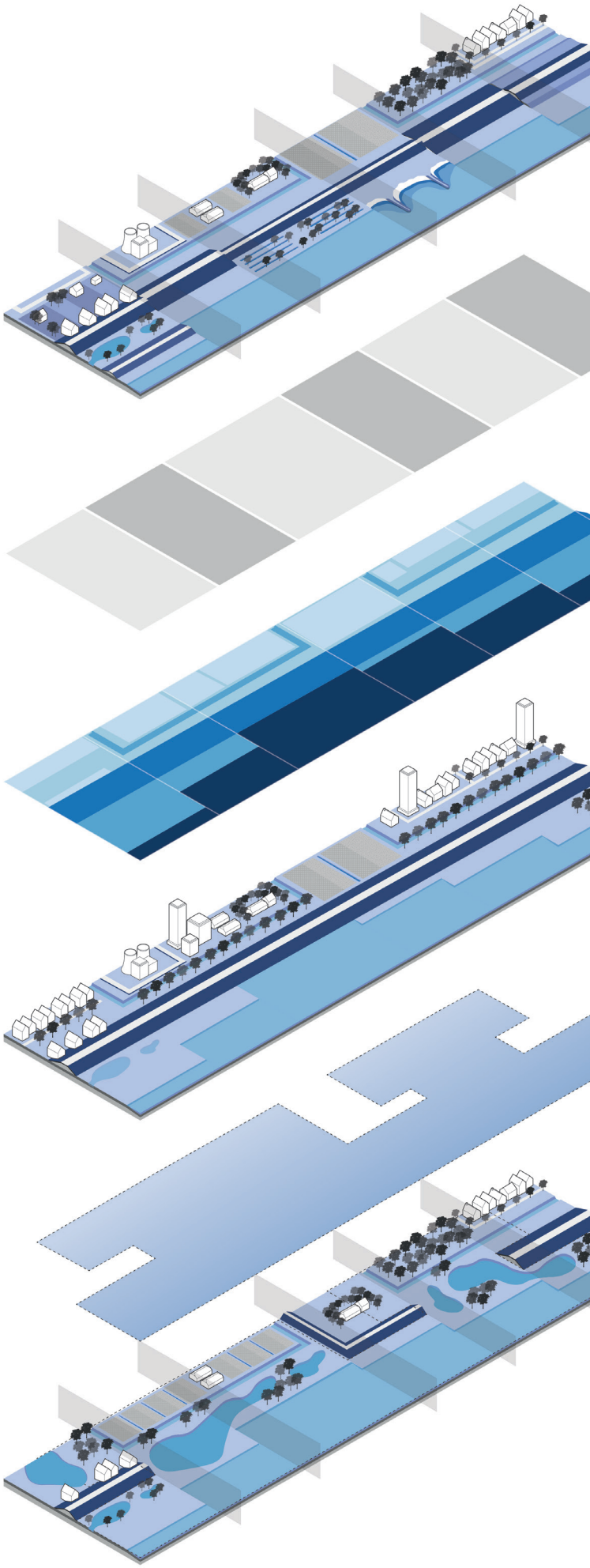
A Change in Dike Management

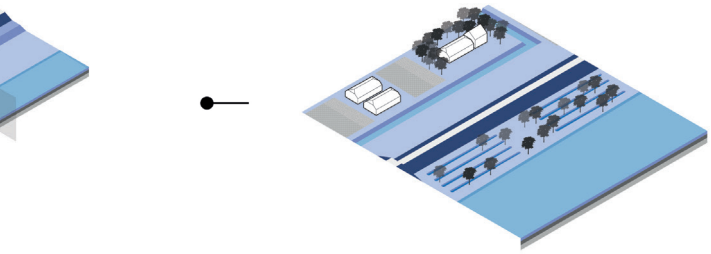
A spatial element that has been central in local management systems is the dike. The history of the dikes in and near the Rhine Basin has been largely related to the lowlands of the Netherlands and Germany and the lower Rhine Valleys of Germany and Switzerland. As the history of the different regions follows a different timeline, the essence of how the historical development took place can be considered a story of the Rhine as a whole.

Historical Perspective of Dikes

From a historical perspective, the first introduction of the dike in the Rhine basin took place in the Netherlands, where residents started to protect their land against the tidal influences of the North Sea (Lola Landscape Architects, 2014). Over time these residents formed management boards, distributing responsibility for dike maintenance among each other. These boards were the base for the Dutch Water Authorities of today. With the introduction of larger national and regional authorities, dike maintenance and construction was taken out of the hand of the local water boards (Delva Landscape Architects, 2013). A scattered patchwork of dike lines became a controlled line of defense against the water. Therefore the responsibility and awareness of local stakeholders in water management faded away. A report in the Netherlands of 2020 has shown that 80% of respondents have faith in their dike defense systems (NOS, 2020). So when a flooding event takes place, residents are dependent on the national or regional government to come into action.

Incidents of the recent past (1995 floodings of the Netherlands, 1986 Sandoz Incidents & the 2021 flooding of the Ahr River in Germany), have created a different view of how to let go of the control against the river and re-facilitate space for the river. Projects like Room for the River in the Netherlands and the Green Agenda of the International Protection Commission of the Rhine (2020) have shown the capabilities and advantages of re-introducing space for the natural dynamics of the river, not only retaining a layer of protection against future flooding events but also establishing new ecological and scenic environments of a natural river landscape (Klijn, et al. 2018). Besides the change of location of dikes in the Netherlands within the RoR program and some European projects in relation to the LIFE Project and EG-KRW, no direct changes have been made to the meaning of the dike in this equation. But as increasing periods of drought and flooding will harm the existing structures of the Rhine at a higher pace than before, only time will indicate the next major event in the Rhine basin.

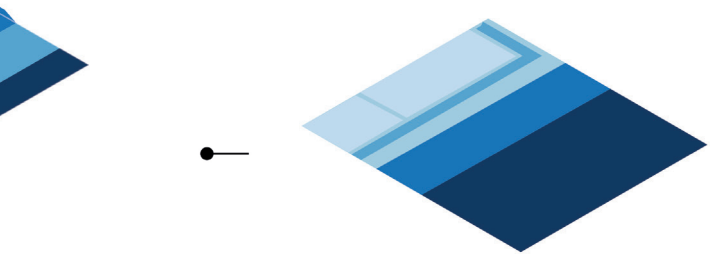




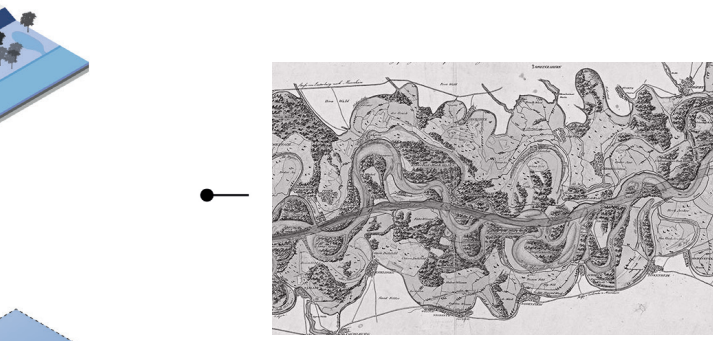
The idea is to underline the capacities of the spatial territories that are in constant relation with water and therefore could facilitate their needs by localized 'dike' management.



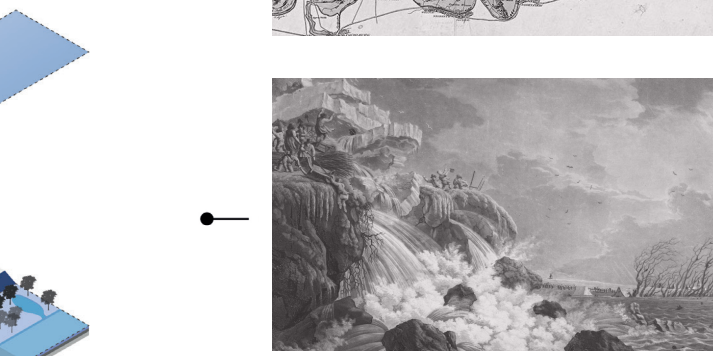
As part of Dutch example, the main reason to change existing legislative and therefore also spatial impact is to return to the acknowledgement of an



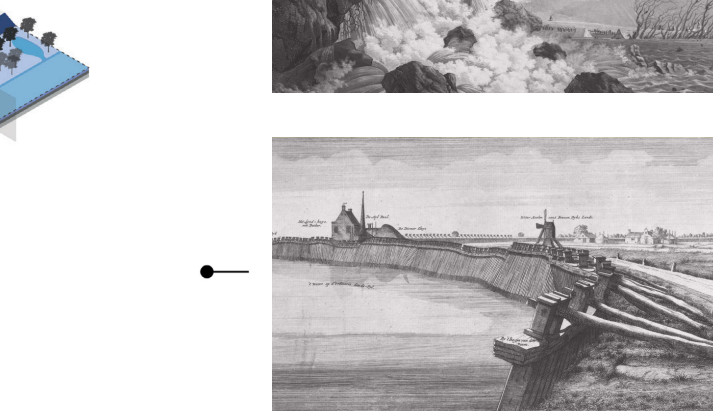
As part of the urban development, the land was divided among responsible authorative territories that each managed and maintained their own property. The further letting go of the legislative actions by governemental bodies, increased self responsibility of further fragementing spatial entities. The role of local water management vanished up to higher authorities.



With the establishment of the river as an integral part of human production, controlling the river was primairly done by constructing large dike bodies from local industries to national governments. A direct line was created between the River and its surroundings, protecting the backland for further urban development.



Floods and droughts were common among the years until the industrial revolution created new constructive water management elements to retain and controll the dynamics of the river, leading to new economies within the sediment trade, energy and industrial production. The river became an international highway



During the first settlements of humans along the shores of the dike, people used the knowledge of the landscape to determine the location of their villages. By allowing the natural river to form a transition between the dynamics of the river and the settlements, people tended to controll the severeness of the dangers of the river.

Figure 15: History of Dike Management. (Author, 2023)

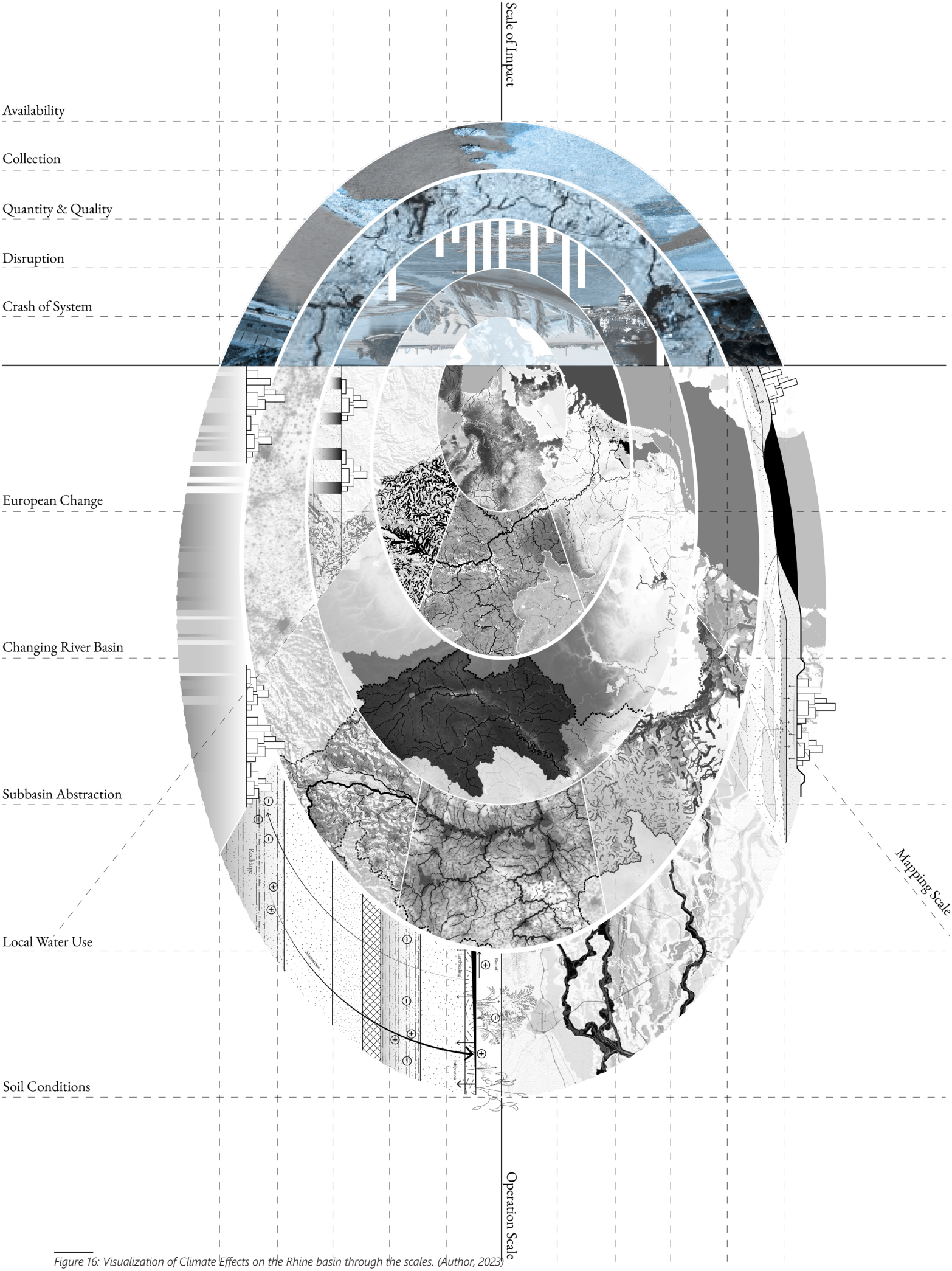


Figure 16: Visualization of Climate Effects on the Rhine basin through the scales. (Author, 2023)

02

Problem Statement

2.0

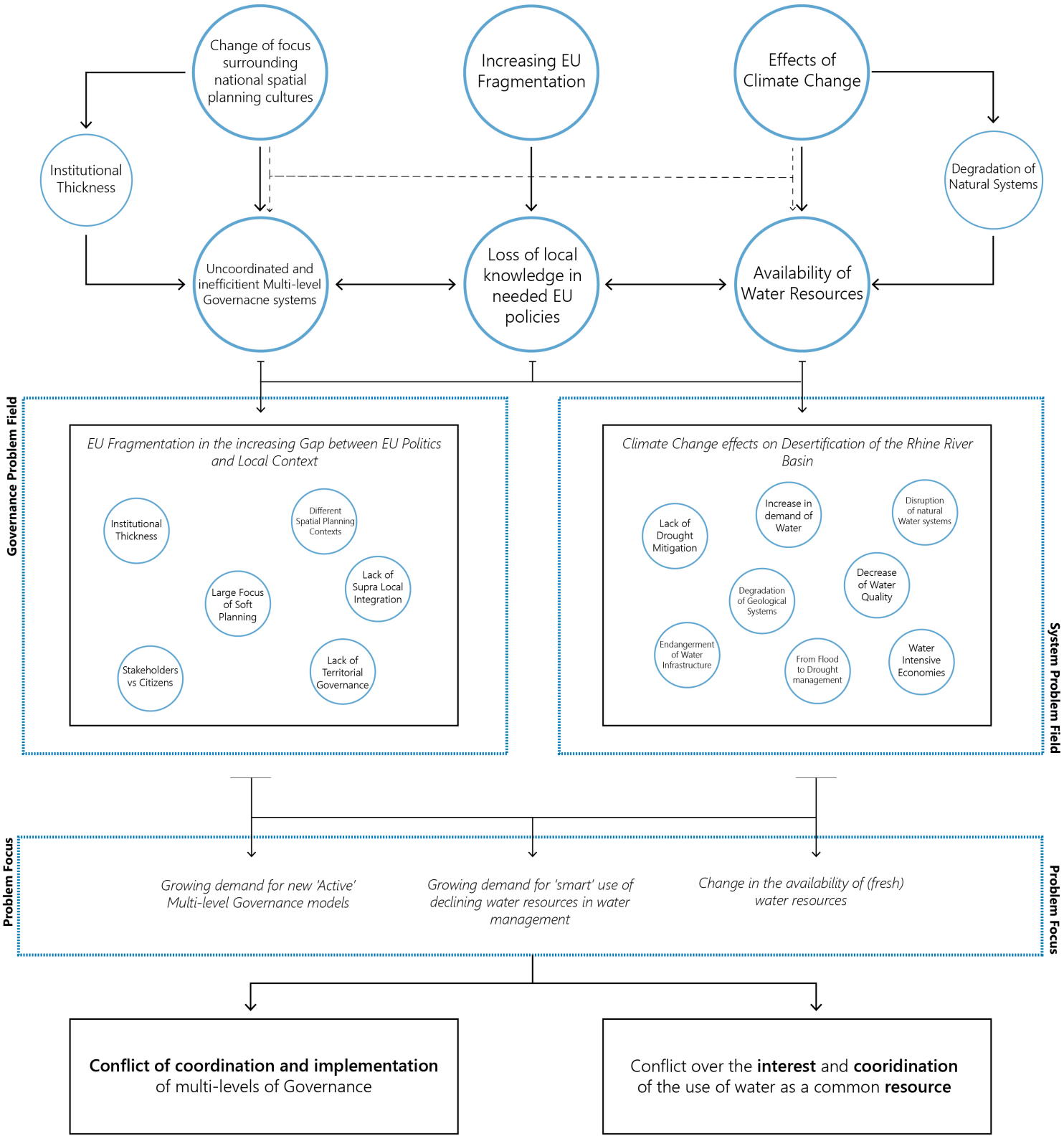
Problem Statement

Finding Common Water

The Rhine River is supported by the largest freshwater reserves in the Alps, but its natural conditions are under threat due to the increasing effects of climate change, putting the current 'stable' Rhine under pressure. Besides endangering the basin with periods of extremely high water (Stahl et al. 2022), increasing periods of extremely low water leading to intense droughts will also significantly impact society. These floods and droughts affect not only existing economic and financial infrastructures but also the quantity and quality of surface and groundwater levels for residential and ecological use (UNESCO, 2009; European Environmental Agency, 2018) and the dike structures that protect the urbanized regions of the Rhine (CTCN, n.d).

Furthermore, increasing uncertainties about future discharge within the water systems hamper soil, ecology, and other hydrological systems. The conflict between the increasing demand for water from all sectors (Water Europe, 2018) and the ever-shrinking water resources demands a governance framework that facilitates the fair distribution of the burdens and benefits for the use and storage of water resources. The issue arises from power interests within European and national governance, seeking joint gains to sustain existing resource-depleting economies (Van Berge et al., 2022). In the anthropogenic age of resource depletion, the natural river systems are overlooked and exploited (European Commission, 2019). There is a need for a representative voice of the river as a way to rebalance the water distribution between human and natural systems (Wilk et al., 2019). Although the impact and importance of climate change are well-known at the European, national, regional, and municipal levels, with the implementation of the EU Green Deal and multiple cross-border and transboundary collaboration programs, the implementation of European (water) legislation in the local context still lacks translation (Moodie et al., 2022; Van Rijswick, 2015). Therefore, there is a need for a change in existing water governance arrangements (Teisman & Edelenbos, 2011; Rietveld et al., 2013; Akamani, 2016). The current Rhine River Basin consists of eight nations, two of which are non-EU members, with a combined total of 15 transboundary programs (Interreg, 2023), three International commissions of river authorities, and other authorities directed at the hydrological, transportation, and navigation sectors. However, the institutional thickness of European and transboundary policies and the lack of coordination between governments facilitate the growing sense of EU fragmentation within the local context of the European mainland (Nadin et al., 2021; Moodie et al., 2022).

As governance related to water systems transcends administrative borders (Teisman & Edelenbos, 2011), the need for European authority is necessary to facilitate the interface for national and regional-wide cooperation. The gap between EU decision-making and local implementation remains a factor for EU fragmentation among societal groups. The concept of active subsidiarity has been researched in recent years to facilitate new stepping stones for the integration of citizen participation measures in EU spatial planning (Moodie et al., 2022). However, the need for active subsidiarity lacks the connection with integrated water management, although it could be related to Dutch multi-level governance structures in various water management programs. Therefore, the relationship between local implementation and EU-based programs should be facilitated from within local conditions and sub-national governance cooperation structures (Akamani,



2016; Carlise & Gruby, 2019; Moodie et al., 2022).

Figure 17: Problem Field. (Author, 2023)

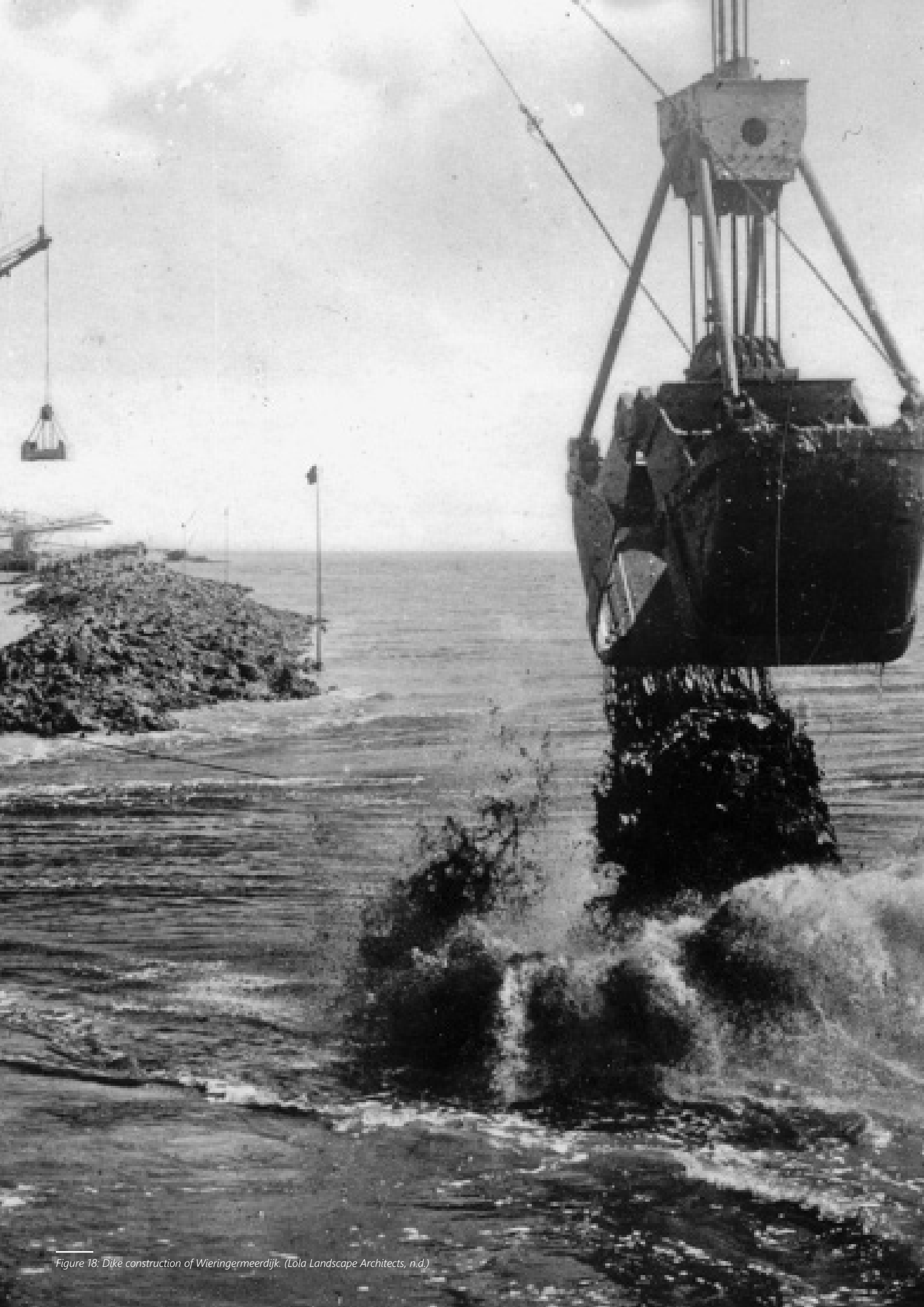


Figure 18: Dike construction of Wieringermeerdijk. (Lola Landscape Architects, n.d.)

03

Research Aim

3.1 Research Aim

Localizing Water Management

3.2 Research Questions

3.1

Research Aim

Localizing Water Managment

Hypothesis

As explained in the problem statement, the conflicts over the interest and coordination of water resources and the implementation and cooperation of multi-level governance arrangements do not facilitate the necessary fair distribution of water resources among stakeholders. To overcome these conflicts, address the decreasing availability of water resources, and restore regional and local empowerment, it is crucial to address the power relations between human and natural systems, as well as between national agendas and local integrations, which pose a threat to the fair distribution and protection of water.

Recognizing the revitalization of natural systems and their ability to store water in times of need and localizing decision-making in water management towards localized autonomy, can establish a more sustainable and fair relationship among the various claims on the use of water resources. As the local relationship with the water can be traced back in history (Boelens, 2016), the underlying cultural aspects of the water and humans should be shared among the various stakeholders.
This report defines the spatial element of the dike as a structure that stands between the natural river system and local users. The dike serves to emphasize the change needed for the fair and equal distribution of water resources. The dike is seen as a structure capable of redistributing water flows on the one hand and as a transitional element highlighted by the relationship between stakeholders and the river on the other. The dike can be implemented in various ways in different locations by different stakeholders, making it an ideal spatial element representing the relationship between local stakeholders and the river.

To integrate this notion of the dike as a transitional element, a roadmap should be created to allow local stakeholder groups to re-establish their relationship with the river. This formulates the steps toward local autonomy in the water management sector.

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Research Aim

This thesis aims to design an adaptive and robust roadmap towards localized dike autonomy. The main goal is to create a framework where local actors can re-assume responsibility for their own 'protection' against the Rhine River, re-establishing the lost relationship between man and water. The concept of the dike is not just a means to divide the land and the river but to organize a newly created transition zone tailored to the needs and context of local conditions. This report uses the managerial concepts of Active Subsidiarity and Adaptive Water Governance to provide localized groups and actors with the freedom and responsibility to reshape their relationship with water, facilitating the needs and self-organizing capacity of the stakeholders involved while addressing the problems of increasing periods of intensive droughts and floods to ensure a fair distribution of water resources.

This report does not seek to solve the problems of drought and flooding but aims to raise awareness of the climate risks to the Rhine stakeholders. To re-establish the local relationship between actors dependent on the

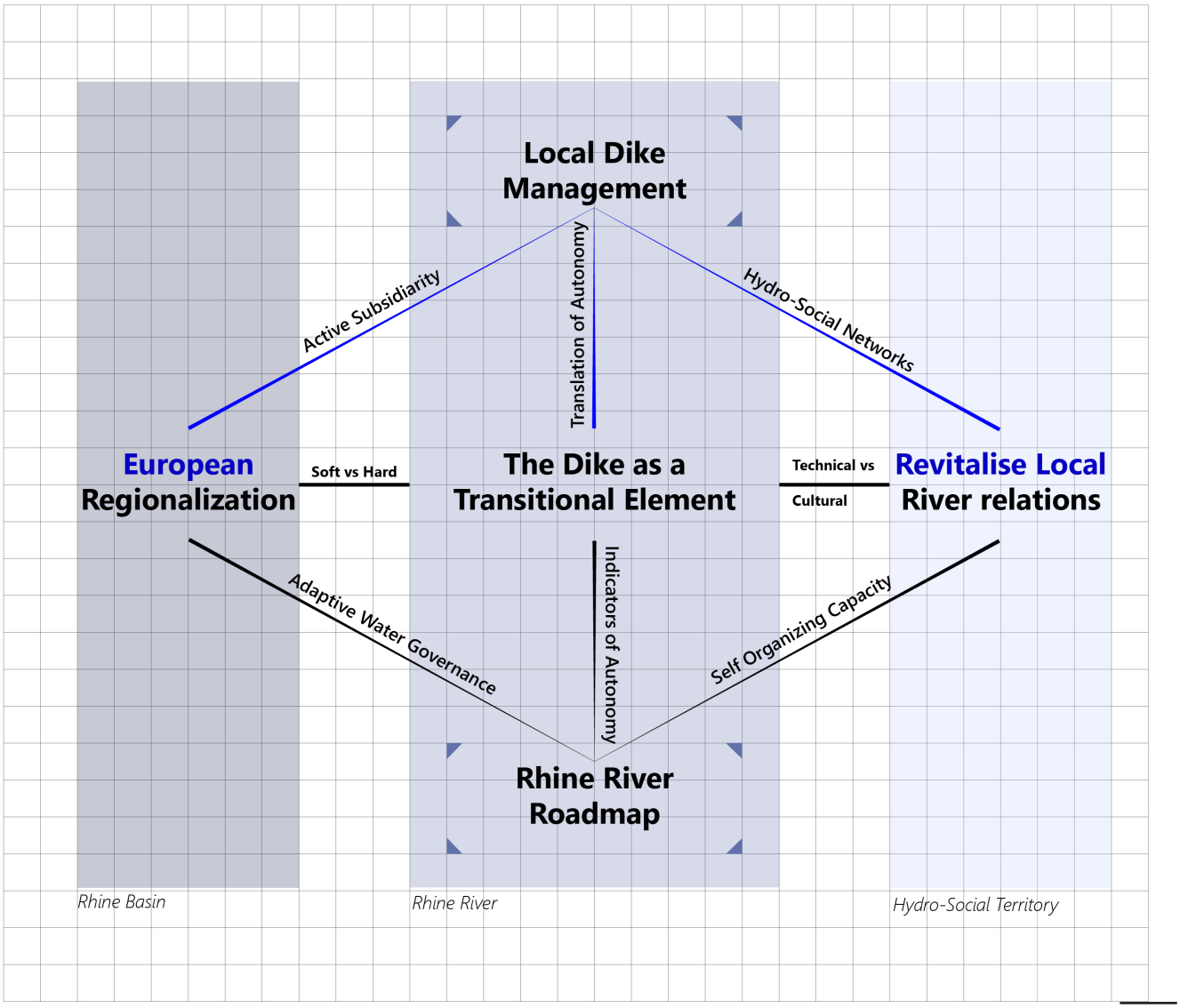


Figure 19: Research Aim Framework. (Author, 2023)

Rhine and the natural river system of the Rhine, a new territorial definition is proposed based on the theory of Hydro-Social Territories. These territories are related to existing natural and administrative zones. This creates the possibility of establishing new localized relations between Rhine territories, leading to opportunities for the distribution of knowledge, resources, responsibilities, and collaboration. As each design location, or Hydro-Social territory, has its own goals and vision for its relationship between water and land, the systemic approach of the roadmap will be used as a guideline based on the local spatial and managerial conditions.

Therefore, the programmatic approach of the Dutch Room of the River is investigated and translated into a roadmap for local dike management arrangements in the Rhine basin. To integrate this newly created roadmap and management arrangements into real-life scenarios, the investigations of the current management cultures of the Rhine nations, the regional and local dike relations, water usage among stakeholders, and the understanding of the current hydrological river systems in the Anthropocene age are vital for the formulation of a robust technical layout while leaving implementation to the local context.

Literature research into the new concept of active subsidiarity will be conducted concerning the boundless systems of water governance of the Rhine nations. The focus on the missing links in the multi-level governance approach of the European Union will center on the integration of EU soft planning with adaptive transboundary regional public-private partnerships and the conditions needed to facilitate accountable top-down authority that leverages bottom-up local possibilities.
In conclusion, this report aims to create a platform on which existing local stakeholders can reinstate their responsibility within the water management system and eventually research what is needed to recreate the mutual bond between man and the water system using the spatial element of the dike as the main component.

3.2

Research Questions

How can Active Subsidiarity empower localized autonomy of dike management, facilitating a new 'line of defense' & awareness of climate extremes regarding the Rhine River?

RQ1:
What does Active Subsidiarity entail in conceptual terms and how can it be implemented into spatial configurations?

Creation of the Hydro-Social Territories as the spatial entities for the implementation of the Roadmap

RQ2:
Which indicators are needed to research the possibilities of Localized dike management and how are these indicators related to the possibilities of local autonomy?

Data analysis (quantatative as qualitative) on the indicators needed for the suitability of local dike autonomy

RQ3:
How can we determine the indication of local autonomy within spatial configurations and how can this be implemented?

Translations of the data based around the creation of the Rhine Line as a spatial framework for autonomy

RQ5:
What is needed in order to facilitate the spatial translation of Autonomy into strategies and how can this process be localized?

Spatial strategies and design interventions towards the creation of a patchwork of localized dike units

To be able to formulate an adaptive framework for the distribution and storage capabilities in the Rhine River Basin, the main research question is:

How can Active Subsidiarity empower localized autonomy of dike management, facilitating a new 'line of defense' & awareness of climate extremes regarding the Rhine River?

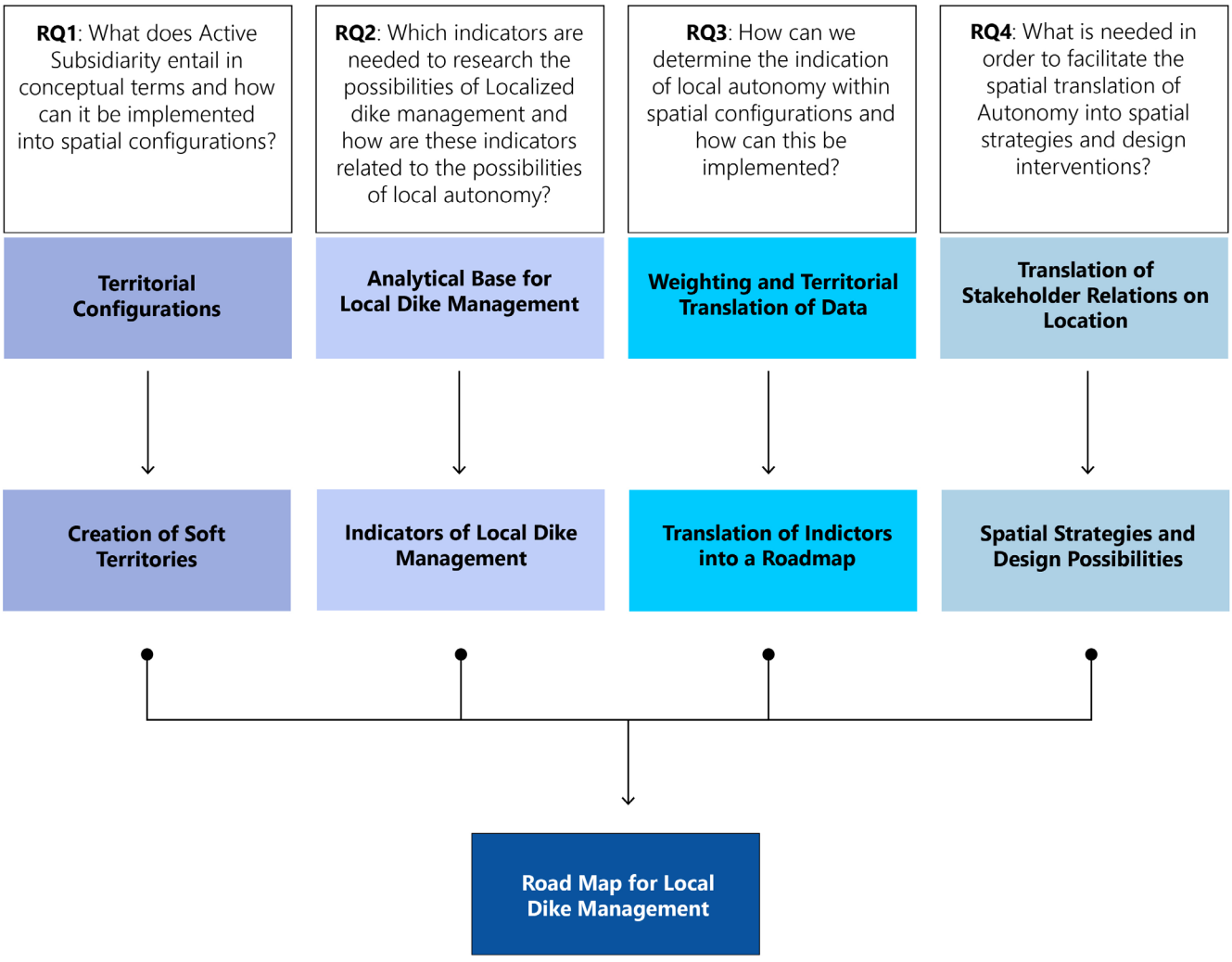


Figure 20: Research Questions Framework. (Author, 2023)



Figure 21: Emerging Shipwreck due to dry Rhine river in Germany. (Gizmodo, 2022)

04

Theoretical Framework

4.1 Governance Principles

Active Subsidiarity

4.2 Spatial Planning

Adaptive Spatial Planning
Adaptive Water Governance

4.3 Adaptive Systems

Complex Adaptive Systems

4.4 Water as a Common Resource

Hydro-Social Territories

4.0

Theoretical Framework

The theoretical framework defines a clear understanding of the different approaches and theories followed and implemented in this thesis project. The following theories and concepts are used as a guiding theme for this thesis project.

The Rhine River Basin will in the future have to deal with increasing seasonal periods of flooding but also droughts. As drought adds another layer of complexity to the already 'experienced' flood mitigation strategies in water management arrangements, it is key to recognize that increasing periods of droughts are inevitable and that the vulnerability to them will increase with time. Therefore the need for continuous adaptation processes needs to be sought out through existing water governance and water management arrangements across the nations of the Rhine River. As Akamani mentions in his paper: 'Adaptive Water Governance: Integrating the Human Dimensions into Water Resource Governance' (2016), we need to seek interconnectedness between existing integrated water management, highlighting the importance of a multi-scalar approach and adaptive management, emphasizing to deal with increasing uncertainty.

In addition to this current trend in water management, the interaction between the human and natural systems of the Rhine River basin has resulted in the conflict over the claim of water as a resource. According to Boelens, et al. (2016), the control revolving around water can be spatialized in Hydro-Social Territories. These Hydro-Social Territories are created through the interactions between human practices, water flows, hydraulic technologies, biophysical elements, socio-economic structures, and cultural and political institutions (Boelens, et al. 2016, p. 1). As these Hydro-Social Territories are not spatially bounded, they can be formulated across a multi-scalar planning field.

Furthermore, as the Water policies and management goals of the Rhine nations are related to the overall frameworks of the WFD of the European Union, the ability to integrate active subsidiarity – the understanding that none of today's problems can be treated at only one level of governance and should be allocated to the level of governance where it can be treated most efficiently (Moodie, et al., 2022).

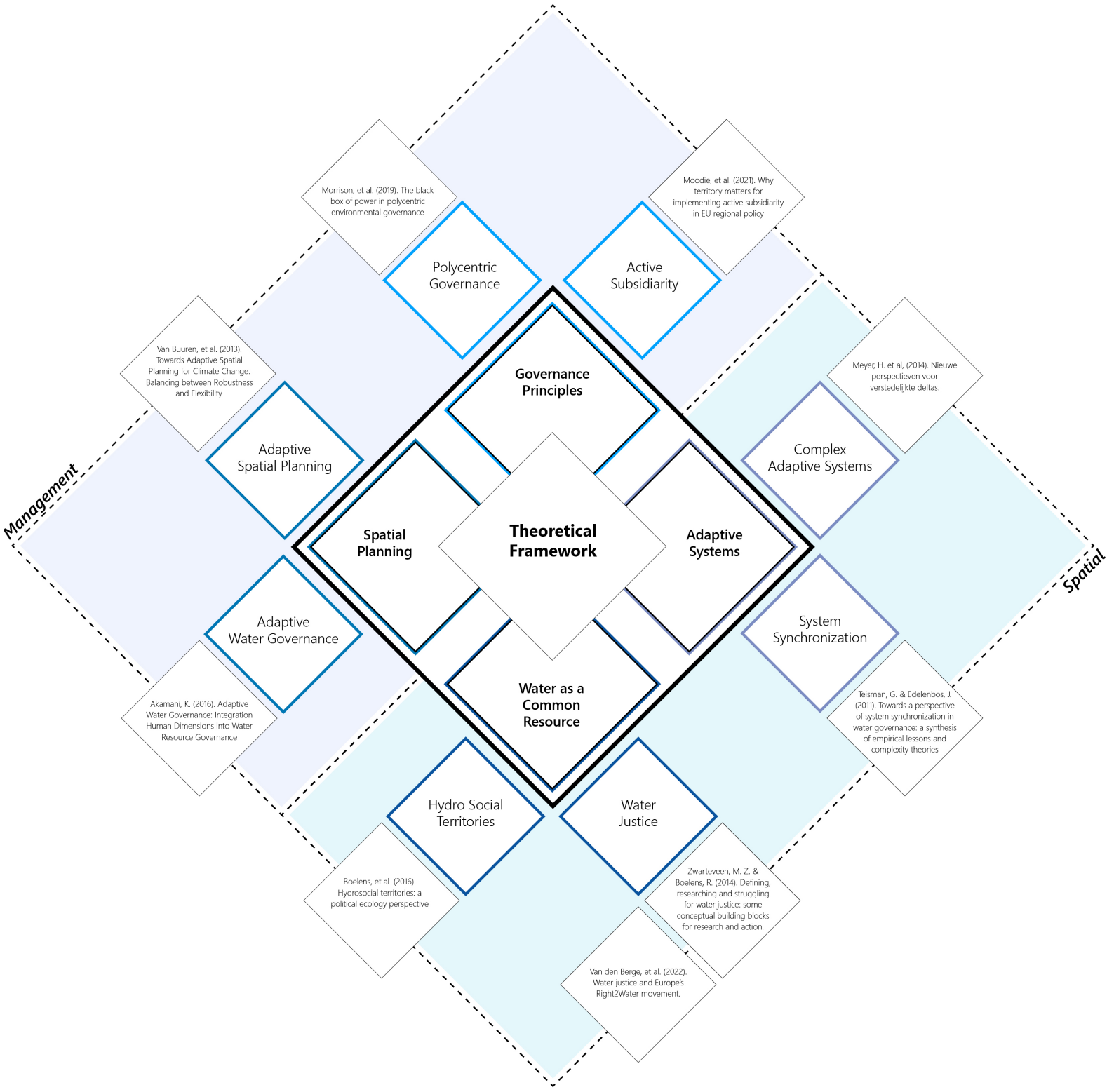


Figure 22: Theoretical Framework. (Author, 2023)

4.1

Governance Principles

Active Subsidiarity

As a means to empower the sub-national levels in defining and implementing their own territory-based regional policy goals and strategies, the subsidiarity principle was introduced in 1992. Although the principle was based on using local and regional knowledge to implement policies and legislation more efficiently by the context, the subsidiarity principle often failed to materialize (Moodie, et al., 2022). Due to the policy sphere being dominated by the European Commission and the national governments, the role of the sub-national levels was considered to be limited, having to deal with a lack of capacity and definition of how subsidiarity should be implemented.

In 2017, the new term 'Active Subsidiarity' was introduced to enhance the transferability of the principle to local governments (European Commission, 2018b). Active subsidiarity is considered to give a stronger voice to the local and regional authorities in decision-making processes (European Commission, 2018b). Key figures and principles for the implementation of Active subsidiarity are seen in Figure (X). The main conclusion from these principles can be understood as increasing the capacity of regional and local authorities in decision-making processes to strengthen the bond, trust, and democratic legitimacy (Stead, 2014) between citizens and the European Union. For this to be accepted by regional and local authorities, emphasis is being put on multi-level and polycentric governance arrangements (Moodie, et al., 2022).

Moodie, et al. (2022) explains in one of their latest papers: "Why territory matters for implementing active subsidiarity in EU regional policy", that the notion of active subsidiarity is closely related to territorial cohesion policy, that aims at enhancing socio-economic territorial collaboration and cross-border cooperation in polycentric networks (Medeiros, 2017, in Moodie, et al., 2022). According to Moodie, et al. (2022), territorial cohesion advocates for a strong implementation of active subsidiarity in governance arrangements, facilitating place-based policymaking on the one hand and transnational collaboration on the other hand.

The subsidiarity principle is built on the need for multi-level governance, as the principle considers the direct connection between European and local levels of government, whilst also advocating for cross-border cooperation in polycentric networks (Medeiros, 2017; Moodie et, al., 2022) As multi-level governance arrangements are constructed to interlink all the various levels of governance, the structural implementation can be visualized in multiple ways and are based on hierarchical and soft space models (Moodie, et al 2022). Therefore the rigid interpretation of territorial boundaries is facilitated by the hierarchical model of multi-level governance, whilst the ability to meet in soft spaces in between allows for the exploration of self-organization and mutual agreements.

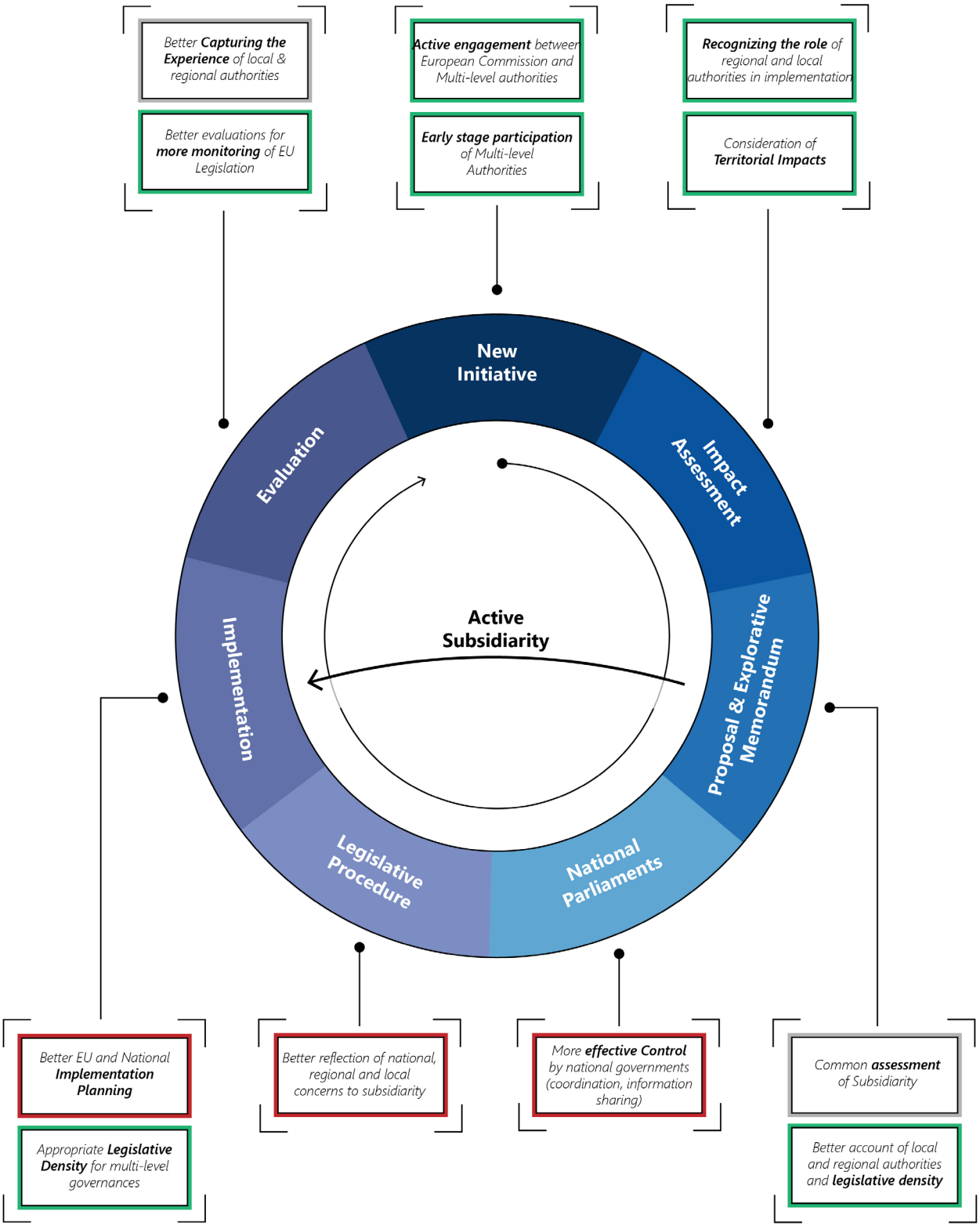


Figure 23: Relation between Academic and European Literature surrounding Active Subsidiarity (Green: Positive, Grey: Neutral, Red: Negative). (Author, 2023)

4.2

Spatial Planning

Adaptive Spatial Planning

Due to the increasing uncertainties and the complex character of climate change, existing spatial planning systems are in demand to encounter in the field of adaptive spatial planning. Rietveld, et al., 2013, advocates for the Governance of Adaptation, where there should be a balance between the demand for decisive and sound governmental actions in governance and the appeal for self-organization and bottom-up strategies. They underline the need for on the one hand the demand for robustness in facilitating solid and judicial guarantees; decisive, clear, and transparent rules, unquestionable policy criteria and institutional arrangement for collective actions among stakeholders (Rietveld, et al. 2013, p. 33.). On the other hand, they also underline the need for flexibility in the possibilities to adjust policy strategies to the local context, to experiment by self-organizing non-governmental actors, to facilitate the potential for joint problem-solving between involved parties, and to allow local governments to build custom-made solutions and bottom-up initiatives. Rietveld, et al., 2013 introduce three main elements of adaptive spatial planning that are needed to align the spatial planning practice with the increasing uncertainties, multiplicities, and complexities of climate change mitigation. First, the institutional context of spatial planning and the role governments have in facilitating the norms and principles for adaptive spatial planning. Secondly, the organization of concrete planning processes and how processes can be managed between robustness and flexibility. And lastly, to distribute responsibilities among stakeholders, they introduce a set of principles. These three elements of adaptive spatial planning are important in facilitating an understanding of the role of governments, their concrete planning processes, and the way responsibilities can be distributed among stakeholders.

To facilitate legitimacy within the entire society, Rietveld, et, al. (2013) argue that the return of the old principles of generality and durability in spatial planning will help create legally binding standards that can be applied and adjusted according to the regional and/or local contexts. As adaptive behavior in society is mostly seen as the responsibility of the individuals, the return of governments setting up rules and legislation based on the standards, society has the chance to integrate their adaptive behavior into it. As this report is based on enhancing local autonomy in dike management, this could mean that governments facilitate basic standards surrounding water protection, and sufficient water for economies, rather than questioning how this can be technically realized. When stakeholders can adaptively arrange these guiding principles, the notion of who bears potential risks should always be considered. As climate change knows no administrative borders, fragmentation of institutional arrangements without collaborative actions of various authorities could hinder adaptive spatial planning (Rietveld, et al., 2013). Therefore the need arises for a transboundary understanding of integrative arrangements. According to Adgers' theory (2003) on enhancing social capital to cope with the increasing uncertainties related to climate change, when the vertical linkages between civil society and the governments are strengthened, institutional arrangements like co-management and co-development will emerge (Adger, 2003 in Rietveld et al., 2013).

New ways to develop planning processes should safeguard the robustness of setting guidelines for climate mitigation, whilst creating opportunities to make innovative combinations of ambitions between societal, public, and private ambitions (Rietveld, et al. 2013). Principles of social learning, learning by doing, and experimentation among local stakeholders become imperative in allowing for flexible governance. It therefore follows the central theory of Active Subsidiarity where the local context is given the freedom to implement basic and robust legislation from high-end government. The need for robust and flexible arrangements of governance calls for the creation of guiding principles provided by higher levels of government, protecting the common resources and their future distribution, whilst facilitating bottom-up approaches for the development of co-management and co-production on the local levels of society.

To understand the capacity of adaptive spatial planning to take place, Gupta, et al. (2010), have introduced the so-called adaptive capacity wheel. They define adaptive capacity as: "the inherent characteristics of institutions that empower social actors to respond to short and long-term impacts either through planned measures or through allowing and encouraging creative responses from society both ex-ante and ex-post" (Gupta, et al., 2010, p. 461). It allows us to understand the characteristics of institutions that enable society to cope with the effects of climate change and to which degree of autonomy institutions allow and encourage actors to change these institutions. According to their research adaptive capacity can be promoted through the encouragement of a variety of perspectives, and solutions, for example: enabling social actors to continuously learn and improve their institutions, mobilize leadership qualities and arrange responsibilities, and support principles of creating fair governance arrangements. Based on the adaptive capacity wheel the indicators needed for local autonomy within the decision-making process are facilitated.



Figure 24: Adaptive Capacity Wheel for Program Assessment. (Author, 2023; based on Gupta, et al., 2010)

Adaptive Water Governance

Akamani's (2016) adaptive water governance is an approach that argues that recent steps taken in water management towards Integrated water resource management fail to consider the complexity of dealing with the increasing uncertainties related to climate change and socioeconomic development. As integrated water resource management facilitates specific governance forms that guarantee multi-stakeholder participation, equitable access, and efficient use of water resources (Gain, et al. 2013), it broadens the planning goals and scopes of water management and creates an intersectoral and multi-actor integration. Although Integrated Water Resources Management could be promising in allowing for multi-actor integration within water distribution, practical implementations have been limited as these programs are often constrained by a lack of clarity, capacity, implementation of integrated sectoral approaches, and assessment (Medema, et al. 2008). Akamani ties the integrated approach of IWRM to the literature on adaptive management, therefore aiming to enhance the resilience and flexibility of existing management systems. Based on Allan and Curtis (2005), Akamani introduces three types of adaptive management: Evolutionary management in the form of trial and error learning; Passive management based on the latest available data, and active management based on the integration of monitoring data with new technical and scientific research. These three types of adaptive management allow local stakeholders to take control of their surroundings. By highlighting this need for information, data, and the freedom to explore alternatives, local autonomy could be fruitful.

Based on the multidisciplinary approach of Integrated Water Resource Management and the explementary approach of Adaptive Management, Akamani formulates four key attributes from existing literature for adaptive water governance to exist in current management ideologies. These key attributes could be used to investigate and establish new principles for existing water management systems, interactions between stakeholders, and integration of uncertainty and local knowledge in decision-making processes.

First, he advocates for embracing complexity and resilience through the recognition of the interdependence between human and natural systems. As explained in the chapter on Hydro-Social Territories, the relationship between humans and their natural counterparts have always been symbiotically connected and are in constant flux with each other in adaptive cycles (Folke, et al., 2010) of growth, conservation, collapse, and reorganization (Carpenter et al., 2001). This amplifies the understanding that human-nature integration is vital in water management approaches to land capabilities and water resources.
Secondly, Akamani advocates for the usage of diverse sources of knowledge in water governance. As water management is often dominated by technical and political agendas, they fail to recognize the important component of the social sciences. Not only should knowledge integration take place among sciences and disciplines but also include the recognition of local and traditional knowledge provided by local stakeholders. To be able to align local and traditional knowledge, Akamami advocates for social learning in decision-making processes, which could help bridge the gap of differences between authorities, scientists, managers, and other stakeholders. For this to happen the need arises for participatory methods in decision-making processes that are not only needed for knowledge integration but also for trust building and empowerment of local stakeholders in water management systems.

Thirdly, Akamani proposes the integration of a holistic focus on resource management, rather than seeking efficiency and optimization of water management. But for a holistic focus, integrating social, economic, environmental, and technical values, to be spatially implemented, stakeholders themselves should gain freedom in establishing their agendas. This enhances the provision of negotiated solutions between conflicting values and uncertainties by stakeholders. Therefore for adaptive governance to be implemented, an overall view of involved stakeholders and their ambitions, values, and practices should be understood.

Based on these three key attributes mentioned by Akamani (2016), the first steps towards facilitating a roadmap towards localized autonomy can be made. Therefore the need arises to re-figure the meaning of the dike as part of the relationship between human and natural systems. As this places the protective character of the dike aside, new room is created for localized knowledge and relations to be integrated into dike management. Based on the existing stakeholders in water management, their relationship between themselves and what they consider to be a dike enhances the negotiation of the design solutions. Therefore a more flexible approach can be conducted allowing local stakeholders to integrate new meaning into their relationship with the river.

4.3

Adaptive Systems

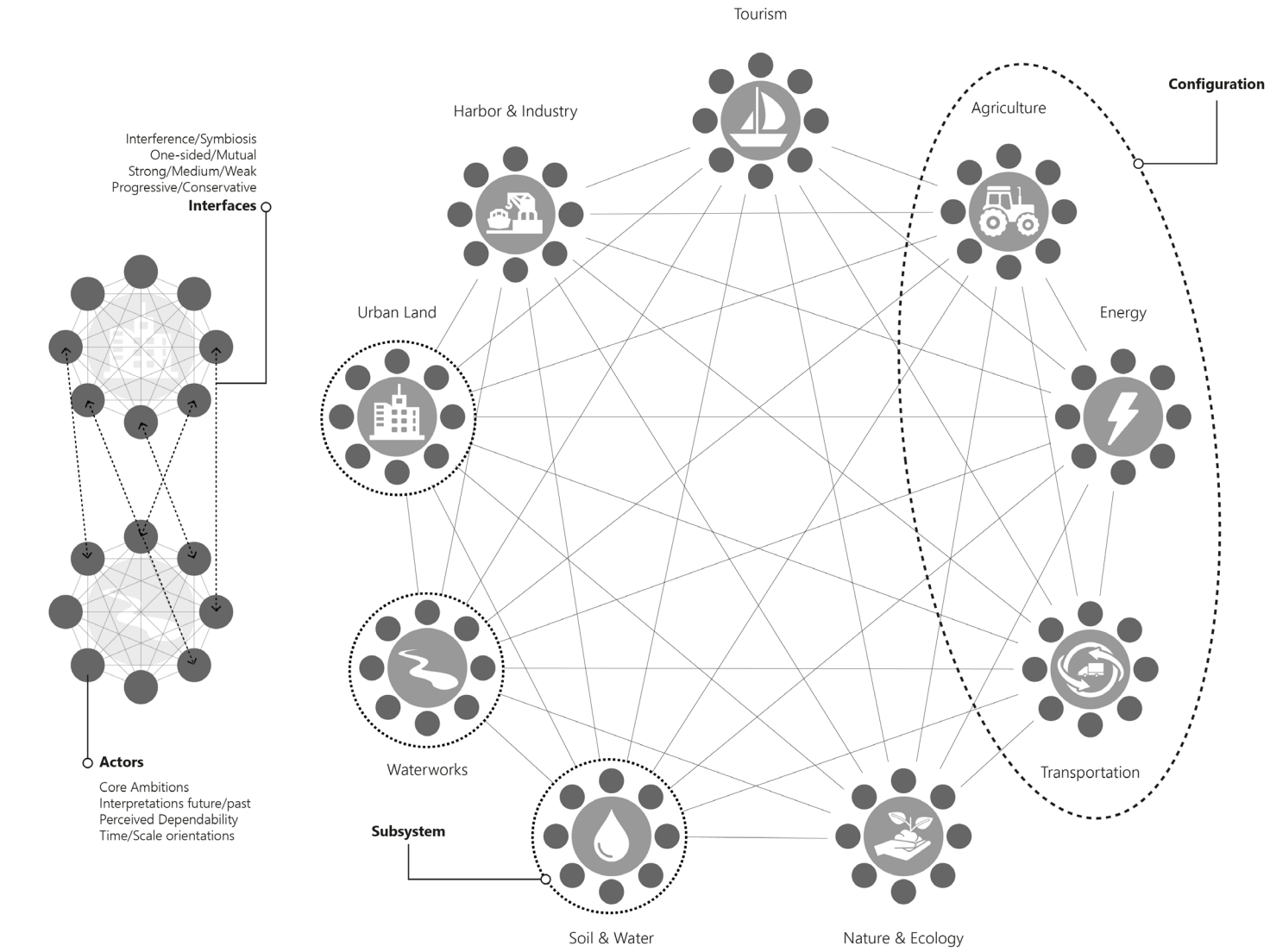
Complex Adaptive Systems

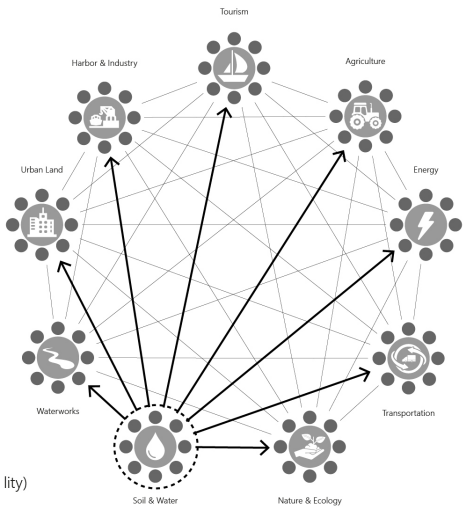
To understand the different values of the stakeholders involved, this report uses the theory of the Complex Adaptive System of Meyer, et al., 2014, to understand and visualize the notions of self-organization, mutual adjustment, and system synchronization among regional subsystems. Changing conditions throughout time have shown the nature of subsystems and their ability to change character, roles, and relations with other subsystems that are connected to the same spatial boundaries. Critical factors for sustaining symbioses between subsystems are based on the ability of the entire system to cope with short- and long-term change. Therefore the abilities of self-organization capacities and mutual adjustment are key components to react to changes like a heavy drought (short term) and decreasing water resources (long term). Each complex adaptive system can be defined by its surroundings. As this system underlines the fact that different subsystems operate on different scales (Boelens, 2016, Swyngedouw, 2004), no real border of the systems can be defined. Although this system is centralized along the notion of multiple flows of resources to facilitate interaction, this report focused on the resource of water, making it, therefore, more reasonable for the creation of clearer borders, but as subsystems are defined by the scale of ambitions and interest of stakeholders (Teisman & Edelenbos, 2011), these borders should be interpreted lightly.

Subsystems are developed according to the representation of the main sectors having a stake within the overall system. Each of these subsystems is represented by a set of actors who share mutual core ambitions but have to be seen as individuals as they can interpret these core ambitions differently, and conform to their situation. Example: subsystems of agriculture are represented by different types of farmers and farmers organizations.

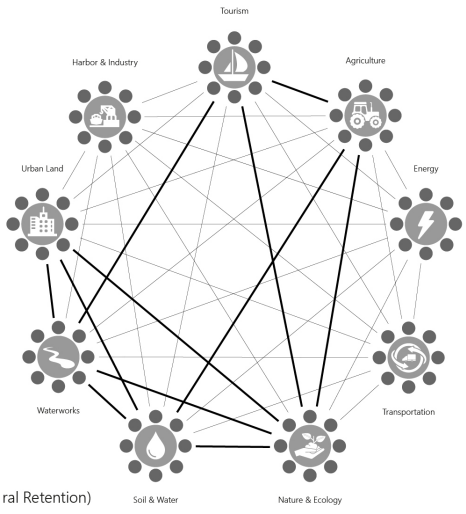
When subsystems change, relations between subsystems can be either strengthened or disrupted. (Meyer, et al., 2014). These relations can be classified according to their relations (symbiotic, intervening), interdependencies (one-sided, two-sided), and the strength of their relation (often based on time factor).

As these relations and co-evolutions between subsystems have been developing throughout history, it has established different beliefs, customs, and ambitions within the core of subsystems, therefore allowing for change to happen more easily or not (Meyer, et al., 2014; Zwarteveen & Boelens, 2014). For change to take form it is therefore vital to understand the cores and overlap between the various stakeholder groups involved.

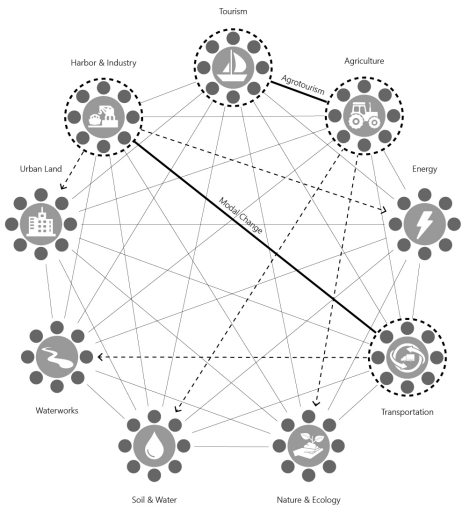




1 Hierarchial Steering
(Common Ambitions - Water Availabilit



2 Network Steering
(Collective Ambitions - Increase Natural F



3 Self Organizing Capacity
(Space for private initiatives)

Figure 25: Complex Adaptive System (CAS) Method. (Author, 2023; based on Meyer, et al., 2014)

4.4

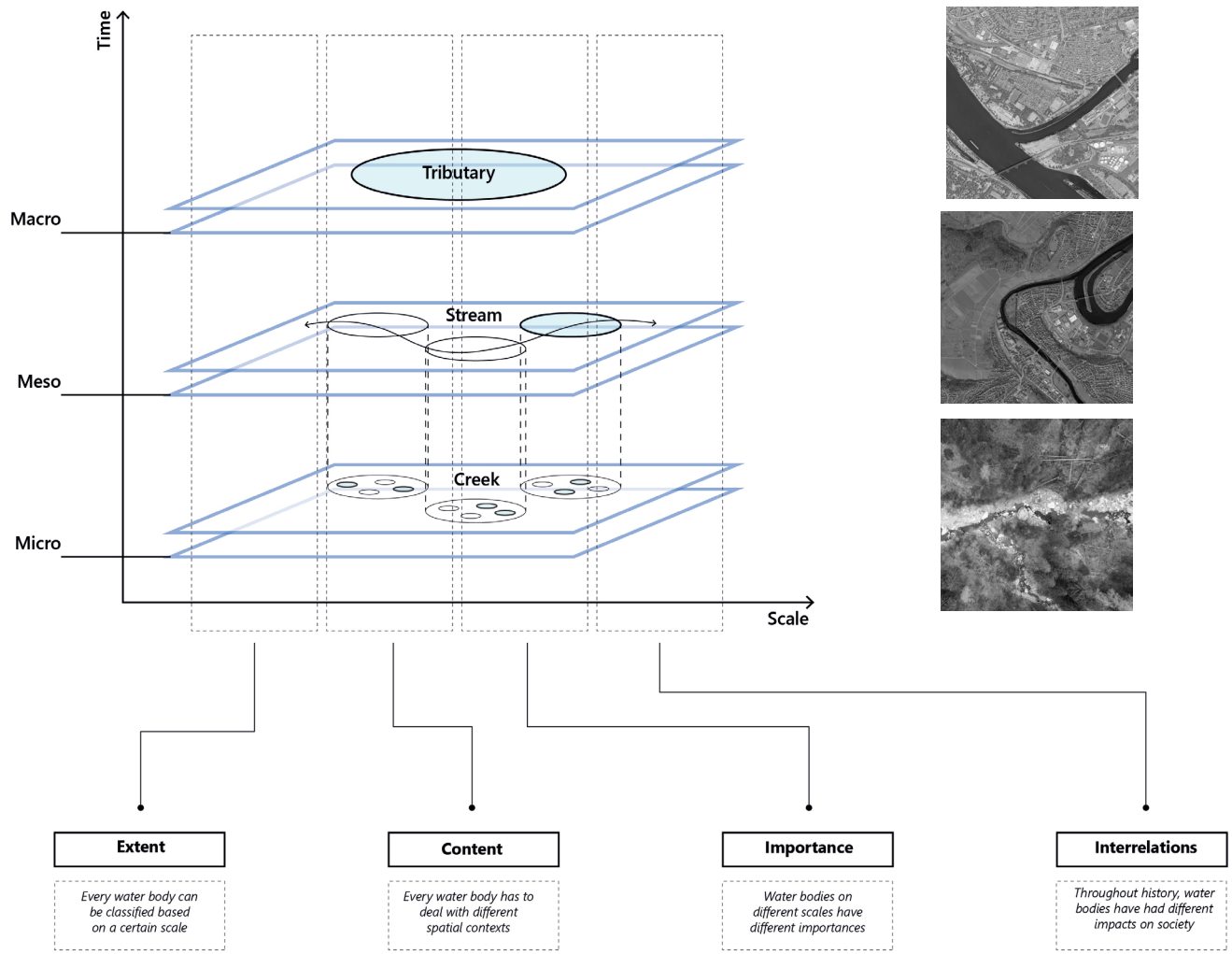
Water as a Common Resource

Hydro-Social Territories

Society is strongly involved in the shaping of the environment and vice versa, therefore an internal dialect is built between the society and its natural surroundings (Swyngedouw, 1999, in Boelens, R. 2016). As water is classified as one of the building blocks of facilitating and sustaining life, water can be seen as the internal relationship that connects society with nature. According to Boelens: "Water flows through landscapes, technologies, and cities, connecting places, spaces, and people". These types of internal interactions can be translated into so-called: Hydro-Social Territories (Boelens, et al., 2016). Hydro-Social Territories can be translated as the socially, naturally, and politically constituted space that is created through the interaction between human practices, water flows, hydraulic technologies, biophysical elements, socio-economic structures, and cultural institutions (Boelens, R, 2016. p. 1). These 6 elements that create certain Hydro-Social territories, can be divined differently when considering different scales of impact.

But because the relationships between society and nature can differentiate between spatial scales, Swyngedouw (2004), mentions that spatial scales are constantly redefined, contested, and restructured in terms of extent, content, importance, and interrelations. So Hydro-Social territories exist only on a particular scale but are always related to other surrounding territories that operate at different broader, overlapping, hierarchical, cultural, hydrological, and organizational scales. The projection of these Hydro-Social territories on particular spatial scales commonly leads to the empowerment of certain actor groups but also the disempowerment of others, therefore creating arenas for claim-making and contestation of water resources. These powerful Hydro-Social territories, often related to large powerful government or economic structures, try to align humans, nature, and knowledge within the network, facilitating their own needs, leading to local spaces of smaller-scale Hydro-Social territories becoming exploitable and controllable (Boelens, 2016). As a result, local production of water knowledge concentrates on the issues of how to align the users to these imagined multi-scalar water-power hierarchical territories. Therefore it is vital to allow Hydro-Social territories to exist, concerning their spatial relations between the human system and its natural conditions, understanding the room of negotiation between the 6 elements and their claim on the water could help facilitate a more fair distribution of water resources.

These spatial scales become an important component in dividing the local relationship human systems have with their natural surroundings. As these Hydro-Social territories can be defined differently when considering a multi-scalar approach, the scalar definition of the water body that interconnects society and nature can also be defined differently.



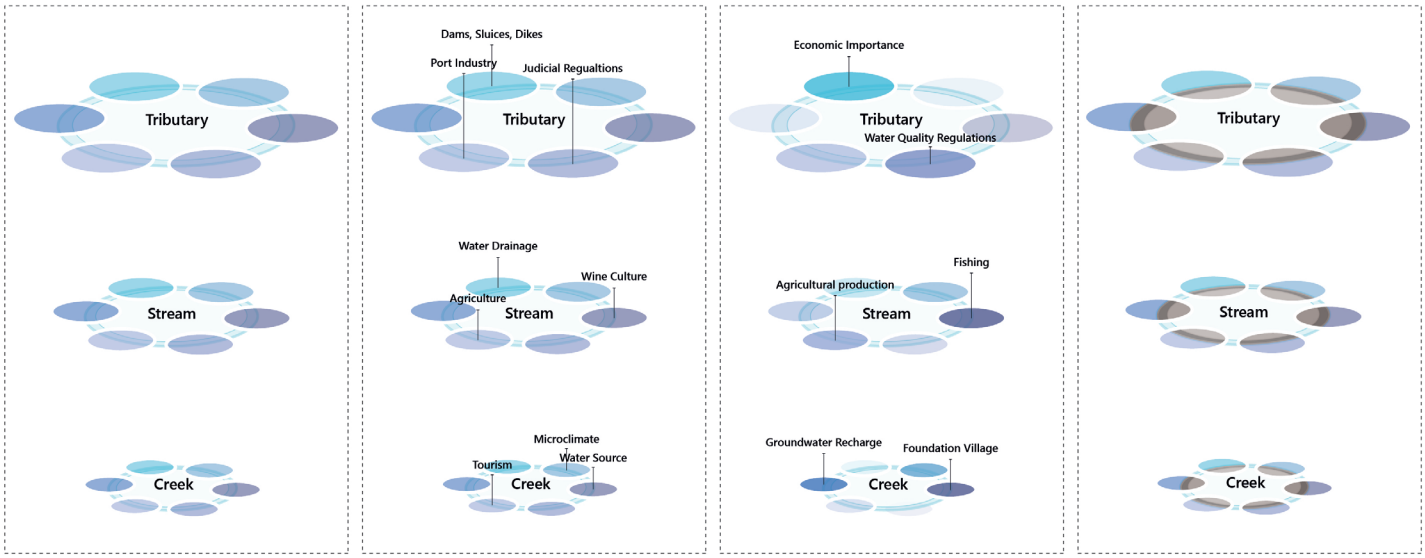


Figure 26: Visualization of Hydro-Social Territories. (Author, 2023; based on Swyngedouw, 2004 & Boelens, 2016)



Figure 27: Beached boat near Lobith, The Netherlands (Sky News, 2022)

05

Methodology

5.1 Methodological Chart

Road toward Local Dike Autonomy
Methods

5.1

Methodological Chart

Road toward Local Dike Autonomy

The methodology follows a structure as proposed in the later-developed roadmap. This so-called 'spine' of the project links the theoretical framework to the analysis included in this report (figure 28). This spine follows the movement through scales, initiating with the European principles of Active Subsidiarity and ending with the local and spatial indicators required to investigate the suitability of localized dike management.

Regional and Local Decision Making Autonomy

Based on an understanding of Active Subsidiarity and the structures of Polycentric governance arrangements, a theoretical foundation for the implementation of Active Subsidiarity is established, leading to the initial steps in regional and local autonomy. By understanding the current spatial planning systems of the six Rhine nations, the potential threats and opportunities for integrating Active Subsidiarity become apparent. This is primarily achieved through literature and policy research into current water management relations and the political landscape of the Rhine nations.

Systemic Development of a Roadmap

Based on the literature research in adaptive spatial planning and adaptive water governance, the primary conclusion drawn is that facilitating these principles requires robust and flexible management arrangements tailored to different levels of authority. Analytical research, based on the water management practices of the Rhine nations and examples of the Room of the River as part of an integrated water management approach, establishes the initial layout of the roadmap.

Self-organizing Capacity of Stakeholders

Initiated by the theories surrounding Complex Adaptive Systems by Meyer et al. (2014), relationships between stakeholders are related to a mutual approach centered around a connective element. This report proposes the dike to become that spatial element. Based on the past, current, and future relations between stakeholders and the dike, mutual adjustments among stakeholders can become apparent. For these local stakeholders to initiate change in dike management, their capacity to understand the indicators needed for local autonomy is related to the knowledge system. Drawing on the expertise of the stakeholders and the nature of the data, specific knowledge can be gathered at the local level, enhancing the self-organizing capacity of the stakeholders.

Territorialization of Spatial Regions

To create spatial territories where collections of local stakeholders can initiate change, the theory of Hydro-Social Territories is used to define areas where a mutual relationship between human and natural systems can be established. Additionally, a scale-based translation model is set up for the Rhine to determine the potential for local autonomy along the river. This model is used to translate quantitative and qualitative data that form the indicators of local dike autonomy.

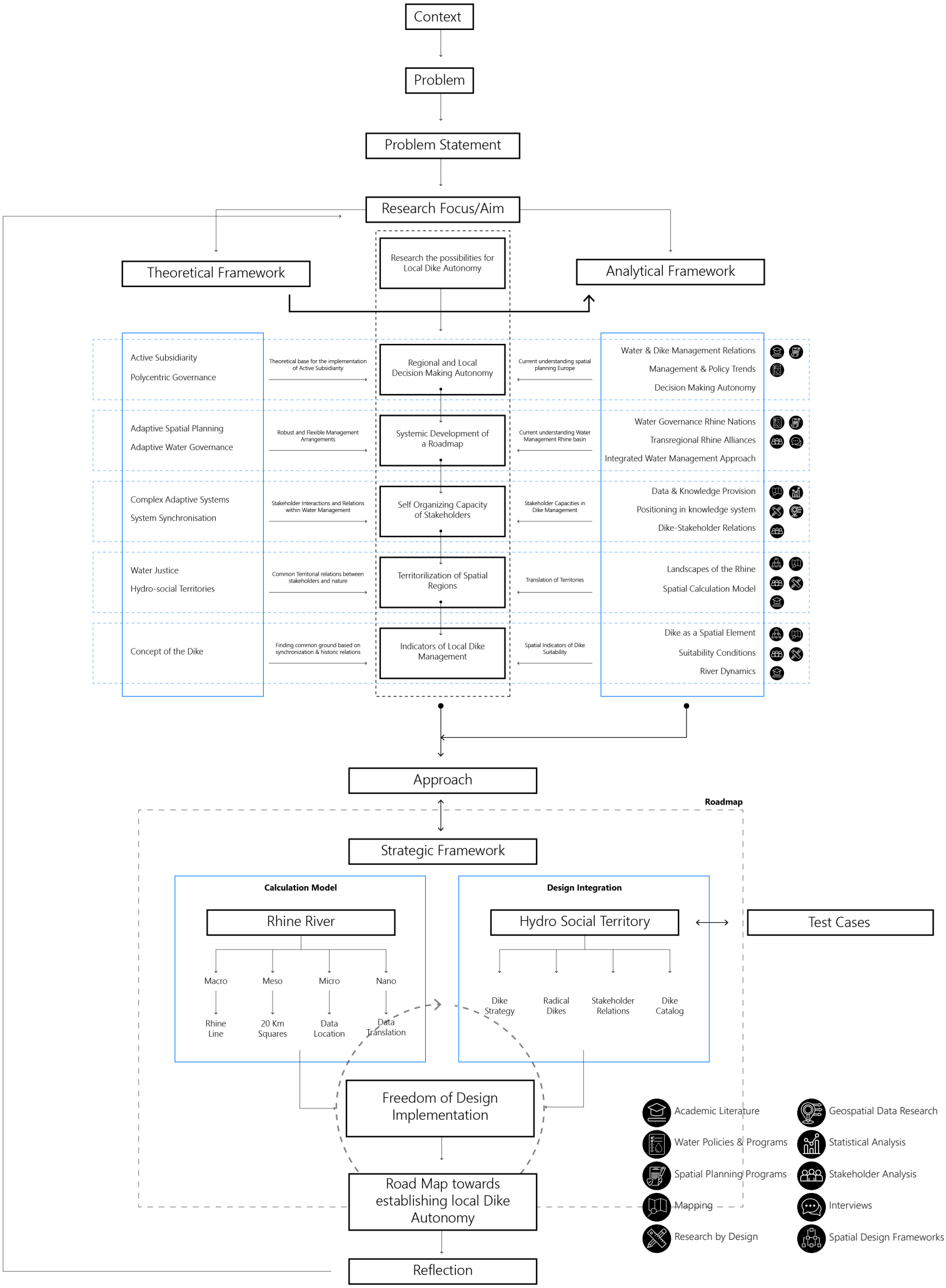
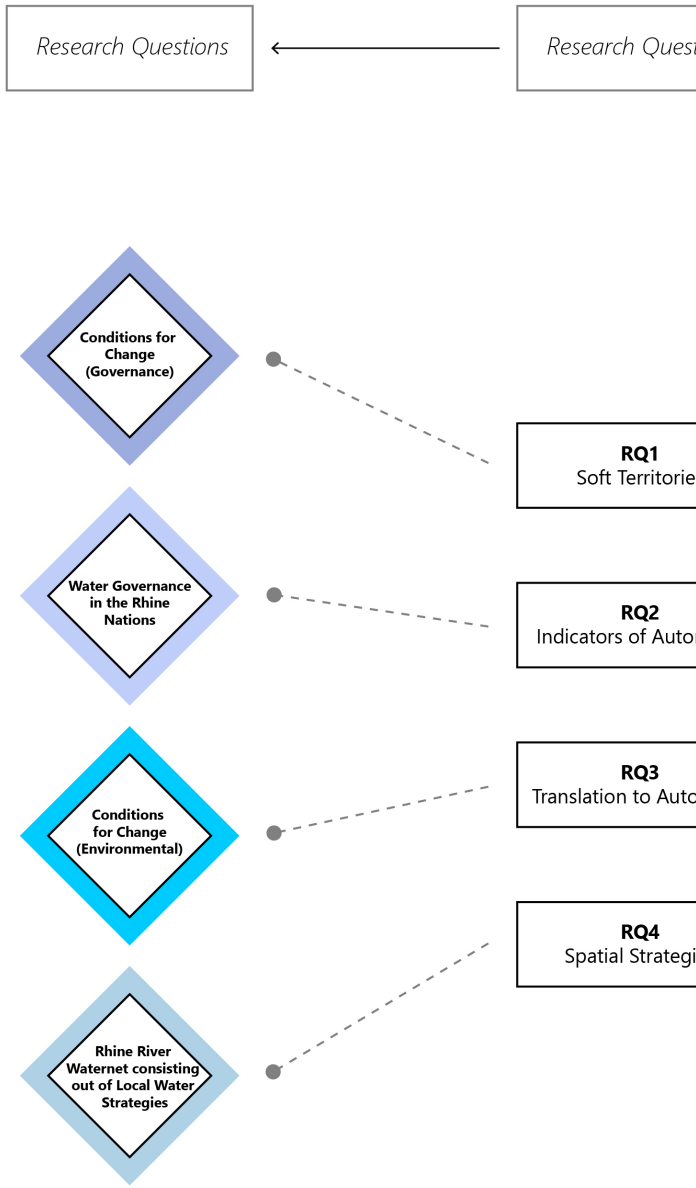


Figure 28: Methodological Chart relating Theoretical, Analytical and Outcomes. (Author, 2023)

Indicators of Local Dike Management

Apart from the information needed to understand the current water and dike management relations and the potential for local decision-making within the political landscape of the Rhine nations, it is important to comprehend the conditions necessary for constructing a dike on-site. Based on spatial and statistical data considering current and future river dynamics, existing soil and landscape suitability conditions, and assessments of the current spatial dikes of the Rhine, this helps understand the spatial conditions influencing localized dike management.

The eventual outcome of this report is to formulate a systematic approach for the Rhine River that indicates the possibilities of localized dike autonomy along its length. This is based on the indicators related to the current political landscape, river dynamics, landscape suitability, and the localization potential of the current Rhine dikes. A calculation model is created based on the importance each indicator holds for local autonomy. The creation of the calculation model enhances the transferability of the different datasets used in this report. Eventually, this calculation model will generate a patchwork of autonomy along a 10 km buffer of the Rhine River. After assessment, dike typology strategies will be integrated to assess the possibilities of strategies when changing the local dike line. Based on a side exploration of the formulation of radical new dike typologies, the relationships between stakeholders and the dike will be related to these new dike typologies. Through an empirical research-based dike catalog, different spatial dike designs will emerge within each defined design location. Although based on qualitative relations diagrams between dikes, stakeholders, and future dike typologies, this project indicates the freedom of the design implementation. As a result, a set of possible outcomes will be presented as the final result of the roadmap towards local dike autonomy.



Methods

For this project, a mix of quantitative and qualitative research methods has been used. Since the project location of the Rhine is made up of multiple European nation-states, large amounts of quantitative data have been provided to allow for the socio-spatial analysis of climate change threats, natural conditions, water use and distribution, and human systems.

Academic Literature Study

This method is used especially to understand the current constructs of the European spatial planning sector and its trends towards new forms of governance (active subsidiarity, soft planning & territorial governance). Non-site-specific theories about adaptive planning systems, adaptive water governance, and water as a common resource are explored and will contribute to finalizing the means necessary for the implementation of localized water management.

Policy and Program Document Research

The use of secondary literature is essential as major transregional projects, organizations and water management ambitions of (inter)national and regional authorities formulate the current political landscape. These policies and programs surrounding the distribution, use, and management of water are vital in understanding current power relations and stakeholder ambitions.

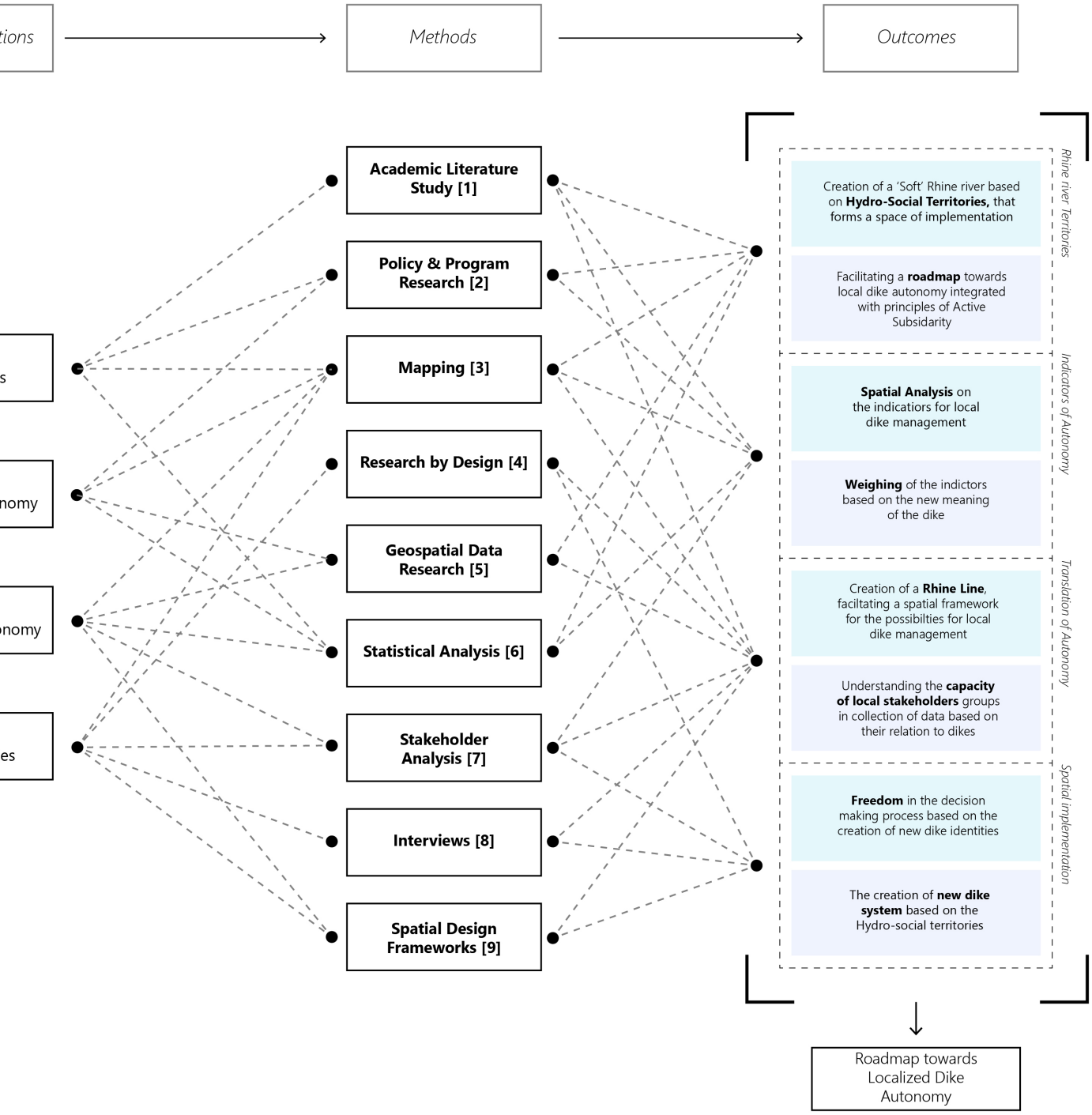


Figure 29: Used Methods and relations. (Author, 2023)

Mapping

The availability of open-source European datasets provided by the EEA, Eurostat, BGR, CHR, IKSR and other organizations, stimulates the integration of quantitative research by mapping current spatial configurations of the Rhine River. The method of mapping can indicate the spatialization of the indications used to establish local autonomy.

Research by design

This method is used for the development of the spatialization of the roadmap from strategies to newly craeted dike lines. Based on spatial interpretation of the contexts of the case study, the steps will be taken from this point onwards.

Quantatative Research

Geospatial Data Research

Available open-resource datasets provided by the EEA, Eurostat, GRDC (Global Runoff Data Centre), Deltares, IKSR, Landsat and other organizations, allow for the usage of quantatative data concerning water use, water distribution, river widths, river discharges and other hydrological systems. Also the use of quantatative analysis when researching stakeholders and managmenet structures can help provide additional knowledge for the establishment of power relations between stakeholders.

Statistical Analysis

The use of statistical analysis can help providing

knowledge on the numbers of water this research is considering to apply within localized water management arrangements. As the Rhine river is considered one of the most monitored rivers in the world, the abondonment of water statistics would be a huge loss.

Stakeholder Analysis

As this report aims to localize water management cycles, the understanding of the need, use and ability to delegate of stakeholders is key. Per watershed level in the allocated focus regions a list of stakeholders can be established corrisponding scale and sector. As the water is shared by these stakeholders, the power relations between stakeholders is also to be analyzed.

Qualitative Research

Spatial Design Frameworks

This method is used for the development of a spatial framework of dike typologies that can be distinguished out of the hydrological and historical contexts. It allows for the formulation of a set of spatial typologies that can be placed around the Rhine river. It could also be used for research considering other river basins.



Figure 30: Dry Rhine river in the summer of 2022 near Nijmegen. (DW, 2022)

06

Conceptualize

6.1 Conceptual Framework

Localized Dike Autonomy

6.2 Design of the Roadmap

Roadmap Towards Local Dike Autonomy

6.1

Conceptual Framework

Localized Dike Autonomy

The conceptual framework is based on the previously mentioned problem fields of 'Water as a common resource,' European Fragmentation, and the effects of climate change. Furthermore, the conceptual framework elaborates on the relevant concepts, theories, and objectives discussed in the theoretical framework.

Conceptualizing the problem

The starting point is to conceptualize the problem statement into two main problem fields. Firstly, the conflict over the interest and coordination of the distribution of water as a common resource has resulted in the disruption of natural systems. Secondly, the conflict over the coordination and implementation of European Governance leads to patterns of fragmentation.

As both the natural and human systems in the Rhine River basin depend on the availability of fresh water provided by glacial and fluvial rivers, the right to use the river's water has always been a prominent question. Despite the Rhine being one of the most controlled and monitored rivers globally, the decreasing water resources may lead to conflicts among its users. Existing legislation is translated into national water plans, primarily focusing on economic aspects rather than ecological stabilization. While coordination between nations exists, each country creates its own legislation, resulting in uncoordinated policies. The abundant use of water resources for public goods has led to the degradation of the natural environment, which serves as the primary reservoir for most of our freshwater.

The aforementioned conflict over the interest and coordination of water resources in the Rhine basin has led to the increase of cross-border territorial programs. Although collaboration at higher government levels is present, the sheer volume of legislation, documents, and programs produced contributes to institutional thickness. This, in turn, can hinder the successful implementation of policies and programs due to a lack of cooperation and coordination between them. The main issue that can arise is that the Rhine nations have different spatial planning cultures, making transboundary collaboration concerning water bodies difficult to achieve at the political level (Klijn, et al. 2018).

One of the primary boundaries that affect the relationship between people and the river is the protective function of dikes. The concept of a dike is often associated with flood protection, managed by national and/or regional authorities. Over time, the ideology of these expensive spatial elements has led to a decrease in residents' awareness (NOS, 2021), resulting in unpreparedness during extreme weather events. Initially, dikes were constructed to protect local communities from flooding, with the responsibility for their maintenance falling on local communities (Redeker, 2012).

Besides the diminishing local water responsibility and the centralization of dike management, the current spatial practices for dike construction along the Rhine are one of the main reasons the river is considered to be constrained.

As water resources are considered a shared public good, fostering water responsibility at the community level can

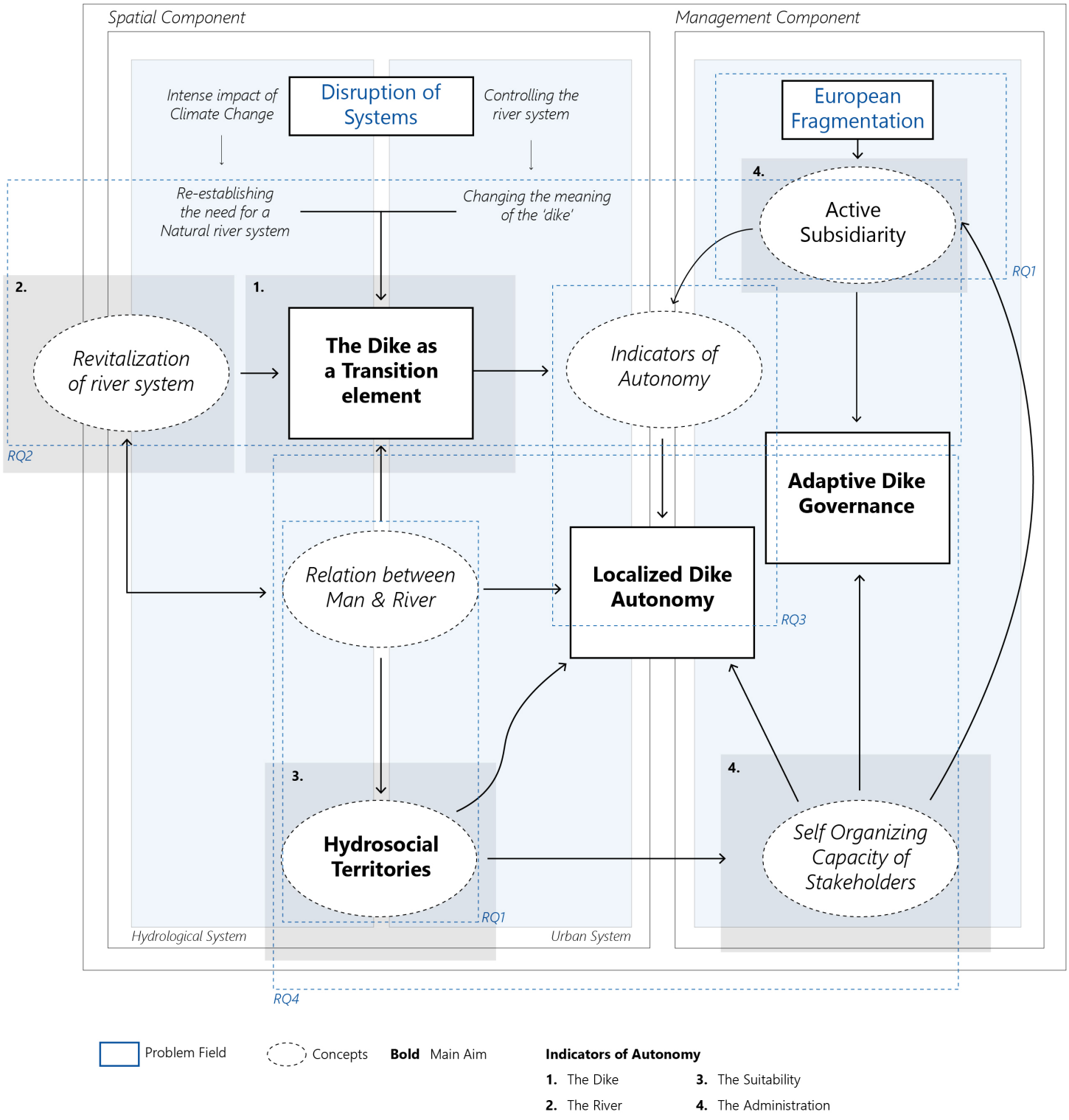


Figure 31: Conceptual Framework. (Author, 2023)

encourage a shift toward sustainable water management. Given that the Rhine River is a transboundary region, it requires coordination from the European Union to facilitate transnational collaboration while primarily empowering regional and local authorities in the decision-making process.

Basic Concepts and Theories

The next step is to define concepts that form the core of the research. Based on the theories of Active Subsidiarity and Adaptive Water Governance, there is a need to identify a set of indicators that can facilitate the transition towards local dike autonomy. Additionally, shifting the meaning of the dike from a protective element to a transitional one, highlighting the relationship between people and the river, signifies a revitalization of the river system.

The concept of Active Subsidiarity refers to a strategy that provides greater authority to local and regional authorities in the European decision-making process while giving the national government a more coordinating role in policymaking (European Commission, 2018b). To implement this concept directly in local contexts, indicators of autonomy are translated from the current political landscape and management relationships. This helps clarify the effectiveness of localized autonomy.

As per the Governance of Adaptation (Rietveld, et al. 2013), which advocates for robust and flexible management systems, the concept of Active Subsidiarity translates this into a firm yet common regulations while allowing flexible implementation facilitated by regional and local formal and informal authorities (Morrison, et al., 2019). Drawing from Ostrom et al.'s definition of polycentric governance (1961), which involves multiple decision-making centers with varying degrees of authority working together through cooperation, competition, and conflict resolution (Carlisle & Gruby, 2019), this allows for self-organization of (in)formal authorities. This concept is translated into Active Dike Governance, where robustness is facilitated through the creation of a roadmap that outlines the basic steps for stakeholders to determine their position in local dike autonomy. Subsequently, the self-organizing capacity of stakeholders to follow these steps needs to be addressed. Considering the relationship between stakeholders and the dike, their capacity to gather information and explore alternative possibilities varies. Therefore, the integration of a knowledge system, emphasized by Akamani as vital in adaptive water governance (2016), is established to gather the available information necessary to determine the position of autonomy in the decision-making process.

Another key concept in this research is to transform the meaning of the dike from a protective character to a transitional character, spatializing the relationship between people and the river. Drawing from the literature of Boelens (2016) and Zwarteveen & Boelens (2014), the relationship between natural water systems and the surrounding human systems has always been mutual, creating so-called Hydro-Social Territories. As these territories take on different foms based on scale and time (Boelens, 2016; Swyngedouw, 2004), a strong historical and cultural bond is established between water and people. Based on this theory, a spatial translation can be conducted to create new hydrological regions that form the spatial configuration for design interventions. This relationship, based on the vision and goals of stakeholders, establishes the framework for local autonomy.

Finally based on the spatial and management components of the conceptual frameworks, a set of indicators is established that translates the information that is needed to determine local dike autonomy. This translation takes place surrounding the four main indicator groups: The Dike, The River (water system), The Suitability (geological system), and the Administration (political system).

Conclusive remarks

The central concept of this report is the transformation of the dike's meaning from a protective element to a transitional one. The dike was selected based on the spatial translation undertaken using the theory of adaptive spatial planning. While the spatial planning field aims to strike the right balance between robustness and flexibility, actual spatial implementation is often challenging. Hence, the dike, as a large, robust earth structure, reflects the robustness of national and regional politics. However, the dike is also multifunctional, emphasizing its local flexibility. Dikes come in various shapes and sizes, serving different purposes. Thus, dike management should also adapt accordingly, as the dike is more than a protection measure; it should convey the Hydro-Social relationship of the area. This establishes a more flexible governance system on one hand, allowing local stakeholder groups to regain responsibility within the water system, and the revitalization of the natural system on the other.

6.2

Design of the Roadmap

Roadmap Towards Local Dike Autonomy

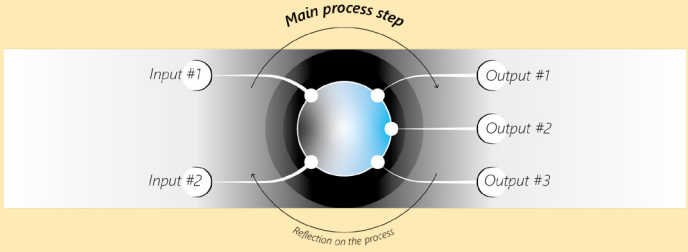
To enable local stakeholders to self-initiate the decision-making process for dike management, a strategic roadmap is developed. This roadmap serves as a programmatic method within the Rhine River basin to establish localized dike strategies. This is achieved by dividing the Rhine into design locations. Comprised of 12 steps, this roadmap outlines the path toward self-organization. Each step represents a process that must be completed to progress to the subsequent step. Each step requires specific inputs to initiate the process and produce a set of outputs. In the following pages, a more detailed breakdown of the steps is provided with the inputs and outputs for each of the main steps. The outcomes of these 12 steps are categorized according to four major scales:

(1). *The Rhine River:* This scale serves as the foundation for gathering information necessary to assess the potential for local dike autonomy. The Rhine River was chosen as the largest scale in the roadmap to underscore the importance of viewing the entire Rhine as an interconnected system. It allows similar stakeholders in different regions to learn from one another, establishing the first steps towards a knowledge system. Moreover, the impacts created within the river system have repercussions along the entire course of the river, making it critical to consider these effects in the final stages of the roadmap.

(2). *The Areas of Impact:* This scale is based on larger segments of the Rhine River dedicated to translating the broader calculations of the Rhine into smaller segments where spatial dike changes are carried out. Here, the primary strategies are developed based on the outcomes of autonomy.

(3). *Design Locations:* This scale involves newly established territories that are granted full autonomy in dike management. These territories are defined through the spatial interpretation of the theory surrounding Hydro-Social Territories, influenced by local stakeholder groups, which have the freedom to define their new dike systems. Dialogues occur among these stakeholder groups to establish new relationships between them and the river.

(4). *Dike Relations Stakeholders:* This scale focuses on the relationship between the stakeholder group and the significance of the dike. This is where the initial steps are taken to facilitate the transition to autonomy (See Step 2). An understanding is developed regarding the indicators of dike autonomy based on the located stakeholder groups. The stakeholder relationships serve as input for the dialogues taking place within the design locations.



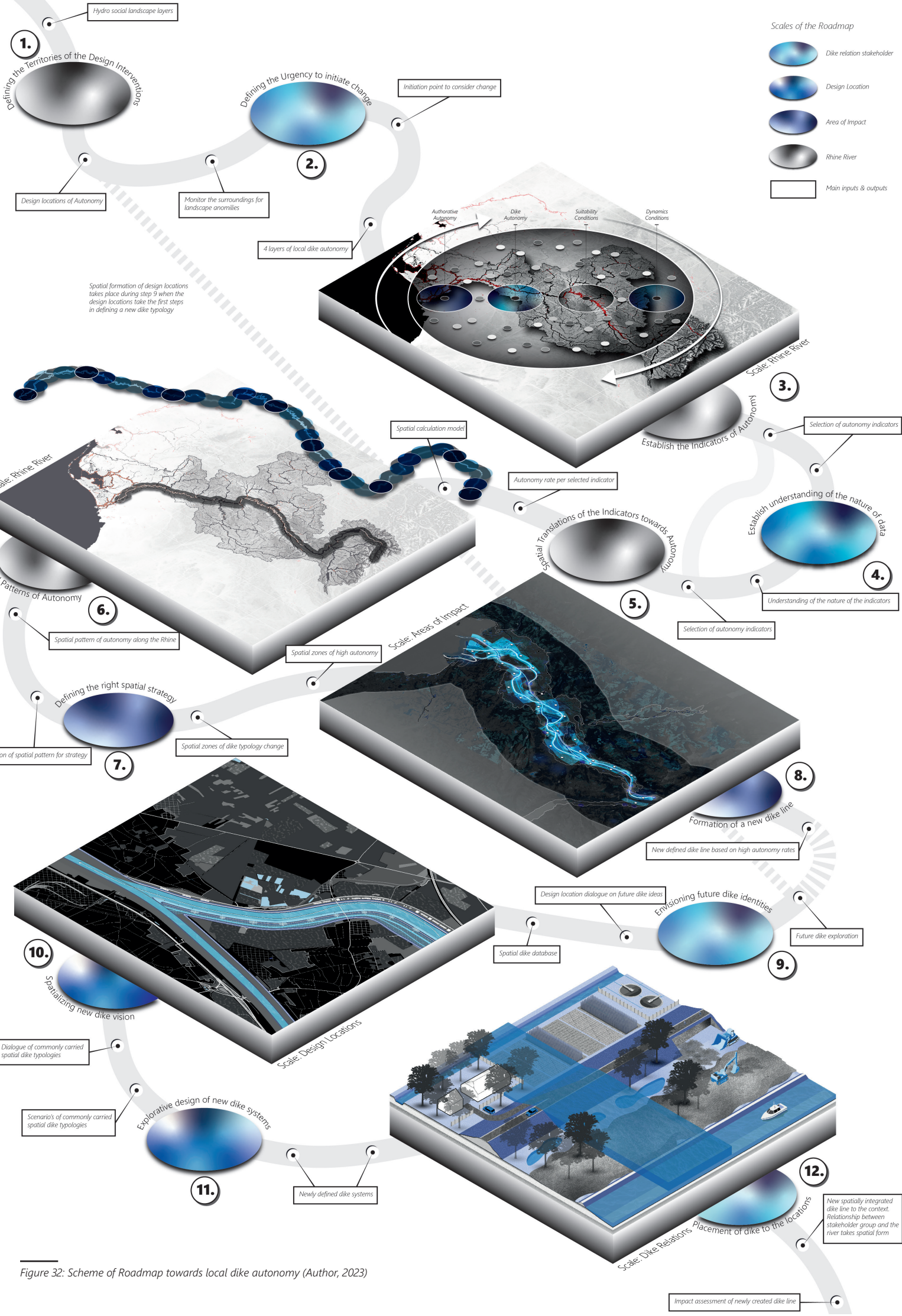


Figure 32: Scheme of Roadmap towards local dike autonomy (Author, 2023)

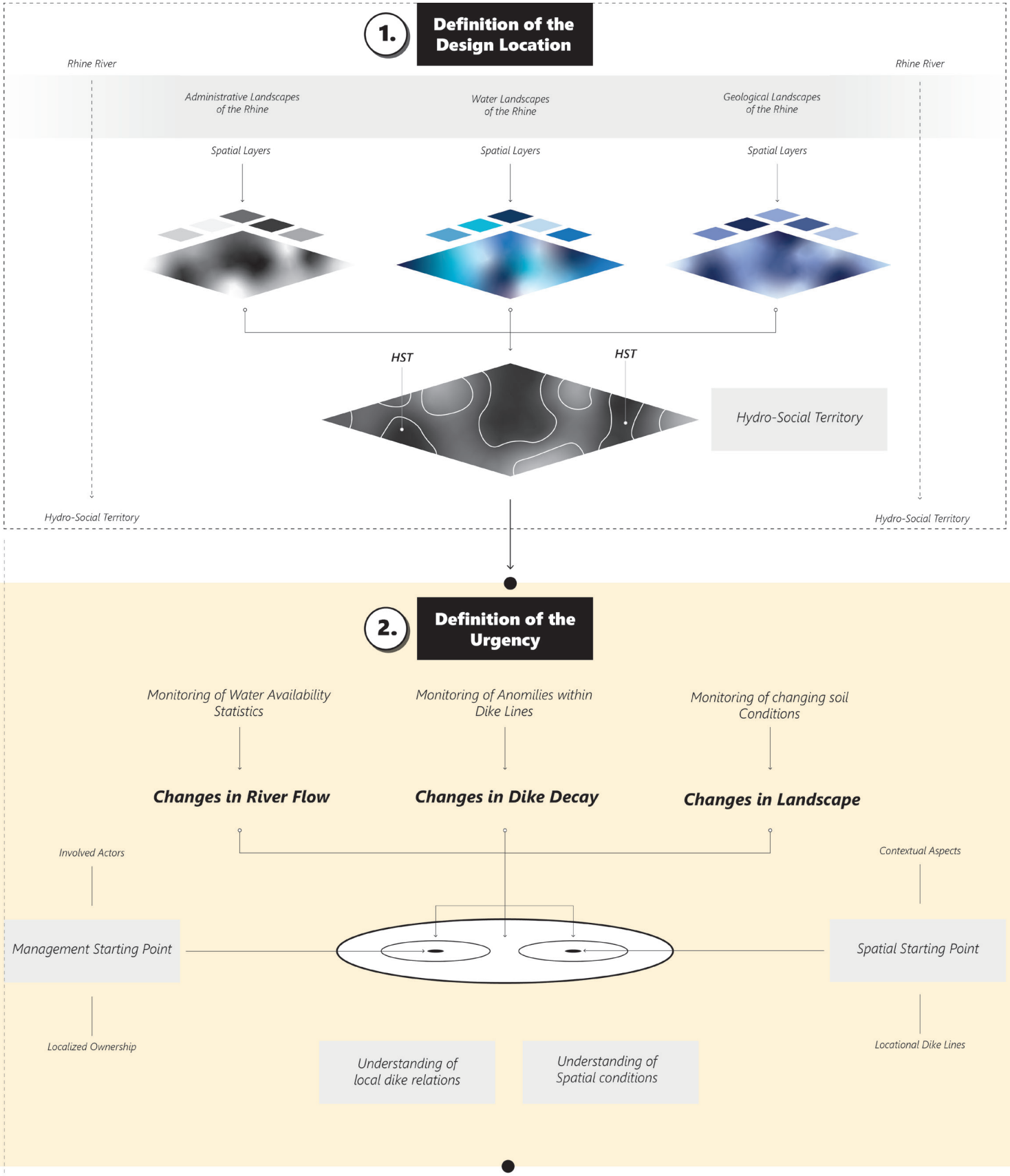


Figure 33: Roadmap part 1 (Step 1 & 2) (Author, 2023)

Roadmap to Local Dike Autonomy

The roadmap has been tested at specific site locations. During the testing of the frameworks on these specific locations, new dike ideas are generated based on the relationship between the dike and its stakeholders. By examining the overlap of relations between stakeholders, new dike concepts are linked to existing spatial dike typologies. A selection of spatial dike typologies is presented to illustrate the various possibilities that can be implemented on-site. As the primary objective of this roadmap is to instigate change within the dike management of the Rhine River nations, the spatial design interventions are presented as test cases rather than final designs.
In the subsequent pages, further explanations of the roadmap's process and its results are provided. Given that the main focus of this research is the newly created method of localized dike management, we pay closer attention to the steps outlined in this roadmap.

Step 1: Defining the Hydro-Social Territory

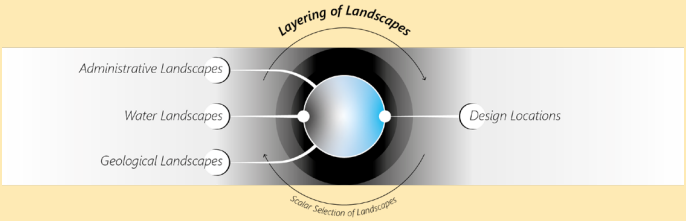
As the definition of the Hydro-Social Territory (HST) is adaptable, this report defines the HST of the Rhine based on the relationship between humans and the spatial element of the dike as the transitional border to the river. HSTs are categorized into three main groups, each adding another layer to the relationship between people and the river. These categories serve as guidelines to define territories but they don't limit the potential configurations of "local" territories. Instead, they provide a possible outcome of a 'territory' considering the spatial layers that construct the relationship between people and water. The three defined categories are as follows:

(1). *Geological Landscapes:* These are defined by the geomorphological composition of a location. The underlying geomorphological compositions have shaped the contours of the environment where Hydro-Social Territories exist. The aquifer compositions add additional layers, highlighting the primary relationship within the water system between the lithological spheres and the water landscapes found above the geological landscapes.

(2). *Water Landscapes:* These are defined based on the structural elements of water and river systems. Here, the boundaries of river basins, groundwater bodies, and drainage networks of the water system form the initial layers of water landscapes. The primary spatial element determines the different territorial units that can be spatialized concerning a common water source or relationship.

(3). *Administrative Landscapes:* This category comprises the administrative regions responsible for water and dike management. These landscapes are determined by national, regional, and local borders of authorities and classifications of primary land use. These spatial territories form mutually defined regions where a shared vision or view is created regarding the relationship with water.

This step introduces a new spatial territory format that can be spatialized, as seen in steps 8 and 9. The creation of these new spatial territories enhances the transformation of the dike's identity as a transitional element.



Step 2: Defining your Urgency

Building upon the formation of the HST, the need for change must be addressed. Based on historical relations between stakeholders and the dike, as well as signs of territory degradation, this roadmap establishes the active starting point for localized dike management by initiating a sense of urgency. The local stakeholders investigating the possibility of local dike management are associated with the nine main stakeholder groups defined by the CAS method (chapter 5). These stakeholders will later form part of new HSTs. An analysis of these nine stakeholder groups is provided (chapter 8), offering stakeholders an understanding of the different perspectives within the area.

Please note that this analysis offers a general overview of the relationship between the nine stakeholder groups and the river throughout the entire Rhine region. Local differences are not specified and should be considered when engaging in dialogues within the strategy and implementation steps (7-12).

In addition to understanding the relations between stakeholders and the dike, urgency for change is initiated by changes in the surrounding landscape. Based on observations of alterations in river flow, dike decay, and other changes in the landscape, local stakeholders determine the existence of urgency. The following text outlines the main observations directed at stakeholders:

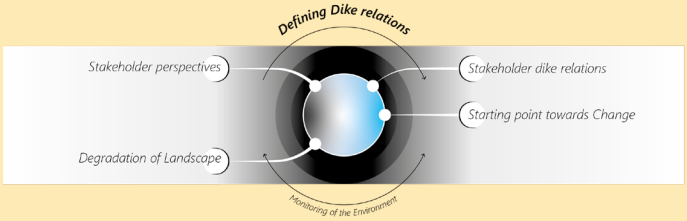
Change in River Flow: Over time, you will notice significant alterations in river flow, resulting in longer periods of flooding and drought in certain areas near you. These changes, compared to previous years, indicate an increasing frequency of extreme conditions.

Changes in Dike Decay: If there is a local dike in proximity, you may observe signs of decay during the summer and early autumn. The dike, infrastructure, river quay, and adjacent houses begin to show signs of deterioration. Over time, these signs become more frequent, leading to concerns about the stability of the levee, dike, or quay.

Changes in the Landscape: Over time, the soil conditions

surrounding the dike begin to exhibit similar cracks as those seen on or near the dike line. This affects the water infiltration rate during periods of heavy rain, leading to stagnant water for longer periods. Seasonal droughts are beginning to have major impacts on available water sources, agricultural production, and biodiversity.

The urgency is now defined and understood by all stakeholders within the HST. The following step introduces four indicators that determine the potential for local dike autonomy.



Step 3: Get to know the Indicators

To establish the potential for local dike self-governance, stakeholders must comprehend that the placement of a dike is determined by four main indicators. These indicators determine the autonomy of the area where the dike currently resides or could potentially be located. The indicators are based on the layers of the landscape, and from top to bottom, they include the following:

(1). *Authoritative Regions:* These indicators are based on spatial configurations where specific rules, regulations, practices, and management systems governing water and dike management are in place. These indicators represent the actions arising from the interaction between humans and the river. They are closely related to the administrative layers of the HST.

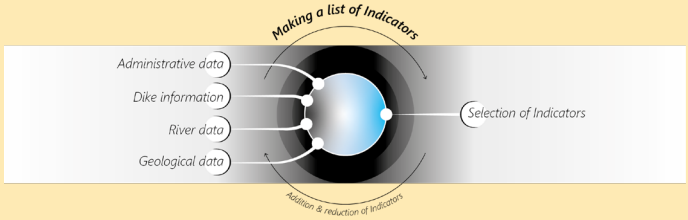
(2). *Dike Typologies:* These indicators revolve around the central character of the dike as a transitional element within the landscape. In addition to being based on technical, spatial, and management-related attributes, these indicators also identify areas that, from a technical perspective, are not considered to be part of a dike line. Therefore, all areas along the Rhine are included.

(3). *River Dynamics:* These indicators are based on the natural conditions provided by the Rhine River itself. The transitional zone between land and water is continually influenced by erosion and sedimentation processes, which can either be accepted or mitigated. As such, these indicators represent the impact of the natural system on the transitional area between humans and the water.

(4). *Suitability Conditions:* These indicators surround whether a dike can be placed in a specific location. The location of a dike line can vary due to constraints related to soil conditions, underground water flows, and the effects of climate change. The easier it is to install a dike without extensive maintenance and monitoring, the greater the autonomy of that dike line.

These four primary conditions are composed of multiple indicators, each of which contributes to the establishment of local autonomy. The criteria for each indicator are detailed at the beginning of Chapter 10, and comprehensive lists of the indicators outlined in this roadmap can be found at the outset of each paragraph in Chapter 10.

Please note that the selection of indicators in this roadmap is based on the author's perceived relevance. Additional indicators can be introduced but should maintain a direct relation to dike management and dike stability.



Step 4: Knowledge Indicators

The criteria for defining autonomy are rooted in spatial, technical, and analytical data analysis. To achieve local autonomy, it is crucial to understand the nature of the data that can be utilized. A distinction is made based on the nature of data that encompasses both the scale and the time aspect of data.

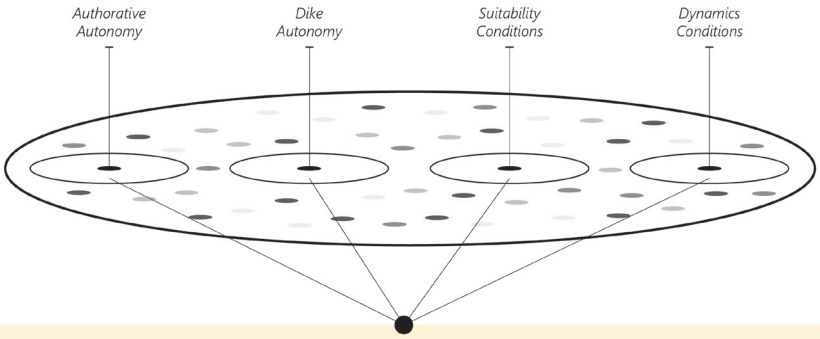
The scale of data is determined by the total area from which data is collected. Following the design location defined in Step 1, data from all scales larger than the design location can be employed in defining autonomy. The consideration of scale is important because the level of detail varies for each indicator. In addition to variations in scale, the time taken to gather information is also significant. Some data is associated with monthly timestamps, while other data may be gathered as part of quantitative data analysis. This step is critical for design locations as it fosters an understanding of when certain indicators become applicable to autonomy calculations.

The next step involves identifying the constraints on the self-gathering capacity of stakeholders. Depending on the composition of stakeholder groups in the Hydro-Social Territory (HST), certain data can be collected locally due to the existing knowledge and expertise of the stakeholders involved. However, the ability to self-collect data is limited. Therefore, it is essential to recognize that if specific data cannot be obtained locally, certain public authorities and research organizations can. Existing knowledge can be obtained from public authorities and research organizations, which are required to share information following the Open Data Charter of 2013 (Carrara et al., 2018). Consequently, national, regional, and local governments all produce information that could be relevant concerning indicators needed for local dike

Figure 34: Right: Roadmap part 2 (Step 3-5). (Author, 2023)

Spatial Constraints are Known

3. Understanding Dike Autonomy



Based on research to the indicators, each indicator has been given a weight in the calculation that will take place. These weights are based on their relation to dike management. The Indicators are Fixed.

High Importance
Medium Importance
Low Importance

Indicators of Autonomy

Geo-spatial Translation

4. Knowledge of the Indicators

Scalar interpretations of data

Time to gather the data

Note: The indicators provide a wide range of information that needs to be gathered/collected when man wants to determine their Autonomy in Dike Management. Therefore it is important to understand the nature of the data that will be used and the difficulties they subject on the actors.

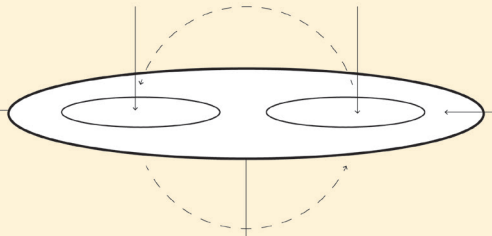
Can be gathered by local actors

Has to be collected from public authorities

Expertise & Responsibility Actors

Local Knowledge Collection

Contextual Capacity & Importance



Public Authorities

Knowledge Provision

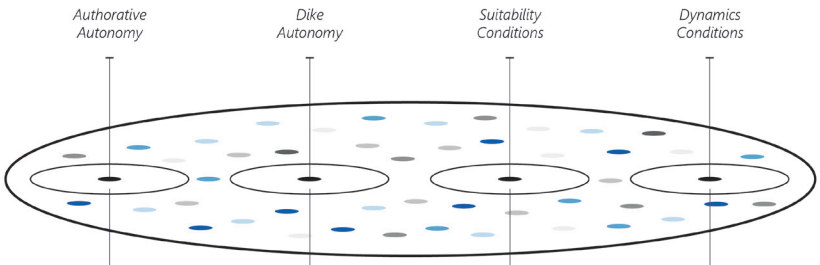
Research & NGO's

If information can not be collected see other public institutions

5. Translation of Information

Negative Dike Autonomy

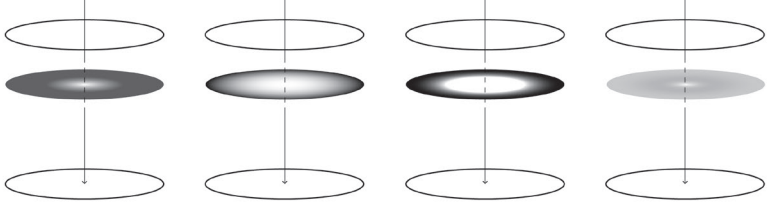
Positive Dike Autonomy



Main area of calculation (Rhine)

Spatial Calculation Model

Definition of data points (1x4 km squares)



Importance in Dike Management

Weighing of the Indicators

Weight between 0.25 - 2.00

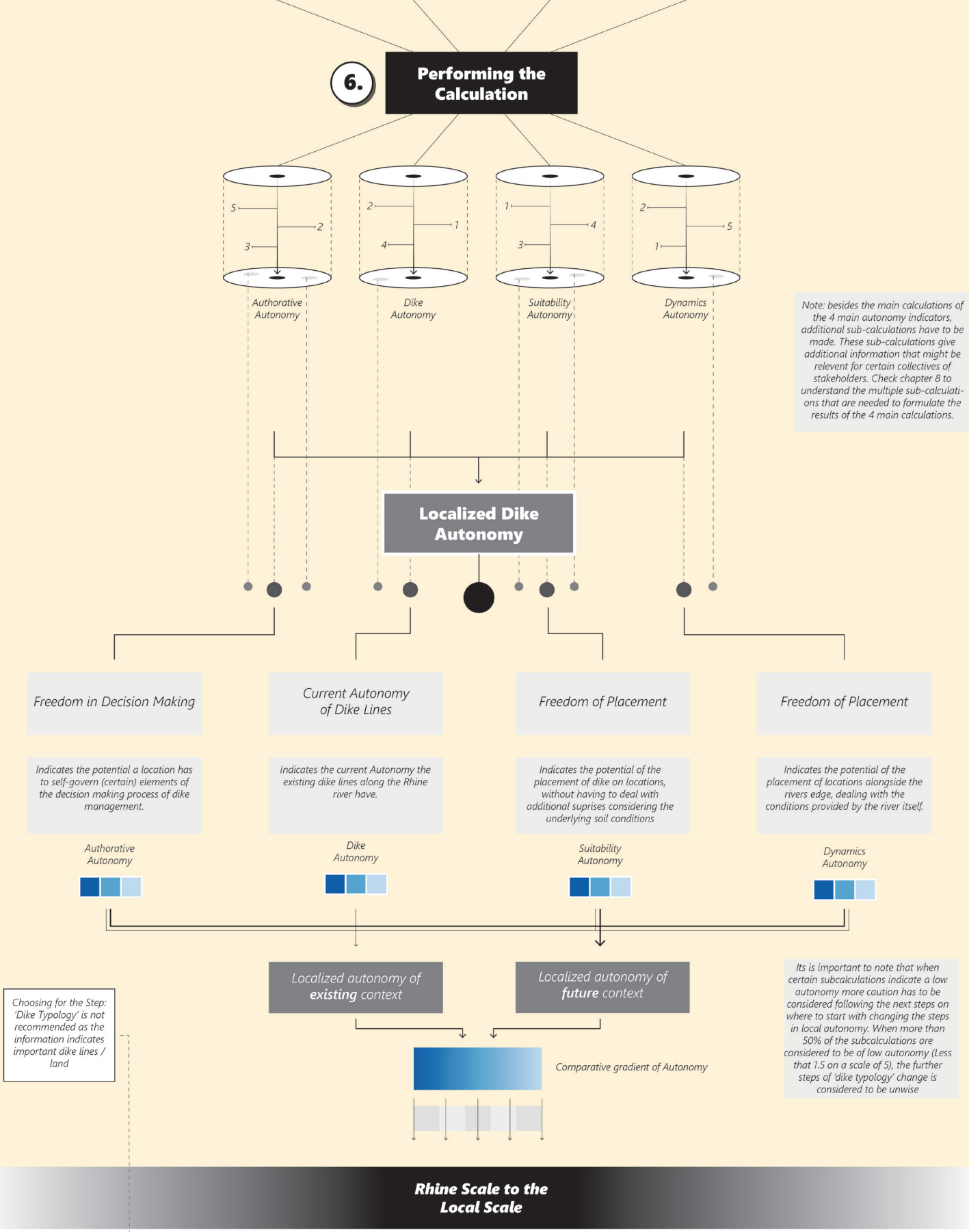
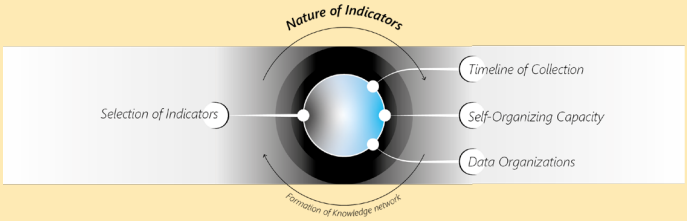


Figure 35: Roadmap part 3 (Step 6 & 7) (Author, 2023)

autonomy (Step 3). More specialized data concerning water and geological information can be gathered from larger organizations such as CHR, IKSR, or BAFG.

Please note that the list of indicators is extensive and as a result, some data may not be relevant due to its scale interpretation (uniform across locations) or its significance to local stakeholders. The list is designed to provide an overview of components that influence local dike autonomy.

It is important to mention that the data used in this roadmap is constrained to the level of detail applicable to the spatialization of data across the entire Rhine. More localized information is not included. This roadmap classifies data based on National Regions, NUTS Regions (EU), Land Use (100x100 m), locational data, and raster data with various raster sensitivities, often at 1x1 km. These considerations pertain to the entire Rhine River. For more detailed information specific to each design location, the scale of the calculation model must be adjusted.



Step 5: Translation of the Indicators

Once the information has been collected, the next step is to spatialize and interpret the data for the design location. Each indicator has either a positive or negative impact on autonomy. Autonomy is assessed based on the degree to which an indicator positively or negatively influences dike management. The primary rule to follow is that if an indicator increases the need for a protective dike element, autonomy is considered low compared to areas where dikes are less constrained by suitability or river dynamics. To provide an overview of the relationship between autonomy and the four main categories of local dike autonomy, the following rules of autonomy have been outlined:

(1). *Authoritative Regions:* If existing practices, cultures, rules, or regulations related to water and dike management suggest greater flexibility in the decision-making process, local dike autonomy can be presumed as high by local stakeholders.

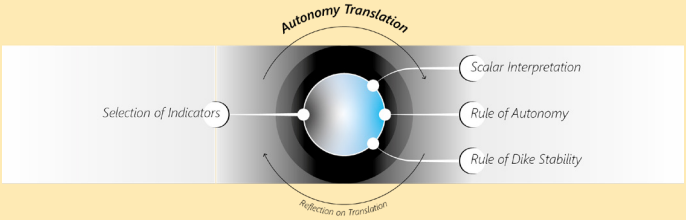
(2). *Dike Typologies:* If the current dike line plays a significant technical role in protecting an area from the river, the autonomy of local stakeholders is reduced. This is due to the substantial dependencies and responsibilities that the dike line has concerning its surroundings. Such lines are often regulated by regional and/or national governmental bodies.

(3). *River Dynamics:* The lesser the impact of the river on the dike line, the higher the autonomy of the area. Since such dikes require less maintenance to preserve their original structural and functional characteristics, more opportunities for local dike management can be created.

(4). *Suitability Conditions:* The higher the suitability of a dike in a specific location, the greater the autonomy of that dike line. As mentioned previously, the dike requires less monitoring by authorities when it can form an integral relationship with the underlying conditions.

Weighing the Indicators

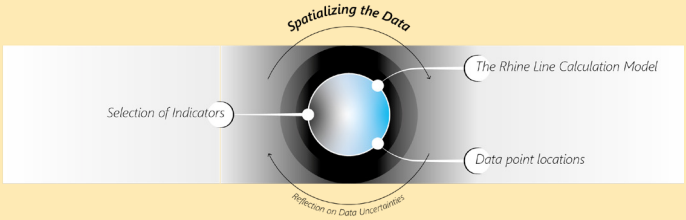
The set of indicators has been translated into a basic 1-5 ranking system and is weighted based on their significance in dike management. This process facilitates the implementation of the roadmap into real-life scenarios. Indicator weights range from 0.25 to 2.00 to address the importance of the indicators in dike management. Subsequent chapters provide more detailed descriptions of sub-calculations and indicators.



Step 5.1: Spatializing the data

To translate the data to the designated location, a spatial pattern is created for data visualization. In this roadmap, given the length and scale of the Rhine basin, a set of boundaries is chosen to spatialize the information. This has resulted in a pattern of 4 kilometers in length and 1 kilometer in width, encompassing a total of 2,800 data locations along the length of the Rhine. For a more detailed description of how the spatial model of the Rhine is formulated, please refer to Chapter 7.

Since not all calculations take place on the level of the Rhine, each design location needs to formulate its own spatial model. Based on the HST defined in Step 1, a manageable spatial pattern can be established, taking into account the level of detail understood in Step 4.



Step 6: Performing the Calculation

Once the data is converted into spatialized units and translated into autonomy ratings, the calculations are initiated. These calculations are carried out based on the four main categories of autonomy indicators, as mentioned in Step 3. These four categories are composed

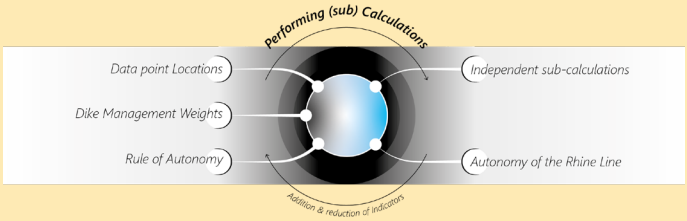
of smaller sub-calculations, each providing additional information that contributes to the overall calculation. These sub-calculations form the foundation upon which the primary calculations rely. Therefore, it is crucial to perform the calculations as outlined in Chapter 10. Since the calculations are based on a 1-5 ranking system, different scalar calculation models can be employed.

The outcome of these calculations is a spatial pattern that assesses the potential for local autonomy. In subsequent steps, two calculations are significant in emphasizing the potential for local dike autonomy:

(1). *The Whole Calculation:* This calculation covers the four main indicator groups weighted equally, indicating the overall potential for autonomy based on the existing spatial area.

(2). *The Calculation Without Dike Indicators:* This calculation involves the three main indicator groups weighted equally, excluding the Dike autonomy indicator group. It reflects the overall potential for autonomy based on future possibilities.

Please note that the eventual result of the spatial pattern doesn't provide a direct understanding of autonomy at specific locations. Rather, it should be viewed as a comparative pattern that portrays a degree of autonomy instead of using the results as direct referencing material. The results of the calculation are not 'fixed' and should be used for reflection, performance assessment, and adjustments.



Step 7: Choosing a Strategy

Based on the results of the calculations, a spatial pattern indicating the degree of autonomy is defined. This newly created pattern of autonomy guides the next step. Based on the comparative results (See note of step 6), a set of 4 strategies is to be chosen. Below the four different options are described, ranging from high to low autonomy:

(1). *Dike Typology Change:* This option is available for locations with a high potential for autonomy. It entails facilitating a new dike line in areas indicating, effectively bringing about a typology change. This allows for a new layout of the land, both spatial and functional.

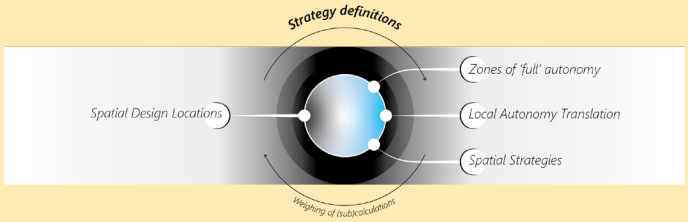
(2). *Dike Location Change:* In locations with medium potential for increasing autonomy, this option is selected. It involves changing the existing location of the dike while maintaining its current function. Based on the results, it is determined that the existing dike is necessary, but a location change is feasible.

(3). *Dike Stability Change:* For locations with low potential to change autonomy, the strategy is to strengthen the existing dike line without altering its function or location. Only small improvements can be made to enhance its stability.

(4). *Remain Existing Dike:* In the final option, the existing dike remains in place, even if a relatively high level of autonomy is perceived. This choice is made when changing the dike's location is not an option. In such cases, specific aspects of dike management, often related to small-scale maintenance or monitoring inspections, can be delegated to stakeholder groups. Therefore autonomy is increased without spatial change.

Since the roadmap primarily emphasizes the pursuit of completely autonomous regions, only the strategy of dike typology change is followed in the subsequent steps.

It is important to recognize that altering dike lines in one location can impact other areas upstream and downstream, influencing their level of autonomy. Although this roadmap highlights the significance of fully autonomous regions, it's important to consider the impacts generated.



Step 8: Formation of a new dike line

After spatializing the areas of high autonomy potential, the initial step is to consider the existing dike line as non-existent, providing a clean slate for the placement of a new dike line. Given the known high-potential locations, a new dike line is outlined following areas with high autonomy. However, not all high autonomy areas are suitable for dike construction. To streamline the selection of potential dike locations, four indicators are employed to determine the extent of the future dike line. Here are explanations for these indicators:

(1). *Extent of the Flood Line:* Dikes should be positioned within the boundaries of the most extreme flood scenarios as defined by BAFG (2015). This allows for the functionality of the dike to cover areas where a dike line is essential. Check the indicator of 'Flooding Extreme Scenario' for more information (page X).

(2). *Slope Indications:* Dikes should be placed on locations with a slope of less than 10-15 degrees. This eliminates higher regions further from the river where dike construction is unnecessary. In these areas, there is no functional need for a dike. Check the "Slope Indications" indicator for more information (page X).

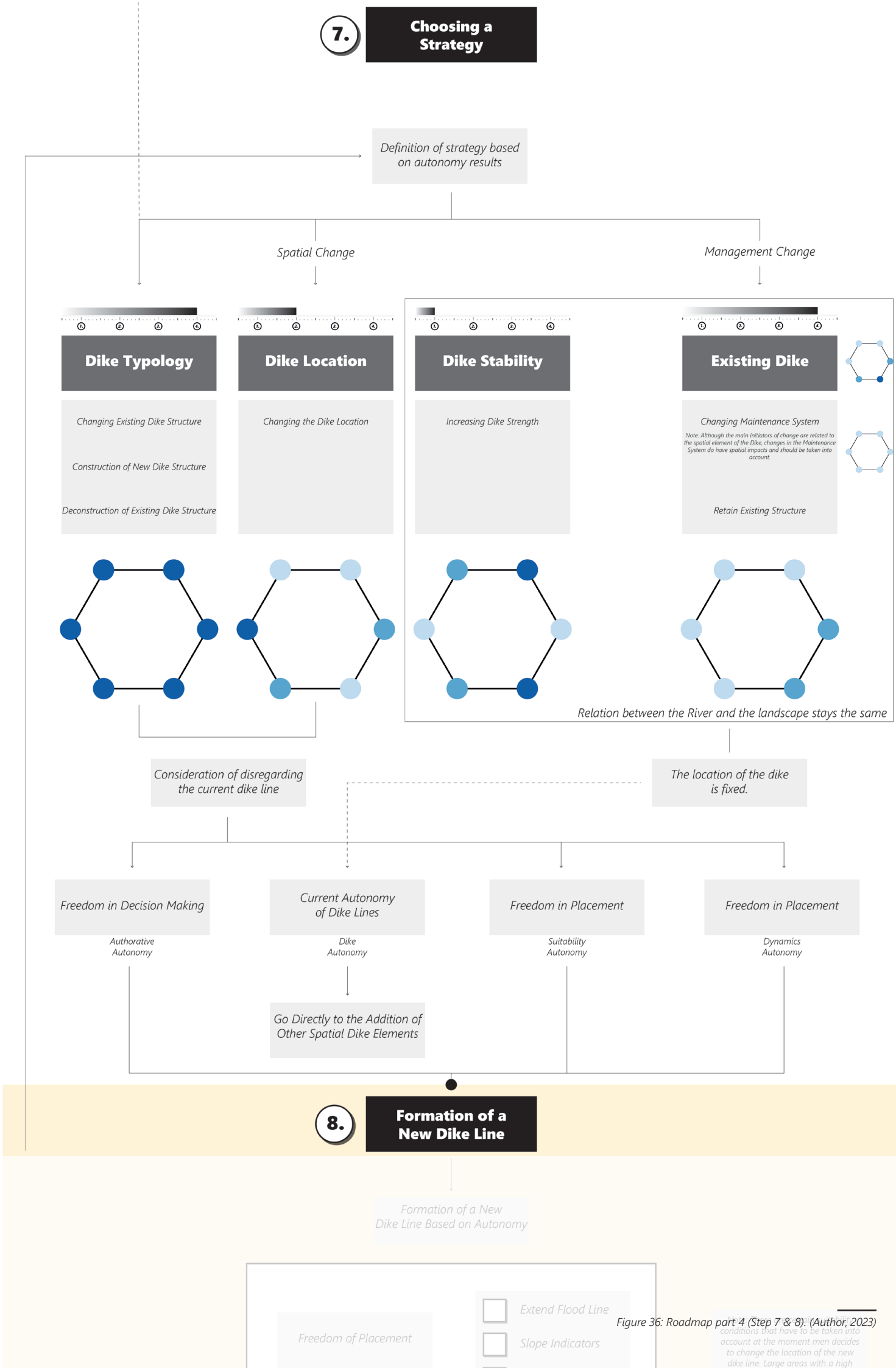


Figure 36: Roadmap part 4 (Step 7 & 8). (Author, 2023)

8. Formation of a New Dike Line

Formation of a New Dike Line Based on Autonomy

Freedom of Placement

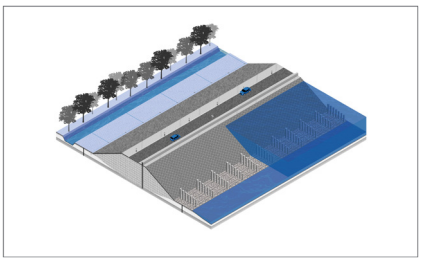
- ☐ *Extend Flood Line*
- ☐ *Slope Indicators*
- ☐ *Lithological Depositions*
- ☐ *Surrounding Water Bodies*

Note: There are certain suitability conditions that have to be taken into account at the moment men decides to change the location of the new dike line. Large areas with a high autonomy are not suited for dike due to their high elevation or other spatial characteristics.

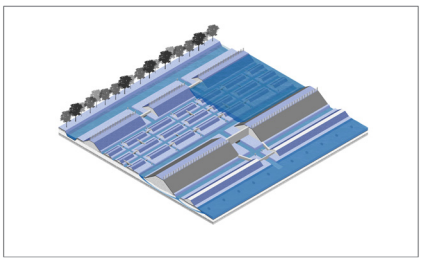
9. Envisioning Future Dikes

Exploration of future dike scenarios based on each stakeholder group

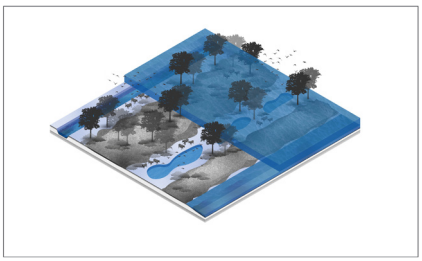
☐ **Protective Dike**



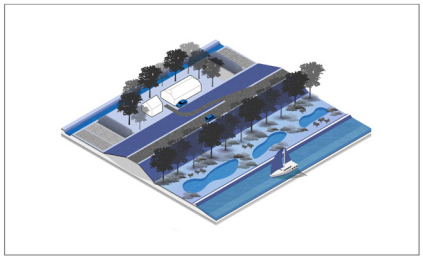
☐ **Distributive Dike**



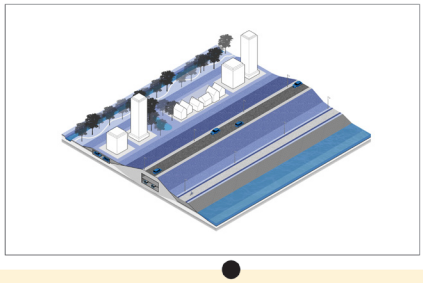
☐ **Tranisiton Dike**



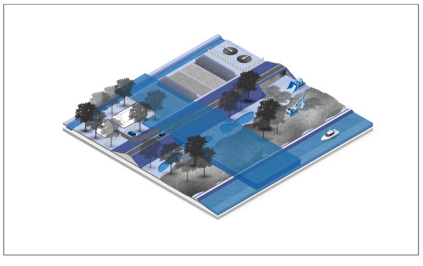
☐ **Landscape Dike**



☐ **Multifunctional Dike**



☐ **Maintenance Dike**



Dike Database → **Spatializing new Dike Typologies** **10.**

The moment the dike line is set out and the actor groups determine their ideologies in dike management, the further design process follows around the relations of actors at the direct vicinity of the dike line. Therefore a patchwork of dike building processes is set up that can take place as autonomous as needed.

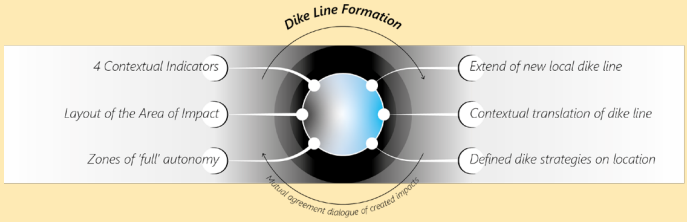
Protective Dike | **Distributive Dike** | **Tranisiton Dike** | **Landscape Dike** | **Multifunctional Dike** | **Maintenance Dike**

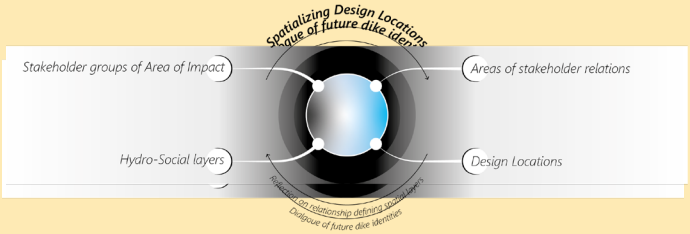
Figure 37: Roadmap part 5 (Step 8-10). (Author, 2023)

(3). *Lithological Deposition:* Dikes should only be located in areas where they can be structurally stable. Without a solid foundation, a dike line cannot be constructed or maintained. Check the indicator of 'Lithological depositions' for further information (page X).

(4). *Surrounding Water Bodies:* Dikes should always be in proximity to water (Lola Landscape Architects, 2014; CTCN, n.d). Technical requirements necessitate the presence of water nearby to relieve the dike line from the pressure it imposes on the groundwater below and for drainage purposes. Check the indicator of 'Surrounding Water Bodies' for more information (page X).

Based on the potential for autonomy and the four location indicators, a new dike line is outlined at the selected location following the context of the design location.

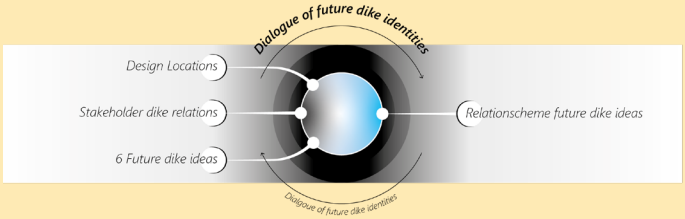




Step 9: Envisioning Future Dikes

With the new dike line outlined, a dialogue is established among the stakeholders of the design location. To facilitate an exploratory dialogue among stakeholders, a collection of six future dike scenarios is created. These scenarios are based on extreme ideas regarding a dike's protective, distributive, natural, landscape, multifunctional, and maintenance characteristics. The primary reason for including this step is to rebuild a relationship between the involved stakeholders and the river that is also resilient to future scenarios.

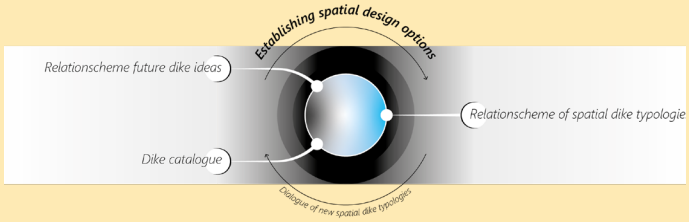
Based on the stakeholder relationships with dikes established in step 2, a relationship scheme is developed. Here, stakeholders are tasked with researching which of the future dike scenarios best suits them based on the technical, spatial, and managerial characteristics. The result of this step is a definition of a relation scheme per design location with the most commonly carried future dike scenarios.



Step 10: Relate vision to dike database

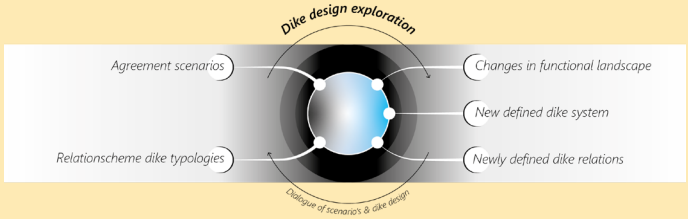
Building upon the relationship scheme provided in the previous step, an additional dike database is introduced. This dike database encompasses a wide range of existing dike typologies from around the world. Subsequently, as was done in the previous step, a new relationship scheme can be calculated based on the connection between the dike scenario and dike typology. The outcome is a set of dikes considered to be linked to the key visions of the stakeholders. Thereafter, a second dialogue is established, where the different dike typologies are discussed among the stakeholders for the creation of new dike systems in the next step.

Please note that a higher relationship between dike typologies and dike visions doesn't necessarily indicate a superior solution for the location. Other options can still be considered, even if their relationship may be lower.



Step 11: Creation of new dike systems

Building on the results of the dialogue in the previous step, an exploratory design exercise is developed to establish a new dike system. To enhance the freedom of the decision-making process, a set of scenarios is created to illustrate the various possibilities that may emerge. The use of multiple scenarios is essential to explore different options considering high, medium, and low-related choices. These scenarios serve as the foundation for crafting new dike systems.



Step 12: Placement on Location

Once the newly devised dike systems are established, they are placed by the context of the design location, following the dike line set in step 8. The outcome is a new local dike line, based on the vision of the stakeholder group, that reestablishes the relationship between man and the water. The spatial changes made alter the existing dynamics of the river, resulting in a range of impacts related to dike functionality, river flow, and flooding and drought occurrences.

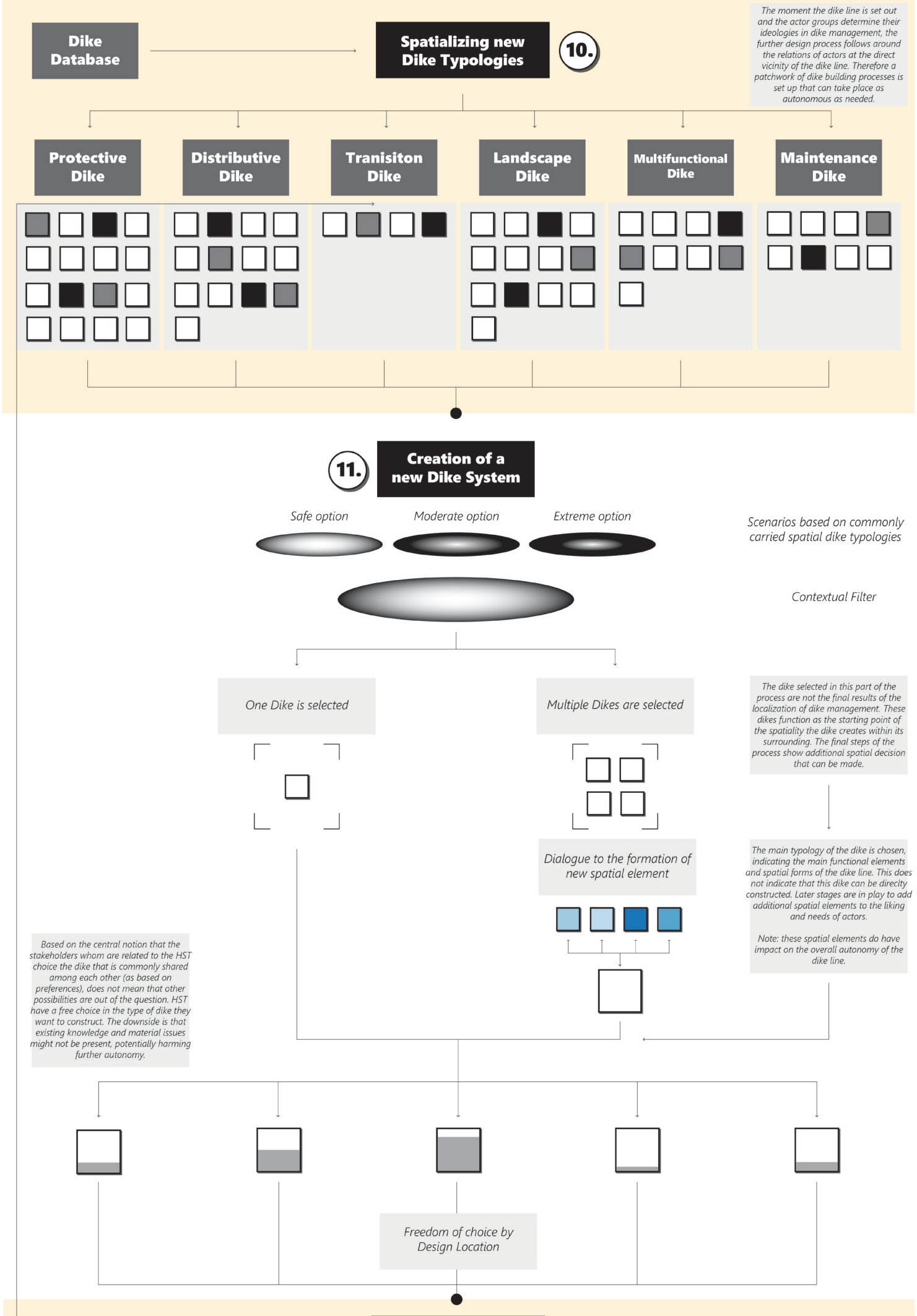
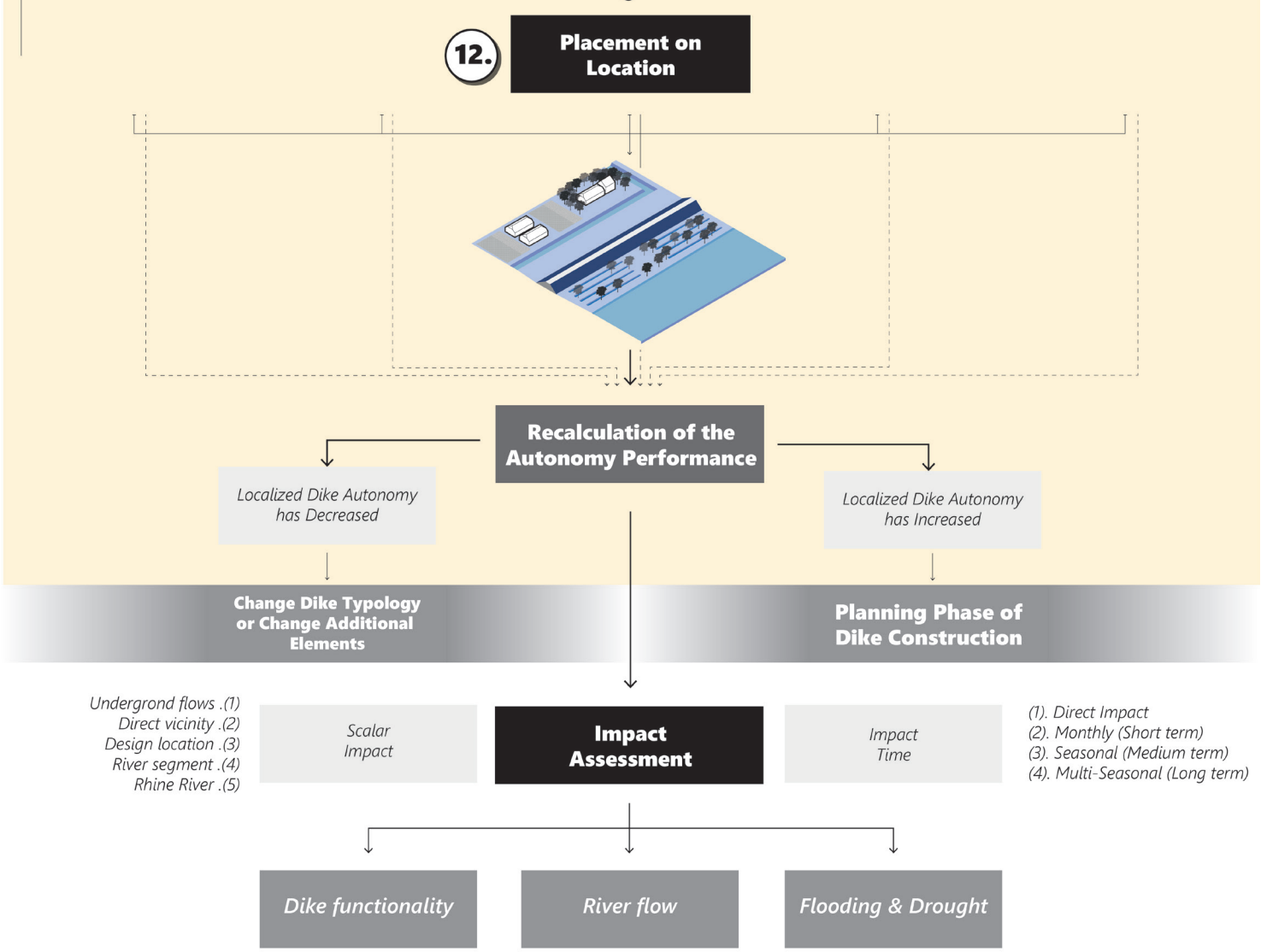
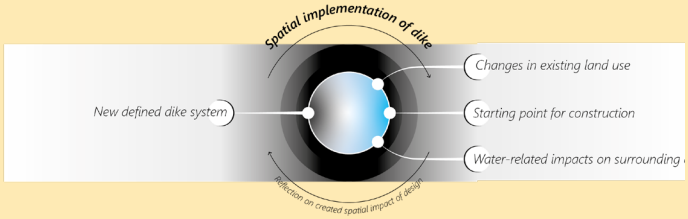


Figure 38: Roadmap part 6 (Step 10-12). (Author, 2023)

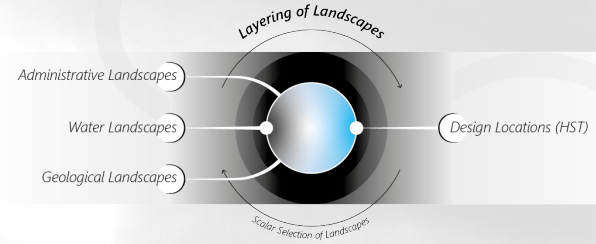




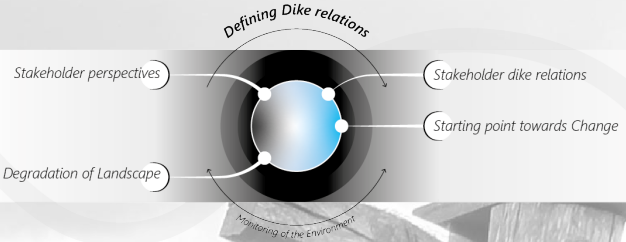
This roadmap aims to restructure the decision-making processes in water management by incorporating both bottom-up approaches from self-organizing stakeholder groups and top-down guiding principles. It introduces a spatial decision-making model that can be followed to define the locations best suited for local autonomy.

Figure 39: Roadmap part 7 (Step 12 & Impact assessment). (Author, 2023)

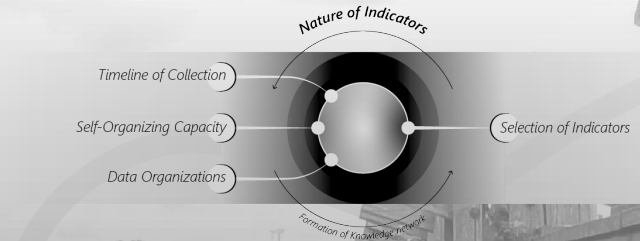
Step 1: *Design Locations (HST)*



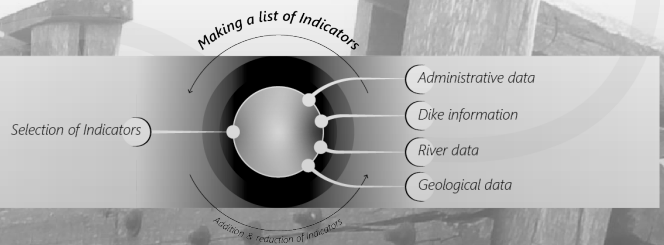
Step 2: *Urgencies*



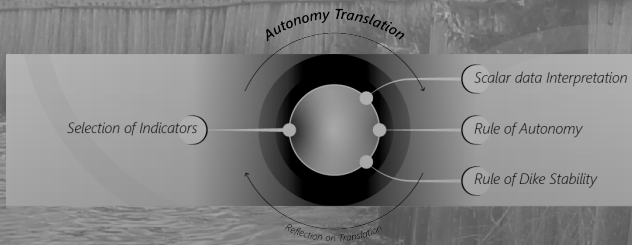
Step 4: *Knowledge Provision*



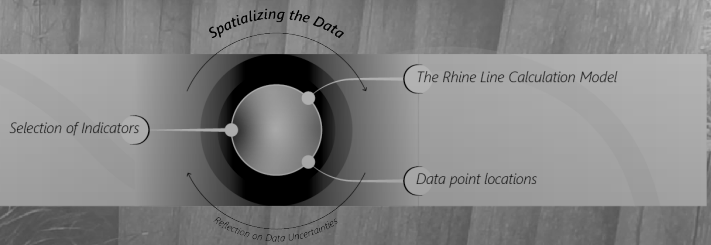
Step 3: *Indicators of Autonomy*



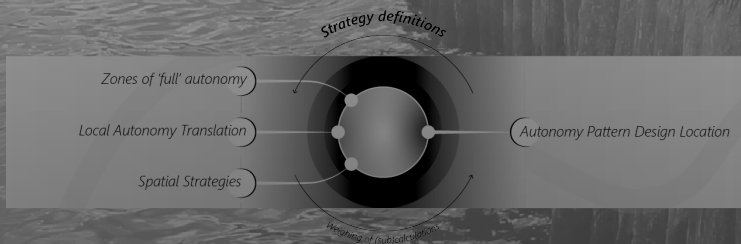
Step 5: *Translation of Indicators*



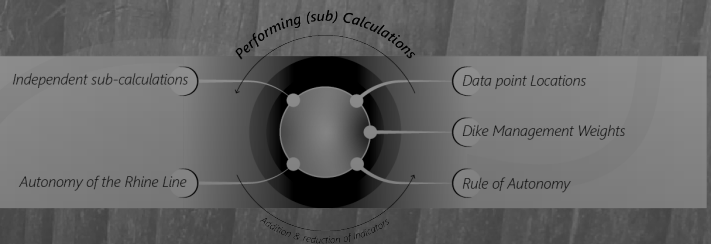
Step 5.1: *Spatialization Model*



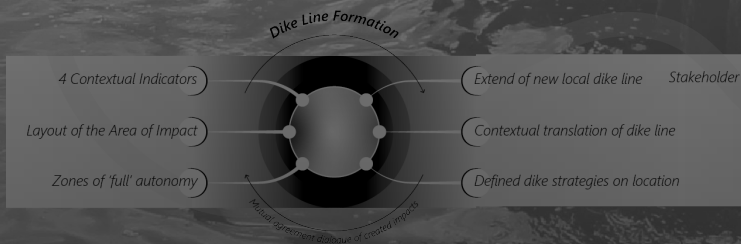
Step 7: *Defining Strategies*



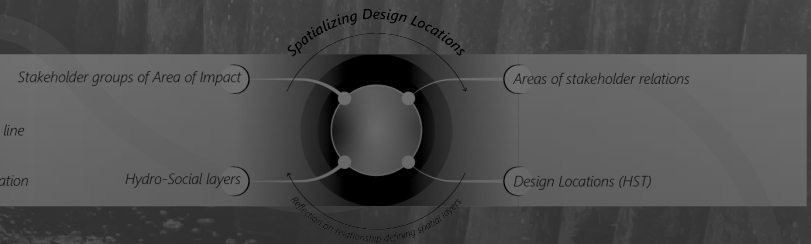
Step 6: *Calculation*



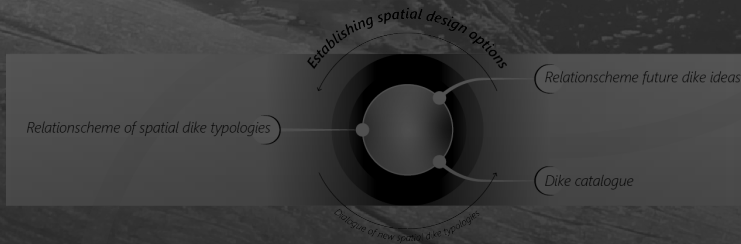
Step 8: *Dike Line Formation*



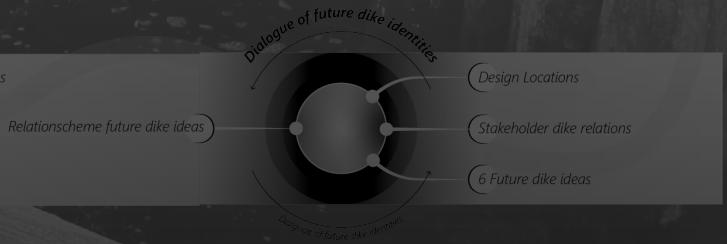
Step 8.1: *Design Locations (HST)*



Step 10: *Spatial Dike Formation*



Step 9: *Future Dike Exploration*



Step 11: *Dike Systems*



Step 12: *Dike placement*

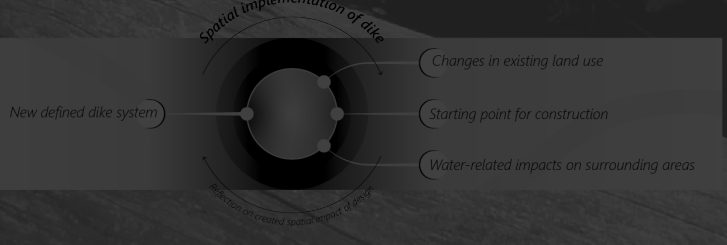


Figure 40: Old pole dike near Eemmeer (NL). (Wikipedia, 2012)

Figure 41: Steps of the roadmap, highlighted Step 1 & 2. (Author, 2023)

07

The Calculation Basin

7.1 The Rhine as a Calculation Model

Spatial formation of the Locations of the Rhine
The Rhine Line

7.2 The Indicators of Local Dike Autonomy

The Indicators

7.3 The Rhine as a Hydro-Social Region

Geological Territories of the Rhine

Elevation Profile
Aquifer Conductivity
Lithological Compositions

Water Territories of the Rhine

Water board Regions
Drainage Network
Groundwater Bodies
Rhine River Subbasins

Urban Territories of the Rhine
Administrative Regions
Urban vs Non-Urban areas
Dike Management Regions

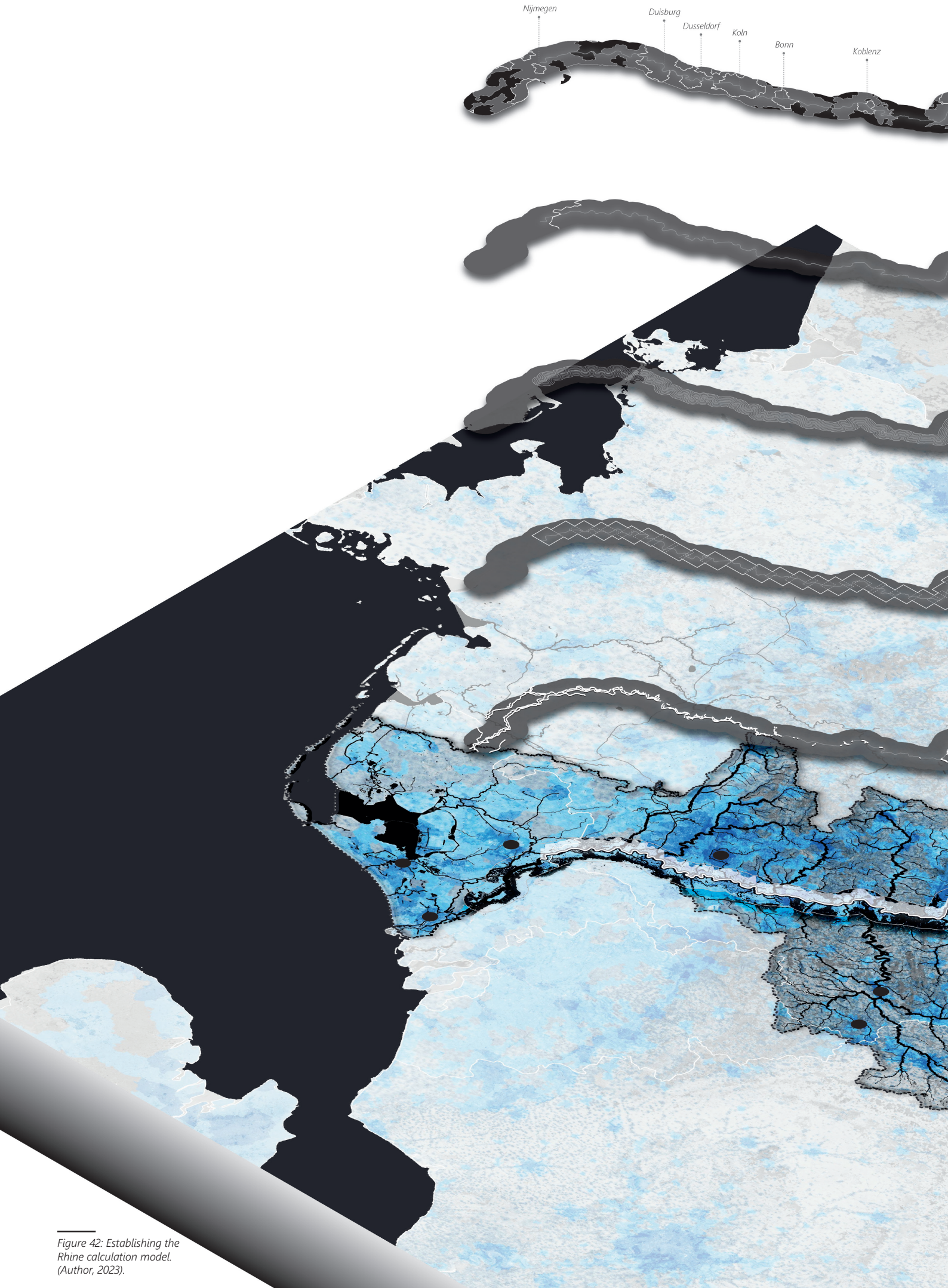
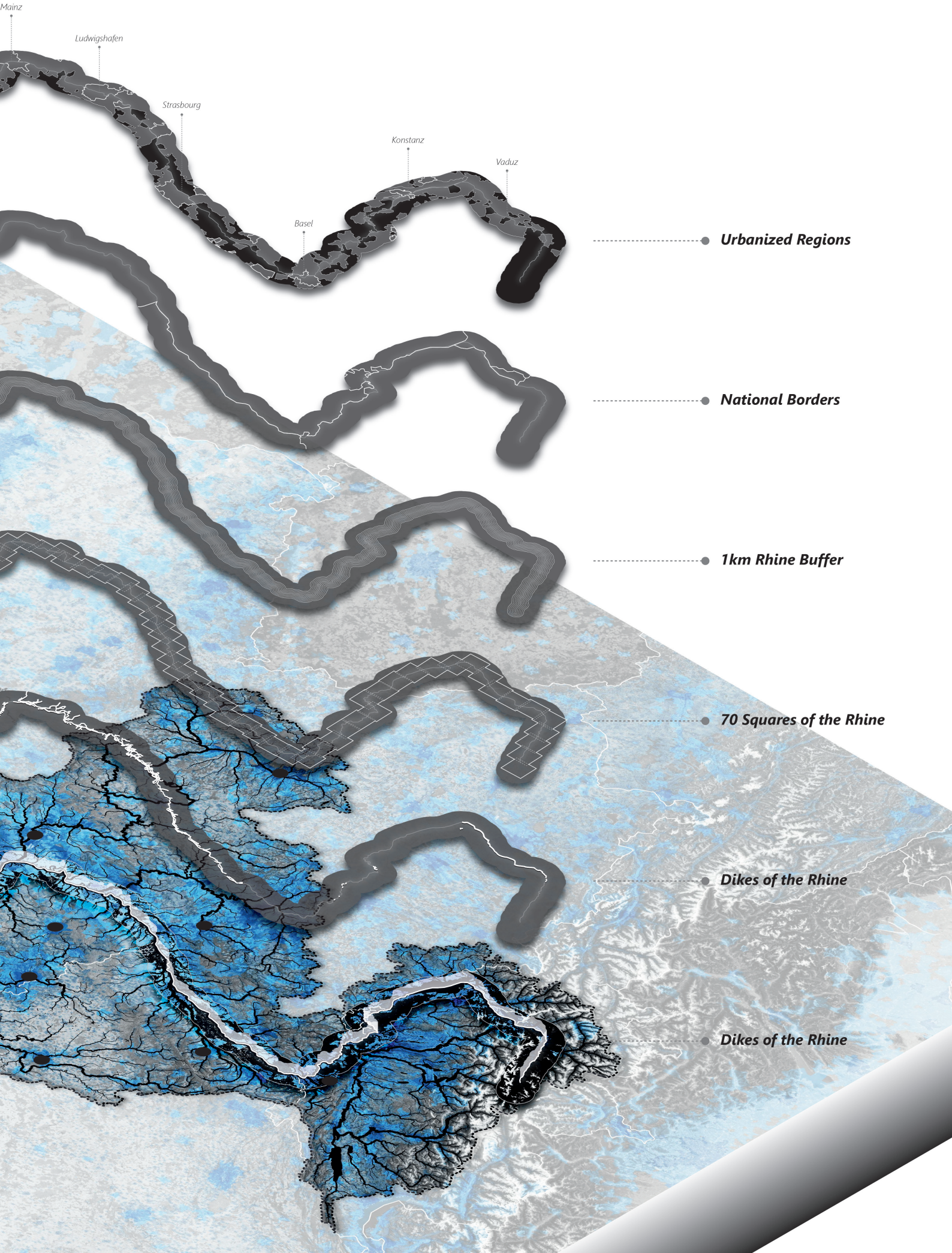


Figure 42: Establishing the Rhine calculation model. (Author, 2023).


Mainz
Ludwigshafen
Strasbourg
Konstanz
Vaduz
Basel
Urbanized Regions
National Borders
1km Rhine Buffer
70 Squares of the Rhine
Dikes of the Rhine
Dikes of the Rhine

7.1 The Rhine as a Calculation Model

The main idea of this chapter is to introduce the different spatial layers of the Rhine as connected to the understanding of the theory surrounding the Hydro-Social Territories. The idea is to give the reader the impression that the large historical connection between the water and the people is rooted in the different Hydro -Social (Geological, Administrative, and Water-related) Territories that the Rhine currently possesses.

Spatial formations of the Locations of the Rhine

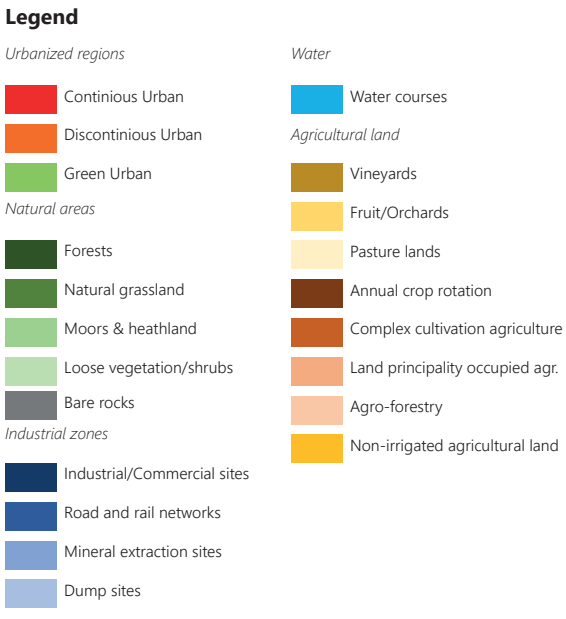
As the Rhine River is 1.233 km long from its source in the Alps of Lake de Toma to the location where the river meets the North Sea at Hoek van Holland, the research towards how local dike management can be spatialized is a research topic of its own. The scope of this project only relates to the Rhine course of the source until the Rhine split near Pannerden, the Netherlands, where the Rhine changes its name into the Ijssel & Lek on one side and the Waal on the other. This scope is defined as based on two main reasons. The first reason lies in the fact that the official name of the main Rhine river stops at the Rhine split near Pannerden. As the further course of the river is considered to be located within the delta region of the Rhine basin, the main Rhine river is divided among its various distributaries. Therefore the main Rhine river cannot be followed any longer.

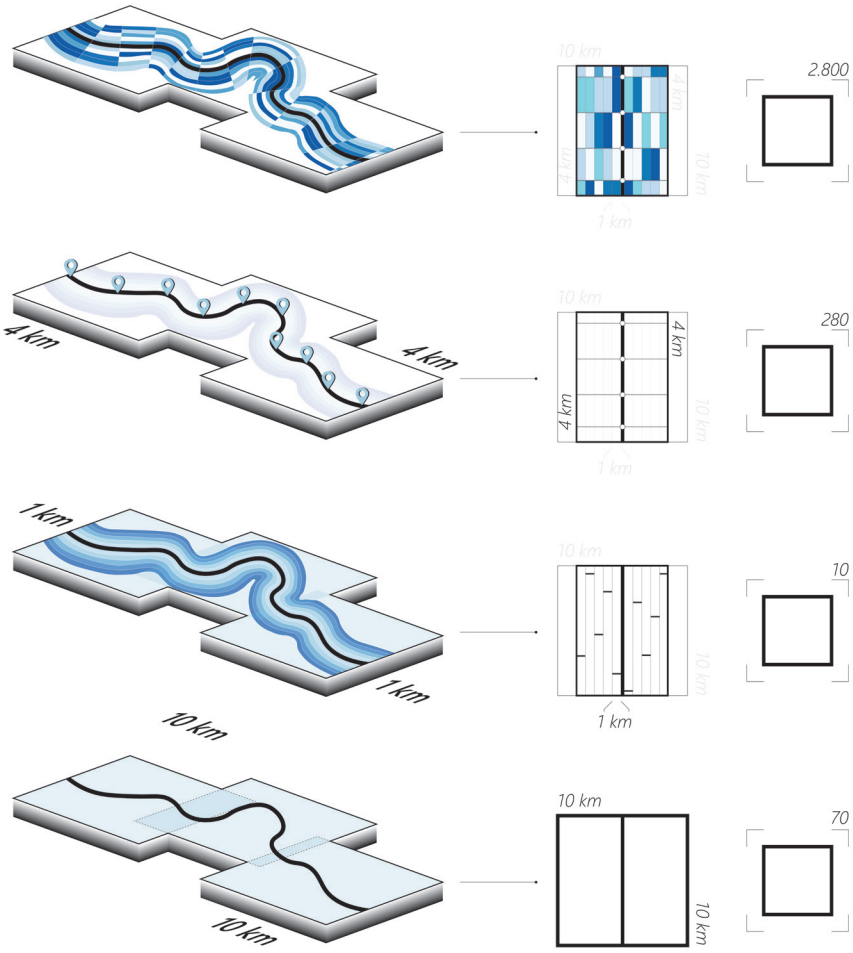
The second reason lies in the fact that the country of the Netherlands has a large history of dike management and this practice is fiercely routed within administrative and regulatory practices. Due to the overall thickness of the legislation of dike management in the Netherlands, localized dike management can hardly be implemented. Therefore we rather those the regions along the Rhine, where dike management is not yet fully understood or integrated into harsh legislative management schemes of national and regional public authorities.

As the central notion of the Hydro-Social Territory addresses that humans and the river are in constant relationship with one another, this research states that the focus of projecting local dike autonomy on the Rhine should be adjacent to the main course of the river itself. Therefore, the Rhine is composed of 70 squares of 15x15 km that overlap each other. These 70 squares are named based on the adjacent largest city to gain an understanding of where the spatial areas are located. Next, we define a 5 km buffer on each side of the river, which is further divided into 1km zones. These zones are used to identify the distance between the main river and the degree of interaction. Here this report states that the distance between the Rhine and the buffer regions has a distinct relationship between human activity and the river itself. The next step is to divide the 1 km buffer zones into different pieces. Due to the large length of the Rhine that is used in this research, the division of the Rhine takes place in lengths of 4 km. The 4-kilometer boundary is chosen to allow for the most detailed datasets used in this report (locational and land use data) to be allocated to its spatial translation. These 4 km buffers are directed into the 15 km squares, facilitating 3 to 7, 4 km buffers per square, depending on the course of the river within the squares. By the end a line of the Rhine can be established, with 5 columns on each side and 280 rows of 4 km zones, creating eventually 2.800 data fields to be filled in.

The Rhine Line

Based on the previous creation of the new spatial translation of the Rhine a model is created. On the next page, the main characteristics of the Rhine line are shown based on the land use classifications as defined by Corine Land Cover (2018). This land use classification will also be used as a spatial component to calculate, decision-making autonomy and water use autonomy. As the main classification of the 9 stakeholder groups that are defined by the Complex Adaptive System by Meyer, et al. (2014) relate to the land use classifications defined by Corine Landcover, these will be used in further analysis.
The Rhine line is defined based on the large land uses of the Rhine river. As per the main classification group of Urban, Nature, Agriculture, Industry, and Water, the main areas that classify the Rhine are shown.





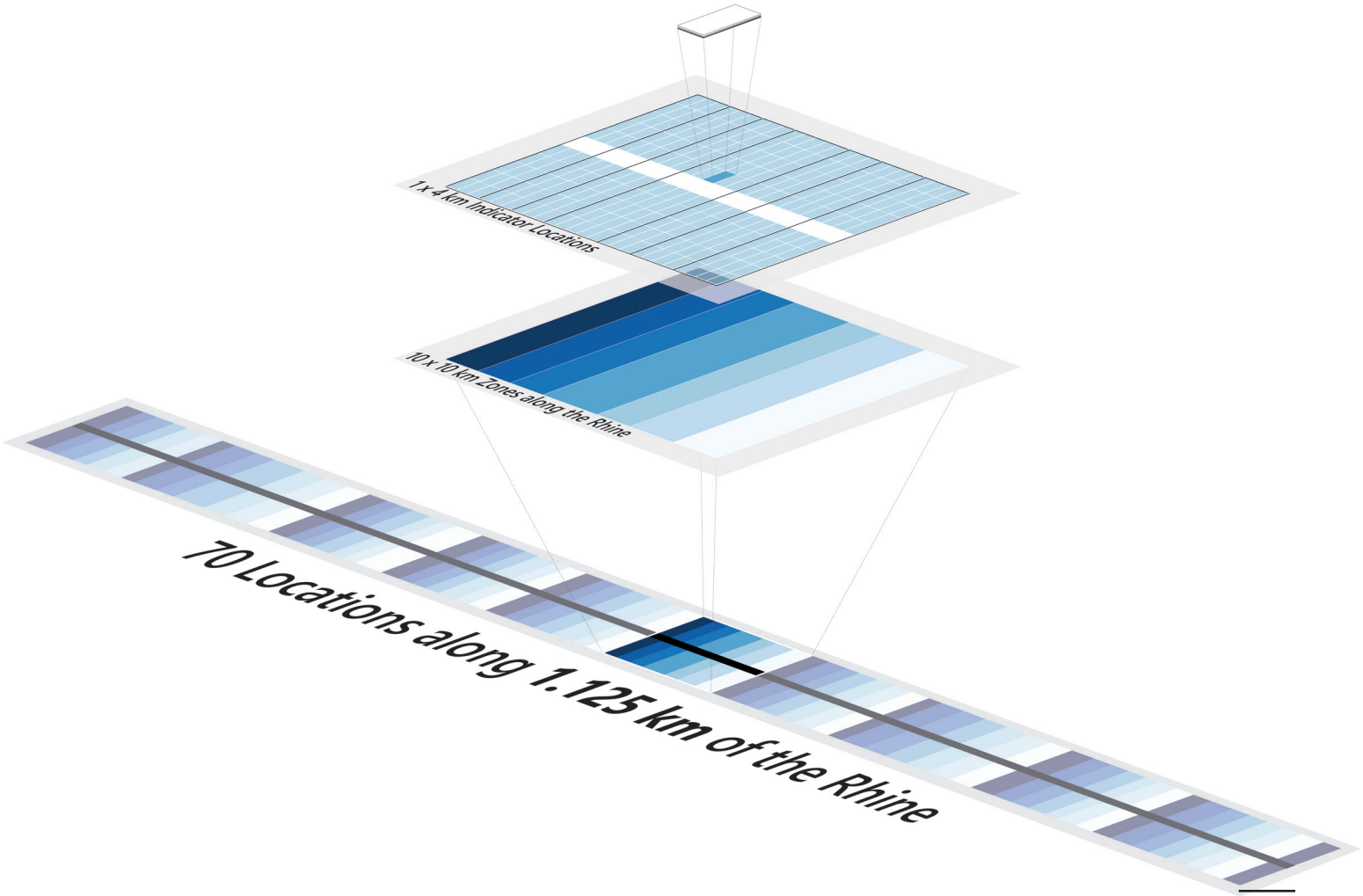
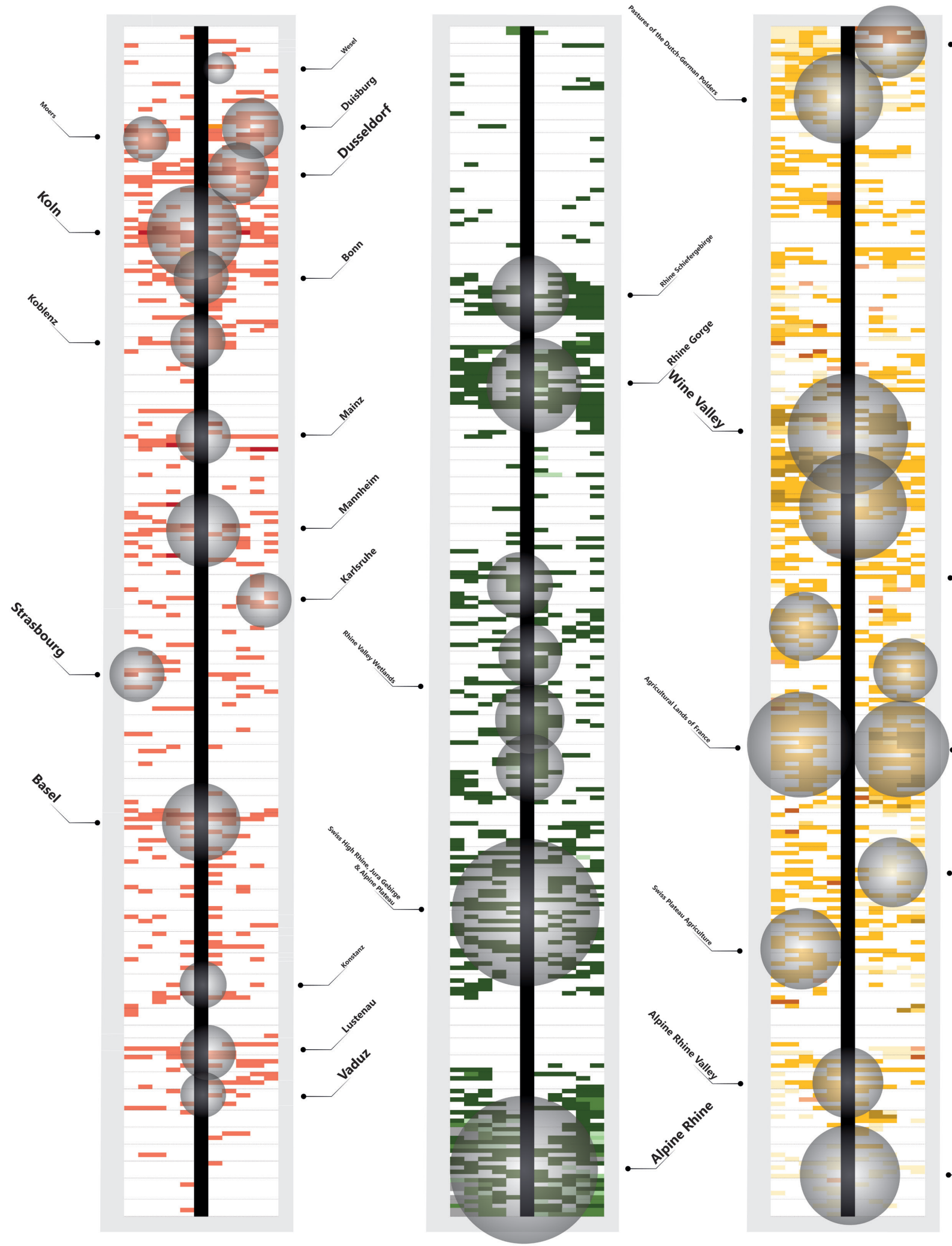


Figure 43: Scheme of the formation of the Rhine Line. (Author, 2023).

Figure 44: From the Rhine Line to small data locations. (Author, 2023).


Wesel
Duisburg
Moers
Dusseldorf
Koln
Bonn
Koblenz
Mainz
Mannheim
Karlsruhe
Strasbourg
Rhine Valley Wetlands
Basel
Swiss High Rhine, Jura Gebirge & Alpine Plateau
Konstanz
Lustenau
Vaduz
Pastures of the Dutch-German Polders
Rhine Schiefergebirge
Rhine Gorge
Wine Valley
Agricultural Lands of France
Swiss Plateau Agriculture
Alpine Rhine Valley
Alpine Rhine

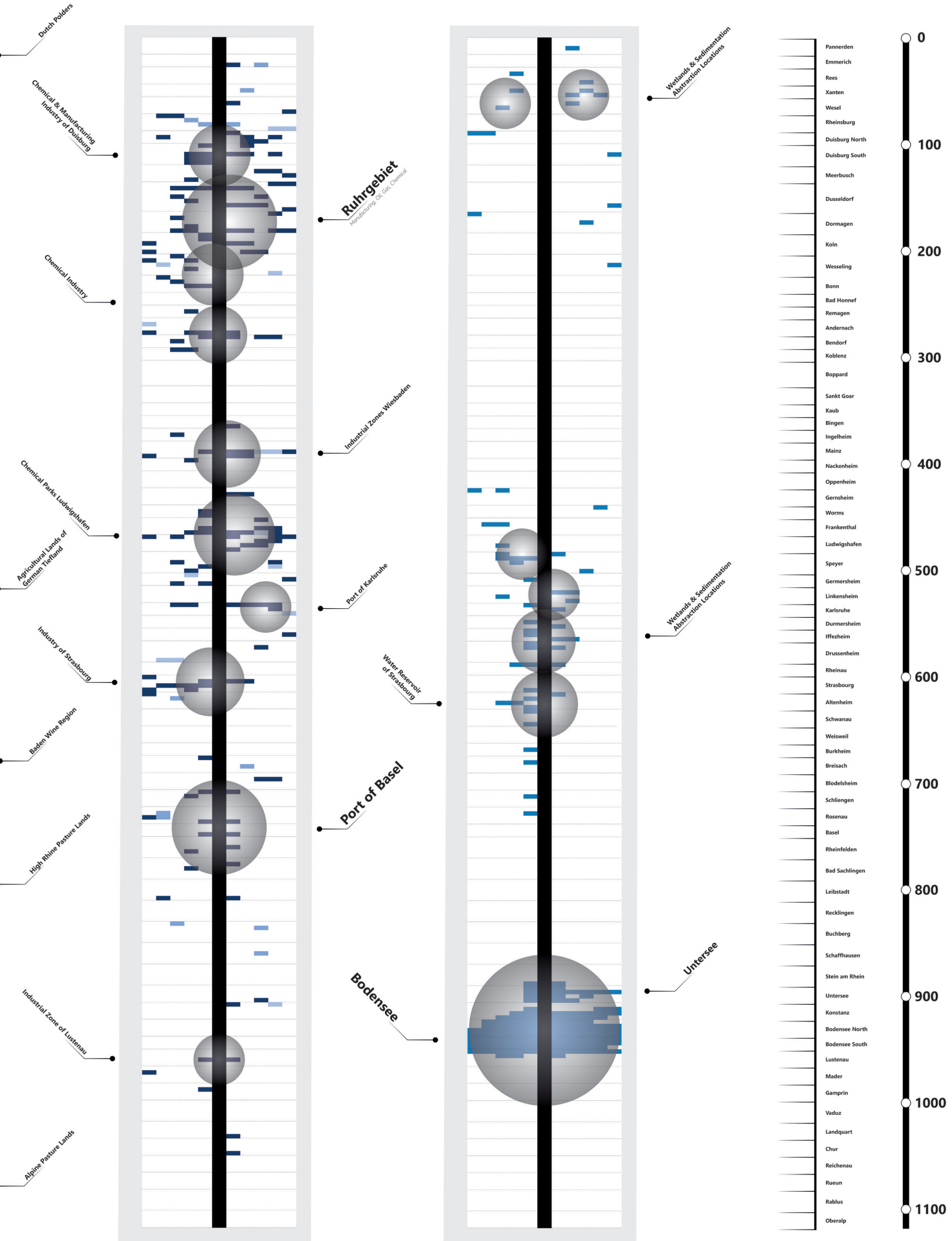


Figure 45: The Rhine Line. (Author, 2023)

7.2 The Indicators of Local Dike Autonomy

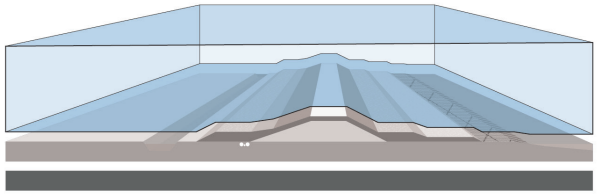
Information is given to underline the indicators that can be used by local actors to calculate the possibilities of local dike management. Based on 4 classified main calculation categories, local actors not only can conduct the entire calculation at once but can also indicate their preferences within performing one of the 4 main sub-calculations and either setting up new calculations by combining important indicators.

This research proposes four main calculations to be made when concerning the exploration of local dike autonomy. These four main calculations all focus on the different layers that classify the suitability of the location of the respective dike line: The administrative, the dike, the river, and the subsoil layers of dike management. Next to the fact that the variables presented in this research can be used to indicate other calculations that might be beneficial towards local dike autonomy (dike costs calculations, water distribution calculations, etc.), the variables used and weighted in this research, therefore, have additional effects on all of the other variables. When for example the available knowledge (B1) within dike management is growing due to newly created knowledge platforms, dike management power relations, maintenance knowledge, and stakeholder involvement will change. Therefore it is vital to understand that when applying new dike typologies, management incentives, and/or other spatial interventions, other variables change accordingly in both positive and negative ways.

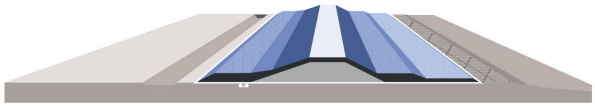
The Indicators

For the calculation towards the establishment of local dike autonomy, there has been made a selection of 63 indicators (of which 3 return twice to their importance in different sub-calculations). The overall calculation has been divided into four main subdivisions, related to layers that classify the potential for local dike autonomy.

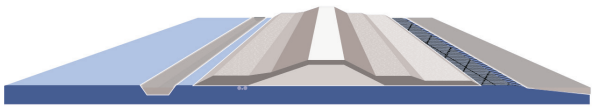
1. Authoritative regions based on spatial configurations where certain rules, regulations, practices, and management systems concerning water and/or dike management take place.



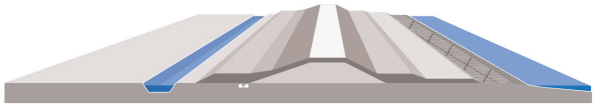
2. Dike typologies based on the technical, spatial, and management-related characteristics of the existing dike lines of the Rhine.



3. The underlying conditions of the surface, which include flooding, drought, aquifer, and soil conditions allow us to understand the suitability conditions of dike management.



But as certain conditions cannot be translated over the entire spatial regions due to their direct impact coming from the river itself, the final condition calculation is created: **4. Underlying conditions River Dynamics.**



These 4 calculations can be conducted separately since in the later stages of this document, the weighing of the indicators relates the indicators with each other at the bases of their subjection to localized autonomy.

Figure 46: Indicator groups of establishing local dike autonomy. (Author, 2023).



Figure 47: Indicators towards Autonomy. (Author, 2023)

7.3 The Rhine as a Hydro-Social Region

When the calculations of the Rhine are accomplished and regions can be selected to test the strategies towards the creation of localized dike lines, there still needs to be a spatial area where this change can take place. Therefore the literature on the Hydro-Social Territories is implemented in the area of the Rhine River. As this report states that a dike line forms a transition between the river and the adjacent territories, the creation of a HydroSocial Territory as the base for localized dike management is logical. But as the Hydro-Social Territory characterizes itself as a soft space that changes character based on the interpretation of scale used to define it, this report only focuses on the fixed territorial conditions that are created by the line classifications of the Rhine. To indicate the spatial layers used for the creation of the Hydro-Social Territories of the Rhine, the same spatial layers are used as to the ones that are translated within the calculations. This allows the same scale to be used throughout the report. Here the 3 main subdivisions of Authoritative regions, Suitability Conditions, and River Dynamics are used to indicate the 3 main spatial layers for the formulation of Hydro-Social Territories. The layer of the dikes is excluded from this part, as the dikes are seen as a spatial translation of the relationship between man and the river, rather than a spatial layer that defines a territory. The three main layers are further explained below. They are divided into Geological Landscapes, Water Landscapes, and Administrative Landscapes.

Based on the formulation of the indicators for the Hydro-Social Territories, later stages of the roadmap concerning the design implementation use the same format as explained in the next pages of the territorial layers.

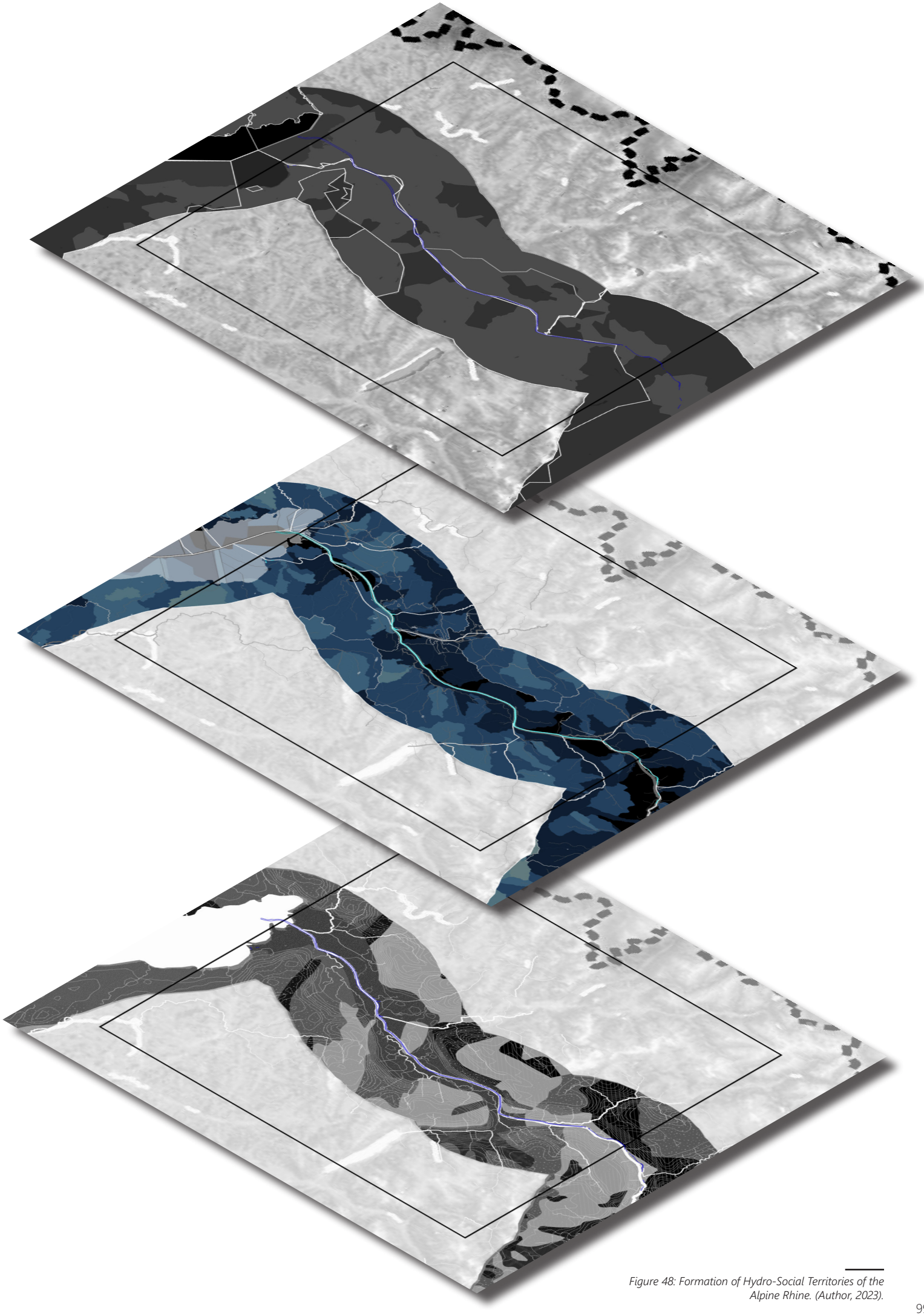


Figure 48: Formation of Hydro-Social Territories of the Alpine Rhine. (Author, 2023).

Geological Landscapes

The first landscape layer to define the Hydro-Social Territories of the Rhine is related to the geomorphological compositions that have shaped the region. These compositions form the foundation of the urban and natural systems. To form the spatial compositions of these landscapes, the layers of the Lithological compositions, Aquifer Conductivity, and Elevation Profile are used.

Elevation Profile

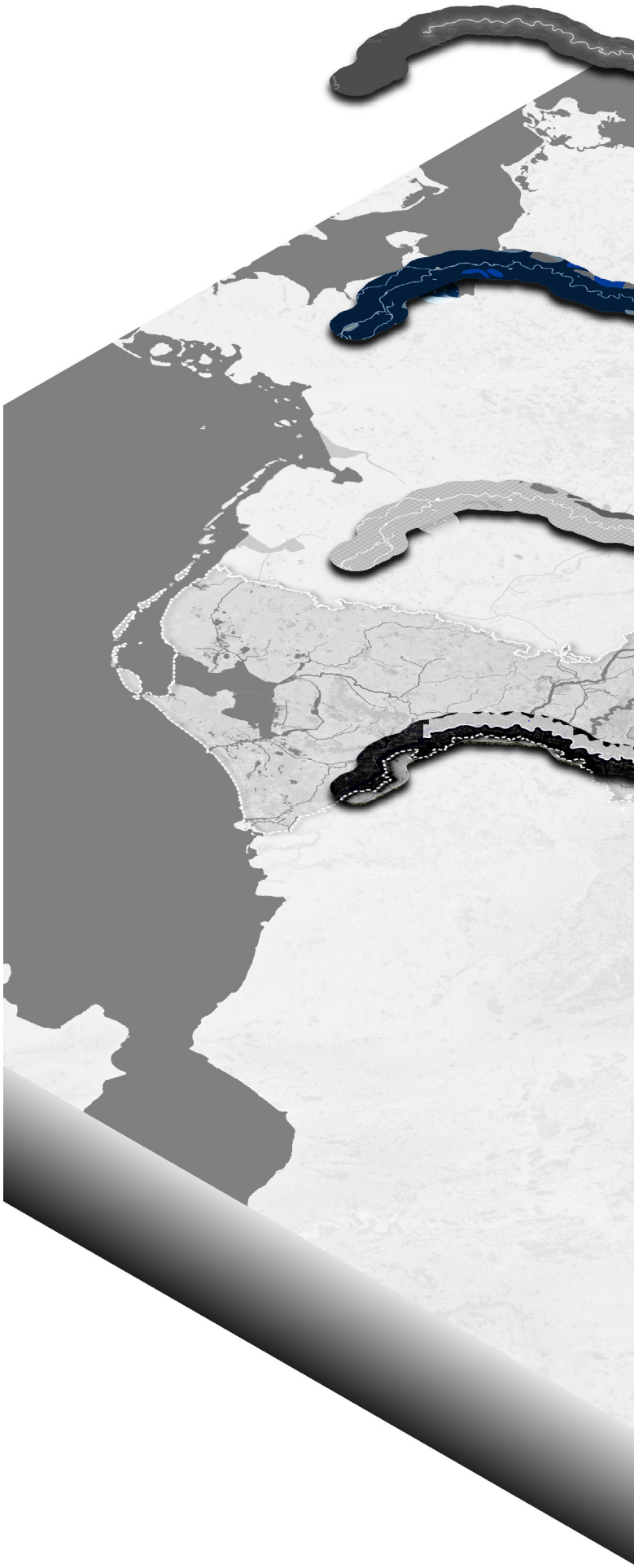
Will only indicate the suitability of a dike based on the height of the surrounding areas. This aspect has to be taken into account but has a limited impact on the dike autonomy of the Rhine River (might have better use for tributaries of the Rhine for water distribution purposes). Based on the contour profiles of a 2m height difference, a territorial translation is made based on the vertical distance between man and the river. Therefore a different relation is made based

Aquifer Conductivity

The aquifer conductivity indicates the current type of aquifers of the Rhine river basin that have established their current form through the forces of geomorphology. An aquifer is an underground layer of water-bearing and permeable rock formations. As these aquifers are water regions hidden in the geological landscape of the Rhine, they add to the geological relation between man and water. These aquifers are the main bodies that form a relation with the water system, which is defined in the next landscape.

Lithological Compositions of the Rhine

The geological composition of the Lithology that over time created the formation of the Rhine Landscape as we know it today, is one of the layers that indicates what type of urban land use and/or other practices are common. The lithological compositions are based on the geomorphological deposits that have formed through the forces of plate tectonics and erosion processes.



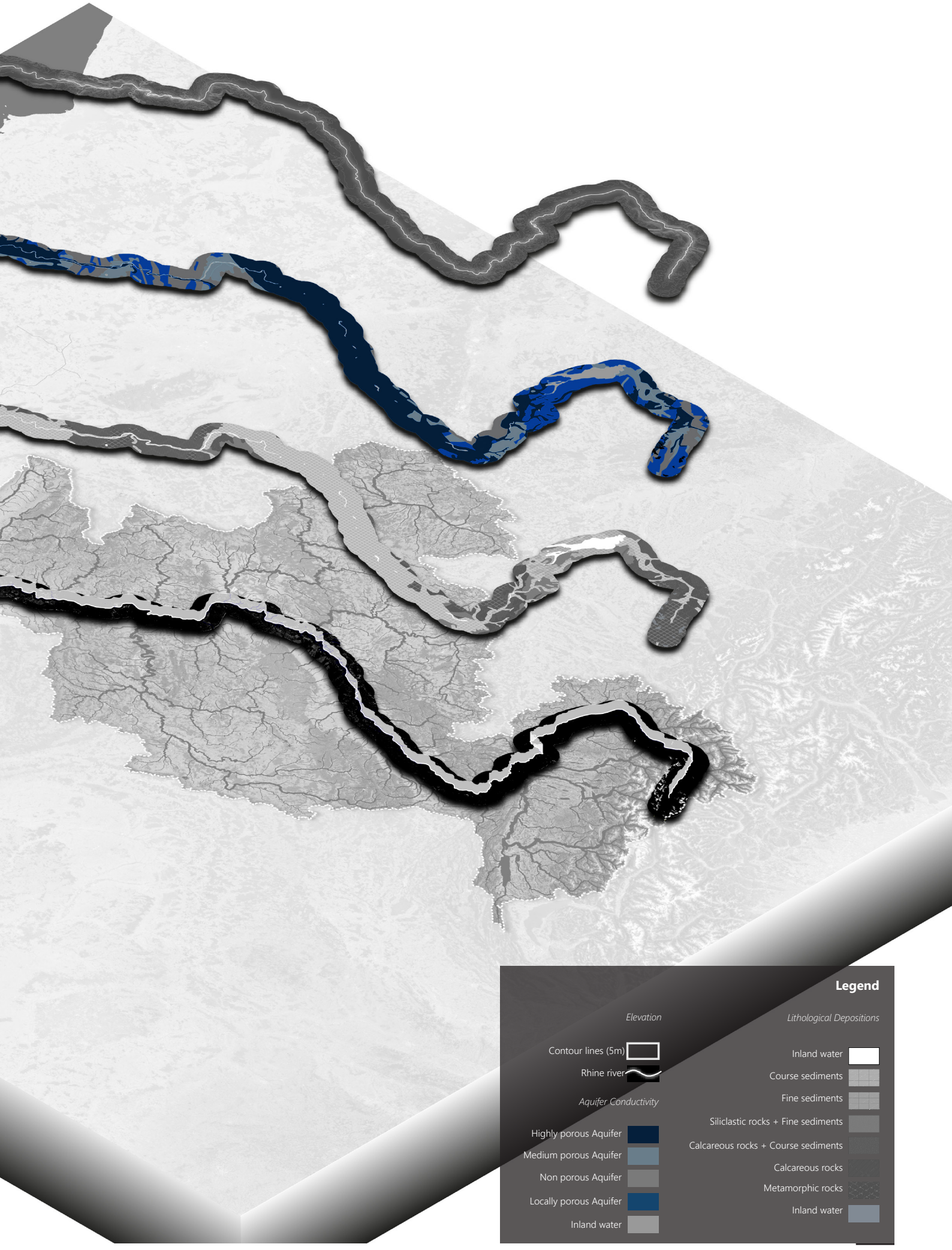


Figure 49: Geological landscapes of the Rhine. (Author, 2023).

Water Landscapes

The second layer of the Hydro-Social Territories is defined by the current water system. Without the water system, a territorial relation between man and the river can not be made. Here four main spatial layers are used to establish the newly created water landscapes of the Rhine.

Water board Regions

Besides the current spatial layers of the water system, an additional layer is created. This new exploration is derived from the establishment of the administrative units of the waterboards in the Netherlands, where the rivers act as the boundary of the administrative units for the management and responsibility of dikes (Lola Landscape Architects, 2014). As these borders are considered to be the courses of the rivers themselves, they form islands of land. The fact that these areas share the same land area, they become an interesting territory for managerial practices.

Drainage Network

The drainage network indicates the small subregions where the hydrological water system is drained from the source to the final destination of the Rhine and its tributaries. Whereas subbasins/catchment areas are often considered to only focus on the catchment of precipitation (in any form), drainage networks indicate the specific regions in which water is infiltrated in the underlying groundwater and aquifer systems.

Groundwater Bodies

The introduction of the groundwater body as a spatial area is made, concerning the fact that the urban and natural systems above share the same groundwater. The groundwater bodies form a spatial translation of the aquifers that stand in constant relation with the river and water system on the earth's surface.

Rhine River Subbasins

The Rhine River basin consists of multiple subbasins that are created based on hierarchical divisions of the Strahler River classifications and the geological catchment areas. These subbasins are divided based on the difference in intrabasinal elevation. This creates the notion that water that is introduced within a particular area is subdued to the territorial composition of the subbasin. This allows the main river basin to the divided into smaller regions that share the same source of water.



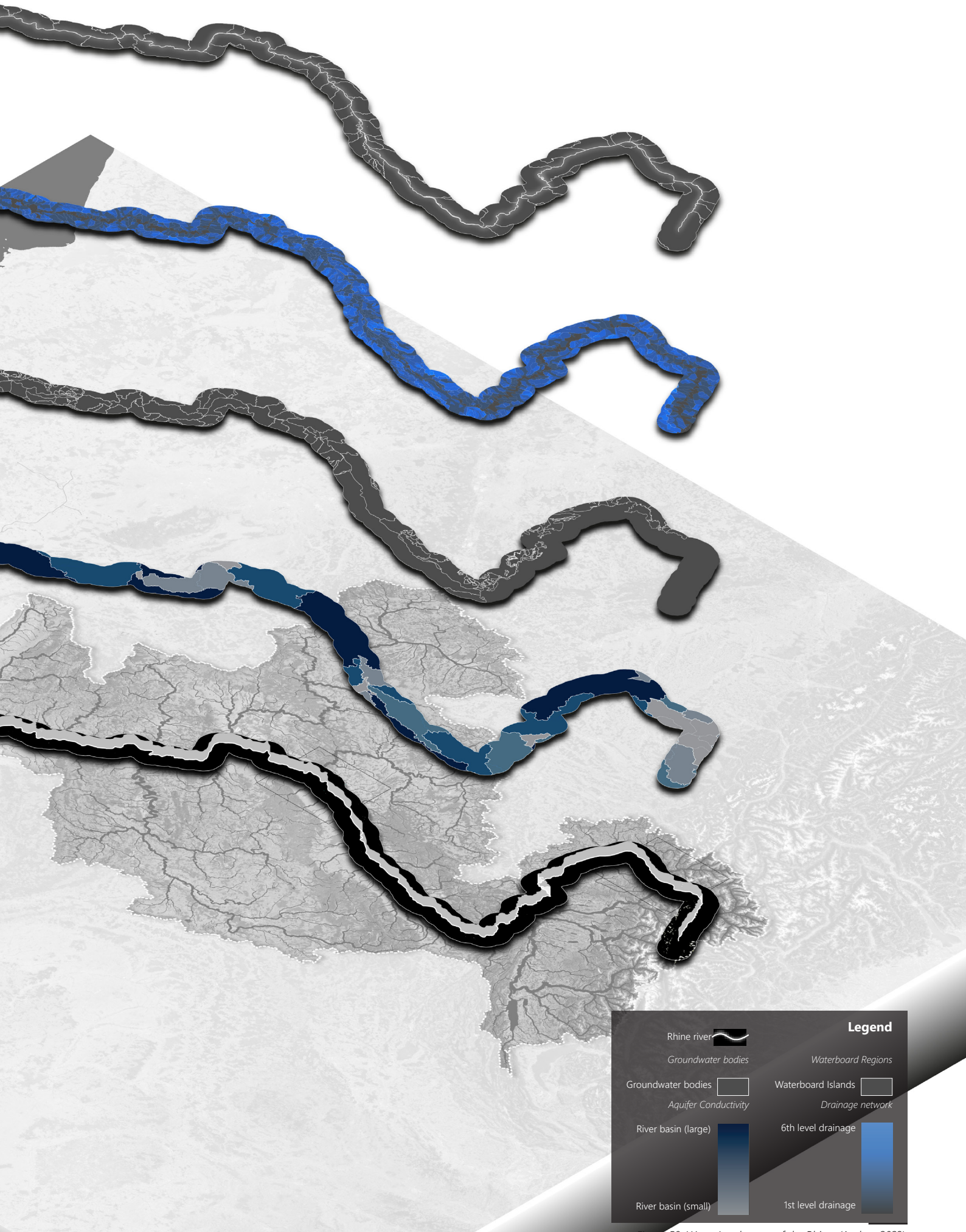


Figure 50: Water Landscapes of the Rhine. (Author, 2023).

Administrative Landscapes

The last layer of territories is defined based on the existing administrative regions of the Rhine. Here two major layers define the current extent of the administrative regions of dike management and the underlying classification of land use. Both of these layers have formed on the foundation laid out by the other two landscapes.

Administrative Regions

The administrative Regions indicate the different layers of administration due to the existing governmental bodies over different scales (Rhine Authorities, National, Regional, Local). These form the areas where decisions can occur and represent human interventions to territorialize specific regions.

Urban vs Non-Urban areas

Based on the European Classifications of what is considered to be Urban, Rural, and Non-Urban land, a basic interpretation can be made of the human-occupied vs 'natural' occupied space. Based on the interpretation of the main classification of land use, a different relation between man and water is established. Whereas urban regions often see the water as a resource for urban activities, Non-Urban regions often see it as a source of life.

Dike Management Regions

The regions that share equal administrative boundaries based on the level of authority decisions are made concerning dike management. These regions are defined based on the authorities responsible for dike and/or water management*

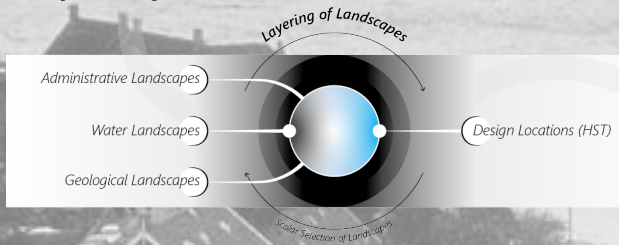
*Water management is also included as certain nations do not have responsible authorities specialized in dike management and is considered to be a component of the water management or Infrastructural sector (Austria, Switzerland, Liechtenstein)



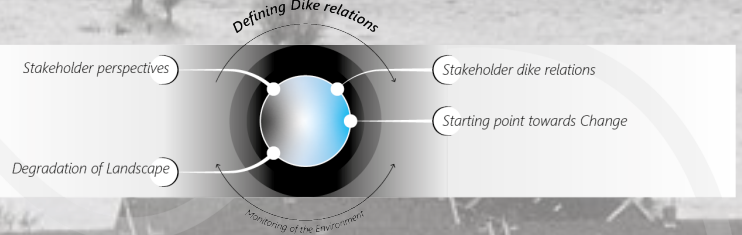


Figure 51: Administrative Landscapes of the Rhine. (Author, 2023).

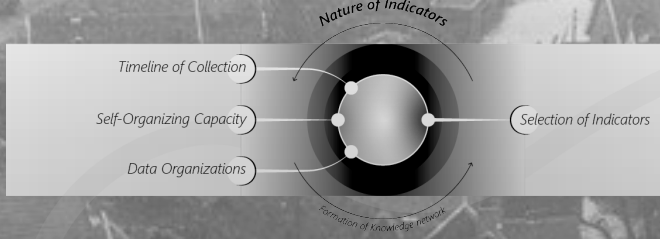
Step 1: *Design Locations (HST)*



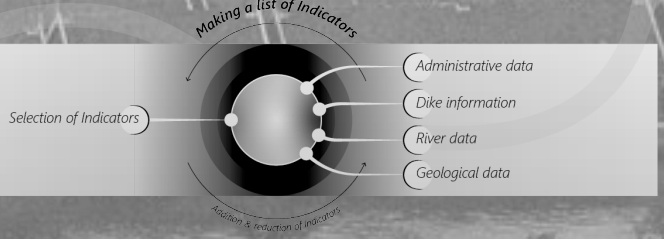
Step 2: *Urgencies*



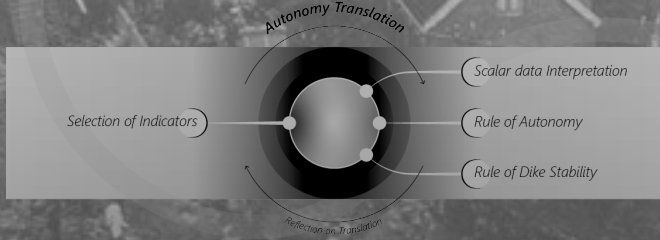
Step 4: *Knowledge Provision*



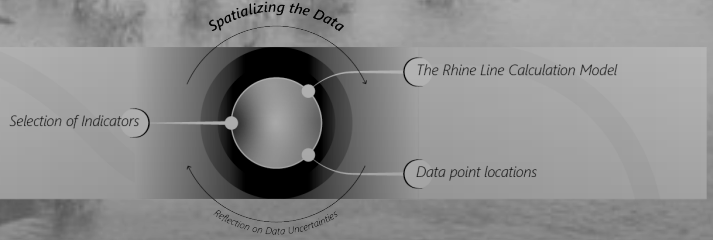
Step 3: *Indicators of Autonomy*



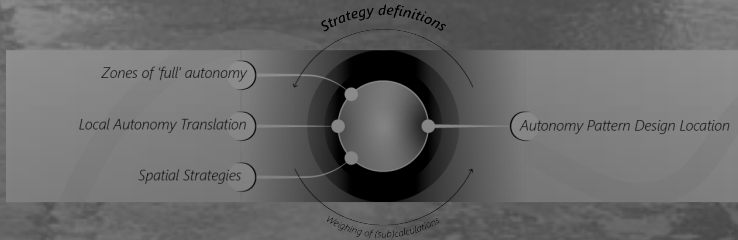
Step 5: *Translation of Indicators*



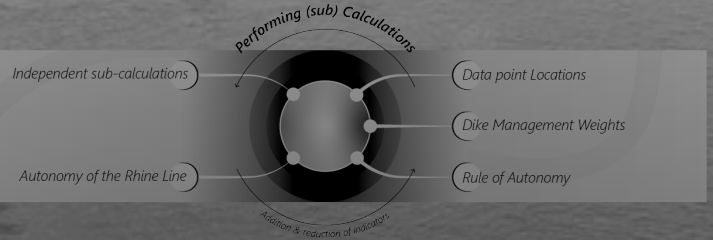
Step 5.1: *Spatialization Model*



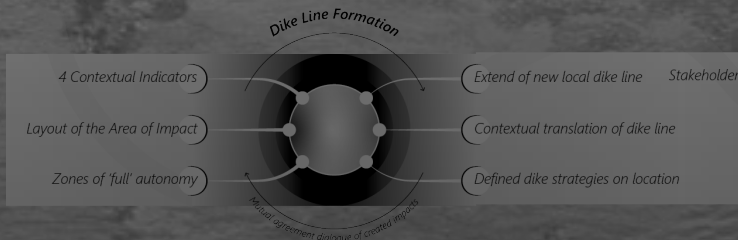
Step 7: *Defining Strategies*



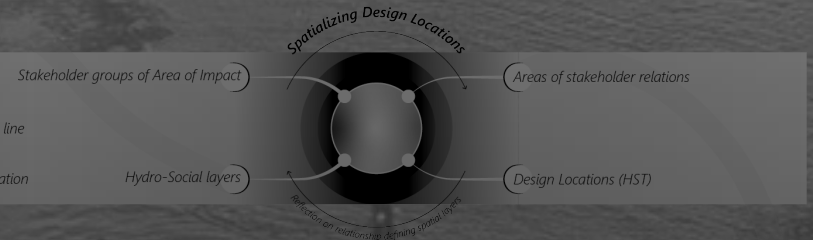
Step 6: *Calculation*



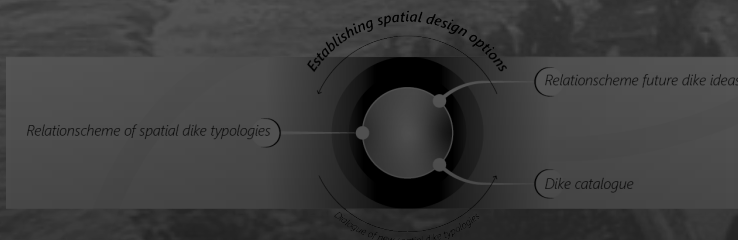
Step 8: *Dike Line Formation*



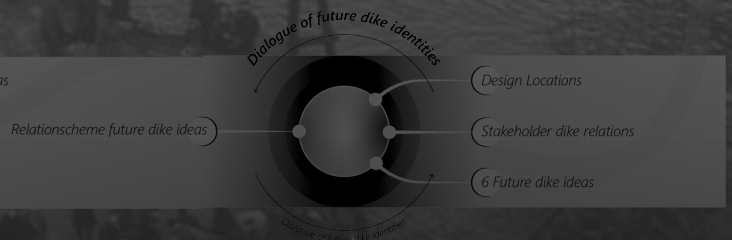
Step 8.1: *Design Locations (HST)*



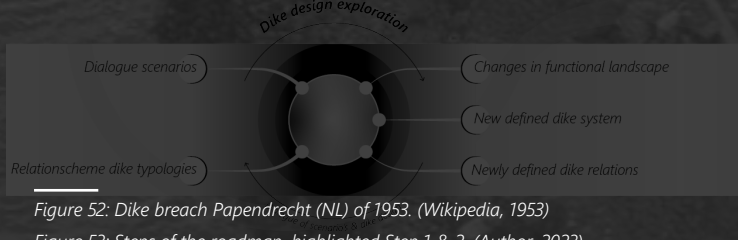
Step 10: *Spatial Dike Formation*



Step 9: *Future Dike Exploration*



Step 11: *Dike Systems*



Step 12: *Dike placement*

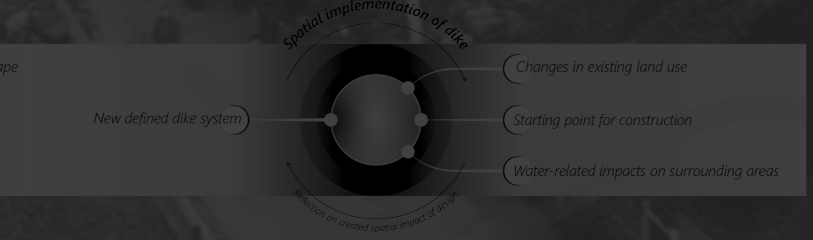


Figure 52: Dike breach Papendrecht (NL) of 1953. (Wikipedia, 1953)

Figure 53: Steps of the roadmap, highlighted Step 1 & 2. (Author, 2023)

08

Defining the Personal Urgencies

8.1 Dikes & Climate Change

Changes in Dike Decay

8.2 Dikes Management Actors

(Historical) Relations of Actors & Dikes

8.1 Dikes & Climate Change

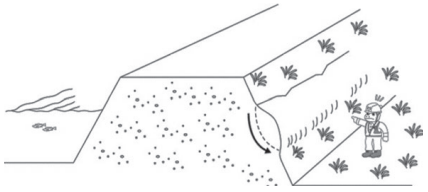
This chapter introduces the different indicators that need to be addressed and shown to local stakeholders for them to start looking out for impacts that can harm the existing dike line. Therefore this chapter introduces the physical elements stakeholders need to look out for that can indicate future threats of flooding and drought concerning their dike line. Additionally, this chapter introduces the main relations between the stakeholders of the CAS method (Meyer, et al. 2014) and their dike history. Therefore an analysis is made of the relationship stakeholders have with the dike. Therefore, two starting points are chosen that can start up the localized autonomy process concerning the spatial configurations and the managerial configurations.

Due to the increasing potential of flooding and drought alongside the Rhine (Stahl et al., 2022), the dike structures are subdued by more intense pressures of the river and the loss of structural integrity. Over time, when not maintained properly, dikes are starting to show signs of failure in their ability to retain their original function. Based on the 'Social Infrastructure Maintenance Book' provided by Yashima and Huang (2021), 9 potential signs of dike decay are created. These visualizations are important features in the initial steps of local dike management, as these signs could be used by local stakeholders to determine if they intend to start the process of local dike autonomy. In the map of the Alpine Rhine on the left, a spatial interpretation is made concerning 4 of the 9 potential signs of decay based on existing flood risks (BAFG, 2015) and drought possibilities (Cammalleri et al., 2021).

Sand Boils alongside the dike
During longer periods of high flow, the possibility arises that the dike line becomes over-saturated with water. Without any good seepage of the dike, the structural integrity of the dike starts to show boils, that eventually can lead to a dike breach.

Cracks along the floodplain
After a flood or period of high flow, it is recommended to control the surrounding area of the dike to look for cracks. Due to the force of the water, weak points along the floodplain and the dike line are exploited and are starting to show signs of decay in the form of cracks.

Uncontrollable seepage
During a period of high flow, without any direct seepage channels to distribute the water coming through and underneath the dike, the outer dike zone can be flooded whilst the dike line remains standing. Although the dike line could still be standing, the soil underneath the dike line is washed away, leading to increased risks of collapse in the future.



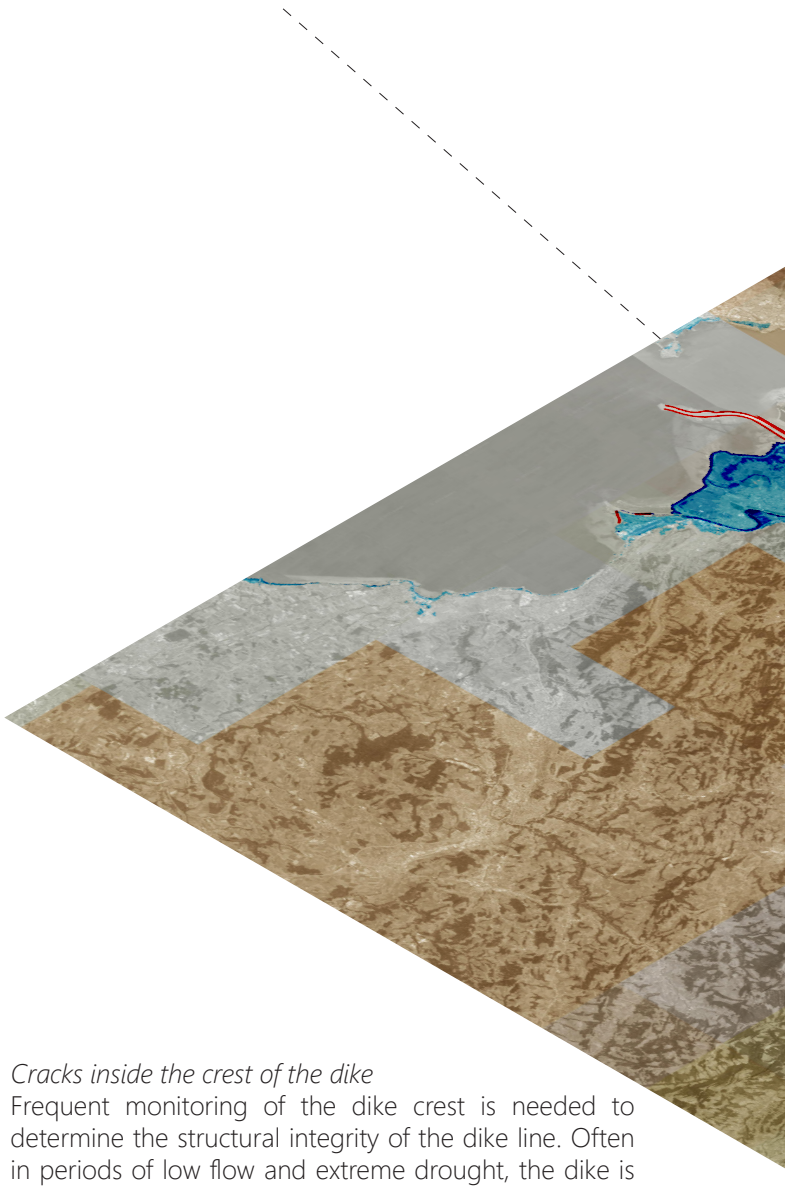


Sand boils alongside the dike

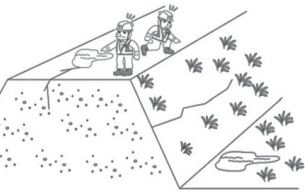




Cracks a

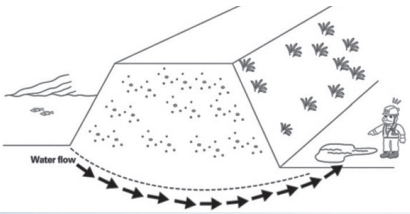


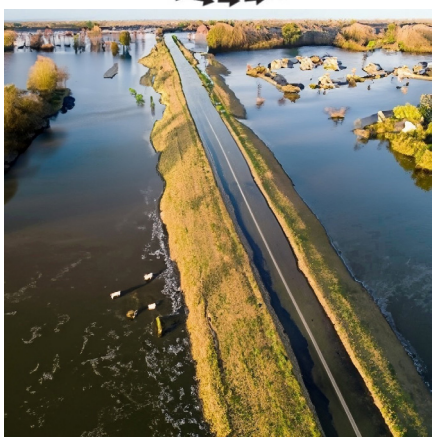
Cracks inside the crest of the dike
Frequent monitoring of the dike crest is needed to determine the structural integrity of the dike line. Often in periods of low flow and extreme drought, the dike is showing signs of degradation, forming cracks throughout its area. If not maintained, the stability of the dike line is lost, leading to the backland being more vulnerable to flooding.



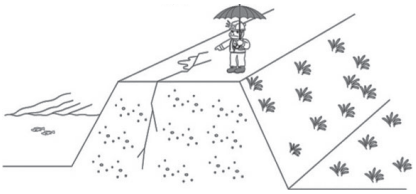


long the floodplain after flood





Uncontrolable seepage through the dike





Cracks inside the crest of the dike

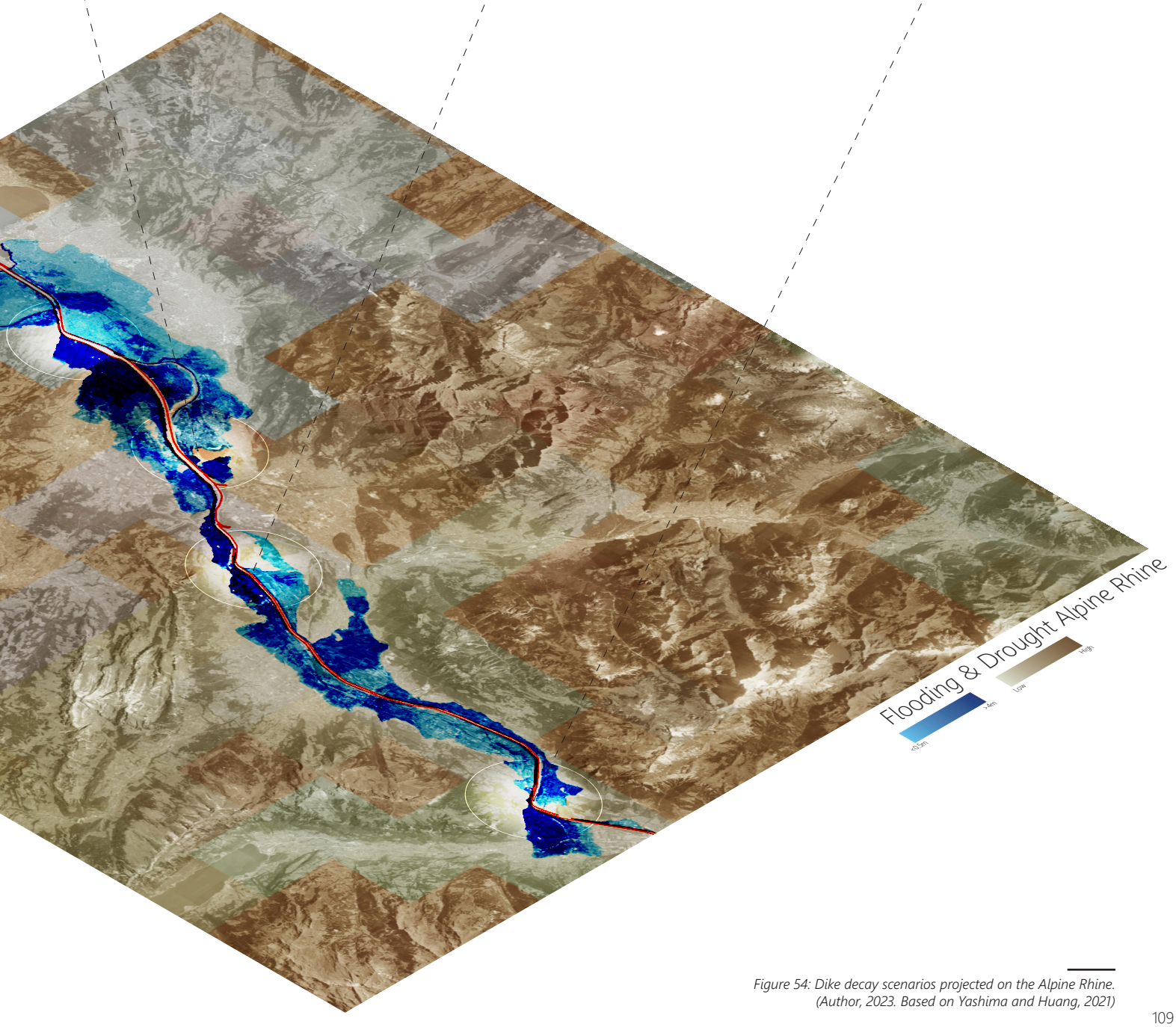


Figure 54: Dike decay scenarios projected on the Alpine Rhine. (Author, 2023. Based on Yashima and Huang, 2021)

Dike Management Actors

To make these steps of showing the steps to local autonomy in dike management more representative for large rivers across the world, we divide the stakeholders that are concerned with local dike management into 9 main stakeholder groups. The steps that are taken will show the impact it will have on these 9 main stakeholder groups. Therefore an understanding can be established on the relation between stakeholder groups and the dike management. For every stakeholder, a projection is made on the relationship between the respective stakeholder group and the dike as a spatial and management construction. This is facilitated by the historical relevance of the dike in relationship to the main practices of the stakeholder groups. Additionally, a future prediction is made as shown in figure 55 based on the future projection of the dike as a transitional element. Note, that this is an interpretation that is made based on the larger stakeholder groups. Individual stakeholders from these groups might have different relations.

The Agricultural Sector

The relationship between the agricultural sector and the dike management sector is considered to be a positive mutual relation, it protects existing low-lying agricultural land from extreme water. The first dikes were created by local farmers to keep their farms protected from extreme flooding (Lola Landscape Architects, 2014). Dikes continue to shield fields from water damage and enable efficient irrigation, highlighting their enduring significance in sustaining agriculture. But increasing periods of high and low water flows, danger the water use of the agricultural sectors. Dikes are becoming more of a border within agricultural water management. Although solutions are already present within existing practices to bypass the dike as a border within water management, increasing pressures on dwindling and increasing water resources put large uncertainties within the agricultural sector. Self-organization of these dike bodies has become increasingly more difficult for local agricultural practices as the safety regulations and dike regulations set by regional and national authorities increase the maintenance and construction costs of dikes.

The Energy Sector

The relationship between the energy sector and the dike management sector is considered to be a relatively neutral relationship. Large energy sectors along the Rhine depend on a stable water source. Therefore energy power plants are often located right on the edges of rivers as they need the source of water to retain energy production. Besides, large power plants often integrate the spatial dike elements within their practices leading to secondary compartment dikes as part of industrial facilities. Additionally, they often serve as routes for transmission lines, facilitating the distribution of electricity. Therefore, dikes have a multifaceted relationship with the energy sector, simultaneously protecting it from natural hazards and contributing to sustainable energy production and distribution. But as changes in the resource of water can hamper energy production over time, dikes could become a boundary between production and water resources.

The Transportation Sector

The transportation sector along the Rhine River is primarily dedicated to the useability of the river as the main source of transportation of goods, people, and other services. But in the areas where the Rhine is not considered to be a navigable passage for transportation vessels, the sector is primarily dedicated to transport on roads and railways. Their main stand on dikes is related to retaining a constant flow of water and protecting connective infrastructure from the forces of the river. Therefore their relationship with the dikes is primarily related to creating a secure environment where connectivity, either on roads or waterways, can be maintained.

Nature and Ecology Organizations

The nature and ecology organizations represent the areas that are part of the Natura 2000 regions along the Rhine. Dikes are seen by nature and ecology organizations as spatial elements that disrupt the flow of the natural system. Historically seen, dikes were subdued by the forces of nature leading to plenty of large floods throughout the Rhine's history (Redeker, 2012). Although the current nature of the dike is seen as a large boundary between areas, it also facilitates nature. Dikes often support vegetation growth, serving as green corridors for plants and animals. These linear habitats facilitate the movement of species and contribute to landscape continuity. Programs related to LIFE+ and the projects of the IKSR have established more natural water passages to make sure the river can be a source for nature as well (BAFG, 2015). But as climate change starts to show more extreme weather scenarios, the future of the natural areas along the Rhine is uncertain.

Soil and Water Organizations

Soil and Water groups are nature-oriented organizations that are concerned with the quality of soil and water. Although the industrial areas around the Rhine use water conform to European and national legislation (IKSR, 2021), soil and water quality are still considered to be harmful. Only after the industrialization of the Rhine, the quality of the water of the Rhine dropped with the Sandoz incident of 1986 being its lowest point. With natural retention restorations taking place in Germany and France and the agenda of the IKSR focused on the quality of water (IKSR, 2020), progress has been made.

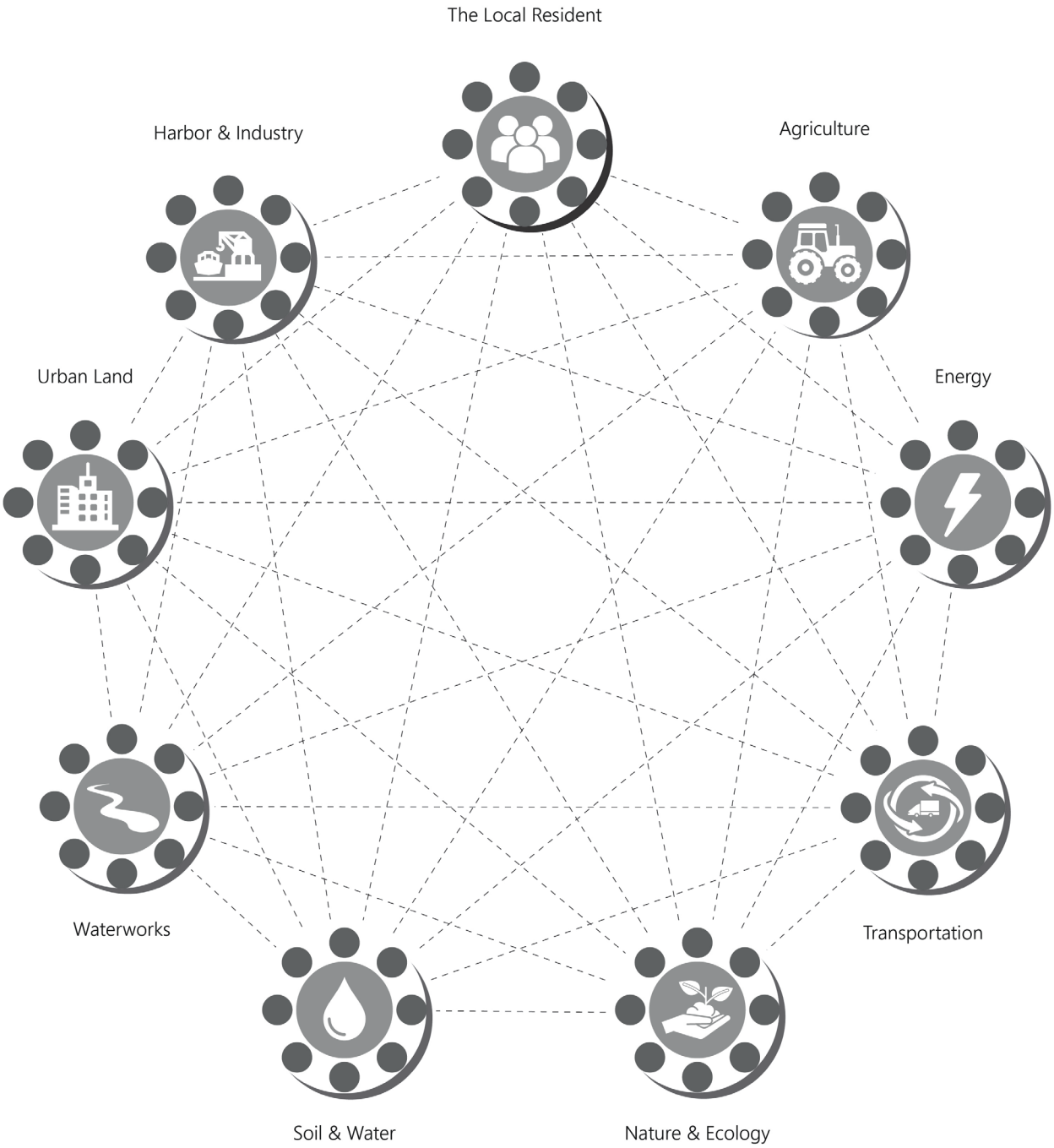


Figure 55: Complex Adaptive System Stakeholders. (Author, 2023. Based on Meyer et al, 2014)

However, the projection of more droughts in the future could increase the saturation of pollutants in the water causing harmful effects on water and soil qualities.

The Waterworks Sector

The historical connection between dikes and the civil engineering sector is profound. Dating back centuries, dikes represent some of the earliest and most impressive feats of civil engineering. This historical relationship underlines the critical role of civil engineering in managing water resources and protecting human settlements. The goal set out to reduce flooding potentials in the Rhine by 15% (IKSR, 2020), indicates the importance of dikes in facilitating protection against the river. As the integration of dike protection becomes a more difficult challenge due to the lack of space within urbanized regions and the integration of natural retention zones in open land, new dike technologies are needed to allow future generations to retain dry feet, whilst also facilitating additional functions.

The Urban Development Sector

The historical relationship between dikes and the urban sector is characterized by the important role dikes have played in protecting cities and enabling urban development in low-lying areas. Therefore dikes have been an instrument in shaping and preserving the urban environment. As urbanization along the Rhine keeps increasing, more land is to be protected. Furthermore, more frequent extreme weather events make urban areas even more vulnerable to flooding. To address this, innovative urban planning integrating resilient dike systems is gaining importance. New dike possibilities like the multifunctional dike (Rengers & Hofmeijer, 2019) and integrated waterfront parks and nature areas, not only create a protective layer but can be integrated with the urbanized regions.

Harbour & Industrial Sectors

The historical relationship between dikes and the industrial sector is rooted in the need for flood protection to ensure that industrial facilities can work uninterrupted. Industrialization in regions like the Netherlands and the Ruhr led to the development of dike systems to protect factories, refineries, and transportation infrastructure. This relationship with dikes is based on a local level, where these dike systems are often owned by large industrial facilities. As the large manufacturing facilities of the Ruhr and the chemical facilities of Ludwigshafen need a constant source of water, they are probably keen on extending the dike lines of the Rhine, to make sure a constant source of water is still present in periods where water is scarce.

The Local Resident

The historical relationship between dikes and residents is one of reliance. Throughout history, communities settling in lower-lying areas of the Rhine have relied on local dikes for protection against floods and to use the dikes as a means of water distribution. But as the dikes have been around since the first developments of the 12th century (Redeker, 2012), the awareness of risks concerning flooding has significantly dropped along the Rhine (NOS, 2021). As evacuation protocols are still implemented by local, regional, and national governments, the question remains whether these protocols are distributed quickly and how people will react. The major flood of Ahr has shown the unpreparedness of German authorities in the gaps of warning systems and evacuation protocols (Mohr et al. 2021).

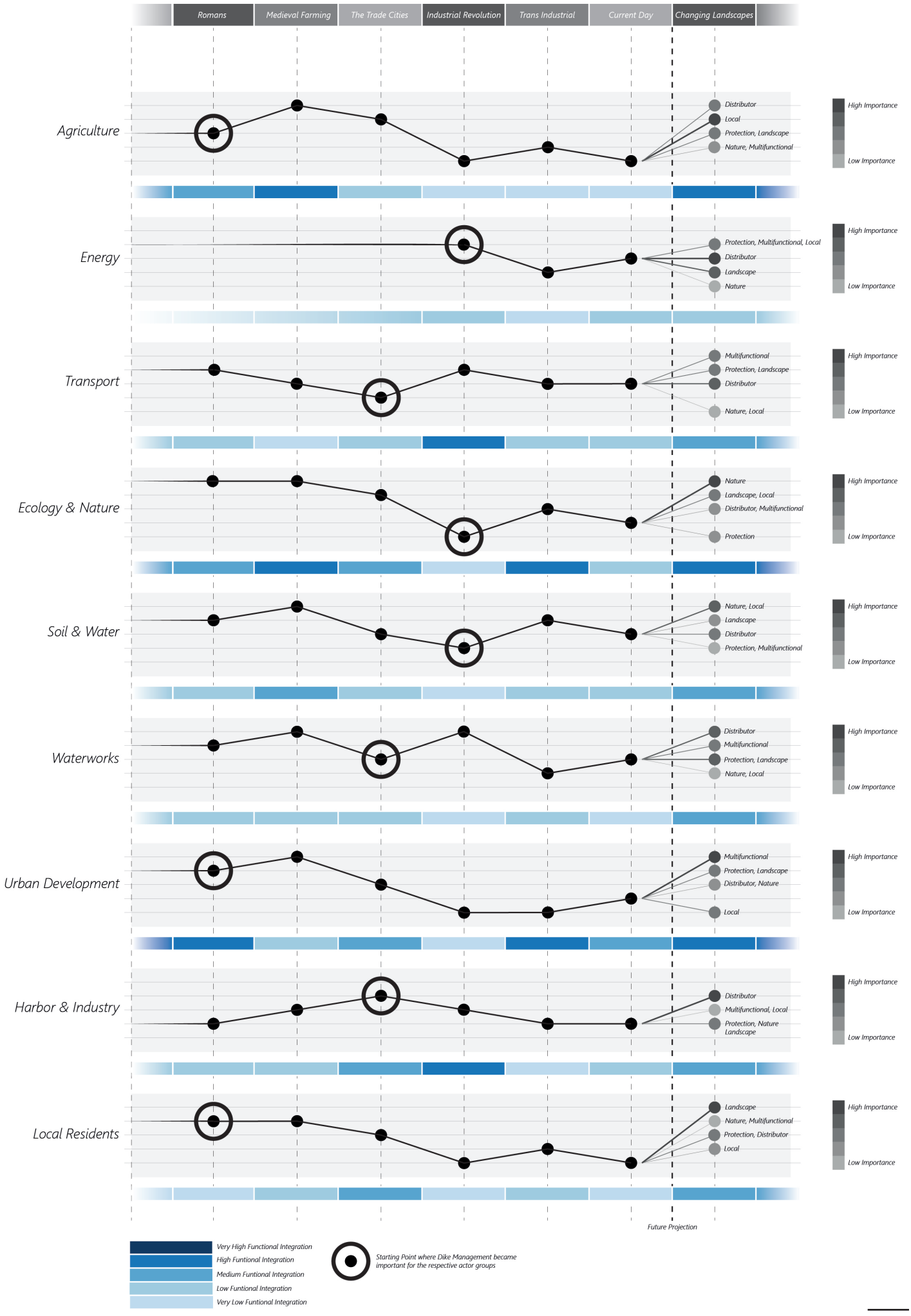
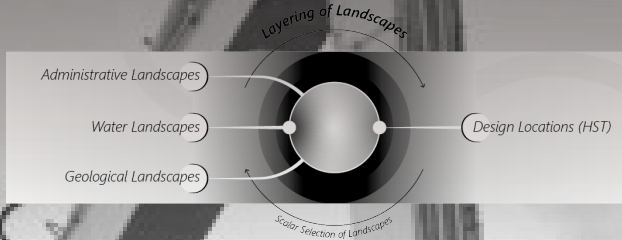
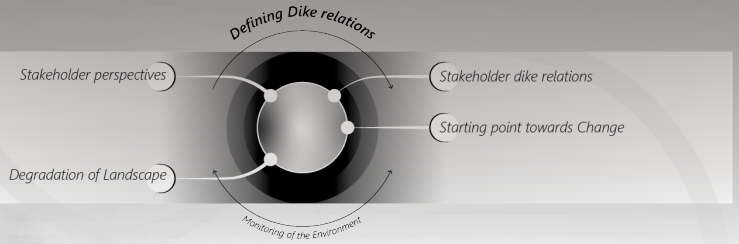


Figure 56: Stakeholder relations with dikes. (Author, 2023. Based on Redeker, 2012)

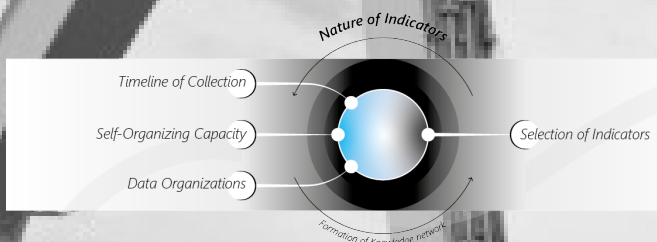
Step 1: *Design Locations (HST)*



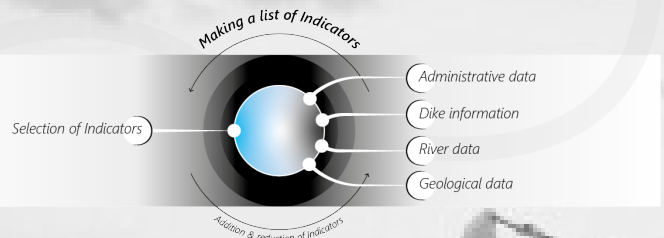
Step 2: *Urgencies*



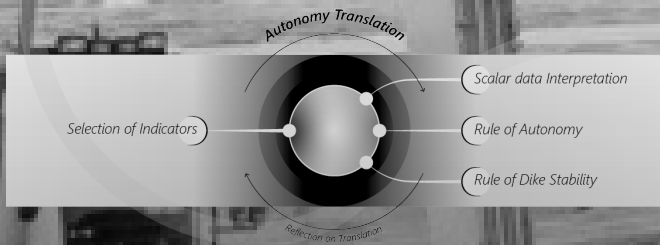
Step 4: *Knowledge Provision*



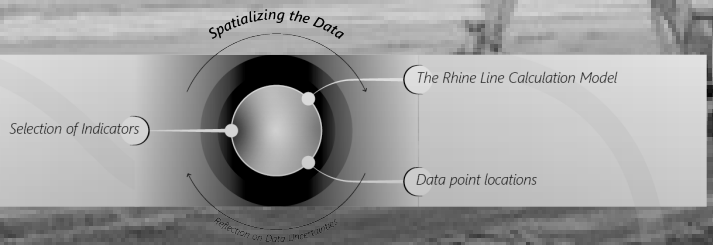
Step 3: *Indicators of Autonomy*



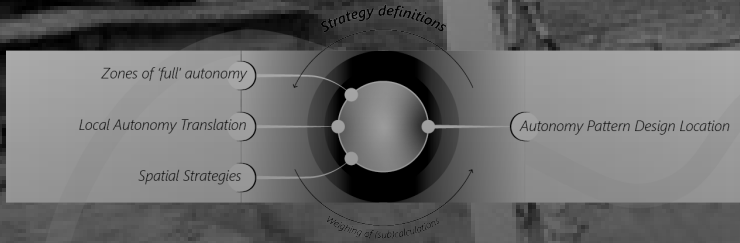
Step 5: *Translation of Indicators*



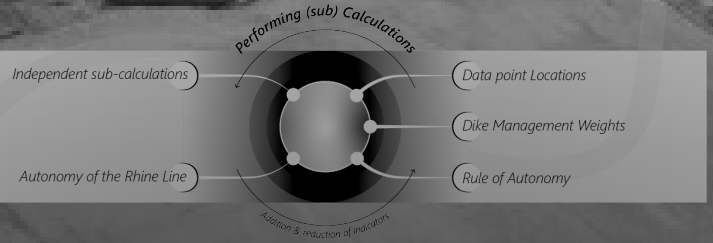
Step 5.1: *Spatialization Model*



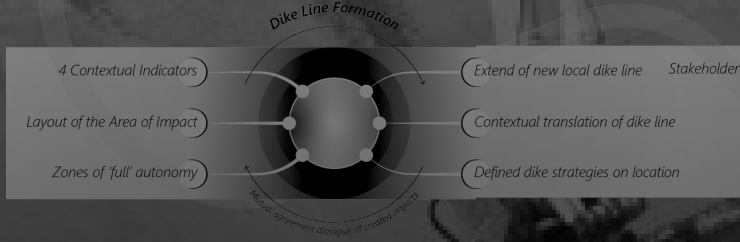
Step 7: *Defining Strategies*



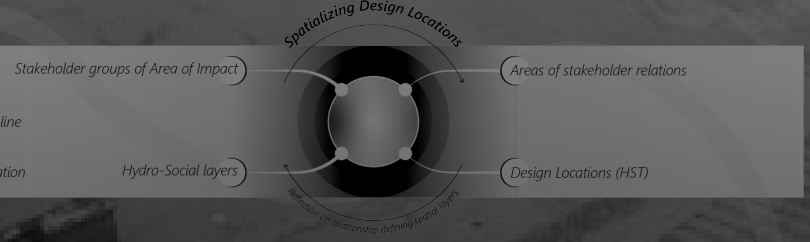
Step 6: *Calculation*



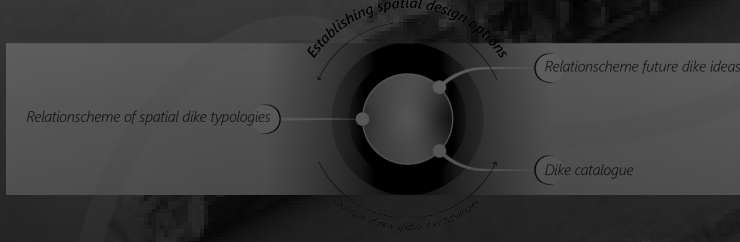
Step 8: *Dike Line Formation*



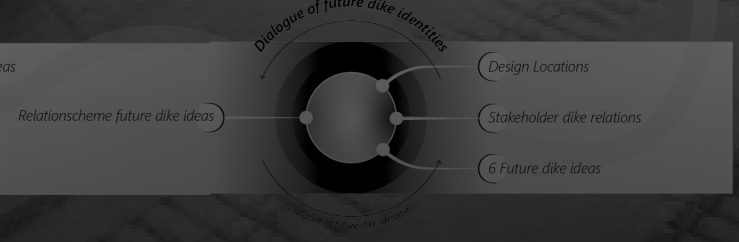
Step 8.1: *Design Locations (HST)*



Step 10: *Spatial Dike Formation*



Step 9: *Future Dike Exploration*



Step 11: *Dike Systems*



Step 12: *Dike placement*

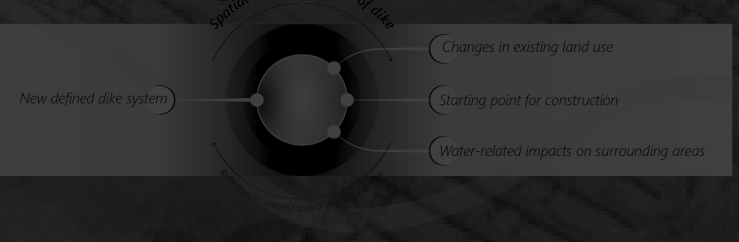


Figure 57: Construction of Dike-in-boulevard Katwijk. (Lola Landscape Architects, n.d.)

Figure 58: Steps of the roadmap, highlighted Step 3 & 4. (Author, 2023)

09

Knowledge Provision of Data

9.1 Gathering the Information

Identify of the Variables for the Data Calculations
Position in the Knowledge System

9.2 Data Providing Authorities

9.3 The Variables of the Information

Scalar Data Interpretations
List of Data Scales Used in This Report
The Time Process of Gathering

Gathering the Information

Identify of the Variables for the Data Calculations

The primary reasons for changing the existing dike autonomy toward localized dikes are confronted by certain indicators that play different roles during the management of the location. The information necessary to understand the possibilities of creating local dike management arrangements can be collected by various actors. To comprehend the sources of this information, as a local actor, the identification of the newly defined Hydro-Social Territory (HST) addresses the available expertise and knowledge present by other stakeholders. This doesn't mean that the information you gather can be directly used in local dike management, but it means you can contribute to the initial steps in understanding your local dike conditions.

Position in the Knowledge System

The main principle of local autonomy is to understand that the knowledge should be gathered as locally as possible. Only then an understanding be formulated of what additional information has to be gathered from other sources. These steps are the initial stages in creating knowledge platforms in dike management. To understand the position that local stakeholders can occupy in data production and collection, we must understand their potential role in the knowledge sector. The knowledge sector is a holistic concept that defines, for each country, the set of knowledge institutions, actors, and their interconnectedness (Hertz et al., 2020). These interactions can enhance the availability of knowledge to inform local policymaking or empower local stakeholders. Various actors involved in this sector are linked to one of the four roles they can play within the knowledge sector:

(1). *Knowledge Producer:* Often the supplier of data itself, mainly universities, research centers, and other research organizations.

(2). *Knowledge Users:* Demand knowledge to gather evidence for policymaking, including government agencies, public authorities, and other agencies that translate data into policymaking.

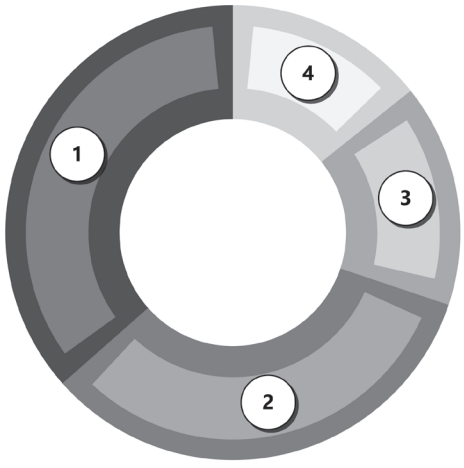
(3). *Knowledge Intermediaries:* Engage in debates over data through public discourse around policy issues. They primarily consist of civil society organizations and the private sector, offering direct input on the information needed to be produced or collected.

(4). *Knowledge Enablers:* Govern the funding and regulation of data generation, comprised of regulatory public authorities and public and private funding bodies.

How to Obtain the Necessary Information for Local Dike Management

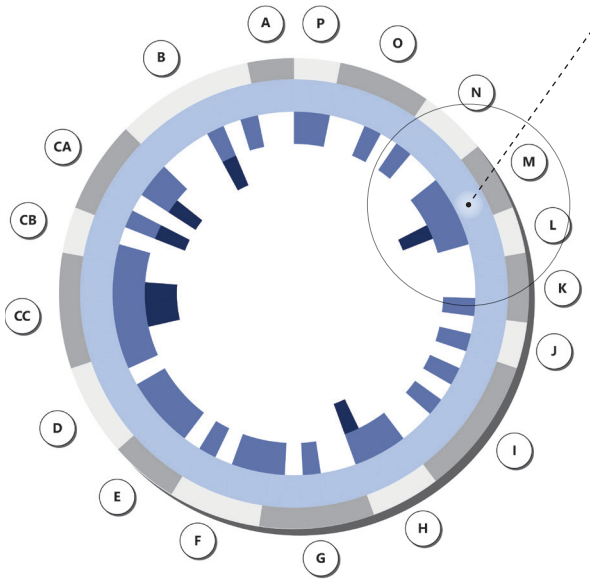
Local stakeholder groups have expressed a high need for information to understand their potential in creating a localized dike line. The stakeholder groups that make up the Hydro-Social Territory provide some of the data locally, while other data cannot. Therefore, every potential stakeholder in dike management is analyzed based on their interaction with the indicators in their daily activities. This analysis concludes that specialized stakeholder groups within the Energy, Industrial, and Urban Development sectors are better positioned to understand their roles and abilities within the water management decision-making process. On the contrary, nature-related organizations have greater capabilities for interpreting information related to underlying soil and river conditions. Due to their influence on national and regional legislation, they also have a significant role in the decision-making process. Although the Waterworks sector is one of the only stakeholder groups that understand the knowledge concerning dikes and other civil engineering constructions, there are potential indicators that can be collected at a local level. For example, residents could use a checklist to list the current spatial elements on and around the dike, gaining information about the type of dike they are dealing with.

To provide an example of the ability of four out of the nine stakeholders to gather information, a brief description is provided below:

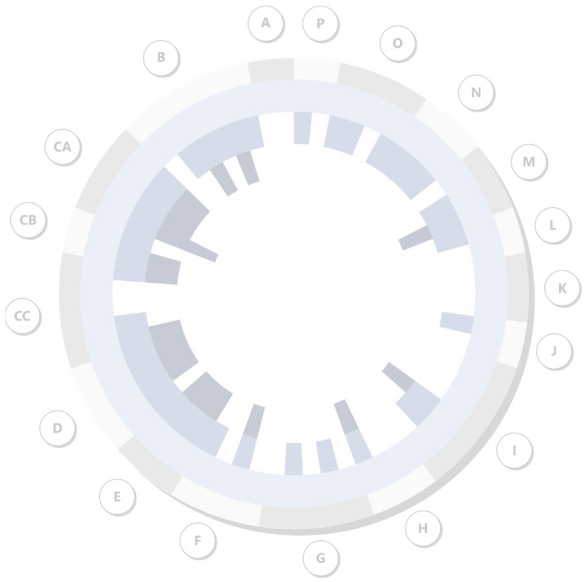


(1). *Authoritative Indicators*
(2). *Dike Indicators*
(3). *Suitability Indicators*
(4). *River Indicators*

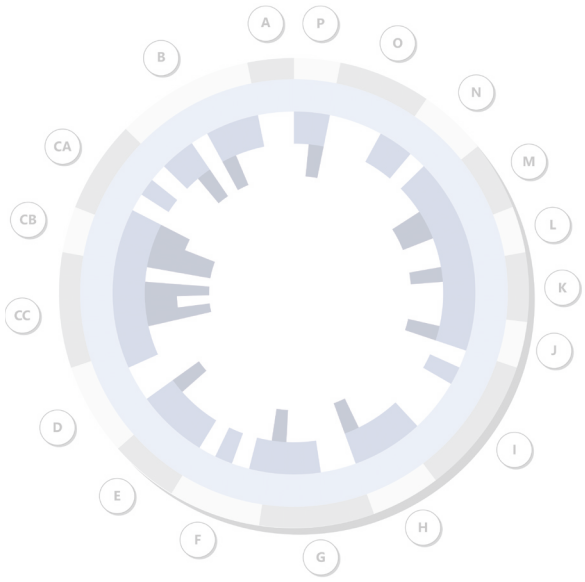
Figure 59: Explanation scheme of the distribution of the 4 main indicator groups. (Author, 2023)



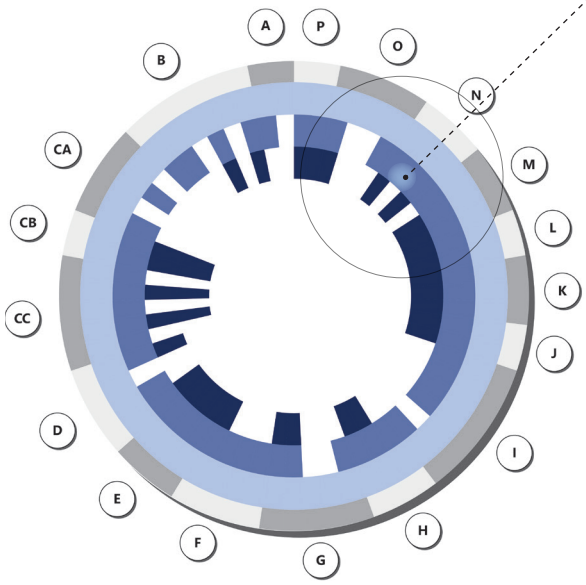
The Agricultural Sector



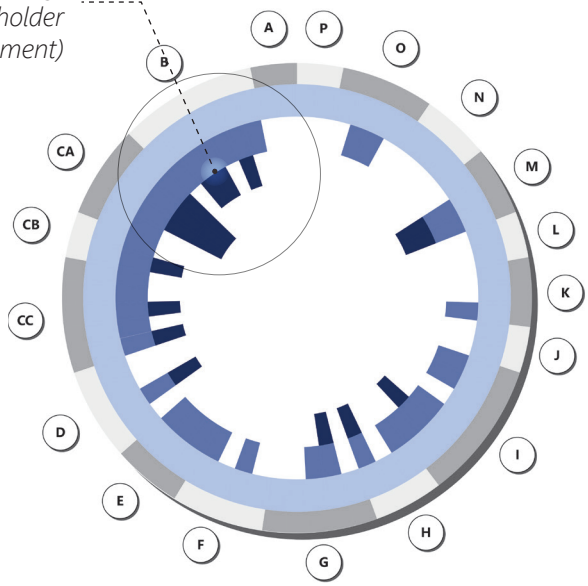
The Energy Sector



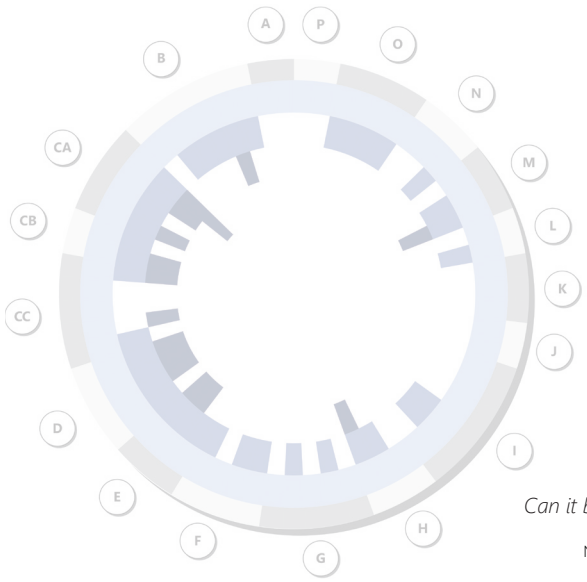
Nature & Ecology Organizations



Soil & Water Organizations



The Urban Development Sector



The Industrial Sector

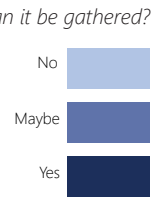
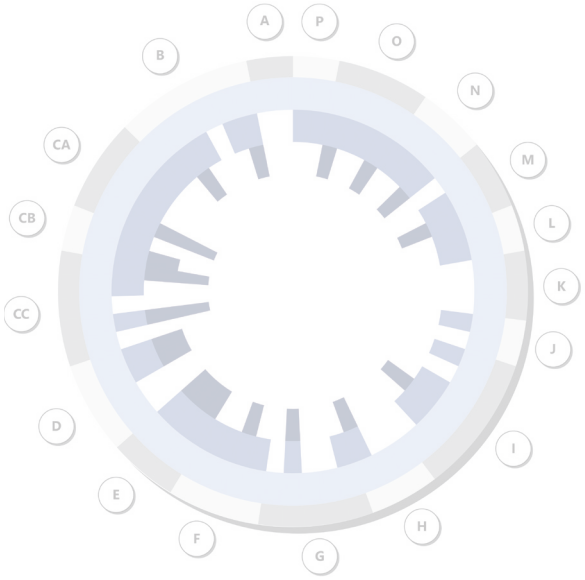
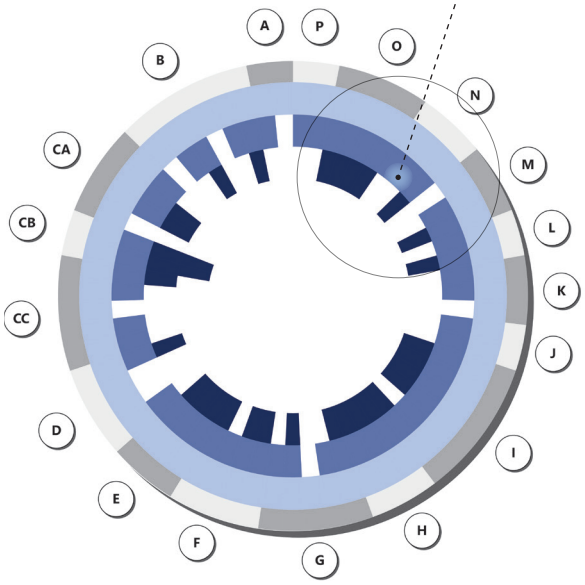


Figure 60: Ability of stakeholder groups to gather information regarding the used autonomy indicators. (Author, 2023)

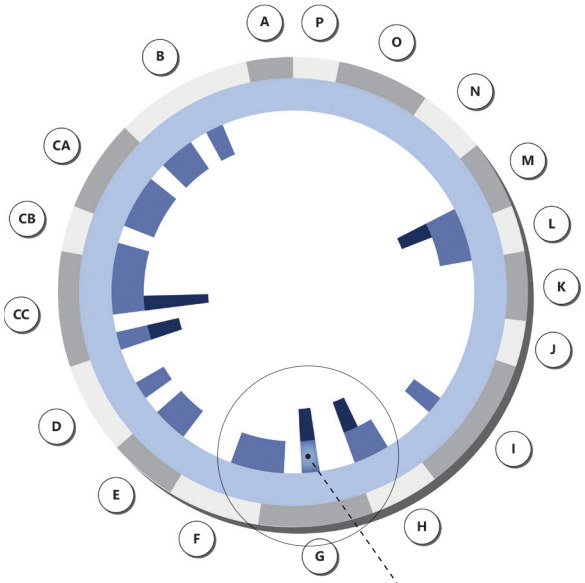


The Transportation Sector

O: River discharge numbers



The Waterworks Sector



The Local Resident

G: Spatial dike profiles

(1). *The Agricultural Sector & N: Additional Spatial Indicators:*

Large areas of the Rhine are dedicated to agricultural lands. Therefore, local farmers play a significant role in dike management. As the agricultural sector relies on a constant flow of water to sustain their agricultural production, they can provide information for the autonomy calculation. For instance, farmers possess exceptional knowledge of their land, which can facilitate information regarding the spatial characteristics of the area suitable for dike construction. Their understanding of changes in slopes and the local water system is beneficial for planning future dike lines.

(2). *Soil & Water Organizations and Waterworks Sector & O: River Discharge:*

Despite the technical and natural water sectors having opposing views on the use of dikes, their combined ability to provide information is advantageous for data provision. While the waterworks sector can offer data on river discharge numbers in the existing situation, soil and water organizations can enhance this information by comparing it to the existing water system. This collaboration allows for the creation of future discharge projections and an understanding of their impact on groundwater conditions.

(3). *The Urban Development Sector & B: Decision-Making Autonomy:*

The urban development sector is often directly related to local governmental authorities, as they are the primary project developers for new urban development. This sector, which includes urban planning offices, project developers, and building contractors, has easier access to information about available funding and stakeholder involvement when a project is initiated. At the level of HST, this enhances decision-making autonomy, as it provides information on the feasibility of dike construction.

(4). *The Local Resident & H: Spatial Dike Profiles:*

The somewhat technical data used to calculate the autonomy rate allows residents to partly contribute to the knowledge provision of the HST. On a local basis, residents can assess the existing dike areas based on spatial characteristics. This involves creating a checklist of spatial dike features, such as tree lines, side ditches, sheep, land posts, and urban activity. This not only adds to the overall knowledge of calculations but also translates the systematic calculations into a comprehensible narrative for the residents to understand.

Additional details regarding the abilities of the nine stakeholders to gather information based on the project's indicators can be found in the appendix 16.1.

Data Providing Authorities

Who is responsible for gathering the necessary data to understand local dike management?

The data used in this report comes from various sectors, from political landscape understanding to specialized geological data on sedimentation and lithological patterns. It also includes information about spatial dike elements and measurements of the river nearby. While some of this information can be easily gathered at the local scale, the main information must be derived from other knowledge users and producers in the public and private sectors. Governments are mandated to publish open-source data that is freely available, including data on social, economic, geographical, cadastral, and business information (Carrara, 2018). Although some local governments may lack the capacity for open data portals, the possibility remains. When local governments can't provide access to data, larger-scale governments might. Therefore, it's essential to start as locally as possible and then move up to regional and national databases. For example, national authorities can provide in-depth statistical data on the GDP rates, and groundwater conditions, whereas local authorities are closer to the ground allowing for more data to be present on existing dike lines and the water system.

In addition to the public sector, there are knowledge producers that facilitate the production of specialized data. Research institutions like BGR and GEMstat, GRDC, BAFG, and Copernicus provide European-based spatial data on geological and water systems. Organizations like Eurostat and the European Environmental Agency offer European-based data on economics, demographics, and climate. Universities and research organizations like

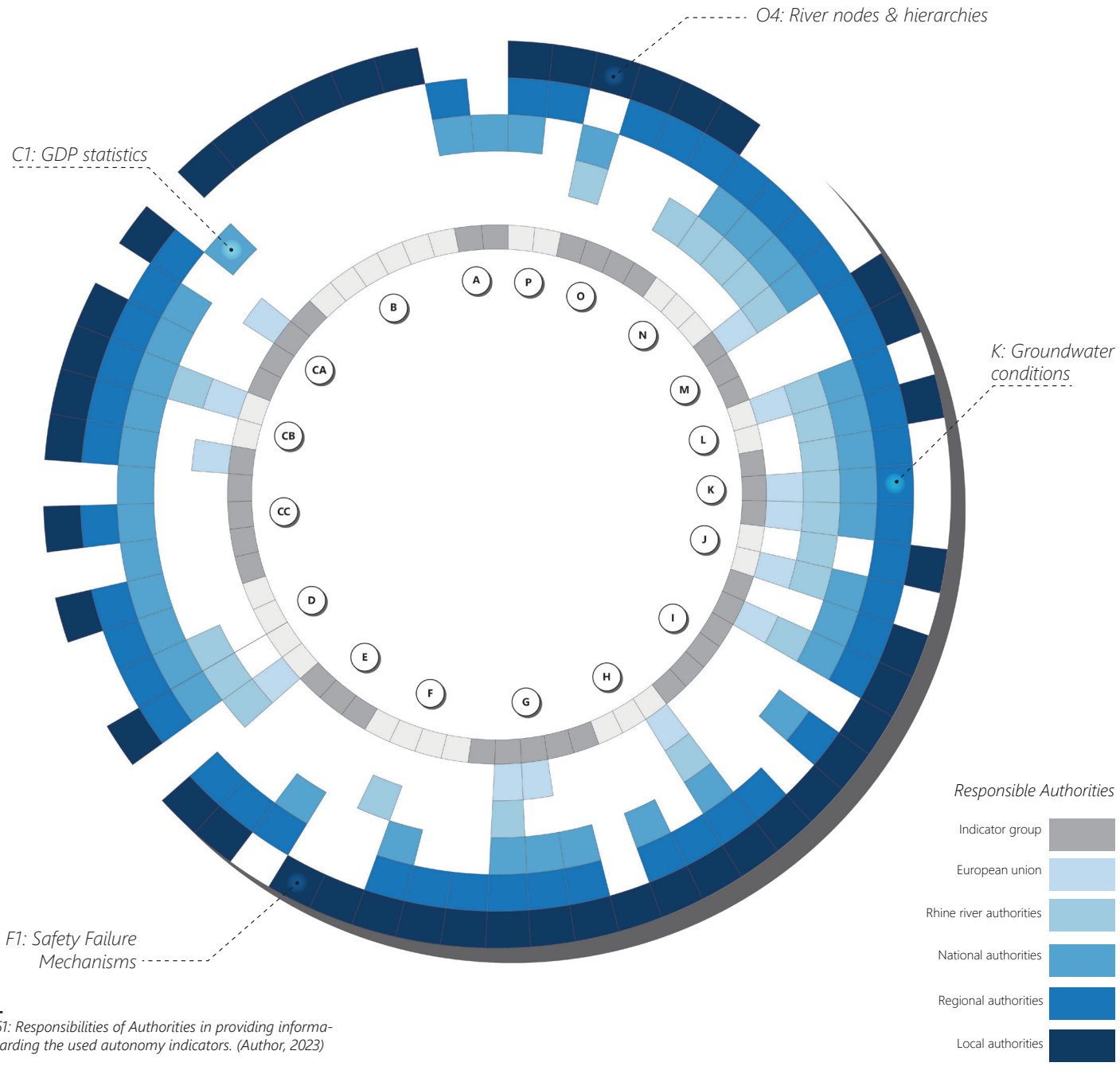


Figure 61: Responsibilities of Authorities in providing information regarding the used autonomy indicators. (Author, 2023)

Deltares provide information for the Rhine region.

These mentioned authorities could help facilitate the knowledge that can not be produced or gathered on a local basis, depending on the stakeholder compositions of the HSTs.

The Variables of the Information

The information required for local dike management ranges from pure technical data on soil conditions to extensive management arrangements related to national politics. Therefore, understanding the differences in data types and the time needed to collect this information is crucial. These insights help identify which types of information take longer to gather for local dike management, which data collections need to start earlier than others, and the spatial scales at which this information should be collected.

Scalar Data Interpretations

As this reports introduces the steps that are needed to take to indicate the local potential of autonomy within dike management to arise, the need for spatialized data is

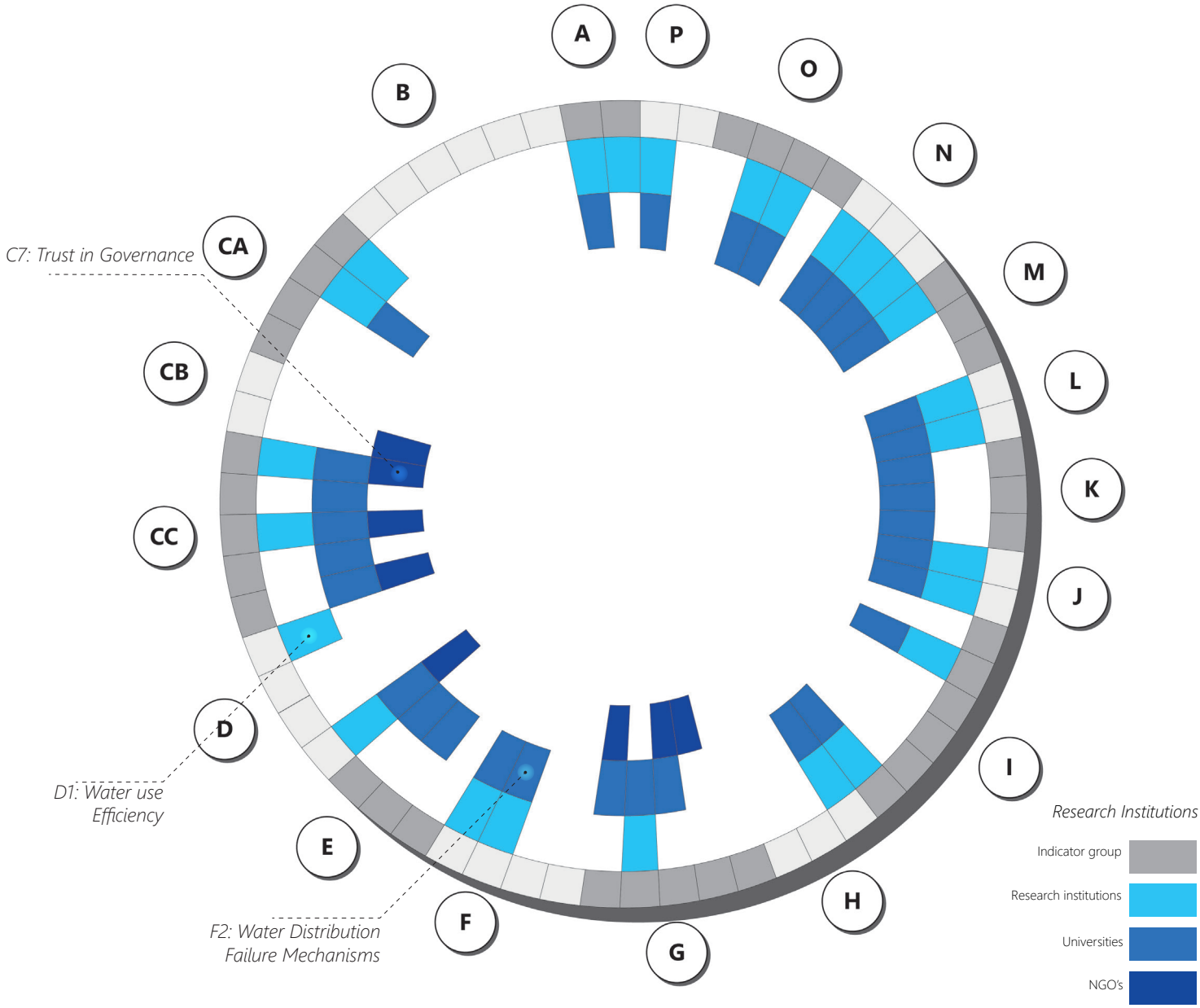


Figure 62: Provision of information by research institutions regarding the used autonomy indicators. (Author, 2023)

vital. Therefore this report uses a large amount of various data that is translated into the potential for autonomy. Although this quantitative process tries to explain the translation to autonomy as detailed as possible, uncertainties do arise within the scalar interpretation of the data used. Therefore this report shows the nature of the data used in the next scheme.

List of Data Scales Used in This Report:

- *Locally gathered data* (Local Scale).
  Local data includes a wide range of point data that can be collected from the spatial layout along the Rhine. This data encompasses all the features of the dikes, water bodies, and the locations of groins.

- *Land Use related data* (Local Scale).
  This category includes data projected onto existing land use classifications from Copernicus (2018). It is used to indicate water use and the decision-making autonomy of the stakeholders.

- *National scale data* (National Scale).
  National-scale data includes information projected onto the nation-states along the Rhine. This data encompasses existing water and dike management relations and national policy indicators.

- *Regional scale data* (Regional Scale).
  Data at the regional scale is projected onto different regional scales used to classify NUTS regions. This information can be related to GDP rates and the larger impact data of dikes, including their effects on dike bodies both upstream and downstream.

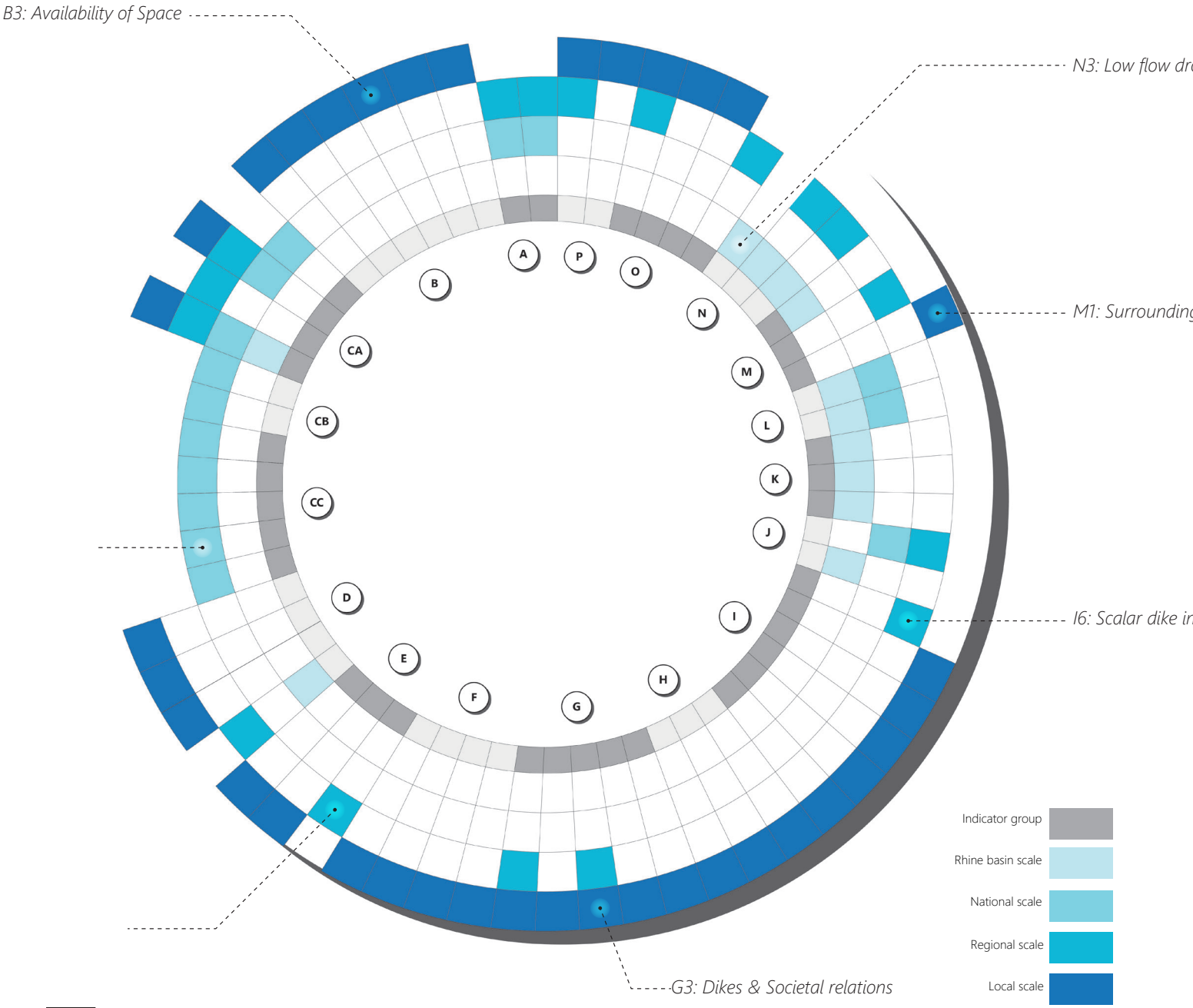


Figure 63: Scalar interpretation of the autonomy indicators. (Author, 2023)

- *Rhine river data* (Regional Scale).
  This category includes data based on the water system of the Rhine, as related to the information provided by IKSR (BAFG, 2015). It pertains to flooding scenarios, water-dependent regions, and existing water-related projects.

- *Dedicated raster data* (Local-Rhine scale).
  Dedicated raster data primarily includes European datasets that rasterize specialized data to various raster extents. It is primarily used for geological and soil information, including groundwater conditions, effective precipitation, and soil moisture.

- *Shapefile data* (Local-Rhine Scale).
  Shapefile data is projected to the spatial extent of a given area. It is often related to larger-scale areas with lithological conditions and aquifer conductivity, as well as smaller areas such as water features.

- *Point data* (Local scale).
  Point data is translated to provide information about specific point locations. It relates to existing power plants, wastewater treatment plants, water distribution mechanisms, and river discharge measuring stations.

The Time Process of Gathering

Understanding the element of time is crucial when local stakeholders are gathering information. Information needed for local dike management varies from technical data on soil conditions to extensive data related to national politics. Therefore, comprehending the time differences for collecting various types of information is essential. This knowledge allows you to identify which types of information require more time for collection, which data collections need to start earlier, and which indicators can be gathered more quickly.

ought of Rhine

g water bodies

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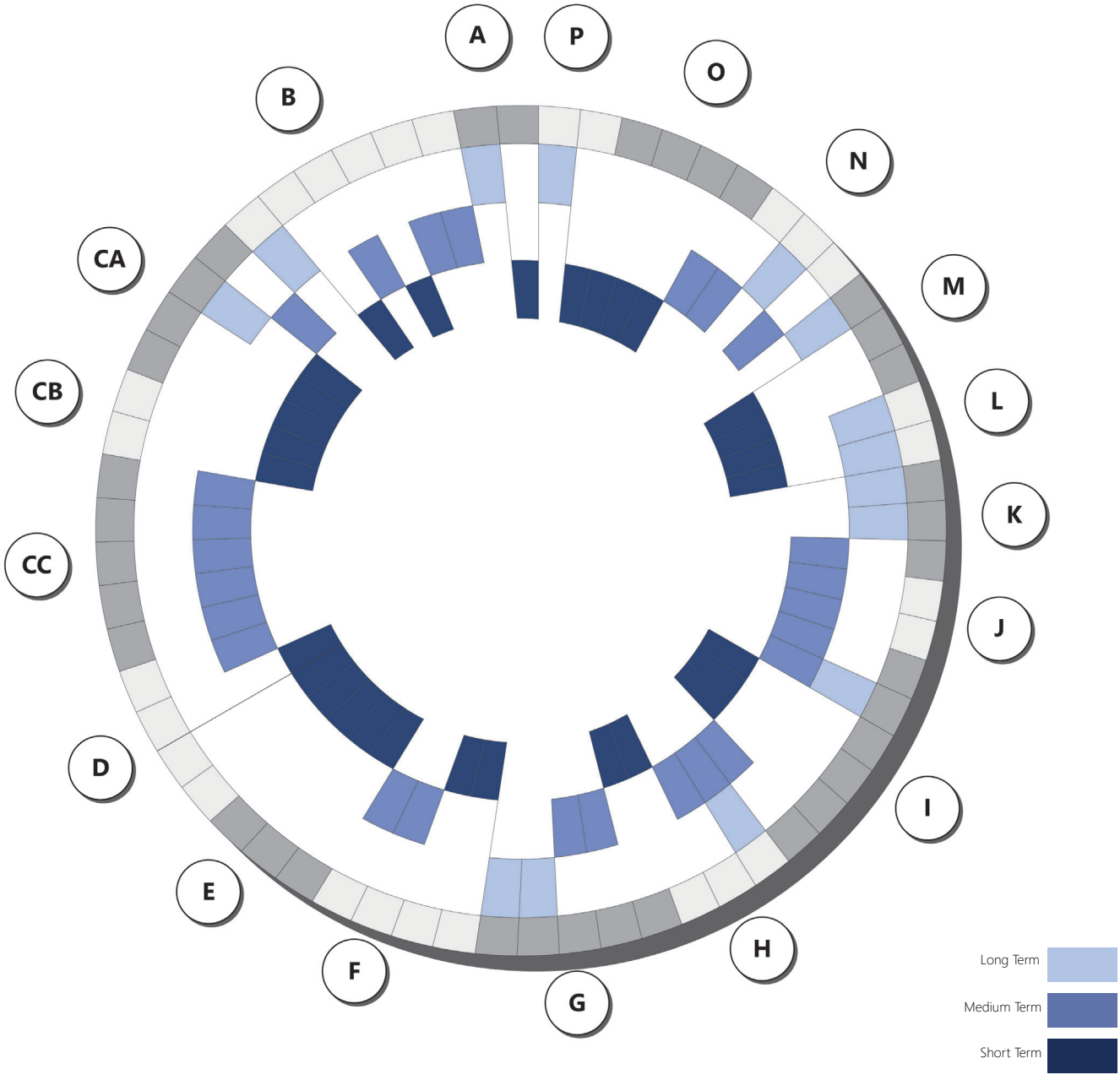


Figure 64: Gathering time of the autonomy indicators. (Author, 2023)

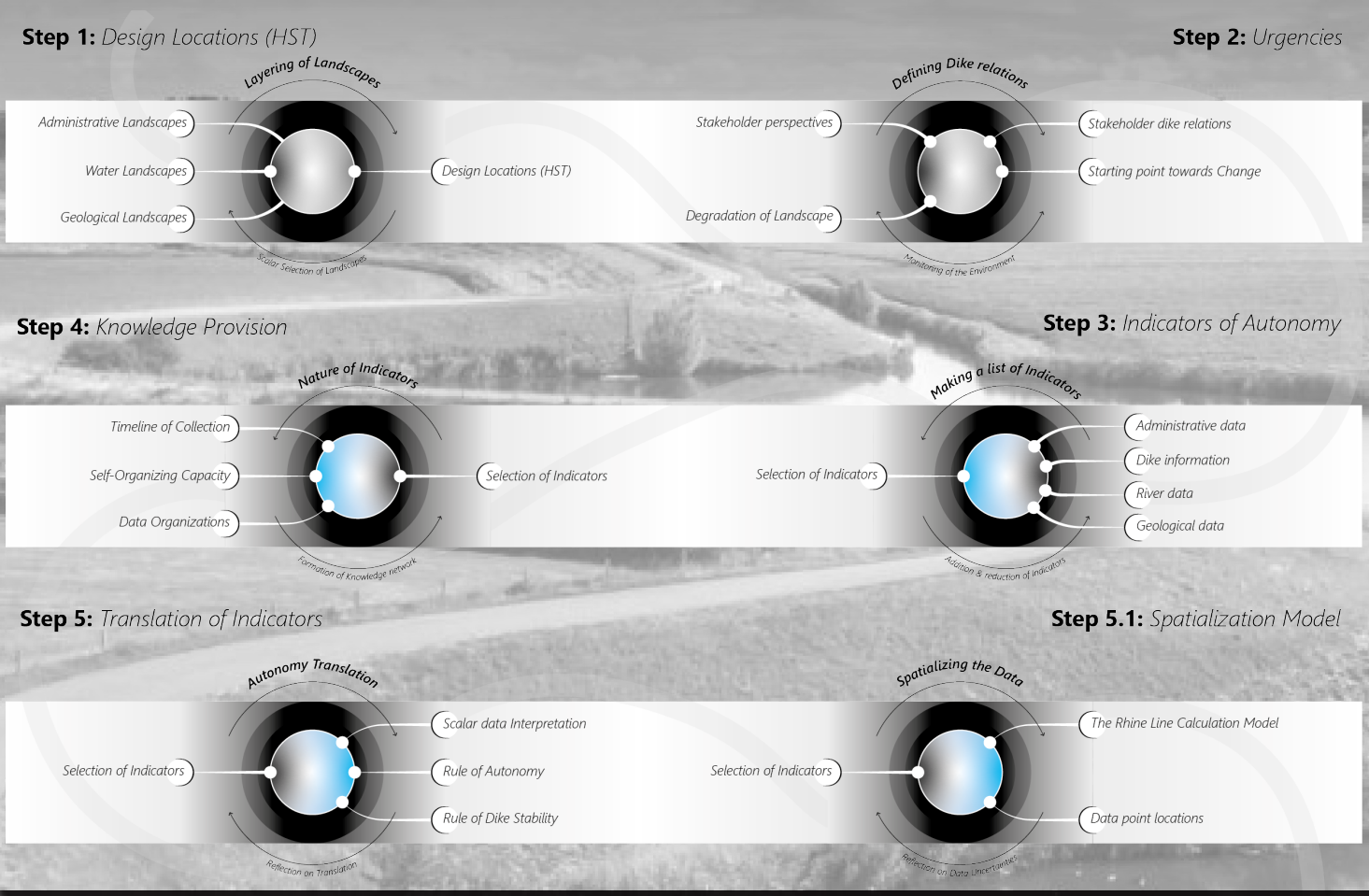


Figure 65: Dike near the city of Schagen (NL). (Van Es, S, 2020)

Figure 66: Steps of the roadmap, highlighted Steps 3-5. (Author, 2023)

10

Indicators for Localized Dike Autonomy

10.1 The Dikes of the Rhine

Main Calculation
Sub Calculation
Dike Typologies
Spatial Dike Indicators
Spatial Profiles
Maintenance Profiles
Technical Profiles
Dike Construction
Additional Conditions

Dike Autonomy

10.2 River Dynamics

Main Calculation
Sub Calculation
River & Water Discharge
Dike System Interruptions
Sedimentation Patterns

River Dynamics

10.3 Suitability Conditions

Main Calculation
Sub Calculation
Soil Conditions
Groundwater Conditions
Flooding & Drought
Additional Conditions

Suitability Conditions

10.4 Decision Making Autonomy

Main Calculation
Sub Calculation
Flood Safety Regions
Decision-making Autonomy
Autonomy of the Administration
Water Use Distribution

Authoritative Autonomy

Reader note

The next part of this report follows the calculation of the indicators. This is done by looking at the existing dikes of the Rhine, the river dynamics, the suitability conditions, and finally the decision-making autonomy.

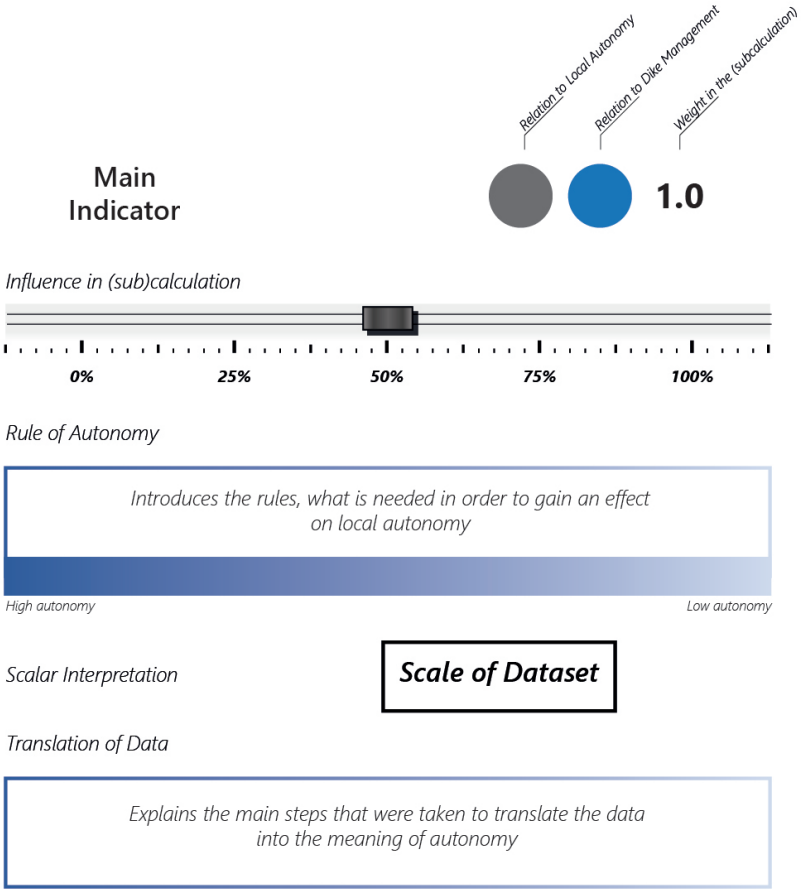
Each of these four main sub-calculations is explained in the following steps.

(1). An introduction is given on the sub-calculation and its main indicators groups that are going to be researched and translated.

(2). The sub-calculations of the indicator groups are explained to indicate the different indicators used throughout the calculation process.

(3). Per the sub-calculation of the indicator group, all of the indicators are mapped, explained, and translated into the Rhine line.

(4). When all the sub-calculations of the indicator groups are explained and translated, a reflection is made to the overall calculation.



Ranking of Autonomy

Each of the indicators is ranked based on the impact it creates on local autonomy. To make sure all of the indicators can be translated equally, this report has chosen to rank the autonomy on a scale of 1-5. A 1 is given if the indicator decreases autonomy and a 5 is given if it increases autonomy. A 3 has a neutral relation to autonomy. Furthermore, each indicator is ranked based on its positive or negative relation to local autonomy and dike management. A weight is given to each indicator based on its representation in the sub-calculations. In the main rule of autonomy, a summary is given of the relation between the indicator and the creation of local autonomy. Furthermore, the spatial scale of the indicator given and the translation of the dataset are to be used within the further calculations.

Figure 67: Indicator tool used to classify the autonomy of the data indicators. (Author, 2023)

10.1

The Dikes of the Rhine

Main Calculation

In this chapter, the calculation of autonomy is performed regarding the existing dikes of the Rhine. The first of 6 sub-calculations is related to the existing dikes of the Rhine, as classified by the IKSR (BAFG, 2015) as well as additional dike lines provided by the author. The 5 latter sub-calculations are based around dike typologies, as the spatial translation of these indicators can not be established on a Rhine scale. These sub-calculations surround the Technical Profiles, Spatial Profiles, Maintenance Profiles, Dike Construction, and two additional indicators. Weighing of these 7 sub-calculations is based on their relation to dike stability and autonomy integration. In the next paragraph, a summary is given of the 7 sub-calculations.

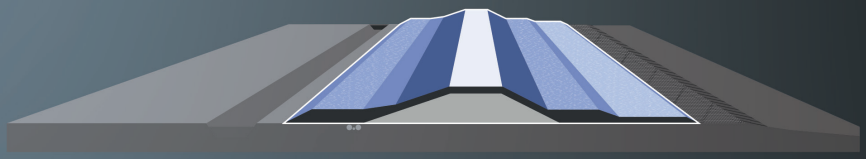
Sub Calculations

Spatial Dike Form

A dike is a large spatial element in the landscape, that has a direct impact on urban and natural systems. The placement of a dike has a direct impact on underground water flows or the connectivity of the infrastructural system. Therefore the first sub-calculation deals with the spatial impacts dikes create within their direct and indirect surroundings. This report classifies the spatial impact based on the Form of a dike (1.0), the Placement of a dike (1.25), the Scalar Impact of a dike (1.25), and finally the impact on other dikes up and downstream of the river (0.75).

Technical Dike Profile

The second sub-calculation is related to the technical profiles of the dike typologies. As a dike needs to be stable and structurally sound to cope with high water pressures, dikes are designed based on the function and safety requirements of its location (CTCN, n.d). Therefore this report focuses on the Safety failure mechanisms (1.0) of a dike and the Water retention function (1.25) of a dike as the two main indicators for the structural integrity of the dike. Furthermore, this report also classifies the potential of the distributional function of a dike regarding its technical structure. As a large part of the Rhine is based around a distributive character, the possibilities are researched into how the Safety failure mechanisms (0.5) and function (0.75) of the dikes can contribute to the distribution of water.



Dike Autonomy

Indicates the current autonomy the dikes of the Rhine have based on Dike typology classifications

MAIN CALCULATION

SUB-CALCULATION

INDICATORS

Calculation of River

Calculation of the Dike

Spatial Dike Form 1.5

- Form of the Dikes 1.0
- Location Placement 1.25
- Scalar Dike Impact 1.25
- Dike bodies up & down stream 0.75

Technical Dike Profile 1.25

Dike as a Border

- Safety Failure Mechanisms 1.0
- Water Distribution Failure Mechanism 0.5
- Water Retention Function 1.25
- Water Distribution Function 0.75

Dike as a Connector

Spatial Dike Profile 1.0

- Spatial Impact on: BIODIVERSITY 0.75
- Spatial Impact on: RIVER FLOW 1.25
- Spatial Impact on: SOCIETY 1.0
- Spatial Impact on: ECONOMY 0.5
- Flexible Usage 1.5

Maintenance Dike Profile 1.0

- Area of Protection Zone 1.25
- Frequency of Maintenance 0.5
- Knowledge for Maintenance 0.75

Dike Costs Implication 0.5

- Materials for Dike Construction 1.75
- Water Retention Function 1.25
- Knowledge for Maintenance 0.75
- Flexible Usage 0.75

Additional Indicators

A

- Rhine Riverbanks 0.5
- Dike Systems 0.75

Relation to Created Autonomy

Relation to Dike Suitability

Weight given in subcalculation

Used as an Addition to Autonomy

A

Positive

Negative

Neutral

Figure 68: Indicators of dike autonomy. (Author, 2023)

Spatial Dike Profile

Dikes are considered to be an integral part of the riverscapes. They form an integral part of the (old) identity of an abundance of residents living in the Rhine Valley that have protected them for more than 8 centuries (Redeker, 2012). Therefore the relations a dike has to its direct surroundings indicates how imbedded the dike line is in different sectors. This calculation defines 5 main relationships. These areas are Biodiversity (0.75), River flow (1.25), Society (1.0), Economy (0.5), and Flexibility in Use (1.5).

Maintenance Dike Profile

A large indication to understand the possibility of localized dike management surrounds the field of maintenance. For local stakeholders to understand the possibilities of self-organizing their dike line, it is vital to understand the capacity they have to maintain a dike line. Therefore, this calculation is divided into three main indicators: Area of protection (1.25), indicating the area that maintenance needs to cover; Frequency of maintenance (0.5), indicating per dike typology how often maintenance is needed and lastly: Knowledge of maintenance (0.75), indicating the difficulties and practices of maintenance that arise per dike typology.

Dike Construction

The main financial requirements of dike construction and management are related to material, location, safety margins, and available knowledge (CTCN, n.d.). Although dikes are considered to be basic spatial elements, the cost involved quickly rises above 5 to 10 million euros per kilometer (Waterschap Rivierenland, 2019). Therefore this calculation creates an indication of the costs involved as per dike typology. Here the indicators of Materials for dike construction, including core material (1.5) and cladding material (0.25) are translated into autonomy, following the central notion that the higher the cost becomes, the lower the possibility there is for local dike autonomy. Furthermore, representative indicators of the three main profile classifications (Water retention (1.25), Knowledge of maintenance (0.75), and Flexible use (0.75)) are reintroduced, as are an integral part of defining costs of dike construction.

Ranking of Dikes

The translation of a large set of sub-calculations will be dedicated to dike typologies. The ranking of these dike typologies will take place in the form of the scheme shown below.

Dikes of the Rhine

On the next pages, an overview is provided with the current dikes of the Rhine. Based on the difference in landscape different forms of dikes are seen. Based on the current dikes of the Rhine a classification was made based on 9 typologies, based on the dike typologies of Lola Landscape Architects (2014). These typologies are explained and are spatialized along the Rhine line. Further information about the typologies can be found in the appendix 16.2. Additionally these dike typoligies can be found on page 134-137 within the spatialized Rhine Line.

Indications of the autonomy of the dike are based on Dutch characteristics of dikes. As dikes can be created in different ways showing different levels of scale, implementation, size, and material, basic characteristics have to be used in further calculations as specific German, French, and Swiss data regarding dikes can be different from Dutch examples but share similarities in overall concept.

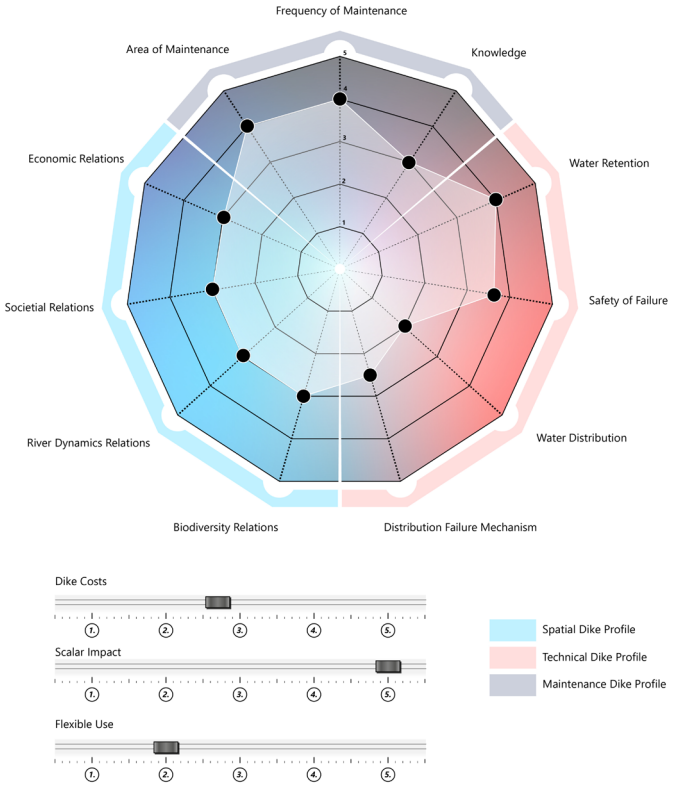
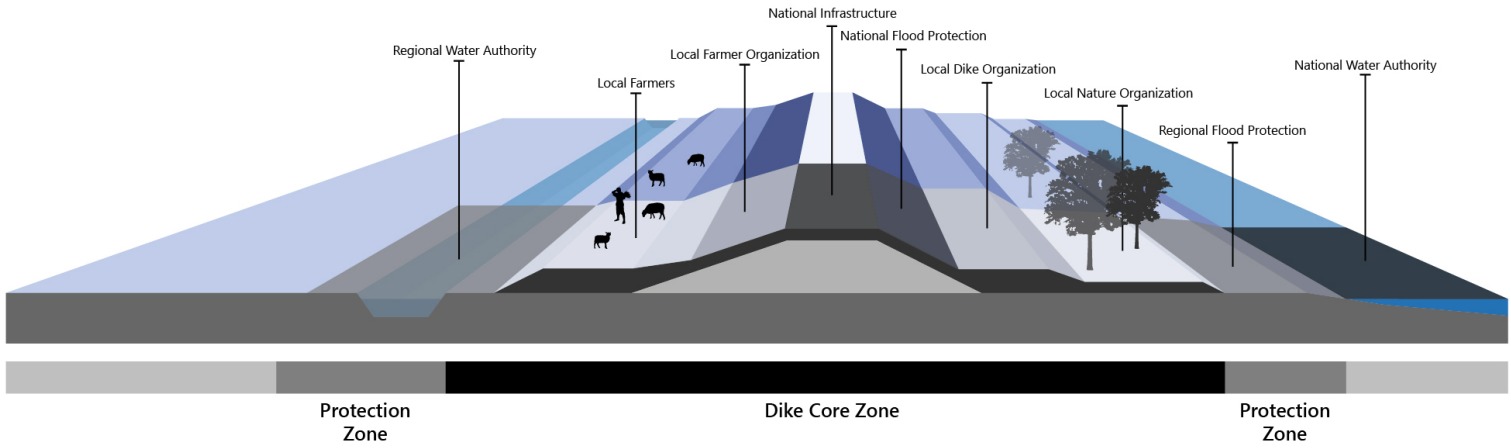
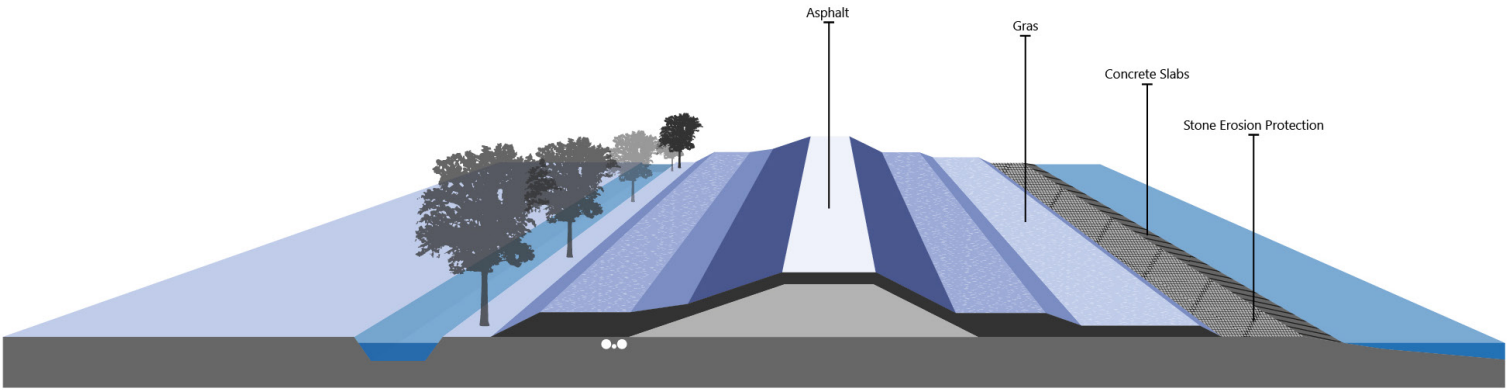


Figure 69: Classification scheme of dike typologies. (Author, 2023).





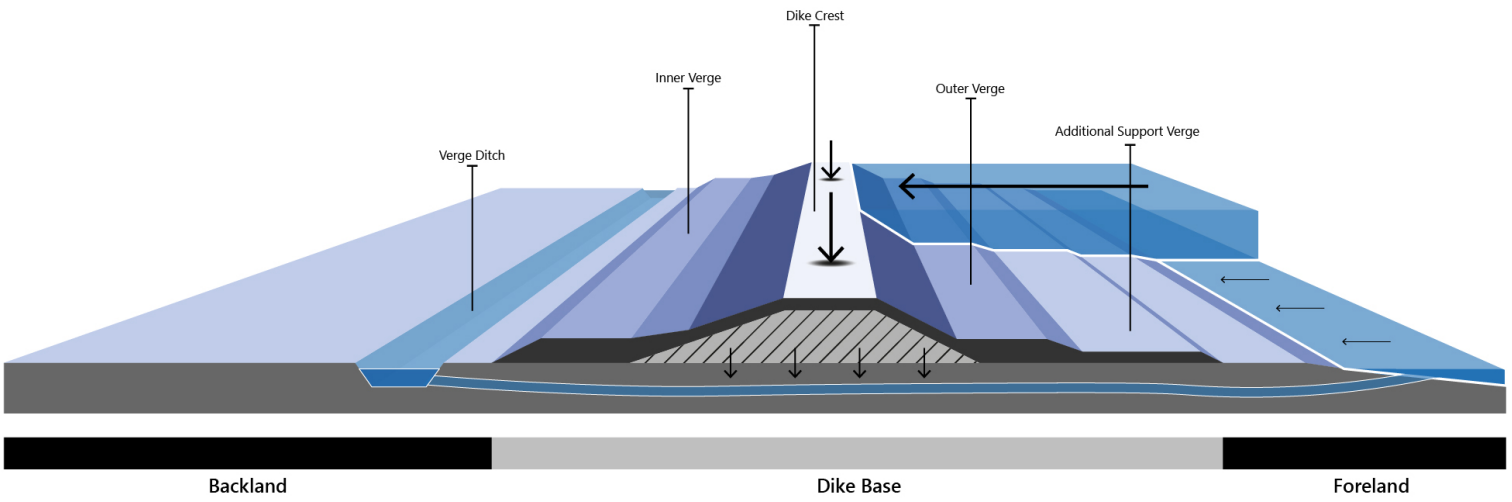
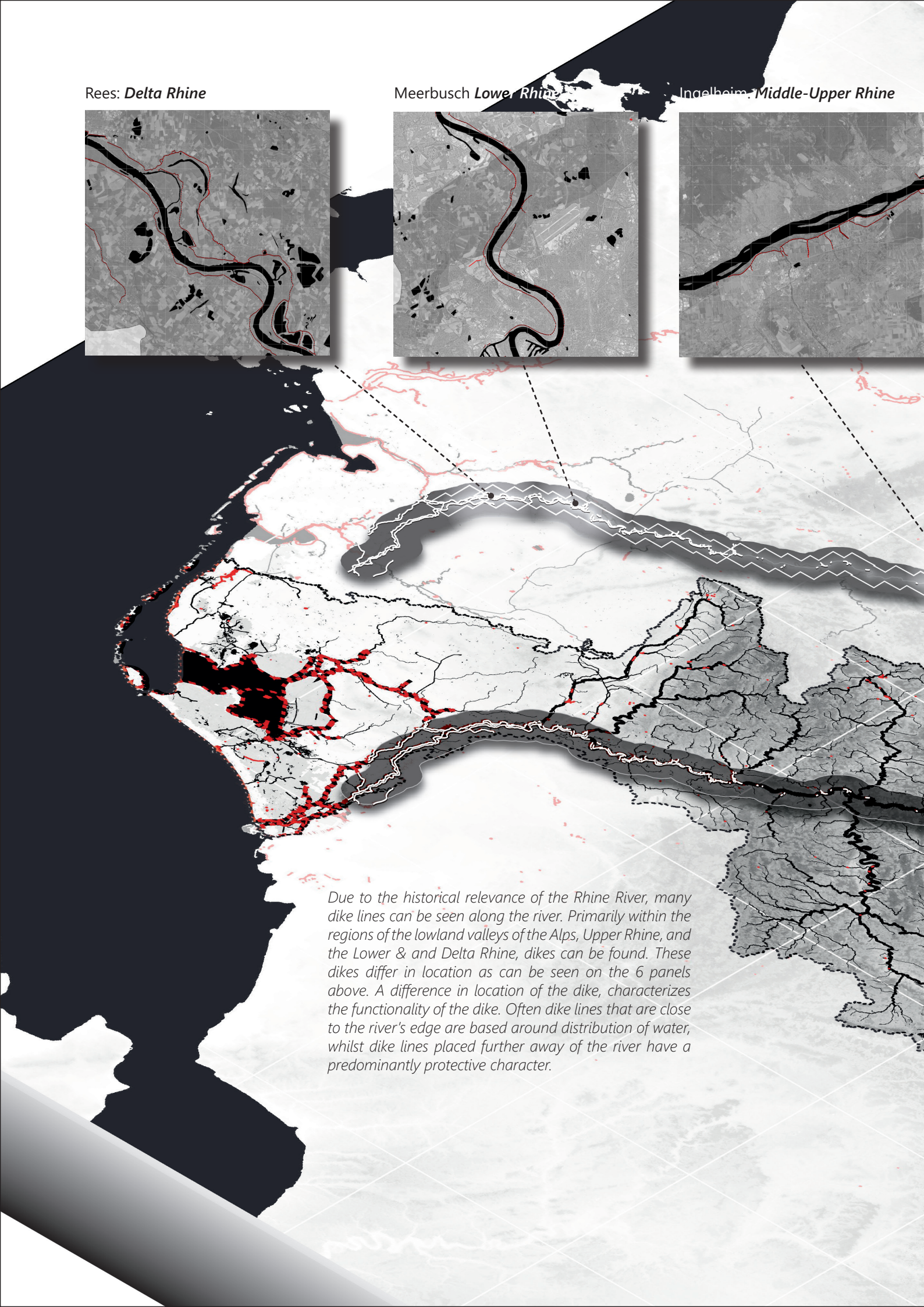


Figure 70: Maintenance, Spatial and Technical Dike profiles. (Author, 2023. Based on Lola Landscape Architects, 2014)

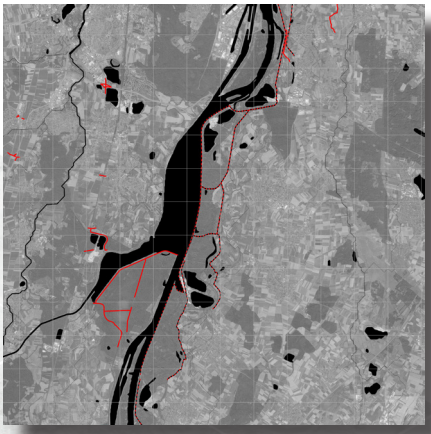


Due to the historical relevance of the Rhine River, many dike lines can be seen along the river. Primarily within the regions of the lowland valleys of the Alps, Upper Rhine, and the Lower & and Delta Rhine, dikes can be found. These dikes differ in location as can be seen on the 6 panels above. A difference in location of the dike, characterizes the functionality of the dike. Often dike lines that are close to the river's edge are based around distribution of water, whilst dike lines placed further away of the river have a predominantly protective character.

Germersheim: ***Upper Rhine (FF)***



Altenheim: ***Upper Rhine (C)***



Vaduz: ***Alpine Rhine***

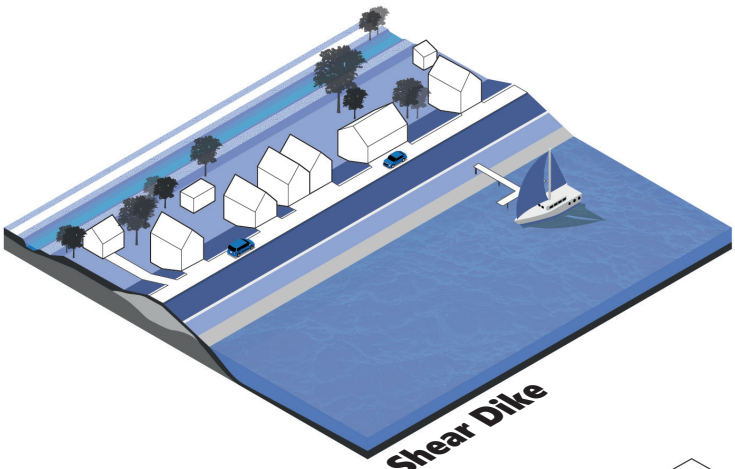


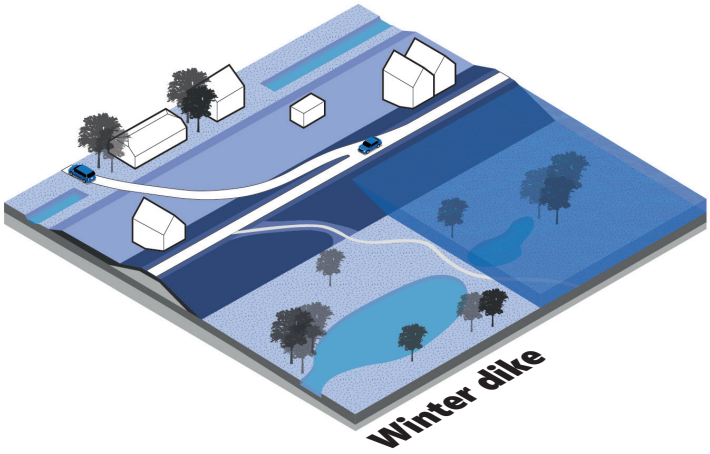
Figure 71: A collection of dikes along the Rhine. (Author, 2023)

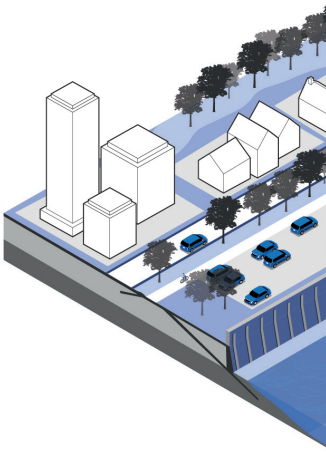
**FF: Free-flowing zone of the Rhine. *C: Canalized zone of the Rhine*

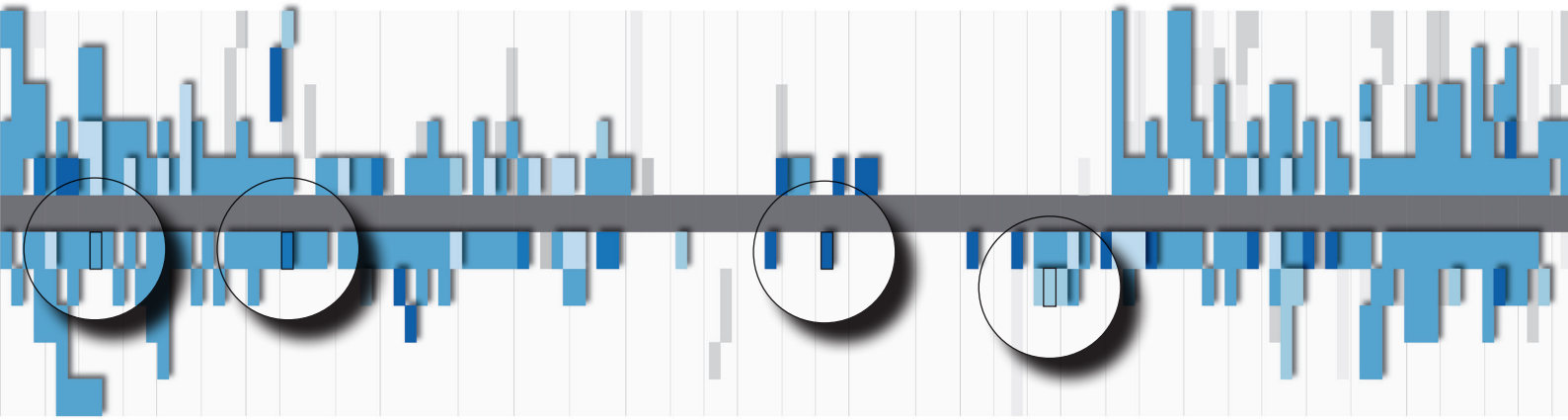
Figure 72: 'Protective' dike typologies mapped along the Rhine and placed in the Rhine Line. (Author, 2023. Based on Lola Landscapes Architects, 2014).

Dike Typologies











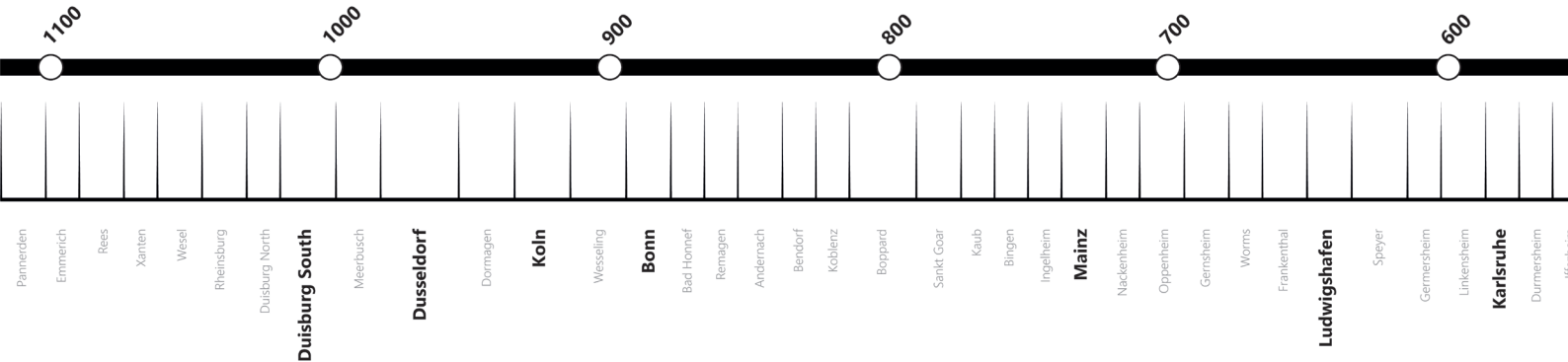
Winter dike (Polders near Rees)



Shear dike (Duisburg)



Floodwall (Koblenz)



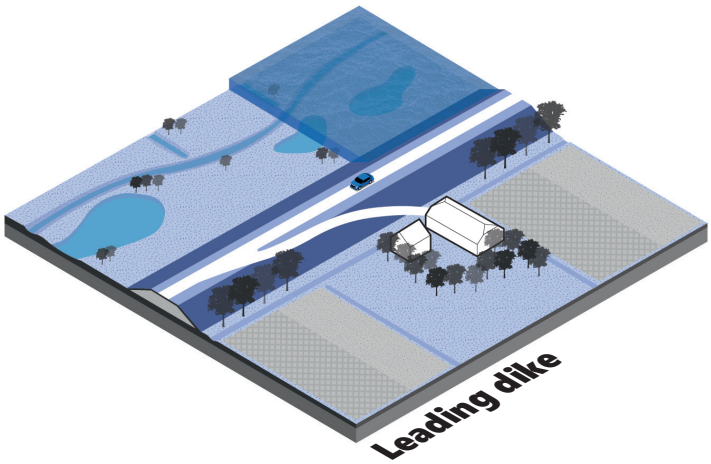
Canal dike
Leading/compartment dike
Dike-in-boulevard
Summer dike
Winter dike
Side dike
Shear dike
Floodwall

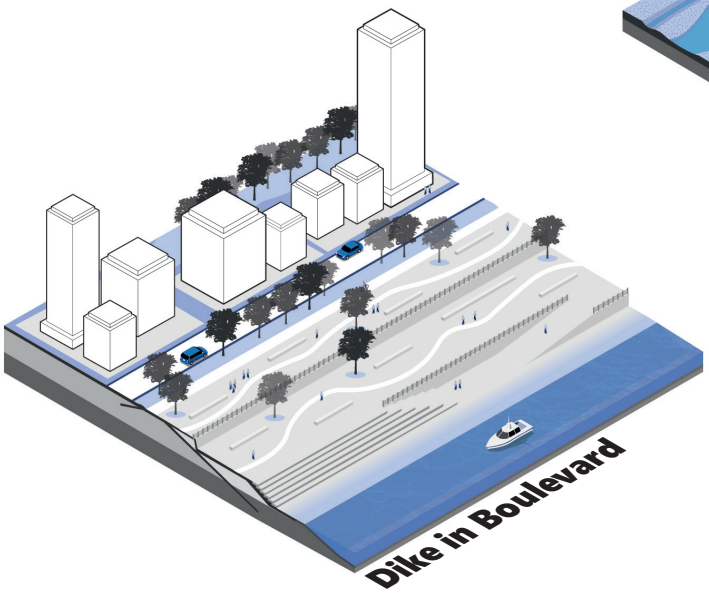
Side dike (Ingelheim)

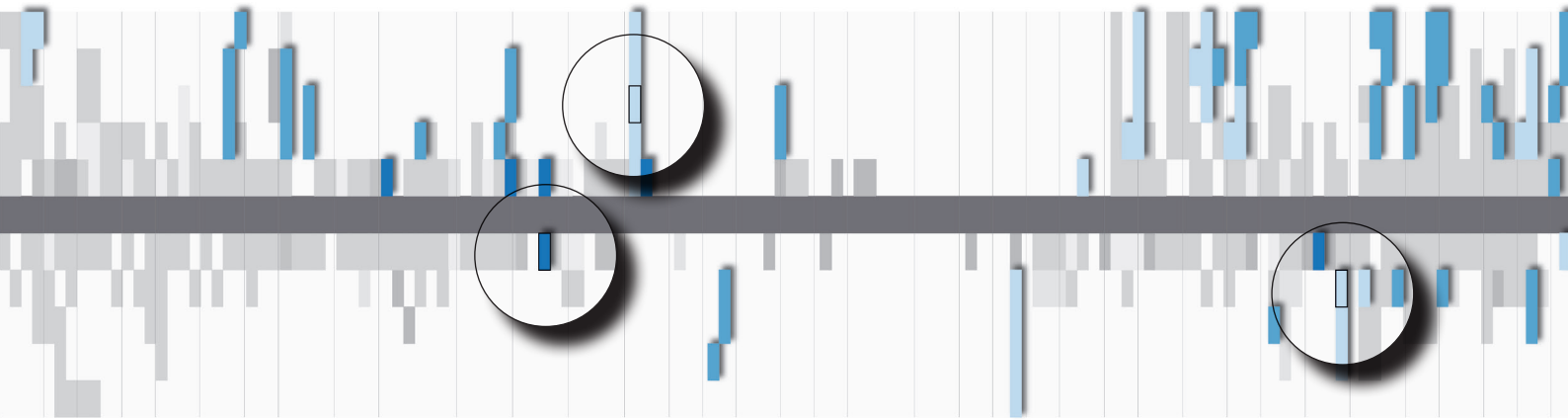
Summer dike/riverbank (Aare near Leibstadt)

Figure 73: 'Distributive' dike typologies mapped along the Rhine and placed in the Rhine Line. (Author, 2023. Based on Lola Landscapes Architects, 2014).

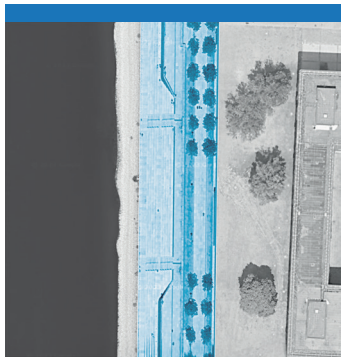
Dike Typologies





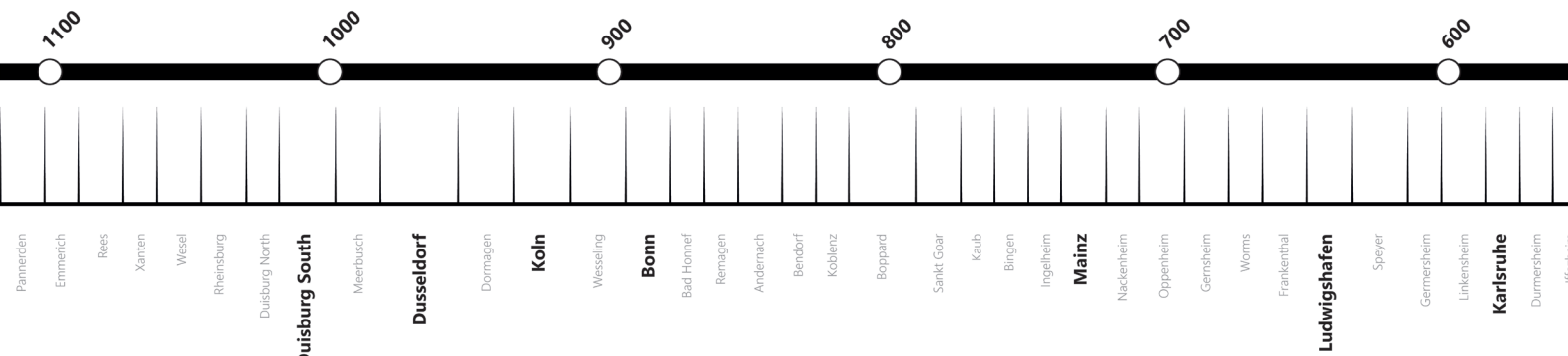


Dike-in-Boulevard (Koln)

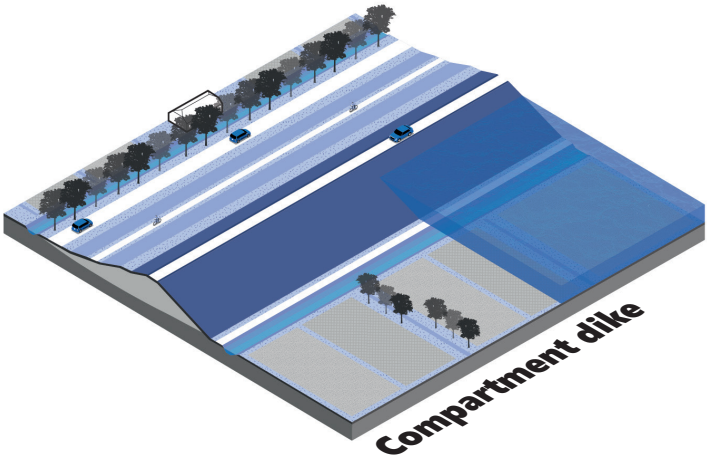


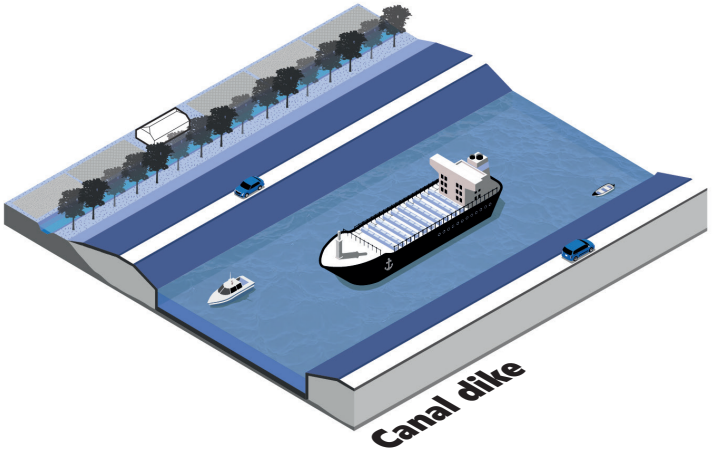
Leading dike (Sieg near Bonn)

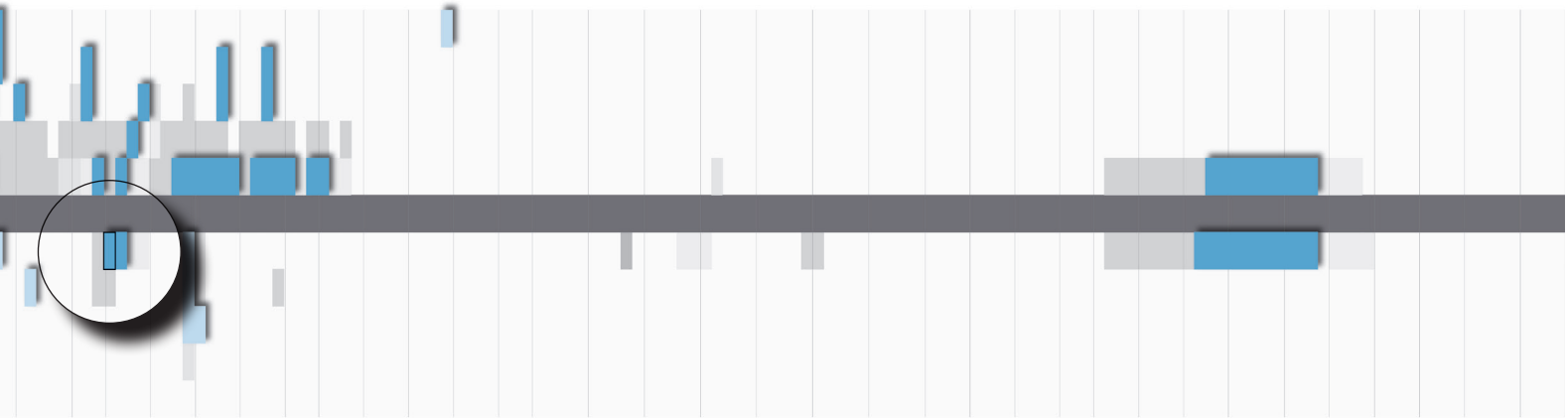




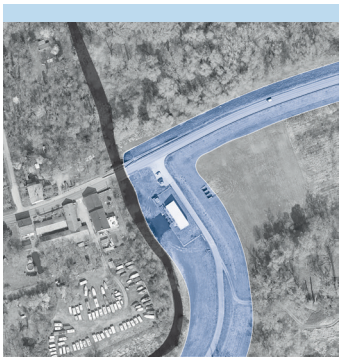
Canal dike
Leading/compartment dike
Dike-in-boulevard
Summer dike
Winter dike
Side dike
Shear dike
Floodwall



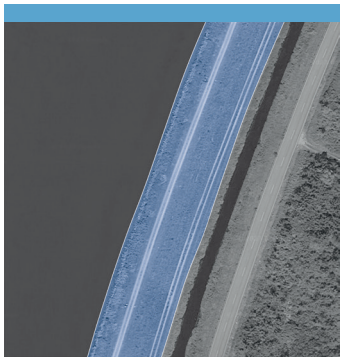


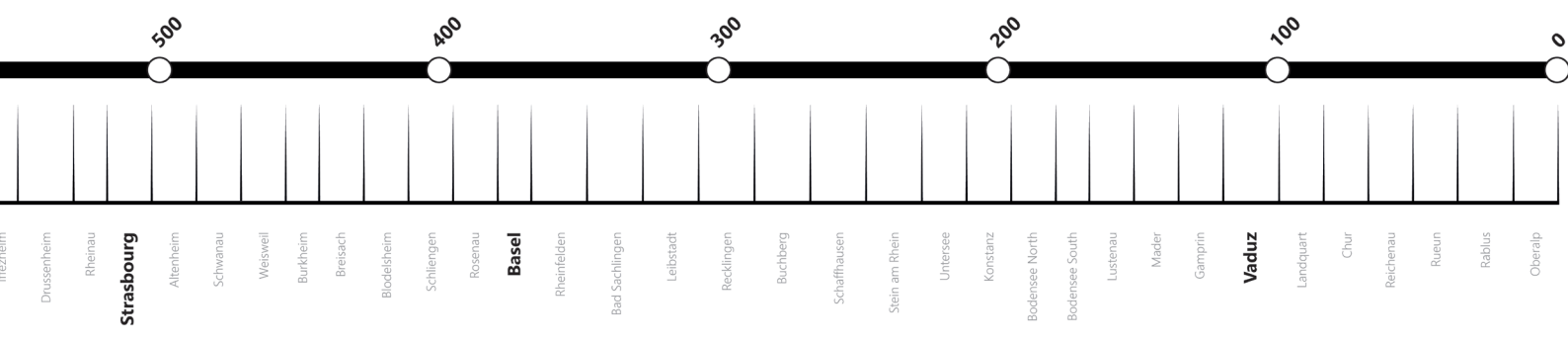


Compartment dike (Ludwigshafen)

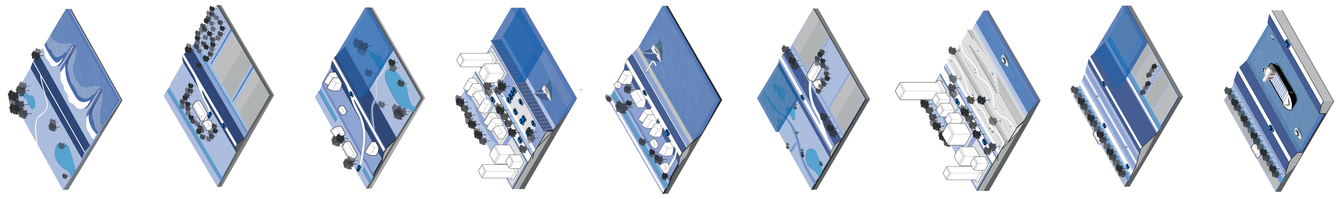


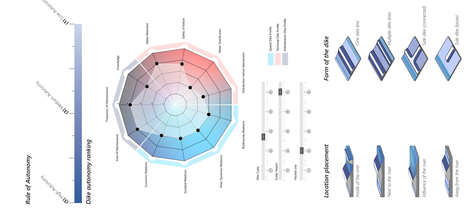
Compartment dike (near Strasbourg)



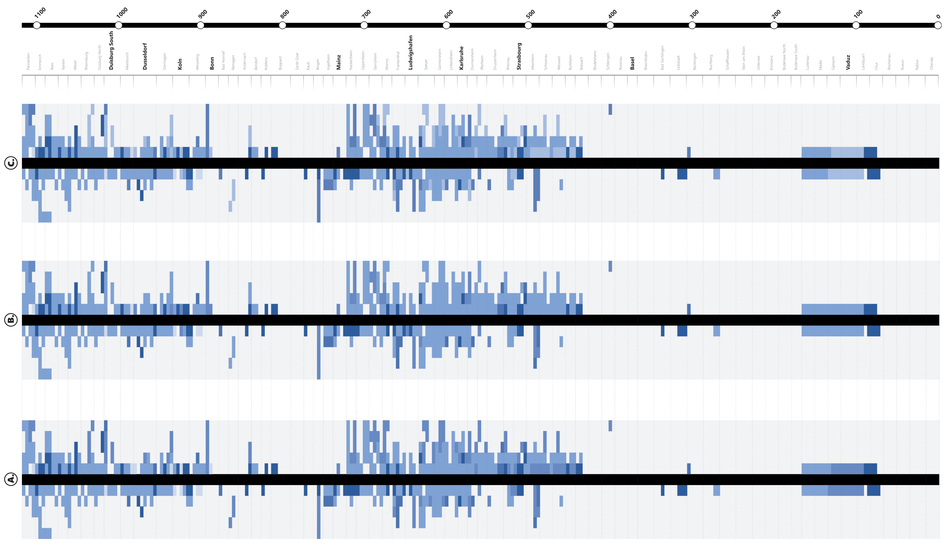


SUMMER DIKE | SIDE DIKE | WINTER DIKE | FLOODWALL | SHEAR DIKE | LEADING DIKE | DIKE-IN-BOULEVARD | COMPARTMENT DIKE | CANAL DIKE





MAINTENANCE PROFILES

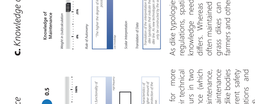


A. *Area of the Protection Zone*

B. *Frequency of Maintenance*



C. *Knowledge of Maintenance*



Certain dike typologies ask for more frequent maintenance due to their technical function. Dike maintenance occurs in two ways: regular, low-scale maintenance that considers monitoring, grass maintenance, and cleaning) and heavy maintenance (large-scale repairs). Certain dike typologies are deemed to have failed current safety and/or integral stability regulations and should therefore be strengthened.

As dike typologies consist of different safety regulations, spatial impacts, and materials knowledge needed to maintain, a dike typology's autonomy ranking is assigned. As often maintained by specialized companies, grass dikes can be maintained by local farmers and dyke stakeholders.

D. *Spatial Relations to Economy*

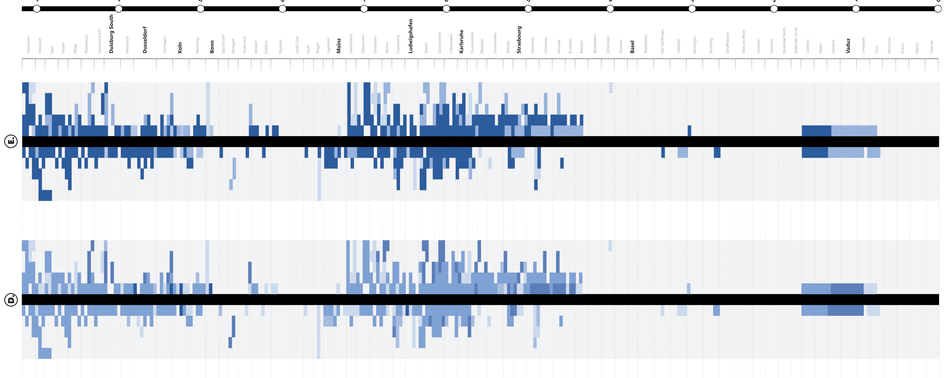


E. *Land Use Flexibility*

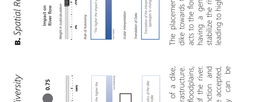


Dikes are considered to be a heavy construction and are often associated with high financial expense (Waterschap Rivierenland, 2019). New technologies considering the integration of dikes with other land uses can be applied on any given location (for example: floodwalls). Higher flexible usage of dikes could increase the carrying capacity of local stakeholders.

SPATIAL DIKE FORMATIONS



A. *Form of the Dikes*



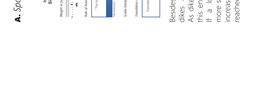
The form of the dike indicates the dike's spatial impact where the size of the dike body and the amount of defense lines per dike section influence the overall mass of the dike on location.

B. *Location Placement*



The placement of a dike relates to the distance between the dike and the adjacent river. The placement directly impacts the dike's spatial impact where a dike's closer proximity of the dike line to the river increases water pressure.

C. *Scalar Dike Impact*

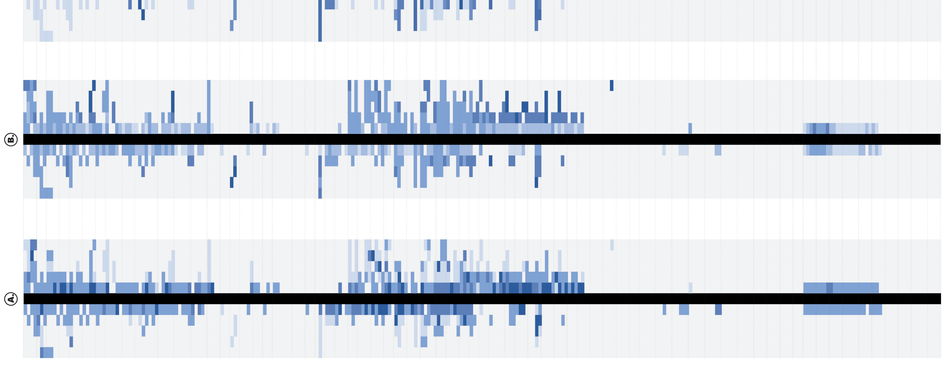


Dikes are part of an integral network of flood protection and are often many kilometers long. This creates a large area to be impacted by the scalar extent of the dike.

D. *Dike Bodies Up & Down Stream*

To allow for autonomous building, maintaining and monitoring of dikes, the understanding of the impact created for adjacent dike bodies up and down stream is established. As certain dike typologies, locations, and forms change the effect of water pressure, flood protection and water distribution systems can be (unwillingly) adjusted.

SPATIAL DIKE PROFILES



A. *Spatial Relations to Biodiversity*

Besides the protective function of a dike, dikes also facilitate green infrastructure. As dikes are often based near floodplains, they have a positive impact on biodiversity. If a lower water-retaining function and more space in the floodplain are accepted, increased levels of autonomy can be reached.

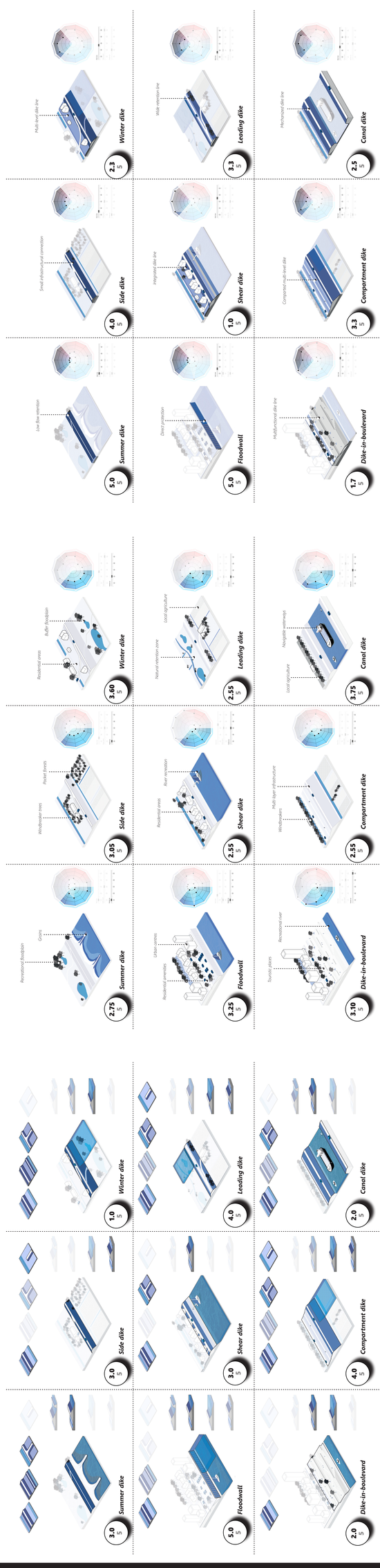
B. *Spatial Relations to River Flow*

The placement and the inclination of the dike towards the river indicate how a dike acts to the flow of the river. Dike typologies that have a lower water-retaining function stabilize the river flow throughout the year.

C. *Spatial Relations to Society*

As dikes have been local constructions throughout history, they have been an integral part of societal life. Certain dike typologies can be more easily integrated into existing flood management practices, leading to higher acceptance by society.

DIKE TYPOLOGY RANKINGS

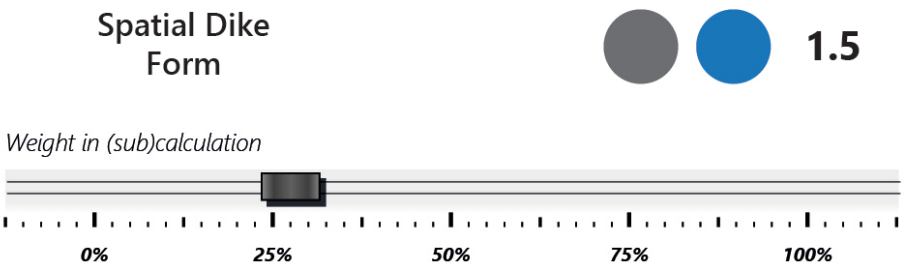


AUTONOMY INDICATORS

THE RHINE LINE

SUBCALCULATION

Figure 74: Visualization of the Rhine Line regarding Autonomy based on Spatial dike forms, Spatial dike profiles & Maintenance dike profiles. (Author, 2021)



Weighting of the Indicators

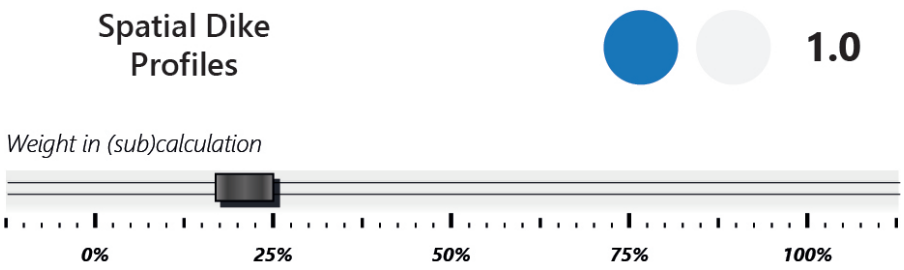
The spatial dike form is based on the spatial impact the dike creates towards its direct surroundings. To create the overall indications of the spatial impact of the dike, this sub-calculation is divided into four categories of Form of the dike, the Location Placement, the Scalar impact & the number of dikes that can be found up and downstream. Chosen is to weigh the indicators of Location placement (1.25) and the Scalar Dike Impact (1.25) higher than the standard of 1. The Location Placement indicates higher risks involved directed at the structural stability of the dike. For the Scaler Dike Impact, the weight is increased as a direct relation to local autonomy is created. Therefore smaller dike lines that can operate on a smaller scale lead to larger possibilities of autonomy.

Although the overall mass of the dike is important to understand the technical functionality of the dike, a lower weight was chosen as less impact is created on the surroundings. This is based on the notion that the mass of the dike can be controlled as part of localized management.

The weight of 0.75 for the dikes up and downstream area only becomes important when real change is initiated. Therefore it is less important considering the calculations based on the current dikes.

Previous page. Figure 74: Spatialization of the Rhine Line regarding Autonomy based on Spatial dike form, Spatial dike profiles & Maintenance dike profiles. (Author, 2023).

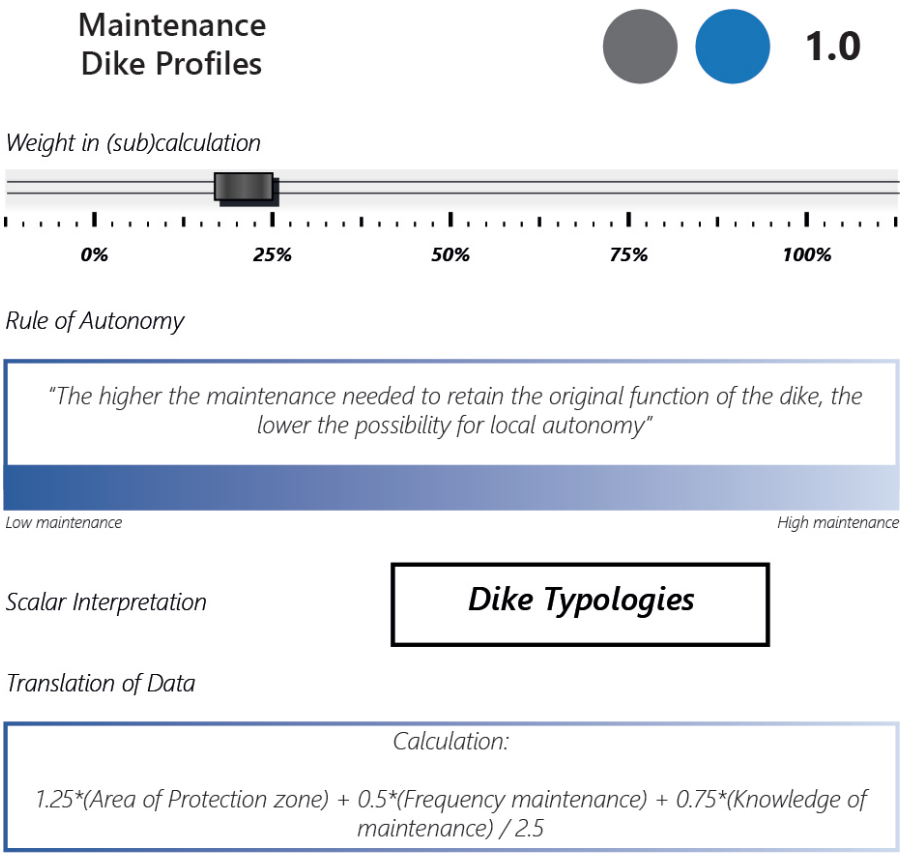
Figure 75: Translation of autonomy regarding the Spatial Dike Form. (Author, 2023)



Weighting of the Indicators

The new meaning of the dike as a transition zone between man and the river enhances the spatial elements used to characterize the dike. Therefore the spatial profiles of the dike concerning biodiversity (0.75), river flow (1.25), and society (1.0) are key in re-establishing the dike as part of the local context. It is chosen to rank the relation with the river flow higher as the main function of a dike still has a retaining character. To indicate the importance of the relationship between man and the dike, the societal relations were kept at 1.0, and the additional features of biodiversity and the economy at 0.75 and 0.5. Furthermore, the indicator of flexible use is ranked the highest. As the multifunctional use of a dike can be interpreted and implemented within different contexts it forms an ideal basis for local dike autonomy.

Figure 76: Translation of autonomy regarding the Spatial Dike Profiles. (Author, 2023)

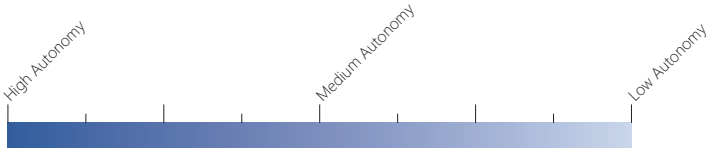


Weighting of the Indicators

One of the main areas where local stakeholders can be integrated within dike management relates to maintenance. The main rule is that an increase in maintenance to retain the original form of the dike decreases local autonomy. Therefore the ideal dike that enhances local autonomy should be directed at low daily maintenance. That is why the Area of Protection (1.25) is ranked the highest of the three used indicators, as this indicator focuses on the total area that needs to be maintained. The ranking of the needed knowledge at 0.75 is based on the notion that certain elements of maintenance can be delegated to local stakeholders (for example monitoring of dike anomalies and grass maintenance).

Figure 77: Translation of autonomy regarding the Maintenance Dike Profiles. (Author, 2023)

Technical Profiles

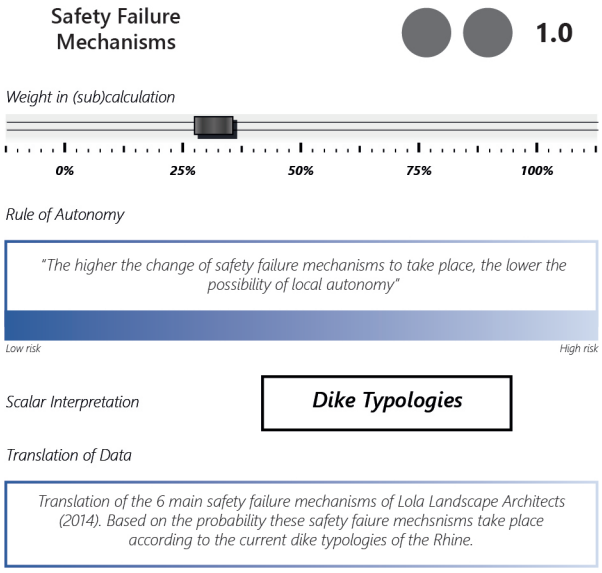


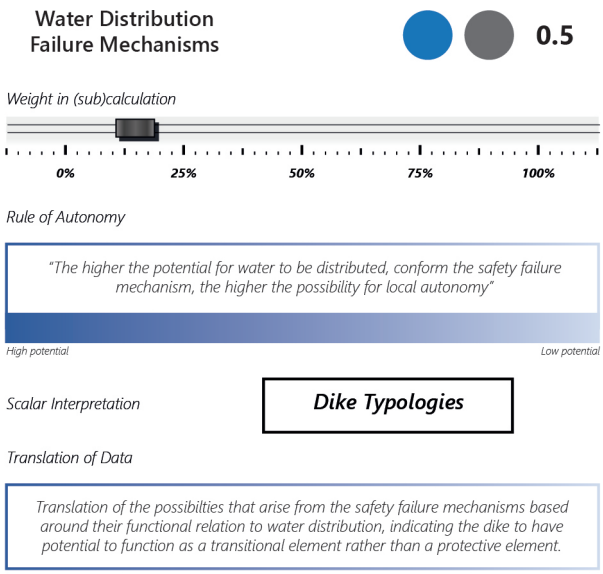
A. *Safety Failure Mechanisms*

Dikes can lose their water-retaining function based on safety failure mechanisms. As each dike typology consists of a different functional composition, material, mass, and height, certain dike typologies are more prone to failure mechanisms.

B. *Water Distribution Failure Mechanisms*

Although failure mechanisms are considered to decrease the stability of dikes, they also create additional features. If the water-retaining function is lowered, controlled failure mechanisms could be used to enhance the local autonomy of water distribution.



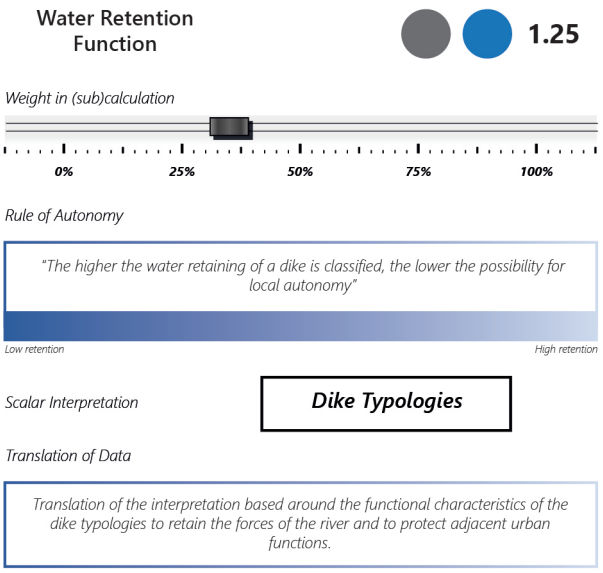


C. *Water Retention Function*

The main function of a dike is to retain the river within its boundaries. The larger the water retaining function of a dike is, the smaller the room for error becomes, lowering its localized autonomy.

D. *Water Distribution Function*

Besides the main function of the dike to protect low-lying areas from high water levels, it also enhances the distribution of water. On local levels, dikes could be used to control water flows to areas of need, increasing potential autonomy.



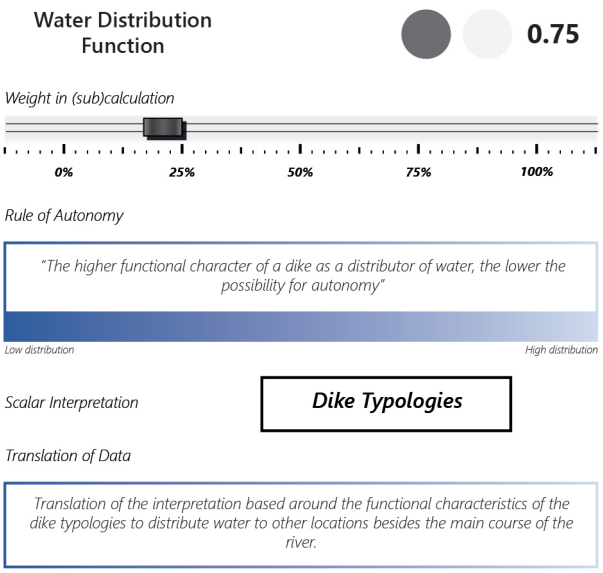


Figure 62: Translation of autonomy indicators of Technical Dike Profiles. (Author, 2023)

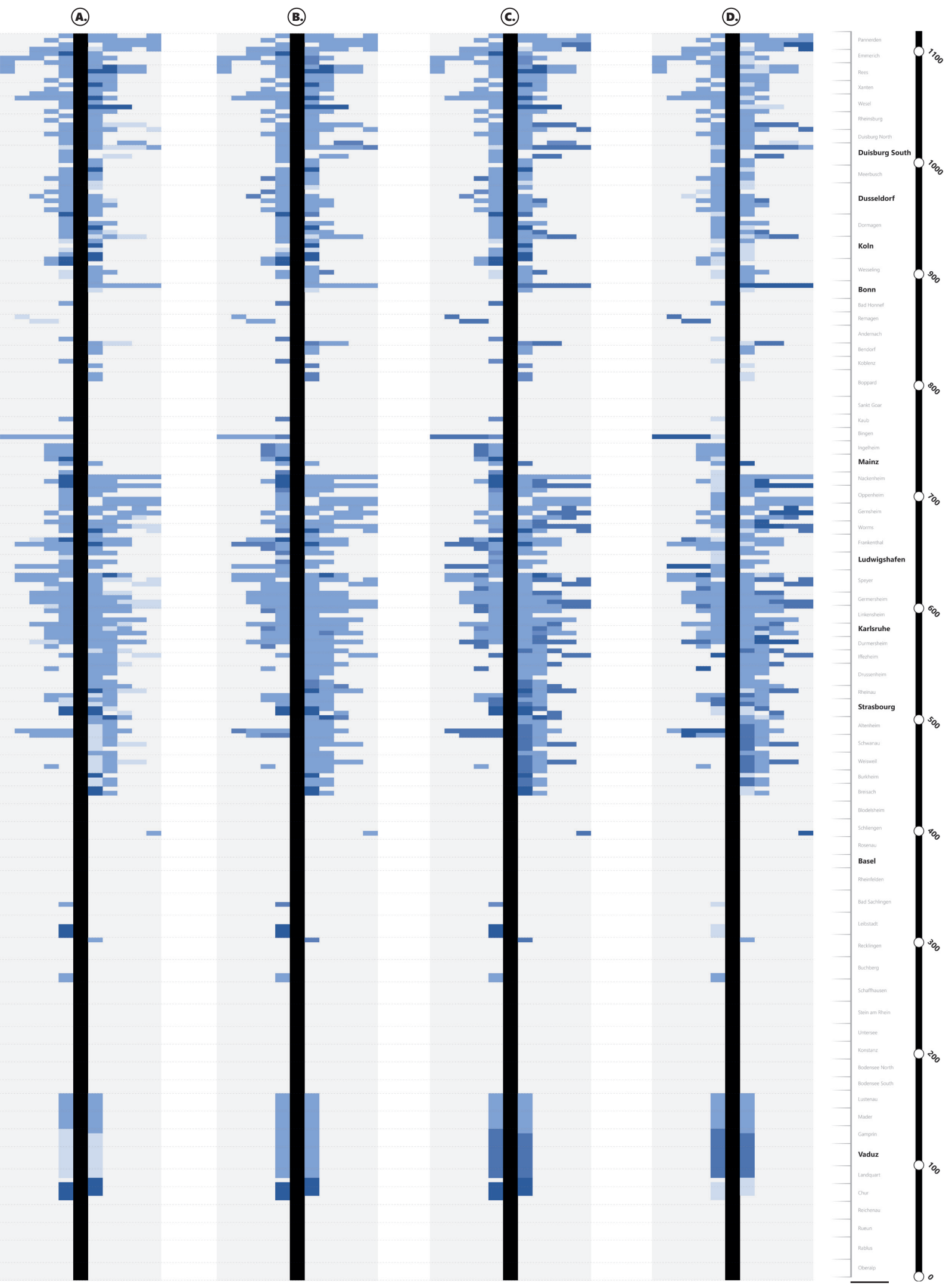
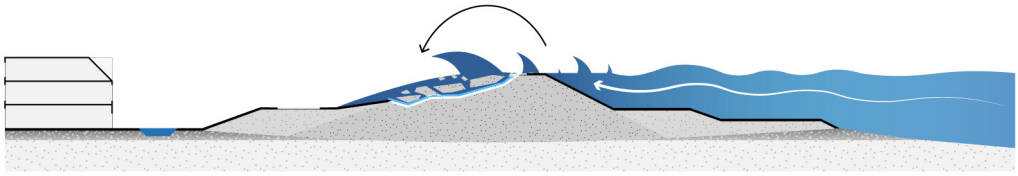
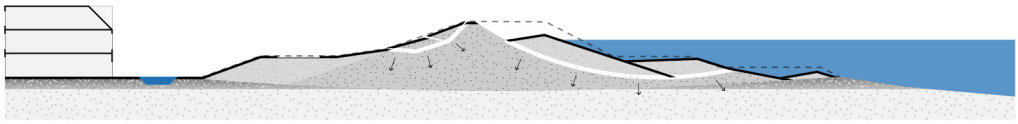


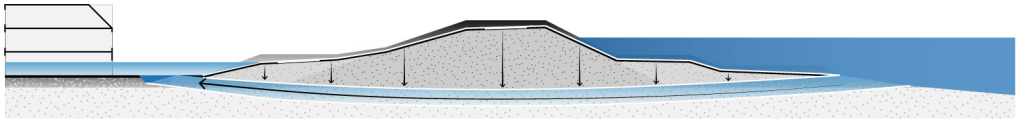
Figure 79: Spatialization of the Rhine Line regarding Autonomy based on Technical dike profiles. (Author, 2023)



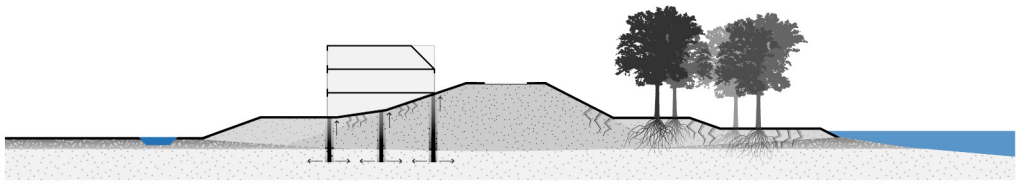
Overflow: If the waterlevel reaches past the crest of the dike, water can infiltrate the outer dike areas. Due to the forces of the water coming down, parts of the dike can be washed away, leading to degradation of the structure of the dike.



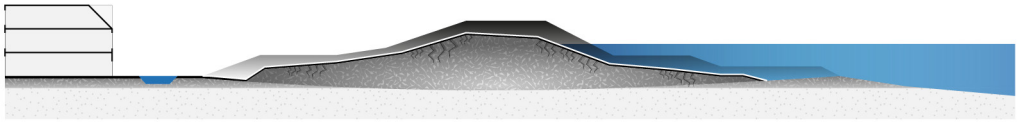
Dike instability: The stability of the dike relates to the forces the dike can resist without losing its water retaining function. Due to the water infiltration a dike can become over-saturated, leading the internal structures of the dike to become instable



Piping and Heave: When longer periods of high water levels push against the dike, water seeks alternative ways to breach the dike. Soft spots in loose sand layers causes the water to penetrate below the dike, leading to structural loss of the dike.

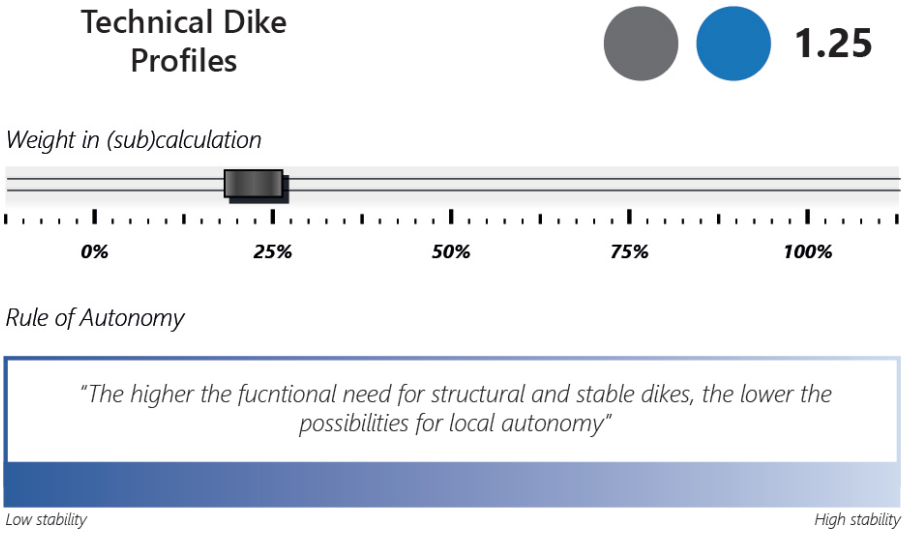


Dike damage: Dikes are often integrated with additional spatial elements that seeks stability within the dike. Roots of trees, foundations of houses and road infrastructure, hamper the force field within the dike, leading towards higher risks of collapse.



Dike setting and oxidation: Due to the mass and the material composition of the dike, different internal structures are established. Over time this could lead to the setting of the dike as the mass pushes the dike line into the ground lowering its height.

Figure 80: Spatialization of the safety failure mechanisms of dike structures.
(Author, 2023. Based on Lola Landscape Architects)



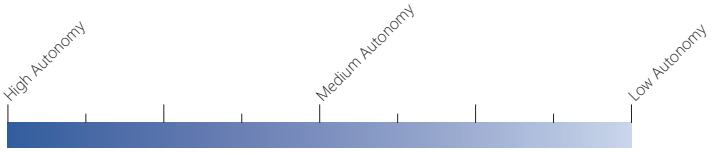
Weighting of the Indicators

The technical dike profiles are based on the main functional character of the dike concerning the protection and distribution of water. Therefore this sub-calculation classifies the dike as a retaining wall against the water, as based on the existing meaning of CTCN (n.d).

Based on the four main indicators that are analyzed conform to the existing dike typologies of the Rhine, increased weights have been given to the water retaining characters of the dike. Here the Water Retaining Function (1.25) is weighted higher than the Safety Failure Mechanisms (1.0) because the latter only focuses on the potential breaches that occur, rather than the overall functional character of the dike.

Additional technical features of a dike concerning its water distributive character (0.75) are weighted lower because it facilitates the loss of the functional character of the dike. Although the dike is constructed to retain water, the possibility of the failure mechanisms as a means of water distribution (0.5) can enhance local autonomy. However, the latter facilitates the loss of the structural functionality of a dike line.

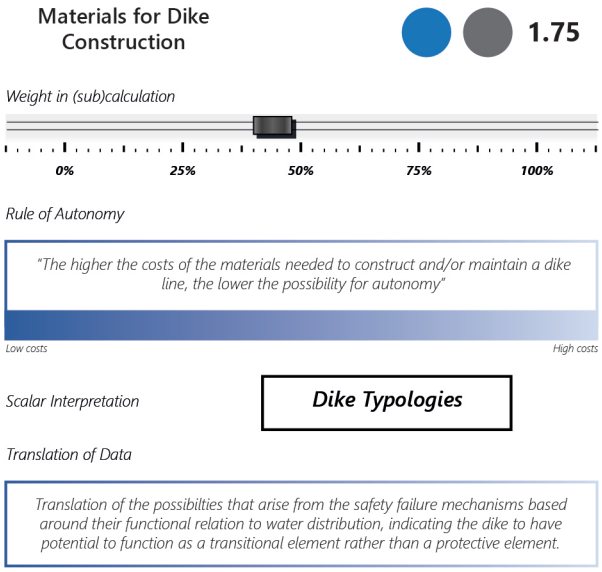
Figure 81: Translation of autonomy regarding the Technical Dike Profiles. (Author, 2023)



Dike Construction

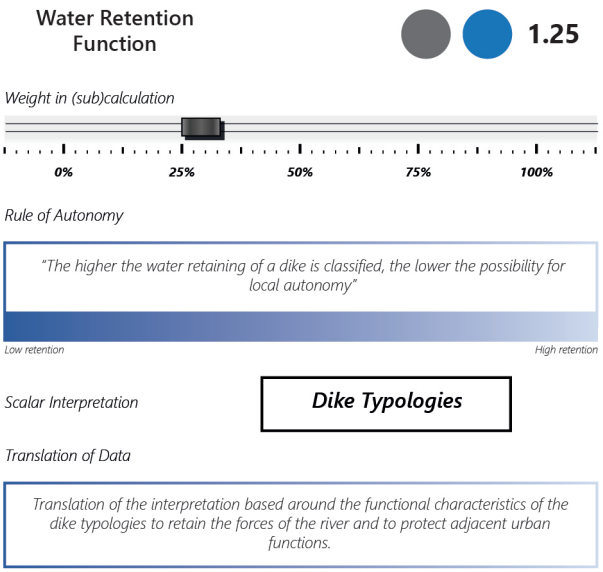
A. *Materials for Dike Construction*

Dikes are primarily constructed out of a sand core with an outer protective layer of clay (Lola Landscape Architects, 2014). Although sand and clay are relatively easy to come by, specific classifications are often required (Fugro, 2012). Also, particular materials such as concrete, asphalt, or stones increase the costs of dike construction.



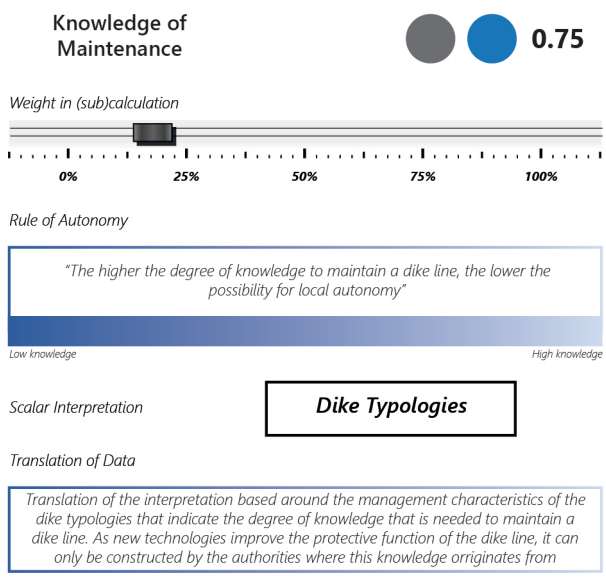
B. *Water retention function*

The main priority of a dike is to retain the water. Different measures can be taken to increase this retention function. By toe protection, revetments, and integrated sheet piling can the dike be strengthened (Lola Landscape Architects, 2014). Although useful, the costs of these interventions increase the cost of construction.



C. *Knowledge of Maintenance*

The effectiveness of the design of a dike is based on the availability of knowledge. Therefore if the knowledge of the long-term environmental data is available, fewer costs have to be made to maintain the dike.



D. *Flexible usage*

Dikes are considered to be the cheapest form of hard defense against the water when the land value is low (Brampton, 2002). If certain dikes can be constructed in various contexts, the costs of the construction can be lowered.

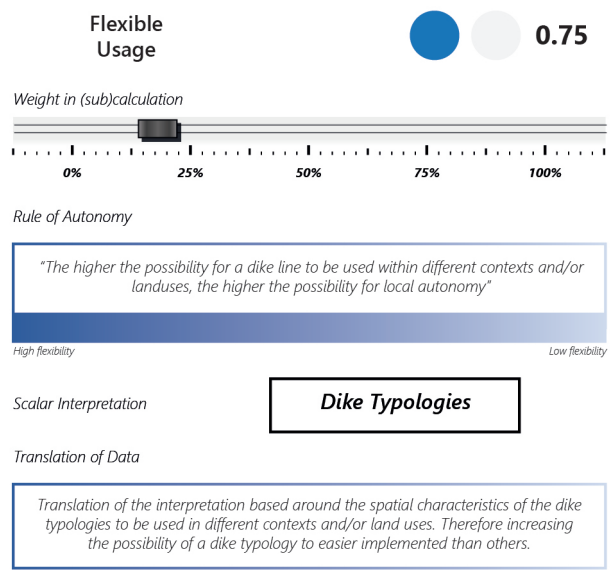


Figure 82: Translation of autonomy indicators of Dike construction. (Author, 2023)

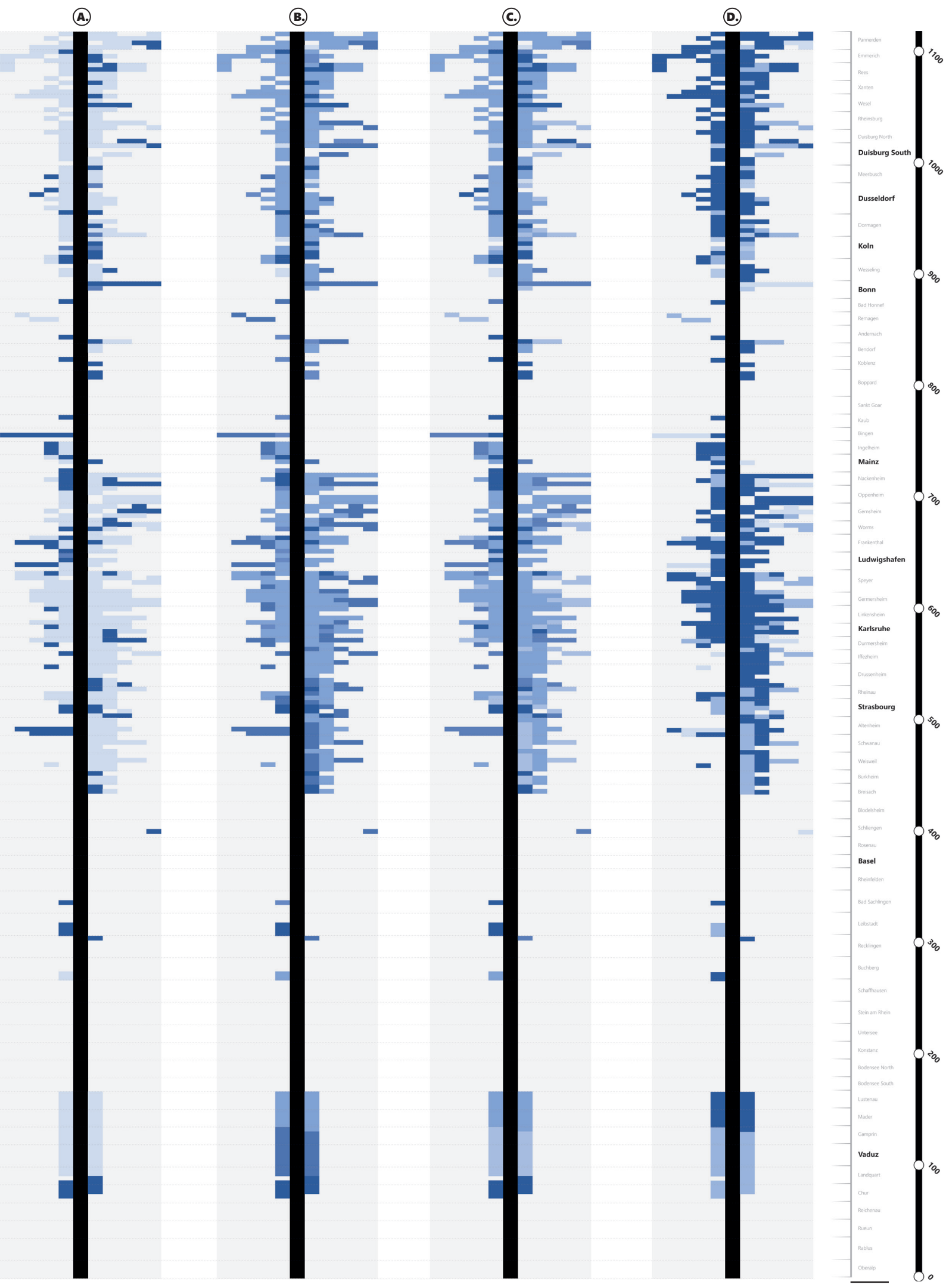
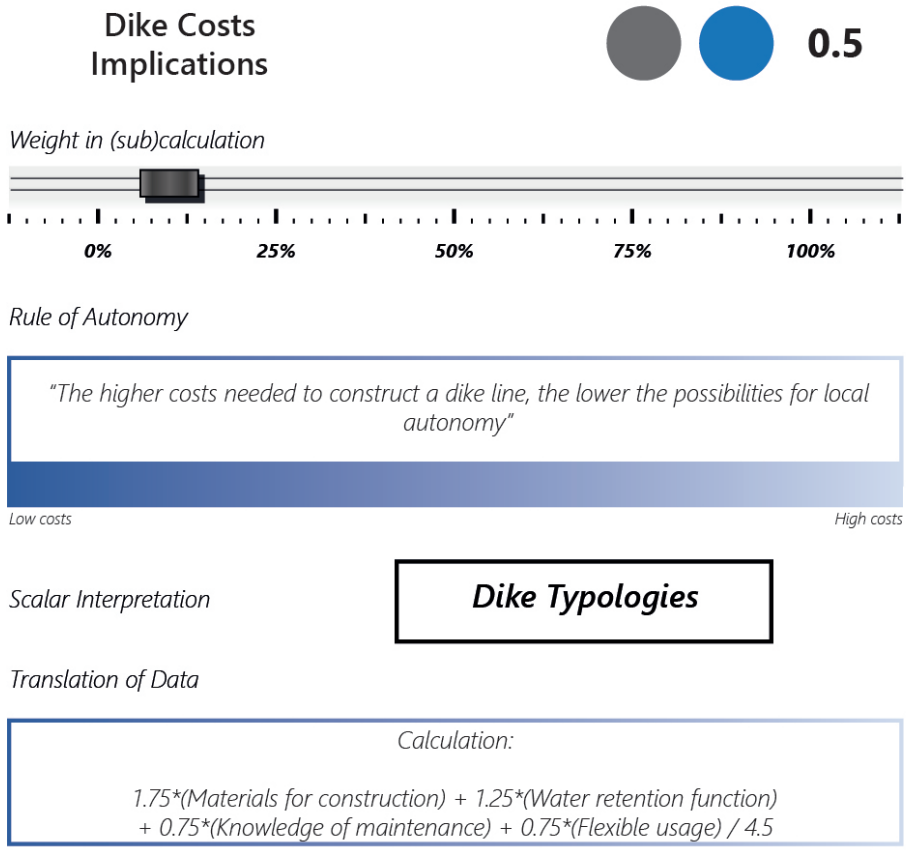


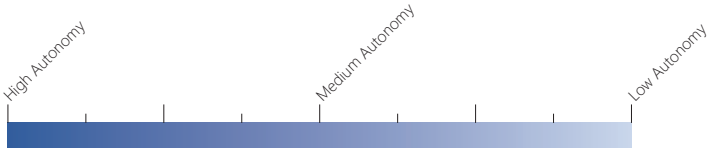
Figure 83: Spatialization of the Rhine Line regarding Autonomy based on Dike construction. (Author, 2023)



Weighting of the Indicators

Although dikes are considered to be the least expensive form of direct flood protection (Brampton, 1992), the costs that are induced are still considerable (CTCN, n.d). Therefore the consideration of the construction of a new dike by local stakeholders is dependent on the availability of materials, the water retaining function, and the knowledge that is needed to build the dike. As most of the costs are dependent on the materials it is chosen to rank this indicator extremely high in comparison to the others. Although the other indicators are not directly connected to the costs, they give indications of the dike decision-making process. Therefore the water retaining function (1.25) is ranked higher than the knowledge that is needed (0.75). The additional indicator of flexible use creates insight into the ease of implementation of a dike.

Figure 84: Translation of autonomy regarding the Dike Cost Implications. (Author, 2023)



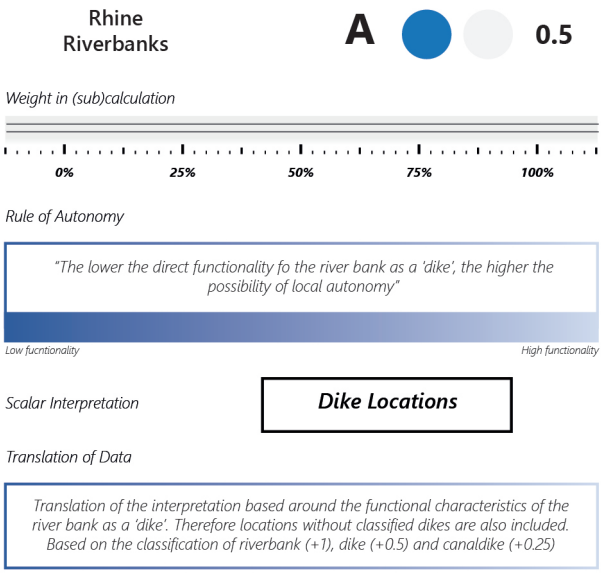
Additional Indicators

A. *River banks*

Besides the existing dikes of the Rhine (BAFG, 2015), additional areas along the Rhine still function as a line of protection. Therefore these locations are also classified as dikes and form a separate indicator.

B. *Dike Systems*

Dikes are rarely self-operation elements. Therefore each dike line is part of a larger system. Whereas certain dikes are built to increase the spillover of water in periods of high flow to other regions, other dikes are merely local floodwalls.



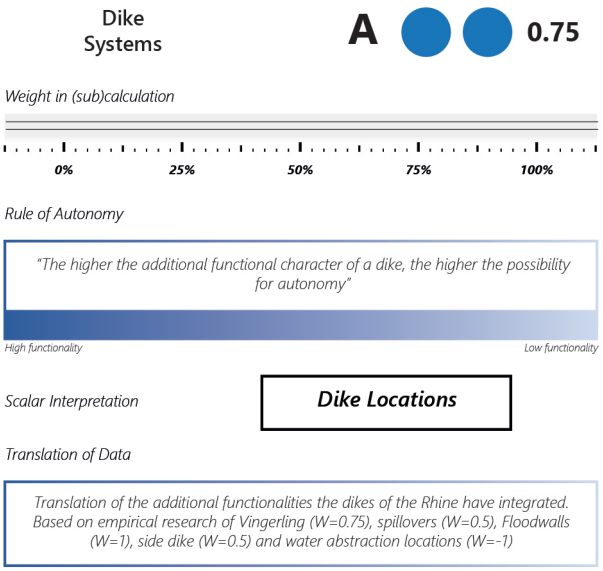


Figure 85: Translation of autonomy indicators of Additional dike indicators. (Author, 2023)

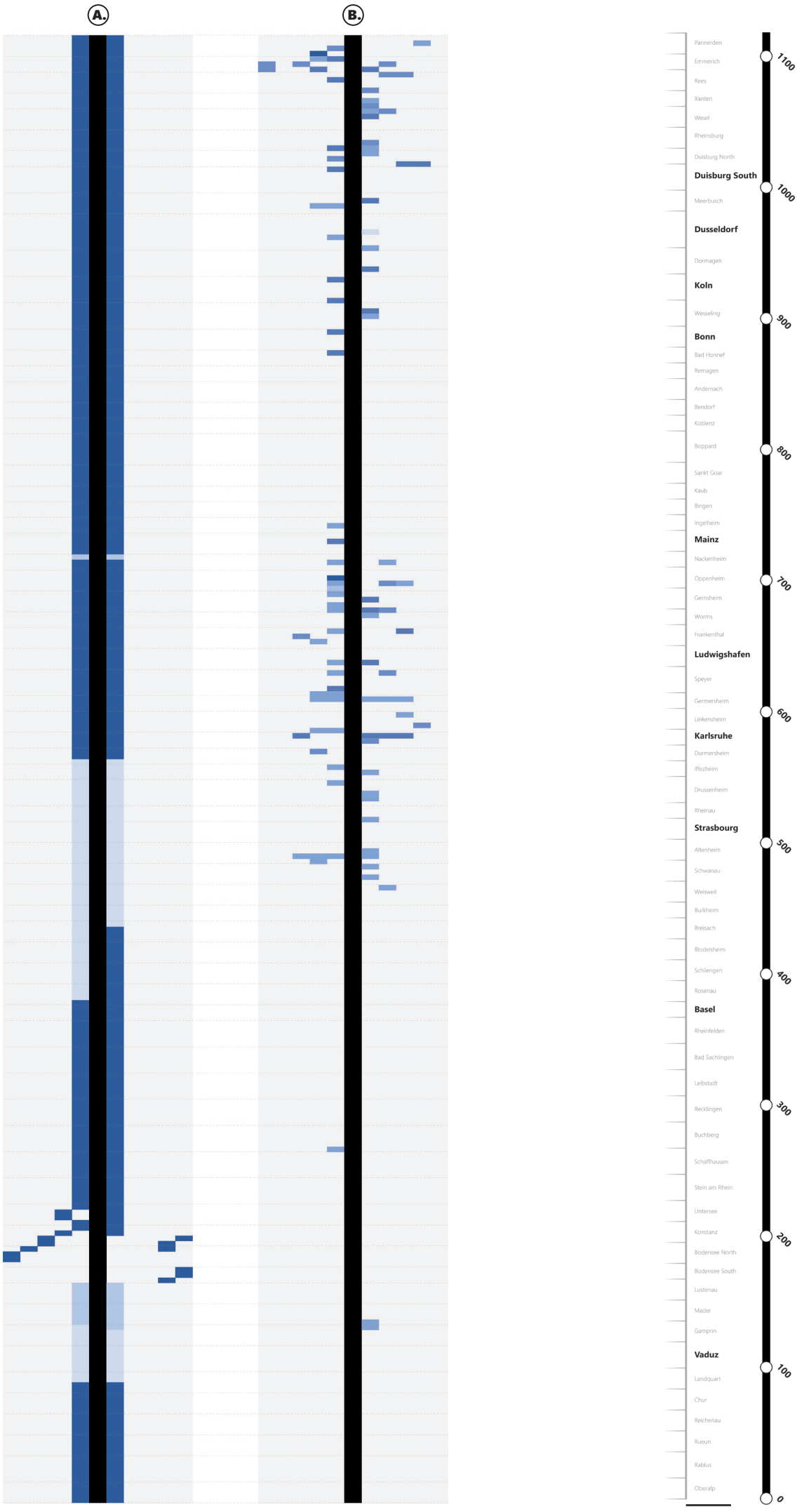
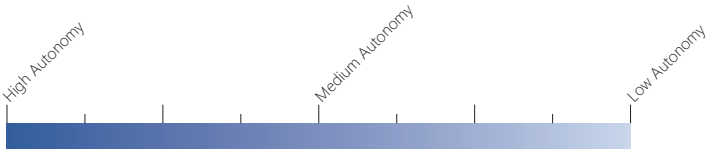


Figure 86: Spatialization of the Rhine Line regarding Autonomy based on Additioanal dike indicators. (Author, 2023)



Dike Autonomy

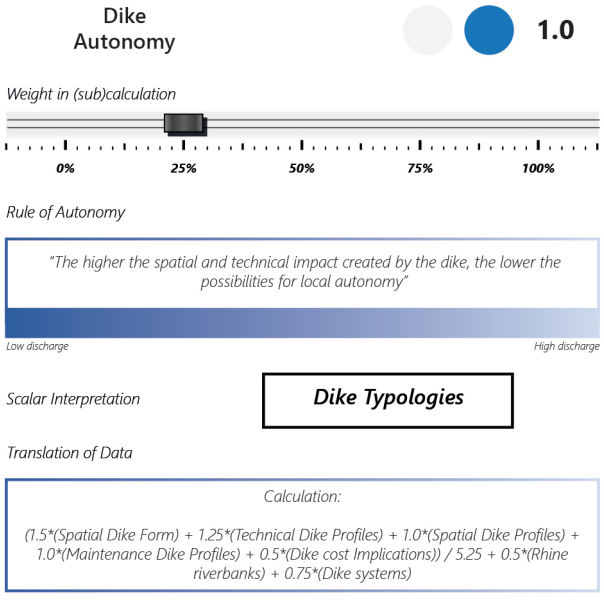
The search for local dike autonomy starts by looking at the current dikes of the Rhine. Based on the calculations provided by the previous five main sub-calculations, we can define locations along the Rhine where the autonomy of the current dike infrastructure is considered to be high. Based on the weights that were given by the indicators and by the mentioned sub-calculations, 5 potential areas are highlighted.

(A). *Lower Rhine (Pannerden-Duisburg)*
This location is highlighted due to its high classification in technical and maintenance autonomy. This is primarily the reason due the large extent of the dike lines as part of the winter-summer dike systems. As this dike system is based around water retention with winter dikes, less maintenance is needed.

(B). *Urbanized Rhine (Dusseldorf-Bonn)*
The collection of urbanized dikes and rural dikes makes this location interesting for local dike autonomy. Due to the extent of the boulevards of Koln, additional spatial features are added leading to a higher autonomy. But primarily the dikes between the large urban areas, show high potential.

(C). *Upper Rhine (Mainz-Ludwigshafen)*
The area between Mainz & Ludwigshafen is classified as wetlands and natural water retention zones. Therefore the dikes are integrated within the existing context, facilitating more space for water, leading to lower technical functionalities of the dikes.

(D). *Canalized Rhine (Stasbourg-Breisach)*
The canalized Rhine of the French-German border indicates a high degree of canal dikes. Therefore based on their functional character of distribution, a higher potential of local autonomy is reached.



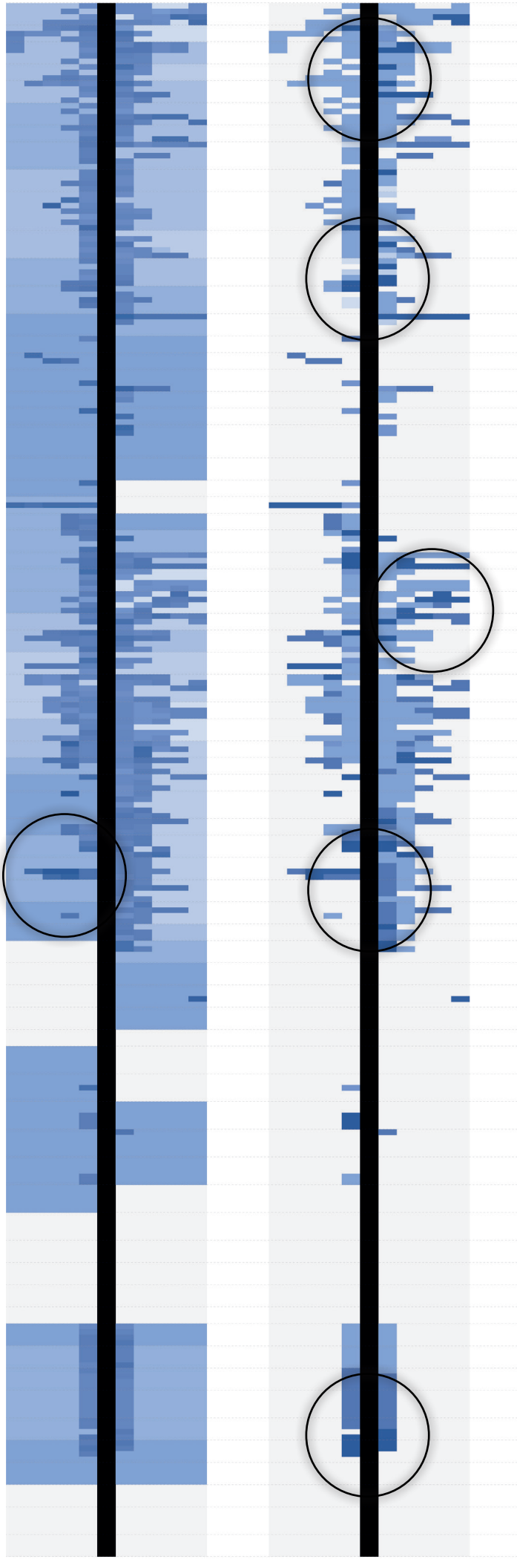
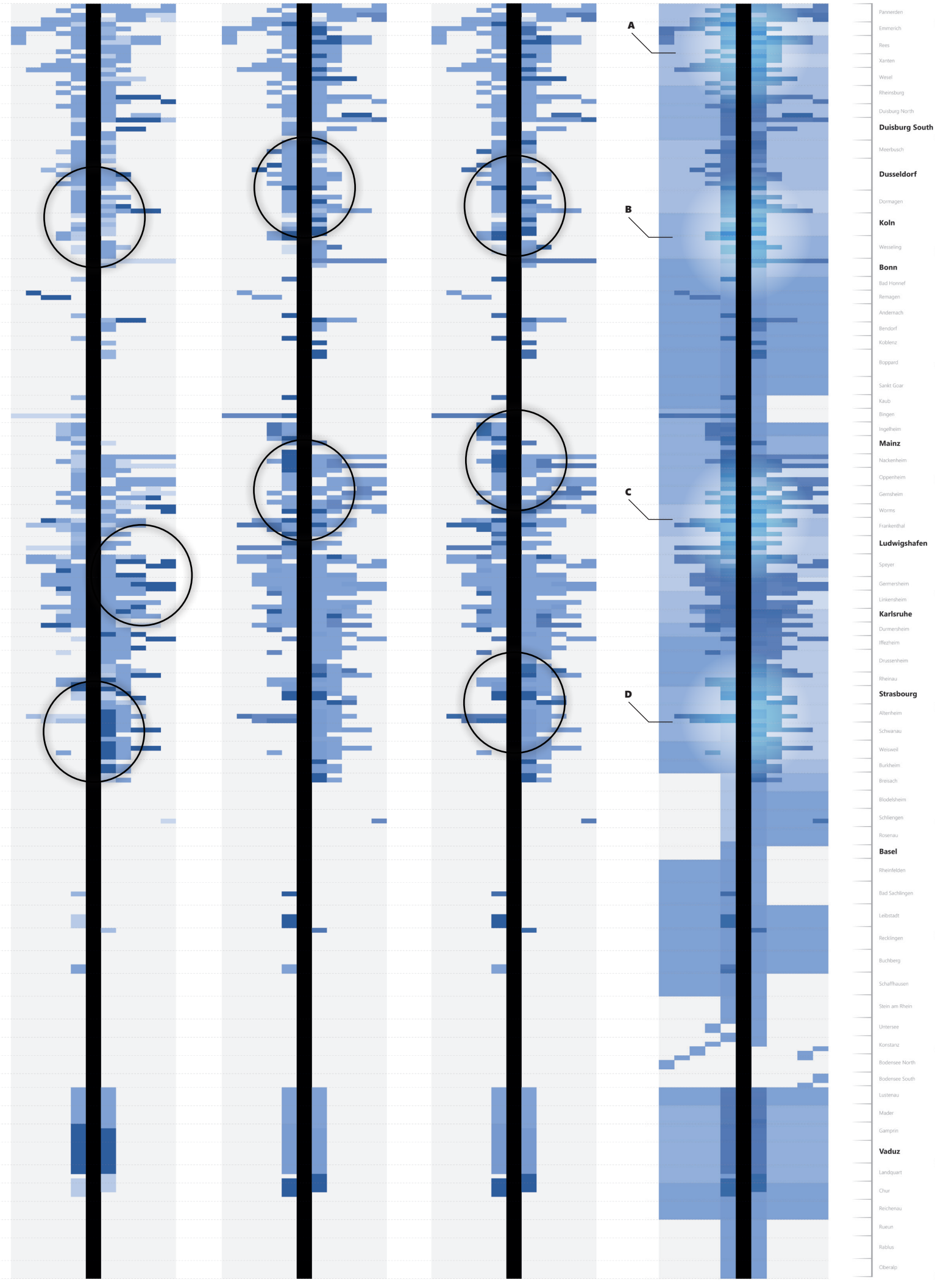


Figure 87: Spatialization of the Rhine Line regarding Dike Autonomy and the sub-calculations . (Author, 2023)



Spatial Dike Profiles

Maintenance Dike Profiles

Dike Construction Costs

Dike Autonomy

10.2

River Dynamics

Main Calculation

The second major sub-calculation aimed at establishing locations suitable for local dike autonomy is dedicated to assessing the forces of the river on the dikes. While canalization projects of the 19th century reduced the potential for Rhine flooding, they did not mitigate the forces of the river. However, when considering the possibility of re-establishing localized dikes, these new dikes must cooperate with the river rather than oppose it. Therefore, it is crucial to comprehend the current and future behavior of the river, especially under the influence of climate change. This section thus explores the current and projected river and water discharges of the Rhine, sedimentation and erosion patterns resulting from natural river dynamics, and the spatial distribution mechanisms used to control or disrupt the natural river flow.

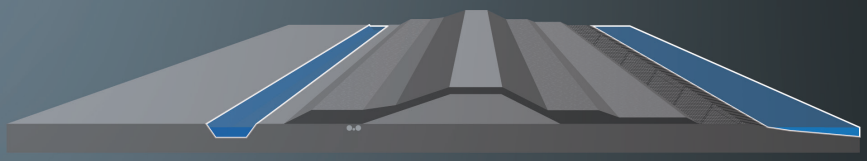
Sub Calculations

River & Water discharge

The first sub-calculation examines the amount of water distributed by the river across its path from the Alps (CH) to the division at Pannerden (NL). In this part, existing and future water data are translated to assess their impact on localized autonomy. The primary rule to follow indicates that high numbers and/or significant changes in river flow place additional stress on the current or future Rhine dikes, thereby reducing the capacity of local stakeholders to self-govern their dike systems. The main indicators in this sub-calculation are associated with the future projection of Rhine river discharge (Stahl et al., 2022), recent issues related to low-flow drought (Cammalleri, 2021), and the current water discharges as measured in the Rhine and its tributaries (GRDC, 2023; GEMstat, 2023).

Dike System Interruptions

To prevent the river from damaging the dike during periods of high and low flow, various spatial elements play a role in controlling or altering the flow. In this sub-calculation, we define two categories that contribute to autonomy (River Hierarchy and River Measurements) and two categories that either enhance or reduce autonomy (Distribution Mechanisms and Groins). These indicators provide insights into the additional pressures exerted on the dikes. These four indicators either increase or decrease the flow and dynamics of the river, thereby affecting the water pressures acting upon the dike lines.



Dynamics Conditions

Concerning the conditions that are influencing the stability and/or location of a dike body

River Discharge
1.5

- Change in High-Low Flow (2050) — 1.5
- Uncertainty High-Low Flow (2050-2100) — 1.0
- Low Flow Drought — 1.25
- *Quantitative Water Discharge* — 1.0
- Total Discharge of the River — 1.0
- Rate of Discharge Change — 1.25
- Tributaries of the Rhine — 0.25

Dike System Interruptions
0.75

- Water Distribution Mechanisms — 1.0
- Groins of the Rhine — 1.0 (A)
- Water Nodes — 0.75
- River Measures (Width) — 0.5

Sedimentation Patterns
1.25

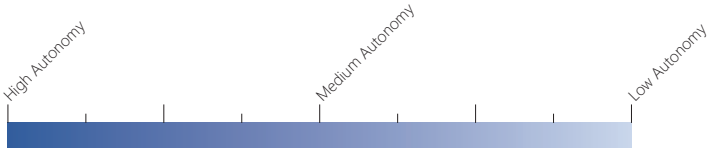
- Sedimentation Material — 1.25
- River Angles & Erosion — 1.5

Relation to Created Autonomy
Relation to Dike Suitability
Weight given in subcalculation
Used as an Addition to Autonomy
A
Positive
Negative
Neutral

Figure 88: River dynamics indicators. (Author, 2023)

Sedimentation Patterns

The final sub-calculation of river dynamics regards the sedimentation and erosion patterns of the Rhine. The meandering effect of the river generates two processes in the river: Erosion in the outer corner and sedimentation in the inner corner. Both of these processes are crucial for bordering dikes. Dikes positioned in the outer corner of the meander are more vulnerable to erosion, which can compromise the structural integrity of the dike. Conversely, dikes situated in the inner corner of the meander may benefit from sediment deposits, gradually shifting the river away from the dike line. This sub-calculation addresses both of these patterns.



River & Water Discharge

A. *Change in High-Low Flow (Now-2050)*

To assess the impact of high and low flow on a dike, discharge numbers have been translated showing the change between projections. The results indicate that the delta and lower Rhine regions (A1) experience a higher change rate compared to the upstream areas (A2).

Change in High-Low Flow (2050) — **1.5**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the change in high-low flow of the river discharge of the Rhine, the lower the possibility for local autonomy"

Low change rate — *High change rate*

Scalar Interpretation — **Rhine Line**

Translation of Data

Translation of the research provided by the Stahl et al., (2022) surrounding projections of river discharge of the Rhine till 2050. Calculation was made to conduct the change rate of high (W=1) & low flow (W=1) from 2020 till 2050. Additional indictions were provided based on the relations between the change of high and low flow to each other (W=0.25). Calculation was run as per 1x4 km location along the Rhine.

B. *Change in High-Low Flow (2050-2100)*

This analysis focuses on the changes between 2050 and 2100, which are considered crucial for understanding the uncertainties in discharge projections. While the lower regions of the Rhine show an increased change rate (B1), the area near Mainz intriguingly exhibits a slower change rate than in 2050. This phenomenon could be attributed to the presence of large wetland areas near Oppenheim (B2).

Change in High-Low Flow (2100) — **1.0**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the change in high-low flow of the river discharge of the Rhine, the lower the possibility for local autonomy"

Low change rate — *High change rate*

Scalar Interpretation — **Rhine Line**

Translation of Data

Translation of the research provided by the Stahl et al., (2022) surrounding projections of river discharge of the Rhine till 2050. Calculation was made to conduct the change rate of high (W=1) & low flow (W=1) from 2050 till 2100. Additional indictions were provided based on the relations between the change of high and low flow to each other (W=0.25). Calculation was run as per 1x4 km location along the Rhine.

C. *Low Flow Drought Conditions*

Low-flow drought's impact on the river is often underestimated when considering dikes. Periods of low flow can lead to the drying out of the dike, compromising its structural integrity. The area of Koblenz was particularly affected by the low flow drought of 2022 (C1), where the narrowing of the river near Kaub formed a bottleneck in the river system. However, other areas remained functional (C2).

Low Flow Drought — **1.25**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the degree of low flow from the year of 2022, the lower the possibility for local autonomy"

Low degree — *High degree*

Scalar Interpretation — **Rhine river**

Translation of Data

Translation of the information provided by the European Drought Observatory for the recent drought year of 2022 (Cammaller et al., 2021). Translated based on the difference in hydrological seasons: Winter (W=1) & Summer (W=1.25). Low flow indirectly destabilizes the structural integrity of the dike line as a constant moisture level is needed.

D. *Quantitative Water Discharge*

This section provides existing discharge data for the rivers of the Rhine basin. The higher the river's discharge, the more pressure it can exert on the dike. This is especially relevant near Koblenz, Basel, and Mader, where you find large tributaries (Moselle, Aare, and Ill).

Quantitative Water Discharge — **0.75**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the quantitative amount of water discharge along the Rhine and water nodes, the lower the possibility for local autonomy"

Low discharge — *High discharge*

Scalar Interpretation — **Point data**

Translation of Data

Calculation:

1.0(Total Discharge of Rhine) + 1.25*(Rate of Discharge Change) + 0.25*(Tributaries of the Rhine)*

Figure 89: Translation of autonomy indicators of River & Water Discharge. (Author, 2023)

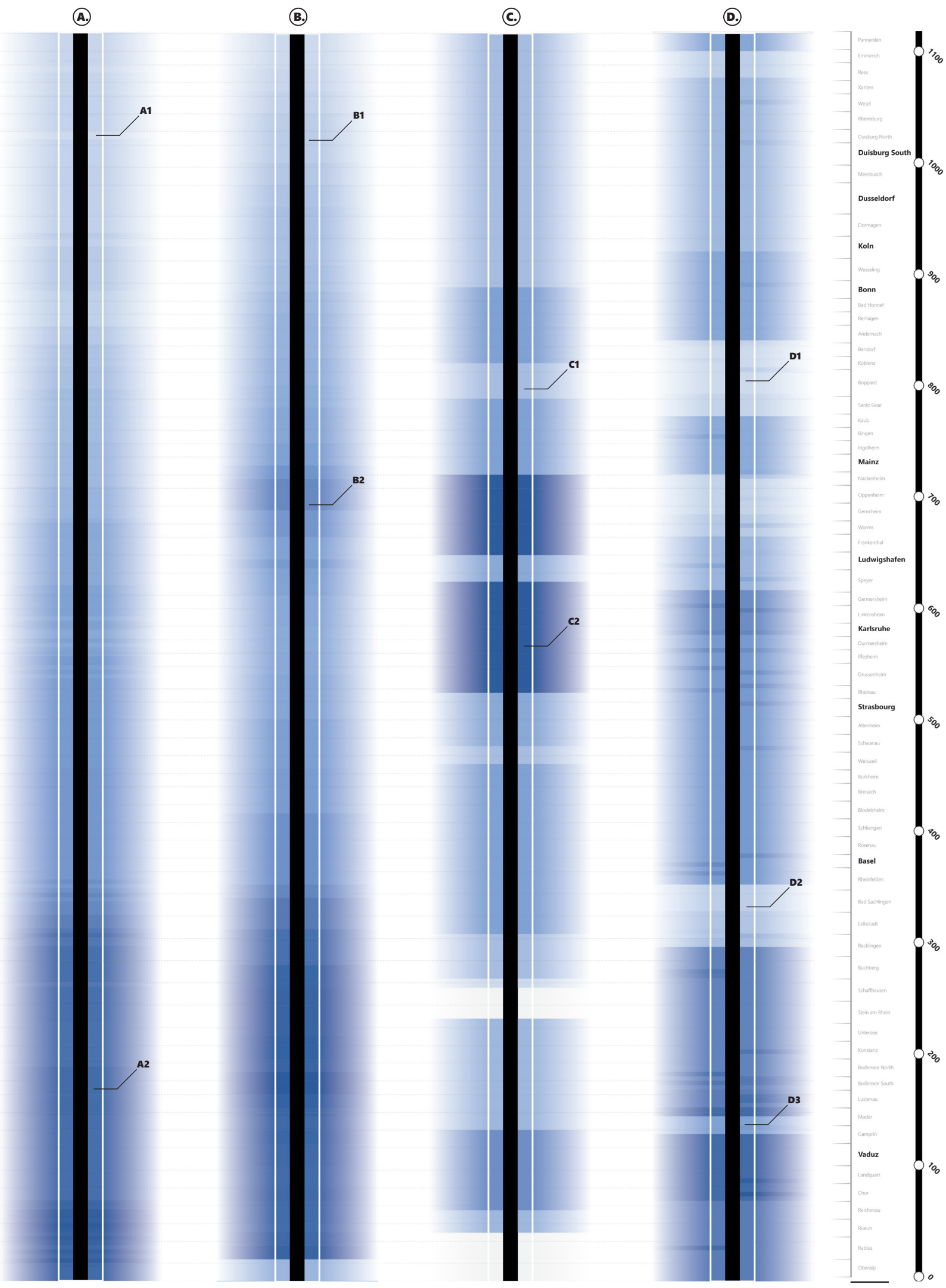


Figure 90: Spatialization of the Rhine Line regarding Autonomy based on River & Water Discharge indicators. (Author, 2023)

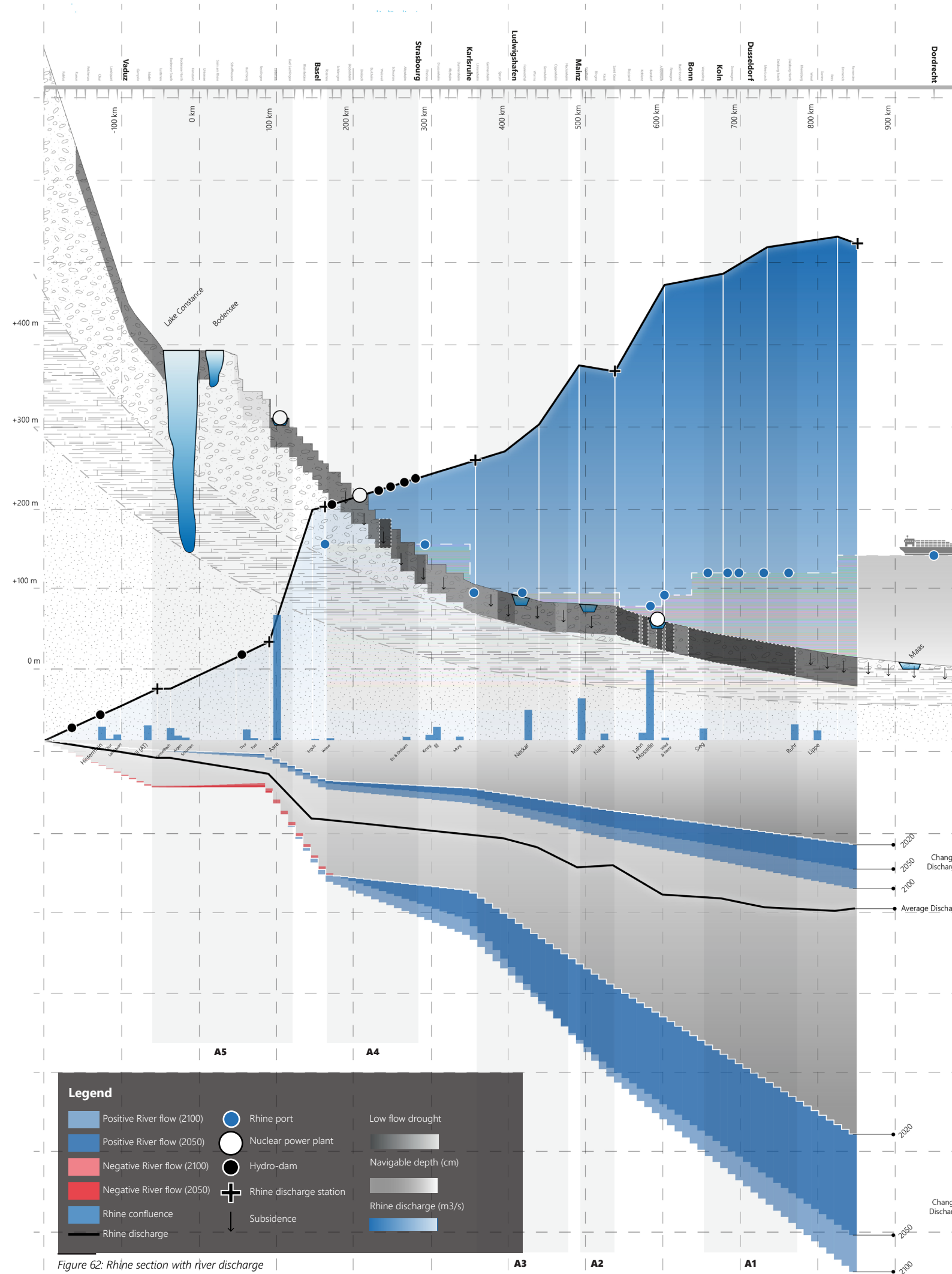
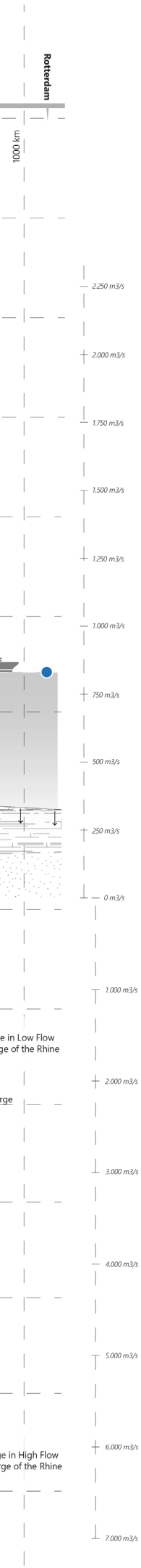


Figure 62: Rhine section with river discharge related information. (Author, 2023)



River Discharge

1.5

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the future changes in river discharge as per high & low flow content, the lower the possibility for local autonomy"

Low discharge *High discharge*

Scalar Interpretation

Rhine river

Translation of Data

Calculation:

1.5(Change High-Low 2050) + 1.0*(Change High-Low 2100) + 1.25*(Low flow drought) + 1.0*(Quantitative discharge) / 4.75*

Weighting of the Indicators

Understanding the pressures exerted on dikes requires careful consideration of river discharge projections and current statistics. Dikes are primarily designed to withstand water pressure. Changes in high and low flow increase this pressure. Interestingly, due to the effects of climate change, the Rhine projections until Basel (A5) show a decrease in high flow projections, increasing the potential of autonomy. Although the increase in high flow is widespread, the area between Mainz and Kaub (A2) shows a stabilization of projected high flow in 2100, likely due to the natural geological landscapes of the Rhine Gorge, which limit the potential for increased high flow. This poses challenges for downstream areas, as the narrowing of the Rhine increases water pressure (A3). It's also worth mentioning the potential for low-flow drought along the Rhine, particularly in the canalized river between Basel and Strasbourg (A4). Beyond this section, current and projected discharge rates increase, leading to higher fluctuating river levels for large ports and industries downstream (A1).

A higher weight has been assigned to discharge projections (2.5) compared to current statistics (1.0), as changes in high and low flow in the future provide better indicators of dike suitability. Additionally, the low flow drought (1.25) has been given a relatively high rank due to its adverse impacts on industrial and public water services downstream and the structural integrity of the dikes.

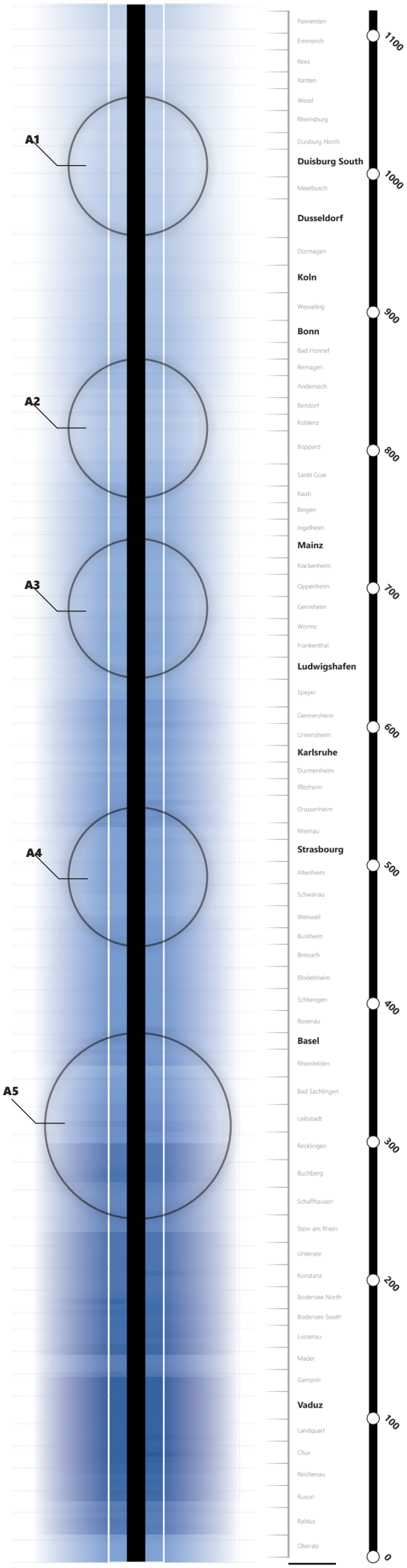
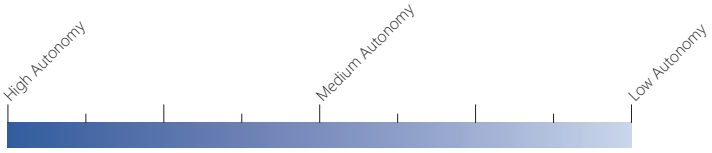


Figure 92: Spatialization of the Rhine Line regarding Autonomy based on River & Water Discharge. (Author, 2023)



Dike System Interruptions

A. *Water Distribution Mechansims*

Distribution mechanisms are primarily considered technical applications to control or alter the original course of the river to manage water flows. In the agricultural regions of the lower Rhine (A1), culverts are used to redistribute water flows, whereas in the areas around Strasbourg (A2), dams and weirs are employed to slow down the water flow. The latter significantly impacts the pressure on dikes.

Water Distribution Mechanisms 1.0

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the amount fo water distribution mechanisms along the river, the lower the possibility for local autonomy"

Low amount *High amount*

Scalar Interpretation **Point data**

Translation of Data

Translation of the data provided by AMBER Consortium (2020), the water distribution mechanisms of culverts (+0.25), sluices (-0.75), Weirs (-1) and dams were mapped within the 10km boundary set along the Rhine. The usage of these instruments primarily results in a change of the river flow increasing the pressures on dike lines

B. *River Hierarchy*

Stahler's classifications address the river's importance within the hierarchical water system (Copernicus, 2019). The Rhine is classified as the highest hierarchical river, with tributaries like the Moselle (B1), the Aare (B3), and the Main (B2) as the largest secondary rivers. A higher classification indicates potentially more intense pressure on the dikes.

Water Nodes 0.75

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the classifcation of thre tributaries of the Rhine based on their Strahler levels, the lower the possibility for local autonomy"

Low degree *High degree*

Scalar Interpretation **Point data**

Translation of Data

Translation of the Strahler classifications of river hierarchies, indicating the importance of the river to the overall water system. Based on the information provided by the Copernicus (2019). Translation was made within the 1x4 km line raster. Indications of higher rivers on the hierachial sclae indicates the importance of that river body, needing dike lines to be able tomore structurally sound.

C. *River Measurements*

The river's width is used to assess the load balance of the river regarding its surroundings. A wider river can generate more water pressure on the adjacent area. This is evident in the section between Bingen and Mainz (C1), where the narrowing of the Rhine Gorge at Kaub increases the river's width upstream.

River Measurements 0.5

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The wider the river flows, the larger constant pressure is put on the adjacent dike lines, the lower the possibility for local autonomy"

Low width *High width*

Scalar Interpretation **Rhine river**

Translation of Data

Translation of the information provided by Allen and Pavelsky (2018) indictating the median river width of the river based on respective river segments of the Rhine.

D. *Groins*

Groins are water distribution mechanisms often found in lower-lying regions (D1 + D2), where the river has more space. Groins are constructed within the river to relieve dike pressures and maintain navigability. However, while they reduce pressure locally, they increase streamflow, which can have impacts downstream.

Groins of the Rhine A 1.0

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The stronger the respresentation of groins along the Rhine, the higher the possibility for local autonomy"

High respresentation *Low representation*

Scalar Interpretation **Point data**

Translation of Data

Translation of empirical data mapping the available groin location along the Rhine within the 1x4 km raster of the line. Representation was measured based on the percentage filled of groins per location. 100%: +1, 75%: +0.75, 50%: +0.5 & 25%: +0.25. Availability of groins reliefs water pressure from the dike lines.

Figure 93: Translation of autonomy indicators of Dike System Interruptions. (Author, 2023)

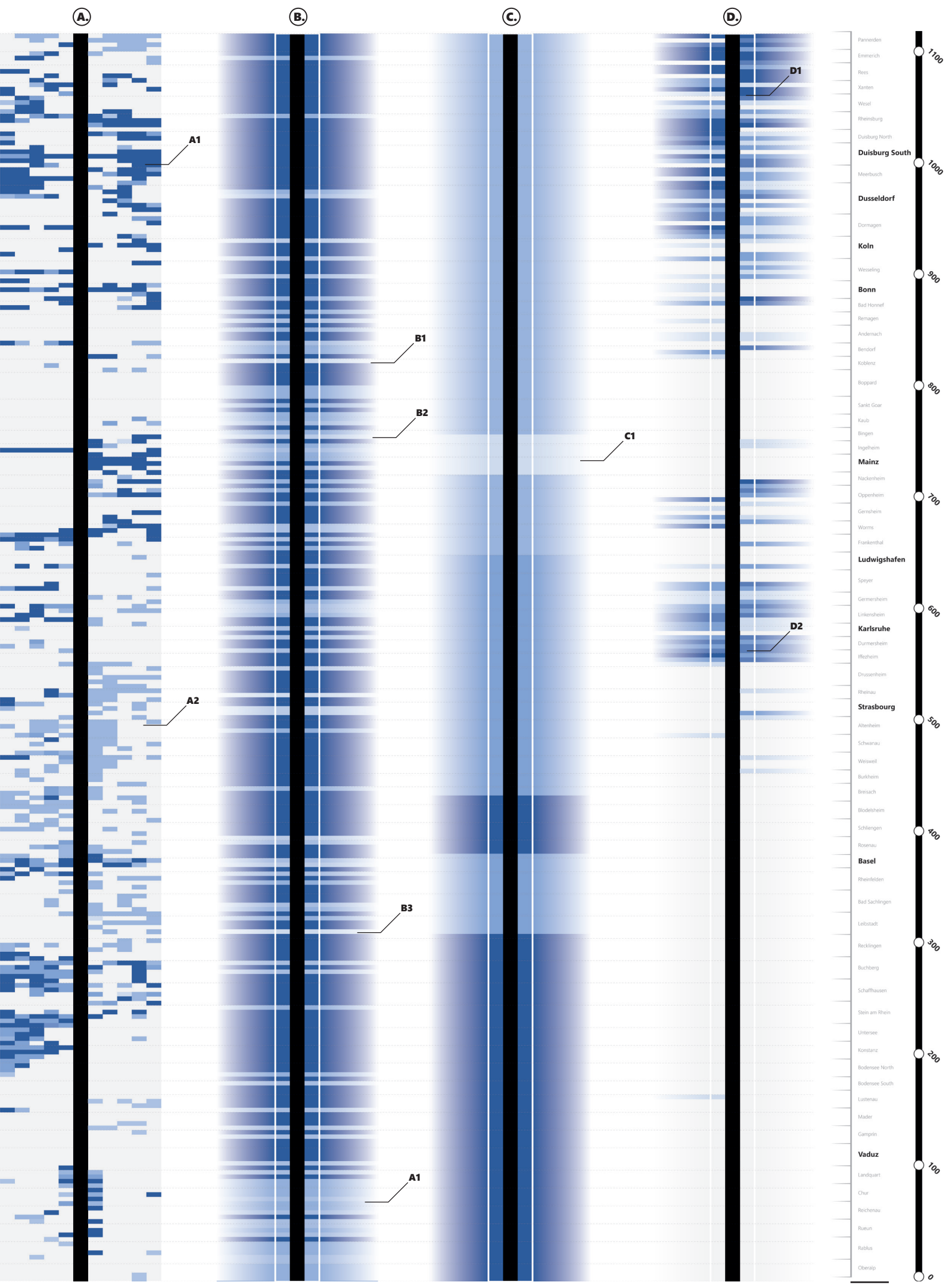
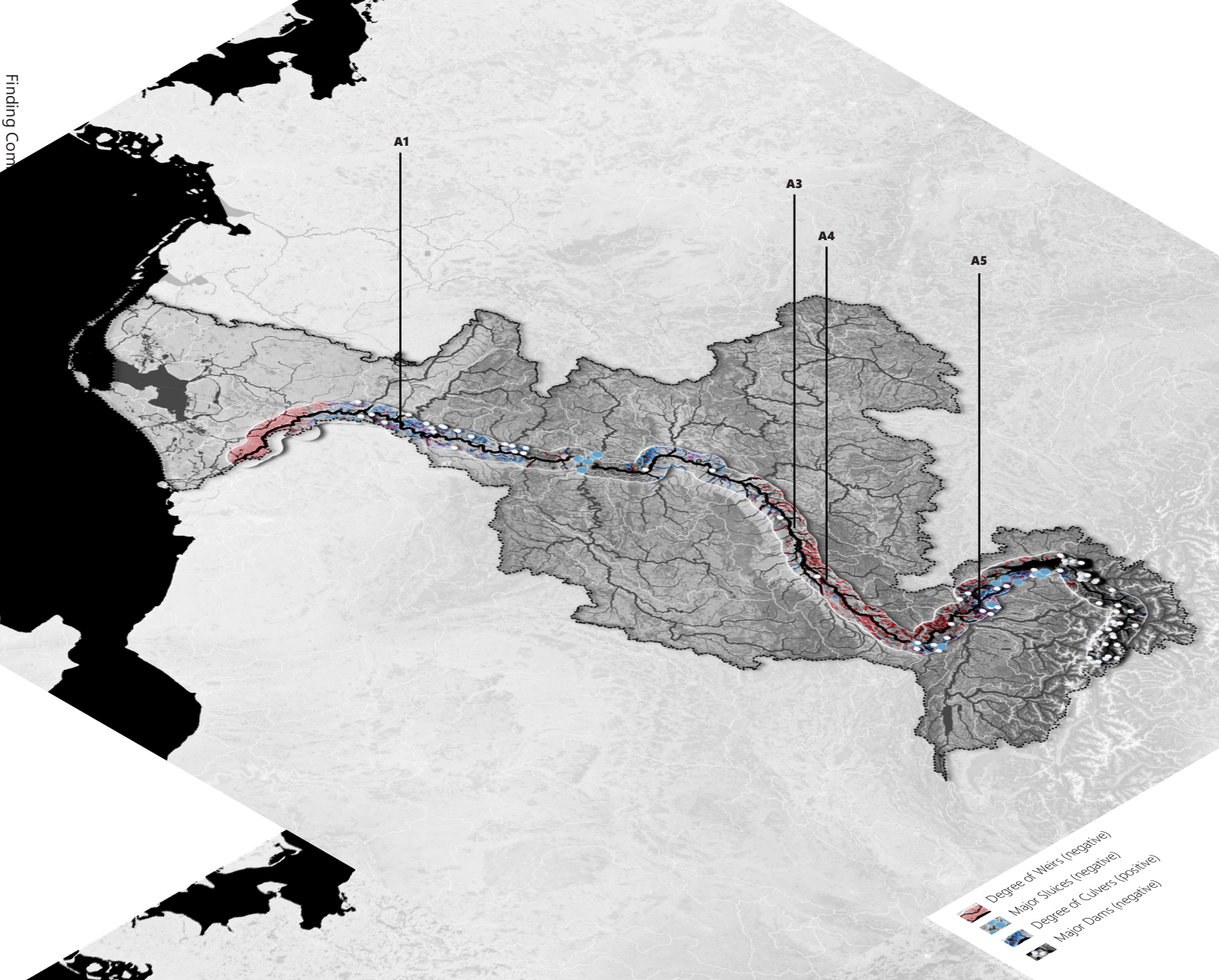


Figure 94: Spatialization of the Rhine Line regarding Autonomy based on Dike System Interruptions indicators. (Author, 2023)



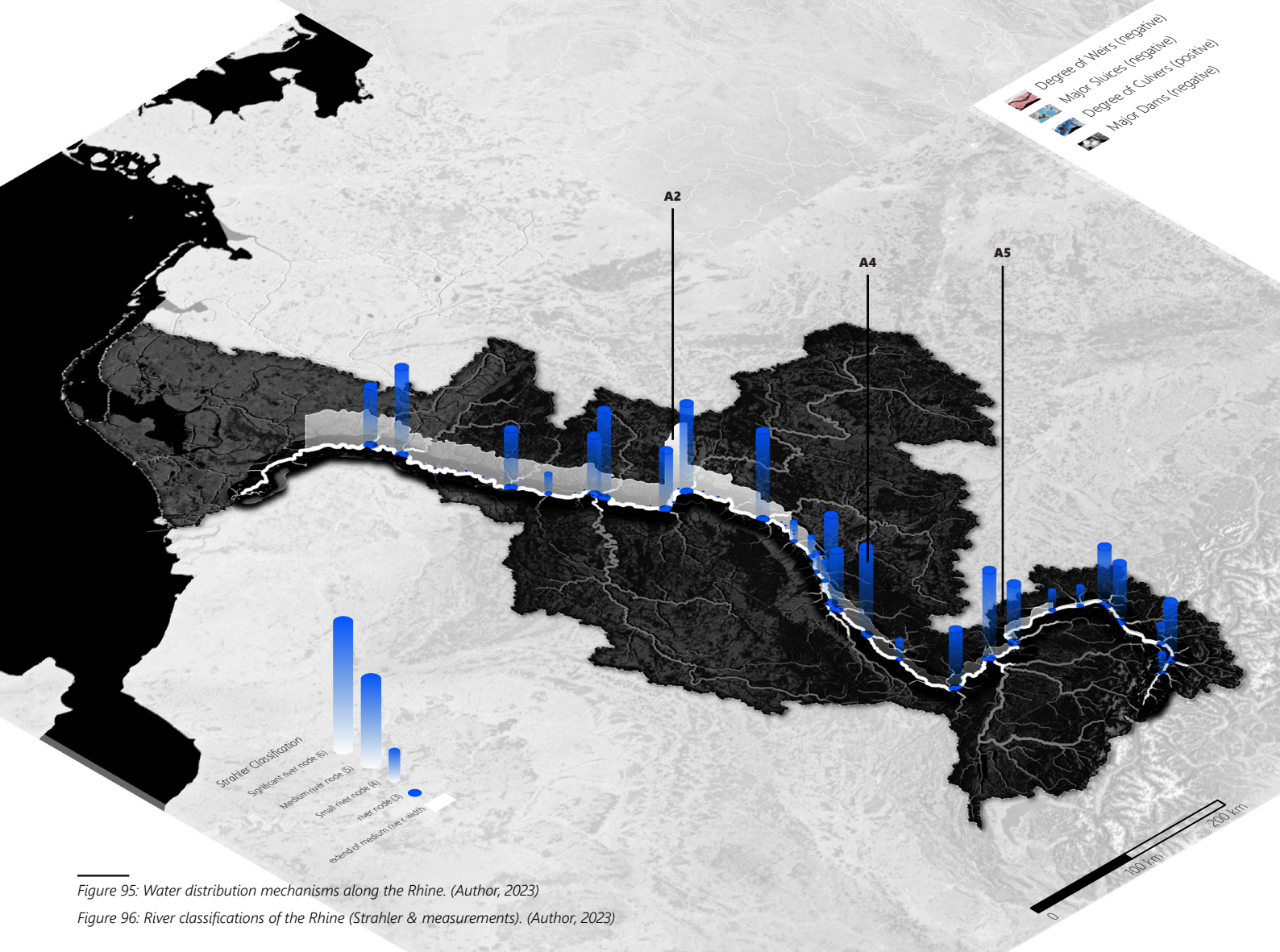


Figure 95: Water distribution mechanisms along the Rhine. (Author, 2023)

Figure 96: River classifications of the Rhine (Strahler & measurements). (Author, 2023)

Dike System Interruptions 0.75

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the amount anomolies along the river, the lower the possibilities for local autonomy"

Low anomolies *High anomolies*

Scalar Interpretation ***Point data***

Translation of Data

Calculation:

(1.0(Water distribution mechanisms) + 0.75*(Water Nodes) + 0.5*(River Measurements)) / 3.75 + (1.0*(Groins))*

Weighting of the Indicators

The sub-calculation for dike system interruptions assesses the technical mechanisms to manage the Rhine's water flow based on its width and Strahler classification. Therefore, water distribution mechanisms are given a higher rank in this sub-calculation (1.0), as they have the potential to yield either positive or negative results for autonomy. For instance, the high number of weirs near the canalized section of Strasbourg (A4) and the High Rhine between Basel and the confluence of the Aare (A5) negatively impacts autonomy. Conversely, the agricultural regions north of the Ruhr (A1) indicate a high potential for autonomy due to the integration of culvert systems with the surrounding dike structures.

The other two indicators primarily relate to the classifications of rivers based on their measurements and importance in the hydrological system. These are assigned lower weights as they are more challenging to change and, therefore, are less influential in autonomy creation. Due to the high width of the Rhine and the large confluences of the Main and Nahe (A2), a higher degree of water pressure is generated, reducing autonomy.

The regions with the highest potential are located near Karlsruhe, where the low number of water distribution mechanisms and confluences indicates a high potential for autonomy.

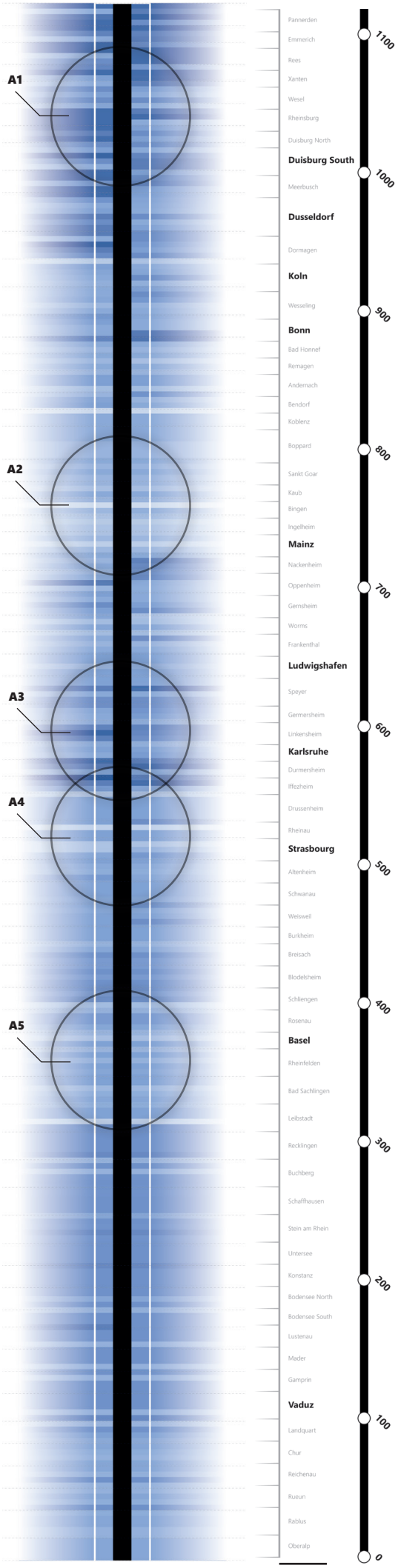
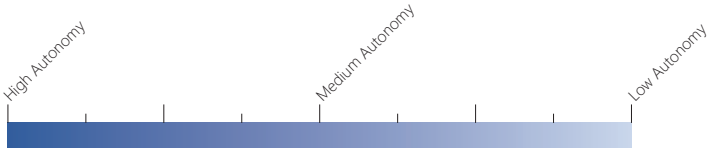


Figure 97: Spatialization of the Rhine Line regarding Autonomy based on Dike System Interruptions. (Author, 2023)

Sedimentation Patterns

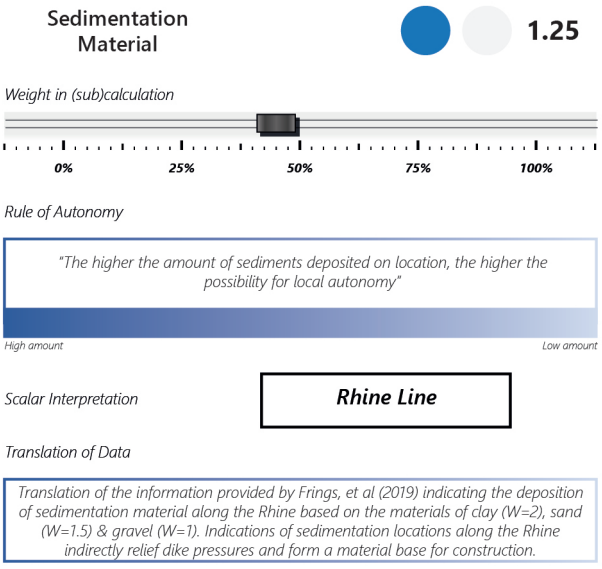


A. *Sedimentation Material*

The types of sediment provide insights into the river's dynamics. Sediment is categorized into three main groups: Clay, Sand, and Gravel. These sediments deposit at varying speeds, impacting local river flow. Sedimentation can create a secondary protective layer near the dike and may also serve as material for dike construction. However, the accumulation of sediment within the river, particularly in slower-flowing areas, can lead to blockages and increased water pressure upstream. Therefore, regular sedimentation abstraction is necessary to mitigate blockage impacts.

B. *Sedimentation & Erosion*

While one side of the river experiences sedimentation processes, the other side faces erosion, as water flows more swiftly on the outer bend of the meander. As the river bend angle increases, the speed of the river flow rises, leading to the erosion of the outer bank. This can compromise the structural integrity of dike, as the dike's toe may erode. Locations with large river meanders are near Dusseldorf (B1), the Rhine gorge area (B2), the High Rhine between Basel and Konstanz (B4), and near the Rhine source in the Oberalppass (B5). One noteworthy location is near Ludwigshafen (B3), where the re-establishment of side rivers (IKSR, 2020) has increased the potential for erosion.



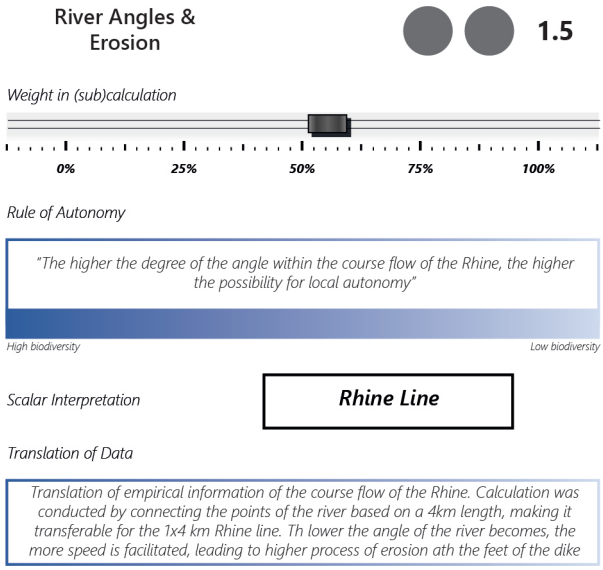


Figure 98: Translation of autonomy indicators of the Sedimentation Patterns. (Author, 2023)

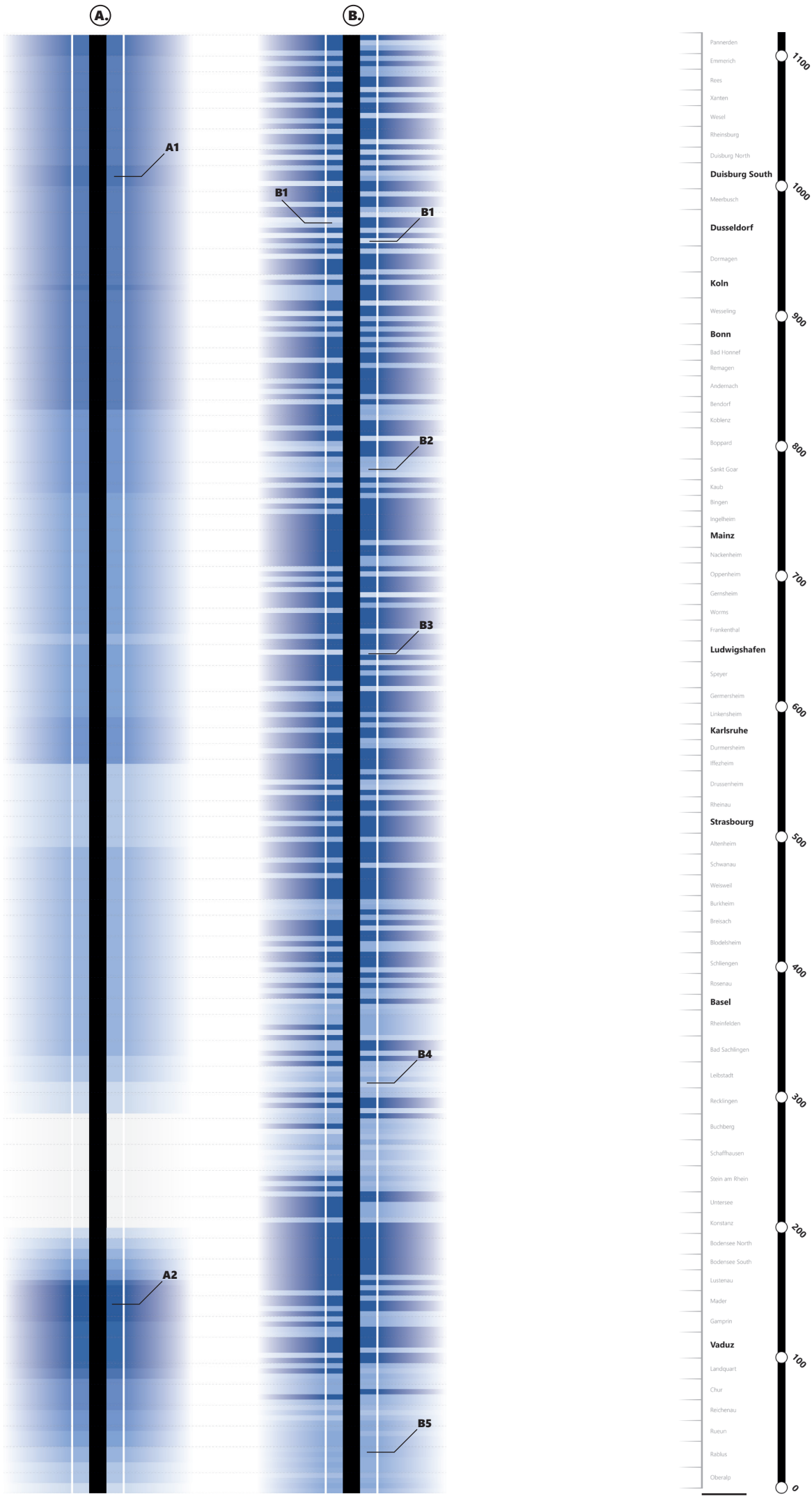


Figure 99: Spatialization of the Rhine Line regarding Autonomy based on Sedimentation Pattern indicators. (Author, 2023)

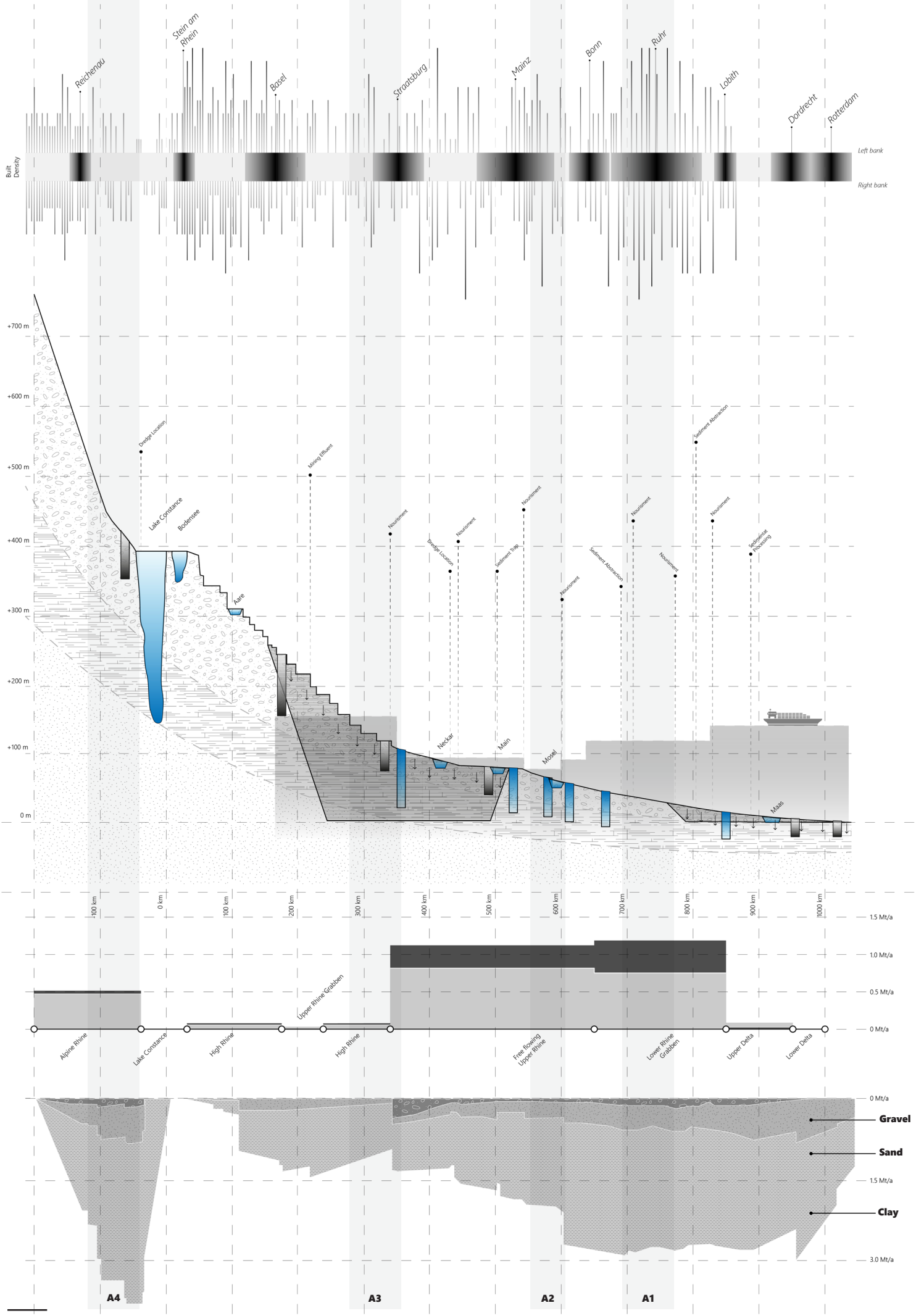


Figure 100: Rhine section showing existing Sedimentation Patterns. (Author, 2023)

Sedimentation Patterns

1.25

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the degree of the angle within the course flow of the Rhine, the higher the possibility for local autonomy"

High sedimentation *Low sedimentation*

Scalar Interpretation **Rhine Line**

Translation of Data

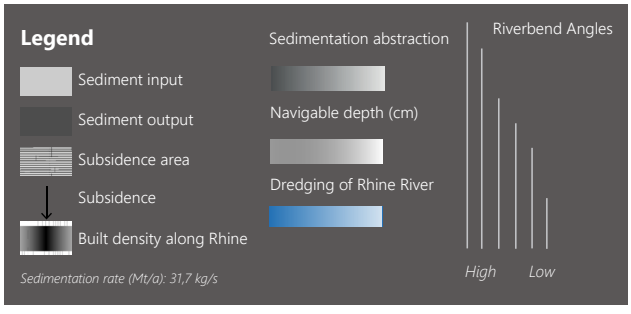
Calculation:

1.25(Sedimentation material) + 1.5*(River angles & Erosion) / 2.75*

Weighting of the Indicators

The calculation of sedimentation patterns explains the impacts and potential benefits that river dynamics can bring to their immediate surroundings. To ensure the structural integrity of dikes, the indicator for erosion is ranked higher (1.5) than the potential benefits of sedimentation (1.25).

In the flat regions of the lower Rhine between Cologne and the Netherlands, where the meandering river affects the surrounding areas (A1), erosion and sedimentation go hand in hand. However, increased autonomy is highlighted due to large deposits of sand and clay. Areas with less potential for sedimentation exist within the canalized section of the river between Basel and Strasbourg (A3), where the stepped section of the Rhine reduces sedimentation further downstream. Only after the Ill River confluence in France is there an increase in sedimentation, driven by the need for sediment nourishment to maintain existing weirs and dams for energy production (Frings, et al. 2019). Consequently, sediment is lost downstream, benefiting the natural water retention areas between Karlsruhe and Main with an increased sediment supply. The high sedimentation rates between Chur and the Bodensee are also noteworthy (A4). The existing mouth near Lustenau is an ideal location for sediment dredging. The high sedimentation rates make it an excellent location for establishing local autonomy.



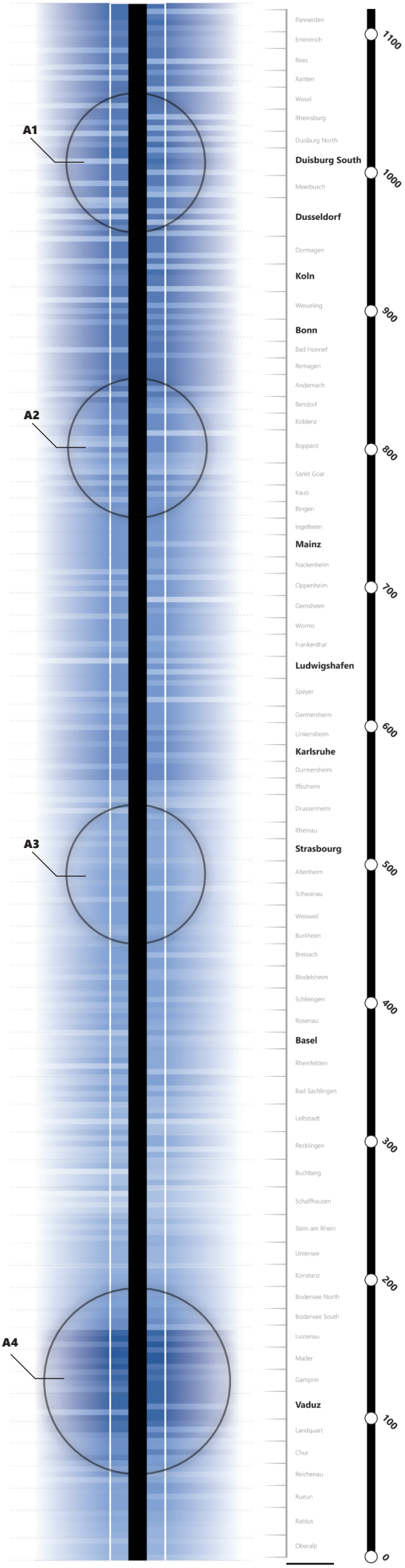


Figure 101: Spatialization of the Rhine Line regarding Autonomy based on the Sedimentation Patterns. (Author, 2023)

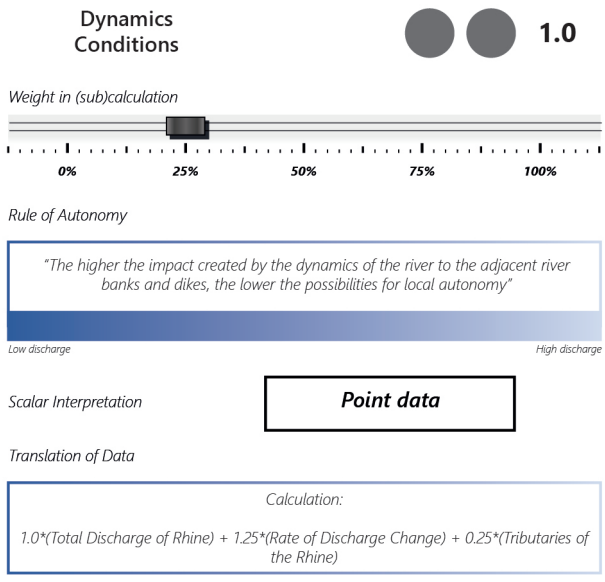
River Dynamics

River dynamics offer opportunities for localized autonomy. Understanding the river's dynamics provides insights into areas where water discharge (1.5) and sedimentation (1.25) projections can be used to establish regions suitable for local dike construction. Based on the calculations of the three main sub-calculations, areas with high potential for local autonomy are highlighted.

(A). *Lower Rhine (Rhine Gorge-Koln)*
The lower Rhine region, situated between the Rhine Gorge and the heavily urbanized Ruhr areas, is considered a prime location for local autonomy. The geological characteristics of this region result in relatively slow river discharge. However, periods of drought may pose a threat. Furthermore, the region's high sedimentation rates, coupled with the fact that the Rhine doesn't meander extensively, create opportunities for local dike maintenance and construction.

(B). *Upper Rhine Valley (Strasbourg-Ludwigshafen)*
The area immediately after the canalized section displays a relatively minor change in discharge and high sedimentation deposition in a region characterized by sediment abstraction locations that have transformed into natural retention zones. Given the likelihood of drought in this area and the river dynamics shaped by the canalized river, this region presents possibilities for local dike autonomy.

(C). *Alpine Rhine Valley (Chur-Lustenau)*
The highest potential for localized autonomy is found in the Alpine Rhine area, where the relatively low river discharge and high sedimentation rates create incentives for localized dike management. However, challenges arise due to the risk of drought are prominent.



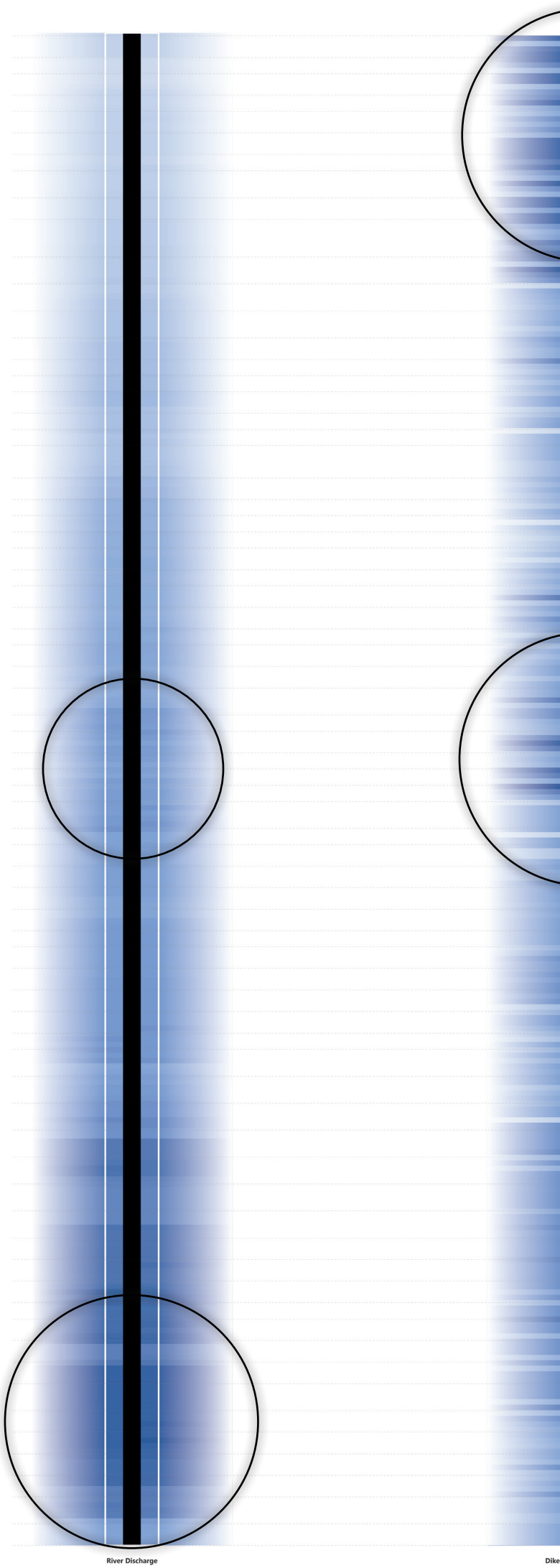
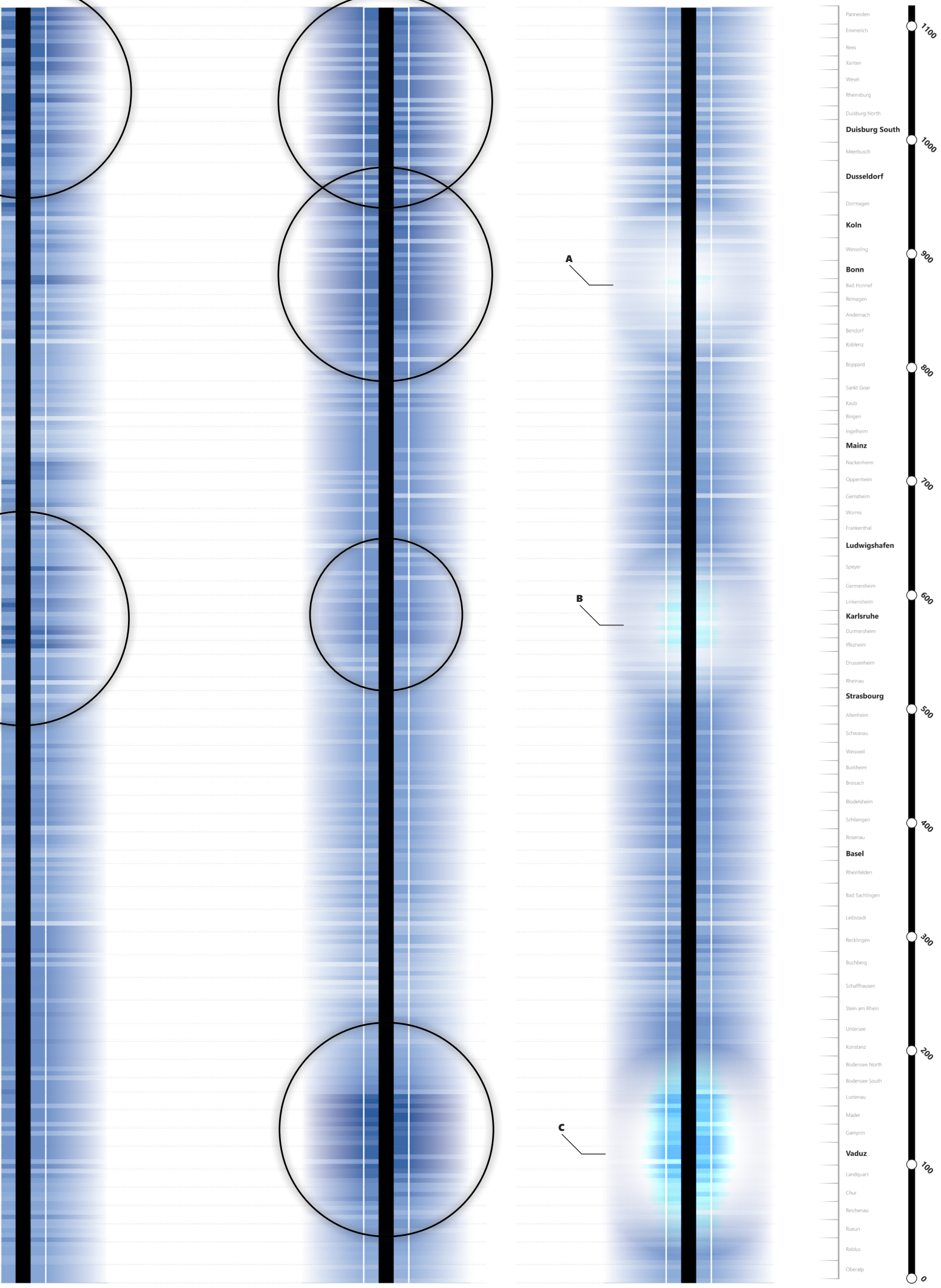


Figure 102: Spatialization of the Rhine Line regarding the autonomy of the River Dynamics and the sub-calculations. (Author, 2023)


A
B
C
Pannerden
Emmerich
Rees
Xanten
Wesel
Rheinsburg
Duisburg North
Duisburg South
Meerbusch
Dusseldorf
Dormagen
Koln
Wesseling
Bonn
Bad Honnef
Remagen
Andernach
Bendorf
Koblenz
Boppard
Sankt Goar
Kaub
Bingen
Ingelheim
Mainz
Nackenheim
Oppenheim
Gernsheim
Worms
Frankenthal
Ludwigshafen
Speyer
Germersheim
Linkenheim
Karlsruhe
Durmersheim
Iffezheim
Drussenheim
Rheinau
Strasbourg
Altenheim
Schwanau
Weisweil
Burkheim
Breisach
Blodelsheim
Schliengen
Rosenau
Basel
Rheinfelden
Bad Sachlingen
Leibstadt
Recklingen
Buchberg
Schaffhausen
Stein am Rhein
Untersee
Konstanz
Bodensee North
Bodensee South
Lustenau
Mader
Gamprin
Vaduz
Landquart
Chur
Reichenau
Rueun
Rablus
Oberalp
1100
1000
900
800
700
600
500
400
300
200
100
0
System Interruptions
Sedimentation Patterns
River Dynamics Autonomy

10.3

Suitability Conditions

Main Calculation

Dikes cannot be placed in every location. The underlying soil conditions determine the suitability placement of a dike. This subcategory addresses the main conclusion: the higher the suitability of the underlying conditions, the more favorable it is for localized dike management. Good underlying conditions yield positive indications for dikes, requiring less knowledge, maintenance, and safety regulations for construction. Therefore the possibility for local dike management can be established. This category is divided into three main sub-calculations:

(1). *Soil Conditions*
(2). *Groundwater Conditions*
(3). *Flooding and Drought Potentials*.

Additionally, three additional indicators are used to further classify the overall autonomy.

Sub Calculations

Soil Conditions

Underlying soil conditions indicate a dike's potential for construction, determined by the stability between the dike line and the soil. The additional weight of the dike and the soil must achieve a balance within the created force field. This balance determines whether dikes can be constructed and managed without causing additional impacts. Such a balance leads to reduced maintenance requirements enhancing the establishment of localized autonomy. This sub-calculation distinguishes three indicators:

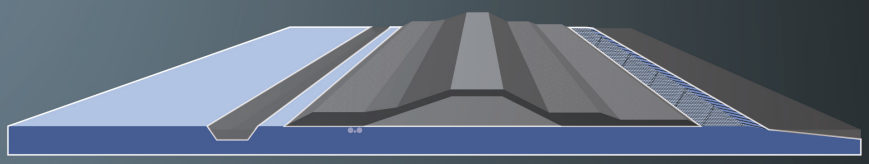
(1). *Lithological Deposits (0.75)*, which serve as the geomorphological foundation for dike construction;

(2). *Soil Moisture (1.25)*, providing insights into how water within the dike integrates with its surroundings; and

(3). *Soil Sealing (1.0)*, addressing the capacity of the dike's material to form an integral system with the underlying sediments.

Groundwater Conditions

The second sub-calculation focuses on the groundwater conditions of the Rhine. The size and weight of a dike induce changes in the underlying groundwater table. Additional weight causes the groundwater to be pushed above ground on both sides of the dike, necessitating the presence of a side ditch to distribute the pushed-up groundwater and seepage water away from the dike.



Suitability Conditions

The potential that is created for the suitability of dike construction

Soil Conditions
1.5

- Lithological Depositions — 0.75
- Soil Moisture Levels — 1.25
- Soil Sealing — 1.0

Groundwater Conditions
1.0

- Groundwater Recharge — 1.5
- Aquifer Conductivity — 0.75
- Aquifer Vulnerability — 1.0

Flooding & Drought
2.0

- Flooding Extreme Scenario — 2.0
- Drought Hydro-Summer — 1.25
- Drought Hydro-Winter — 1.0

Additional Indicators
0.5

- Surrounding Water Bodies (A) — 0.25
- Slope Indications (A) — 1.0
- Effective Precipitation — 0.5

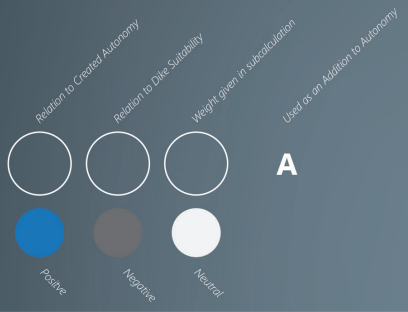


Figure 103: Suitability Condition indicators. (Author, 2023)

Given that the placement of a dike places stress on the groundwater system, a flexible groundwater system is essential to cope with the water pressures. When not managed properly, the groundwater system can exert pressure from underneath, potentially compromising the dike's structural integrity. This sub-calculation examines three main groundwater conditions:

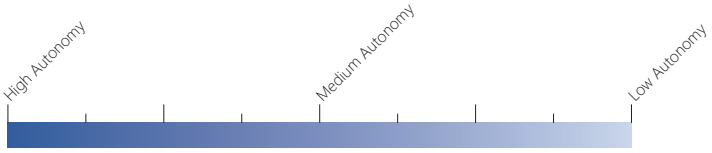
(1). *Groundwater Recharge (1.5)*
(2). *Aquifer Conductivity (0.75)*
(3). *Aquifer Vulnerability (1.0)*

Flooding & Drought

The final sub-calculation of dike suitability is the most commonly understood by society. Dikes are constructed to protect surrounding areas from the potential for floods. While floods are considered the main reason for dike construction, the possibility of extended periods of drought increases the vulnerability of the dike line's structural integrity. Therefore, this sub-calculation focuses on both extreme flooding scenarios of the Rhine (2.0) and examines the meteorological drought possibilities in Europe (1.0).

Additional Indicators

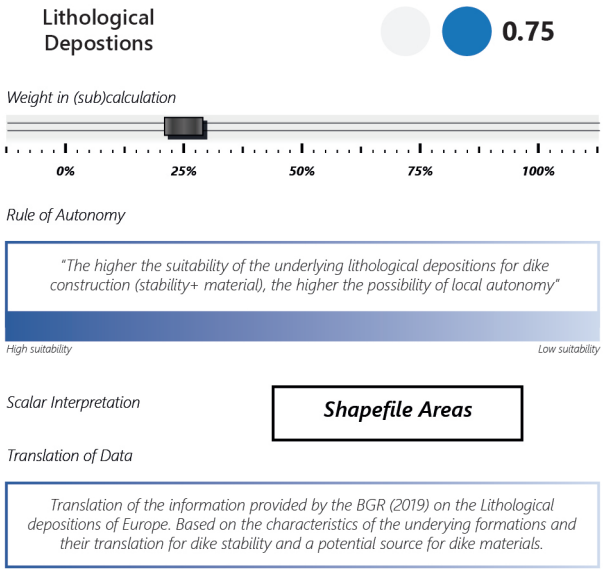
In addition to the three main sub-calculations of suitability conditions, three additional indicators are included. These indicators primarily pertain to the placement suitability of dikes on location. Based on *Surrounding Water Bodies (0.25)* and *Slope Indications (1.0)*, additional information is provided to enhance the suitability of dike placement. The final indicator, *Effective Precipitation (0.5)*, contributes supplementary information to the saturation levels of suitability conditions, as provided by the main sub-calculation of groundwater conditions.



Soil Conditions

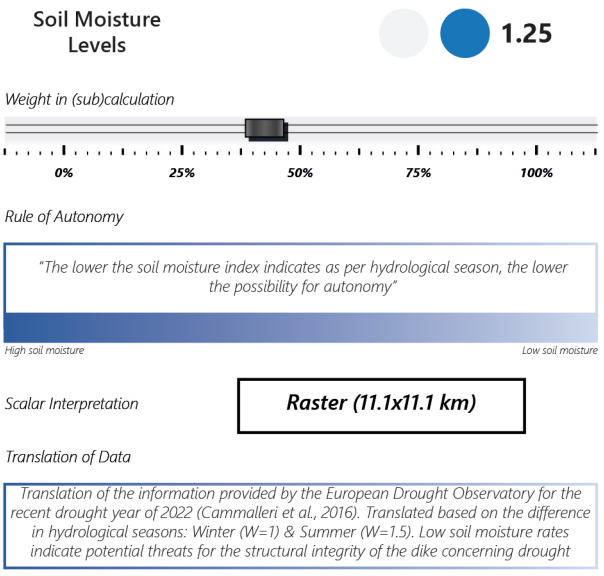
A. *Lithological depositions*

Lithological depositions indicate the underlying geomorphological conditions where a dike can be constructed. Since dikes are primarily built using sand and clay, they are best suited to areas with similar sediment deposits, as found in the lower floodplains of the lower Rhine (A1), the Upper Rhine Valley (A2), and the Alpine Rhine Valley (A3).



B. *Soil Moisture*

Dikes are often located near rivers where soil moisture levels tend to be high. Given that dikes are integral parts of water systems for seepage and drainage purposes, high soil moisture levels are required. On the contrary, in the region between Basel and Breisach before the major hydro dams, low soil moisture levels have been detected (B2).



C. *Soil sealing*

As dikes are primarily constructed from clay and sand, they need to be placed directly on open soil to ensure the integration of force fields. Soil sealing also affects drought and flood possibilities as little infiltration and evaporation of water is detected. Therefore, these locations are primarily found near urbanized regions such as the Ruhr (C1), Ludwigshafen (C2), and Basel (C3).

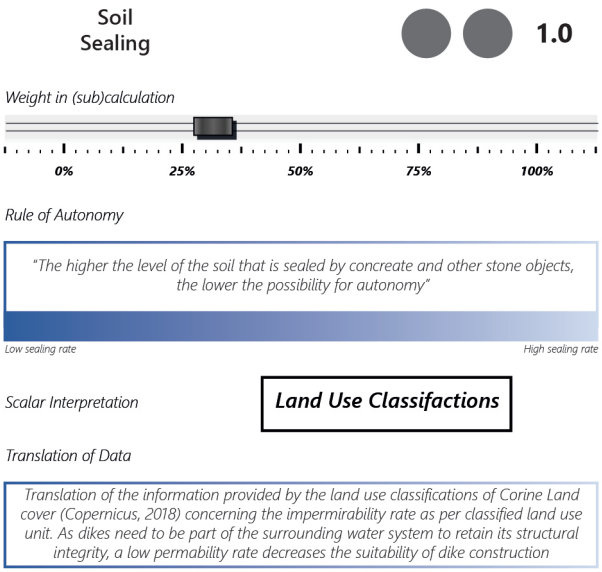


Figure 104: Translation of autonomy indicators of the Soil Conditions. (Author, 2023)

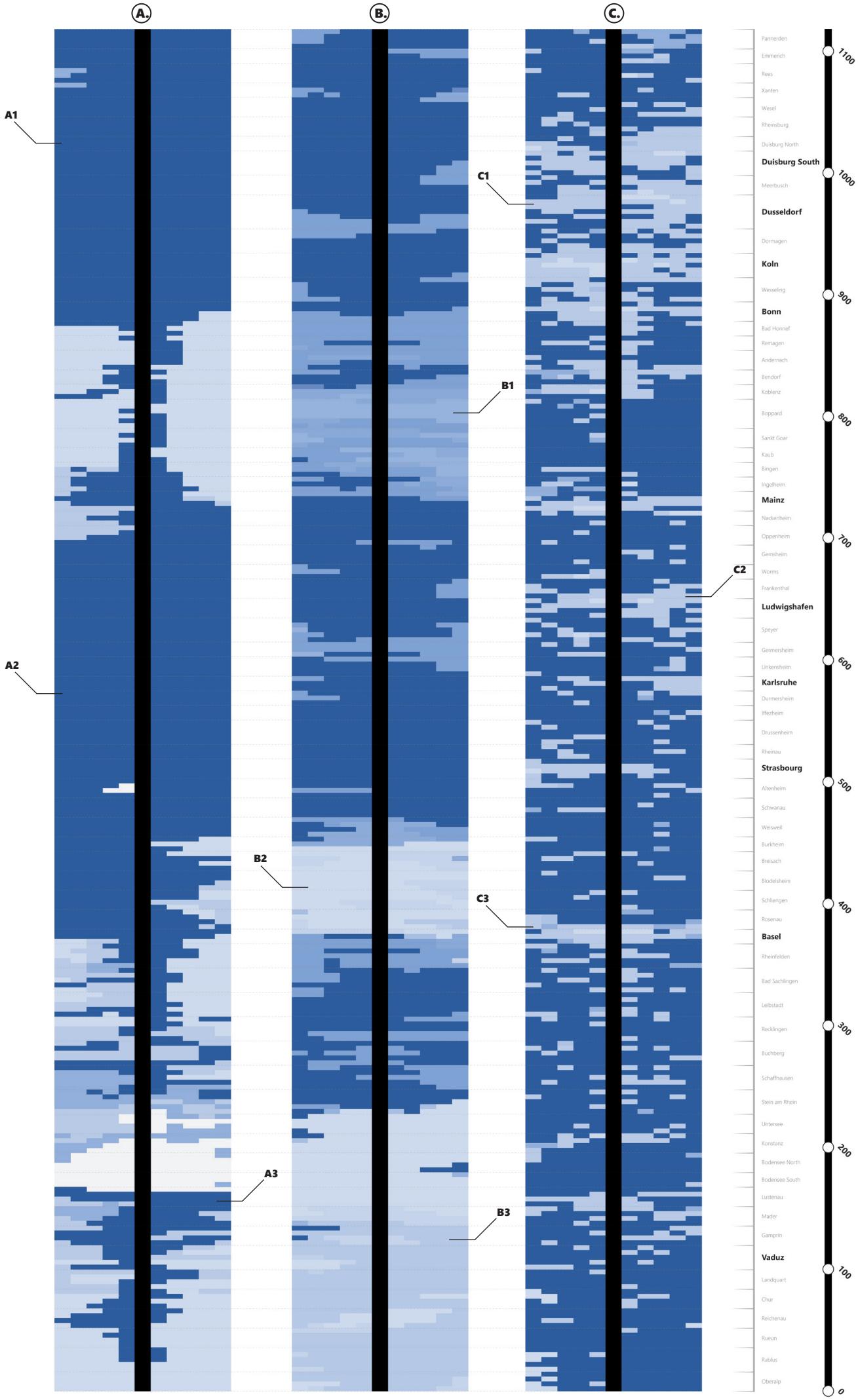


Figure 105: Spatialization of the Rhine Line regarding Autonomy based on existing Soil Condition Indicators. (Author, 2023)

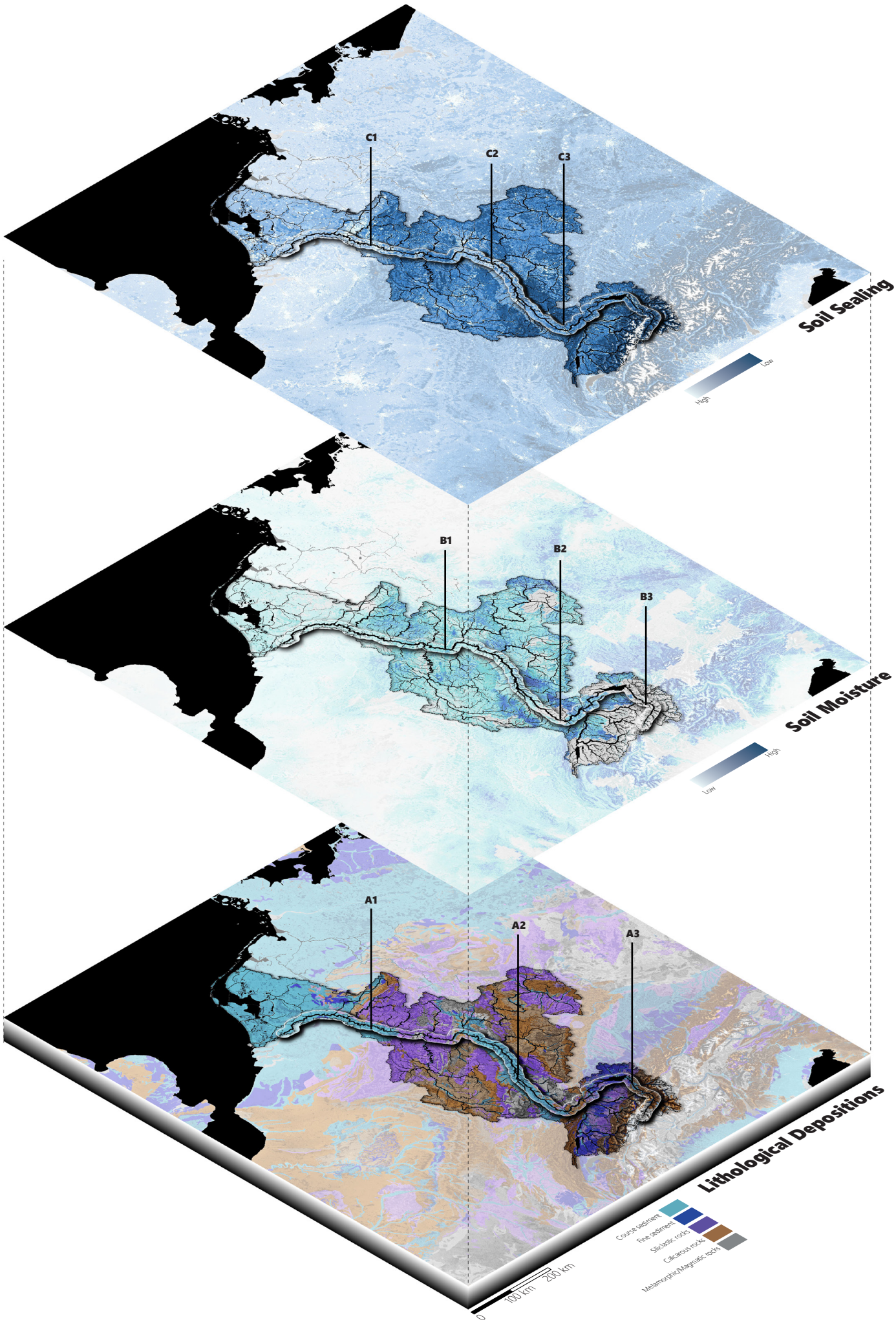
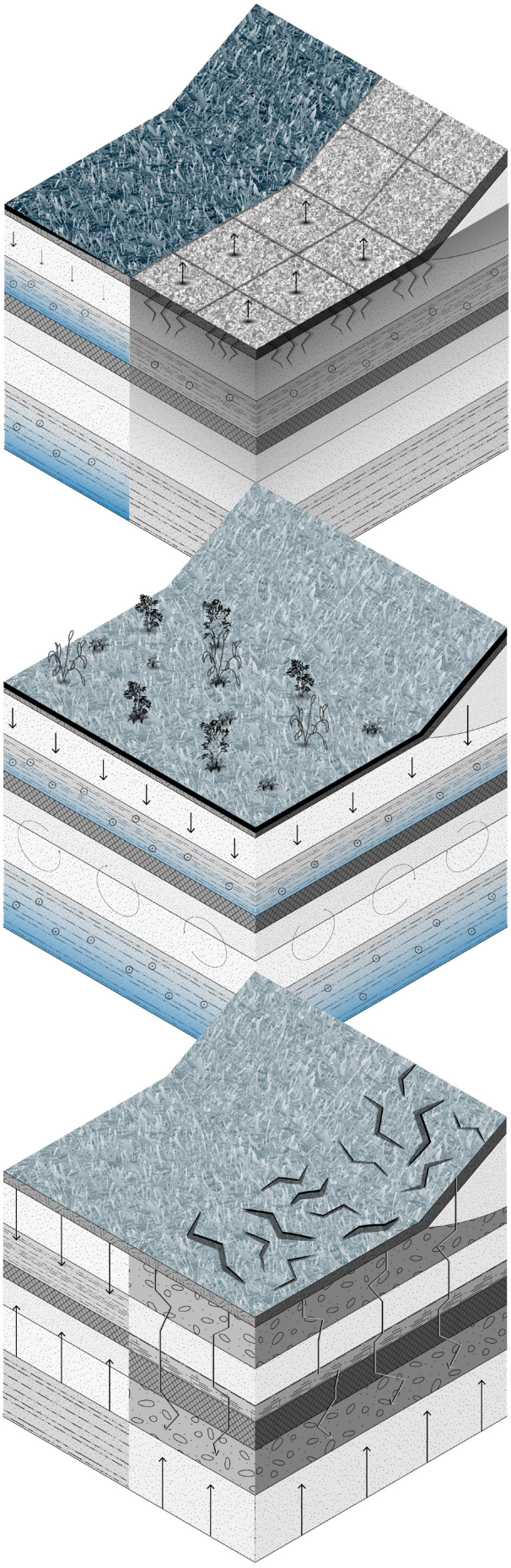


Figure 106: Existing soil conditions of the Rhine regarding, Soil sealing, Soil moisture levels & Lithological depositions. (Author, 2023)



Soil Conditions

1.5

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the conditions of the soil suitable for dike construction, the higher the possibility for local autonomy"

High suitability *Low suitability*

Scalar Interpretation

Rhine Basin

Translation of Data

Calculation:

0.75(Lithological depositions) + 1.25*(Soil moisture) + 1.0*(Soil Sealing) / 3*

Weighting of the Indicators

Understanding the underlying soil conditions is crucial when assessing the stability of a dike in its context. Based on the explanations of the indicators on the previous page, weights have been assigned to the indicators.

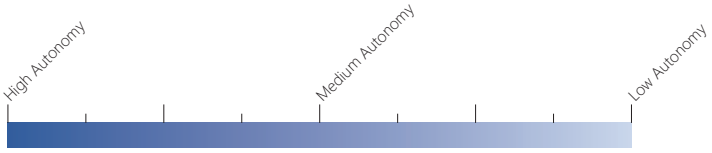
Soil Sealing (1.0):
Dikes must be part of the soil where they are located. When placed on a surface with a low soil sealing rate, this connection is not established, creating risks for the stability of the dike and its vulnerability to floods and drought. Such danger is often found in highly urbanized areas (C1-C3). Hence it's given a weight of 1 to underscore the essential connection between the dike and the direct surface.

Soil Moisture (1.25):
Given a higher weight in the sub-calculation are the soil moisture levels. Since the dike's core primarily consists of sand, a high infiltration rate near the core is crucial. To ensure the dike remains stable and does not become overwhelmed by saturated water levels, high soil moisture levels are required to direct this water to nearby side ditches or groundwater bodies. Low soil moisture levels are often found in urbanized (B2) and rocky (B1, B3) areas where water cannot be effectively infiltrated.

Lithological Depositions (0.75):
Lithological depositions receive a lower weight in the sub-calculation. These deposits indicate the material on which a dike can be constructed. When relatively loose materials like sand and clay are present, forces can be transferred further down, balancing the forces within the dike. In contrast, rocky materials do not provide the same benefits. Therefore, dikes are often found on floodplains where sediment deposits are located (A1-A3).

Figure 107: Effect of Soil Conditions on dike stability. Top: Soil Sealing, Middle: Soil Moisture, Bottom: Lithological depositions. (Author, 2023)

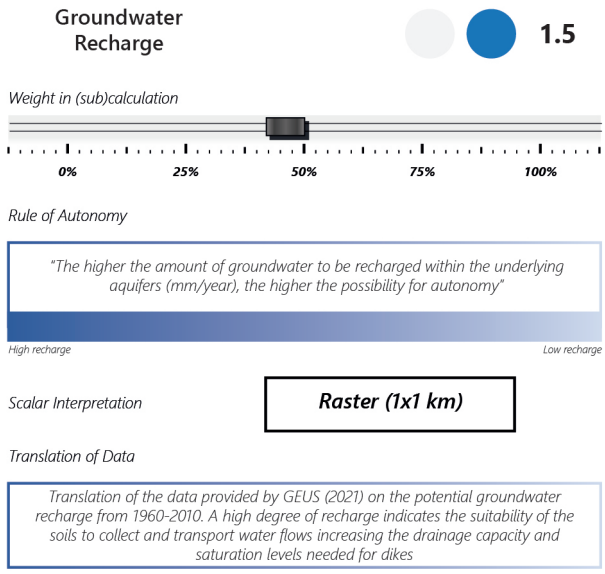
Figure 108: Spatialization of the Rhine Line regarding Autonomy based on the Soil Conditions. (Author, 2023)



Groundwater Conditions

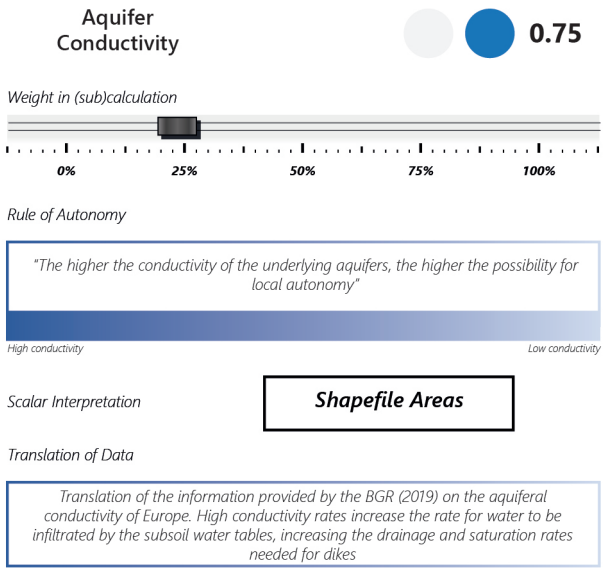
A. *Groundwater Recharge*

High groundwater recharge indicates favourable ground conditions, allowing water to infiltrate naturally (GEUS, 2021). This relieves water pressures within the dike. This is primarily the case in the Alpine regions of the Rhine (A1).



B. *Aquifer Conductivity*

The increasing porosity of aquifers indicates the productivity of an aquifer, reflecting the movement of water within. The higher the aquifer conductivity of an area, the better the conditions for dike construction, as it allows water to be distributed more quickly. This is seen in lower-lying regions (B1 & B2), where the lithological soils facilitate water infiltration into aquifers relatively close to the subsurface.



C. *Aquifer Vulnerability*

In addition to current aquifer conditions, aquifers are also affected by the negative impacts of climate change, posing threats such as flooding or drying out of the soil. This can significantly affect the structural integrity of a dike. Areas between Mainz and Kaub are considered susceptible to both drought and floods (C1). Areas near Basel and Vaduz are more prone to flooding.

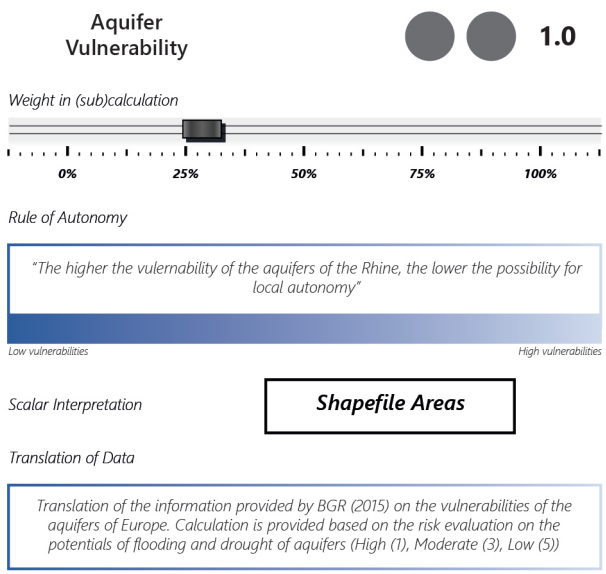


Figure 109: Translation of autonomy indicators of the Groundwater Conditions. (Author, 2023)

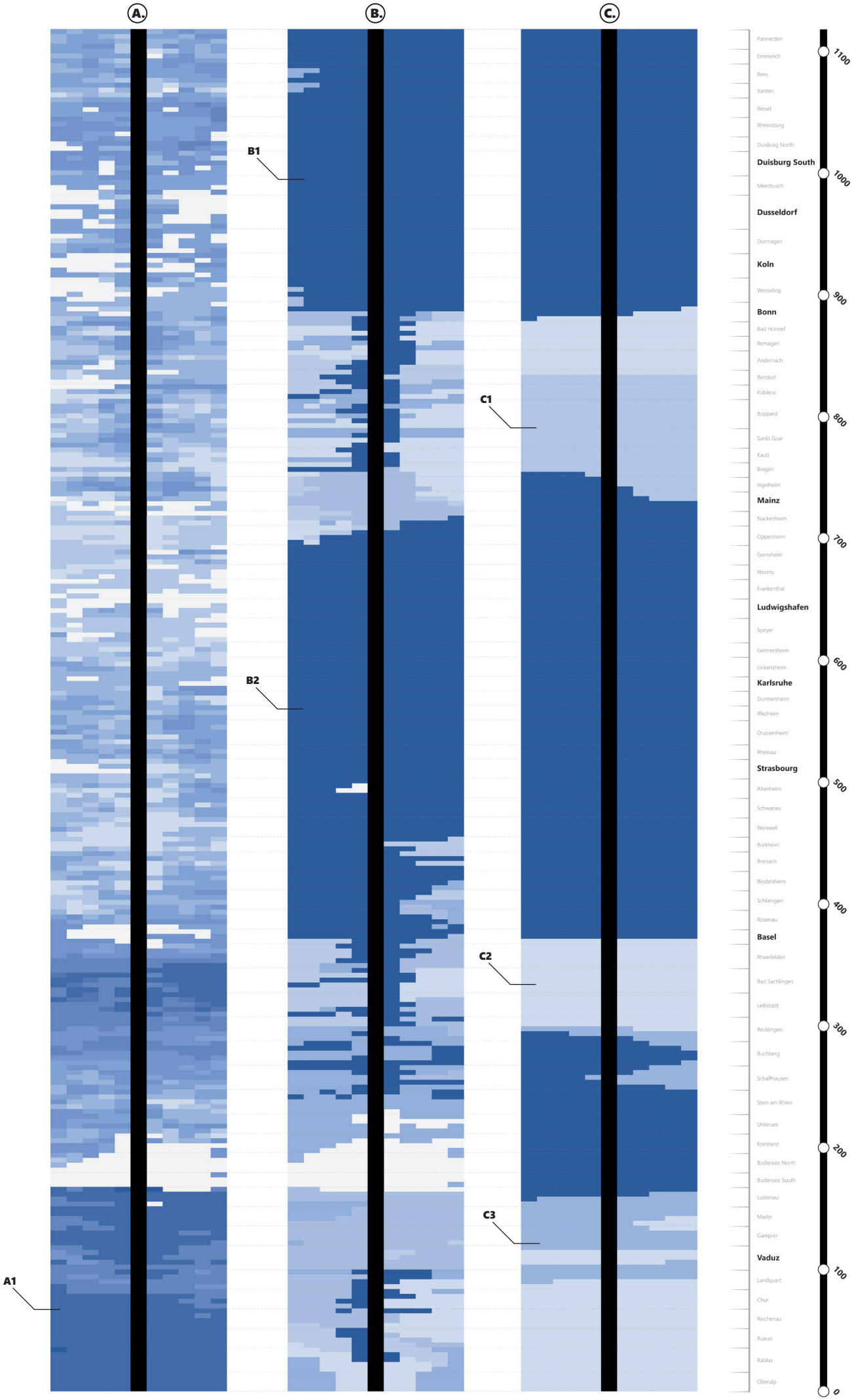


Figure 110: Spatialization of the Rhine Line regarding Autonomy based on existing Groundwater Condition Indicators. (Author, 2023)

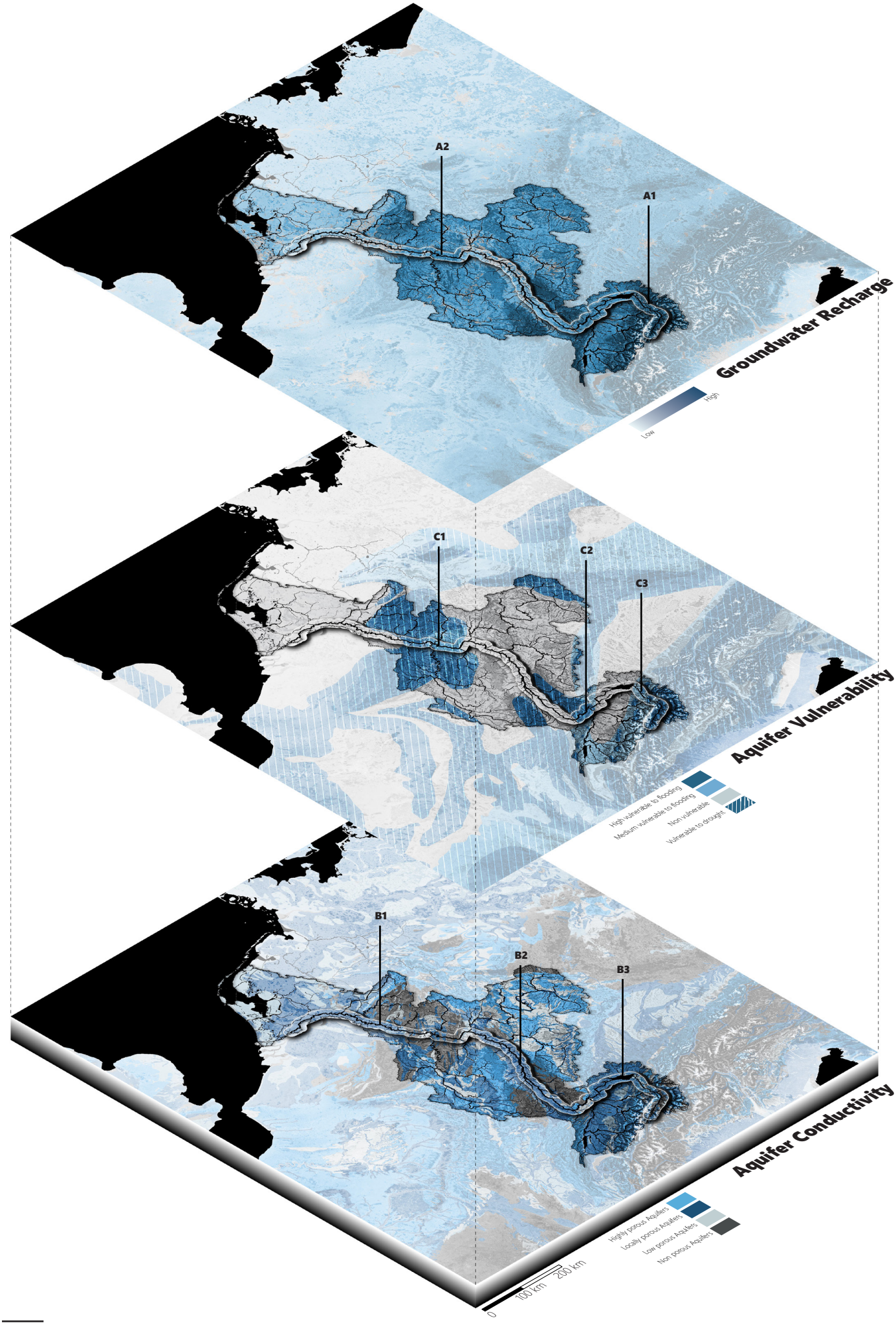
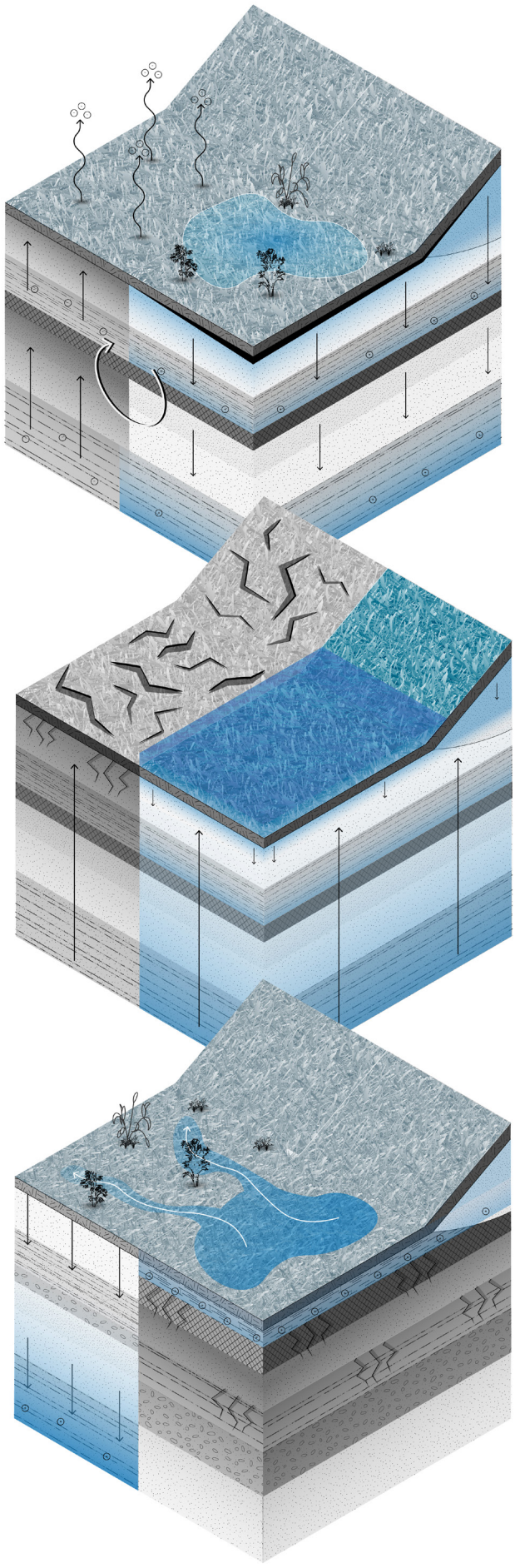
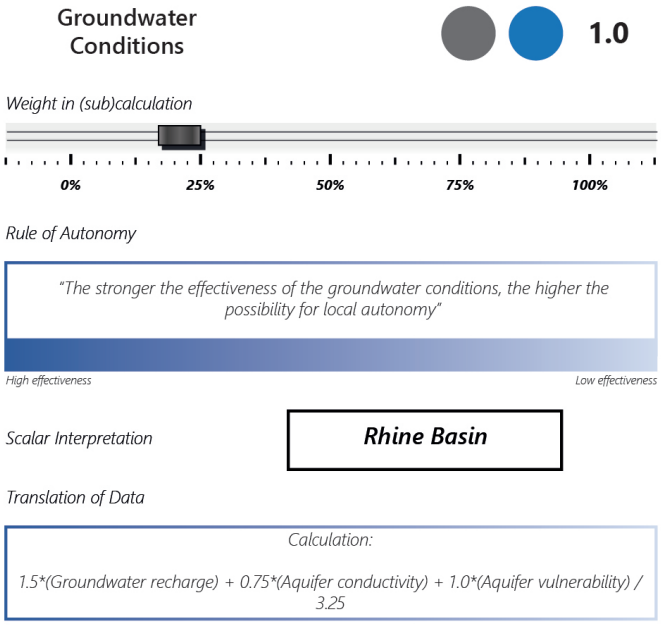


Figure 111: Existing soil conditions of the Rhine regarding, Groundwater recharge, Aquifer vulnerability and conductivity. (Author, 2023)





Weighting of the Indicators

The addition of a dike on a location alters the dynamics of the groundwater. Therefore, it's important to understand existing groundwater indicators when rebalancing groundwater tables with the dike.

Groundwater Recharge (1.5):
Groundwater recharge indicates the amount of water that infiltrates. A high infiltration rate is crucial for dikes, as they need to form a connection between the groundwater system and the water within the dike. This reduces the potential for drought and ensures the seepage of the dike line, along with the saturation of the protective outer clay layer. A 1.5 is given to enhance the notion that the dike needs to form a direct bond with the underlying groundwater at all times. This condition is primarily found in natural areas along the Rhine (A1-A2) where higher infiltration rates can be seen.

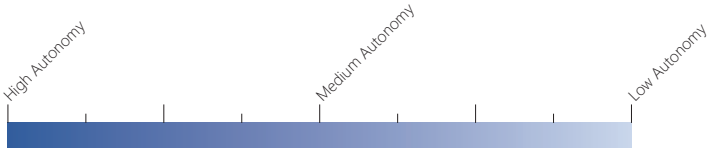
Aquifer Vulnerability (1.0):
Increasing possibilities of more extreme flood and drought events can endanger existing aquifers. A balanced aquifer is essential for dike suitability, so aquifers at risk of flooding (C2, C3) and aquifers prone to drought (C1) could destabilize the dike's structural integrity. This is given a weight of 1.0 as the vulnerability impact is high but does not occur on a regular frequency.

Aquifer Conductivity (0.75):
Aquifer conductivity is given a lower weight. It indicates the existing infiltration rate of the aquifer below the ground. To maintain dike stability, a high conductivity is required. This not only facilitates water infiltration but also keeps the dike saturated during dryer periods. Areas near lower floodplains with sediment content (B1, B2) tend to have more conductive aquifers. Higher in the Alps, diverse lithological depositions often result in local aquifer conductivity (B3).

Figure 112: Effect of Groundwater Conditions on dike stability. Top: Groundwater Recharge, Middle: Aquifer Vulnerability, Bottom: Aquifer Conductivity. (Author, 2023)

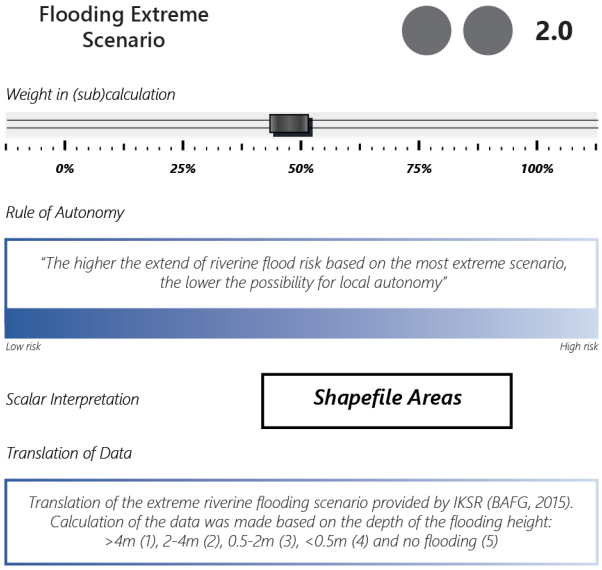
Figure 113: Spatialization of the Rhine Line regarding Autonomy based on the Groundwater Conditions. (Author, 2023)

Flooding & Drought



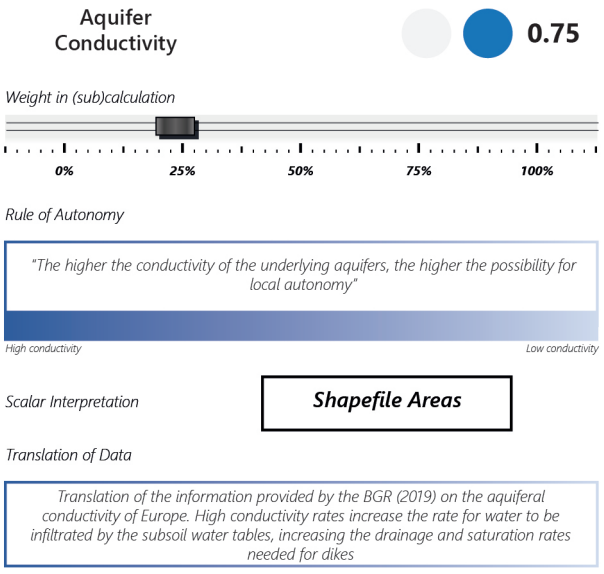
A. *Extreme Flooding Scenario*

Due to increasingly extreme climate scenarios, rivers are more prone to causing large floods. Therefore, dikes must withstand these water fluctuations. The more prone areas are located in the low-lying regions (A1 & A3). The location between Karlsruhe & Mainz (A2) is important as increased floods occur due to the canalized zone of Strasbourg.



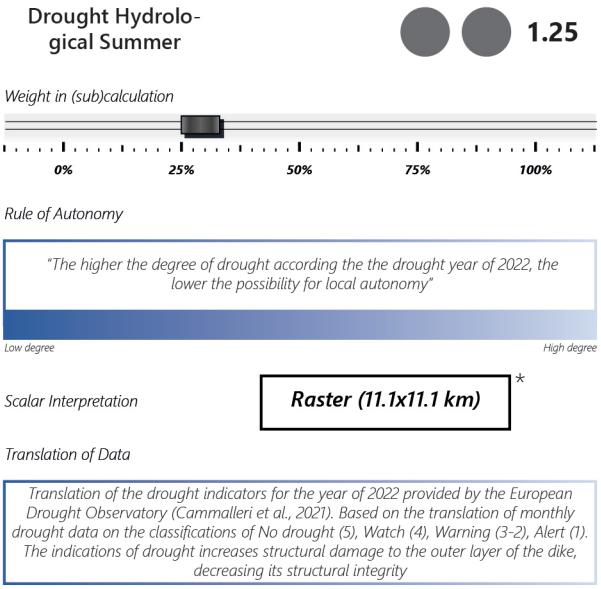
B. *Metrological Droughts (Winter)*

Winter metrological droughts are more common in regions with higher altitudes, where rivers rely more on glacial water than rainwater. This is why regions like the Alpine Rhine Valley (B3) and the High Rhine Hill landscape (B2) are more susceptible to drought.



C. *Metrological Droughts (Summer)*

In the summer, metrological droughts are more common in areas dependent on rainwater. This is often observed in lower-lying regions such as the Ruhr (C1) and the Upper Rhine Valley of the canalized zone in France (C2). Drought can significantly impact dikes, potentially drying out the outer protective layer of the dike and leading to instability.



*The raster of 11.1 x 11.1 is based on the coordinate system used by the European Drought Observatory (2022) as this is related to 0.1 spatial degree.

Figure 114: Translation of autonomy indicators of the Flooding & Drought. (Author, 2023)

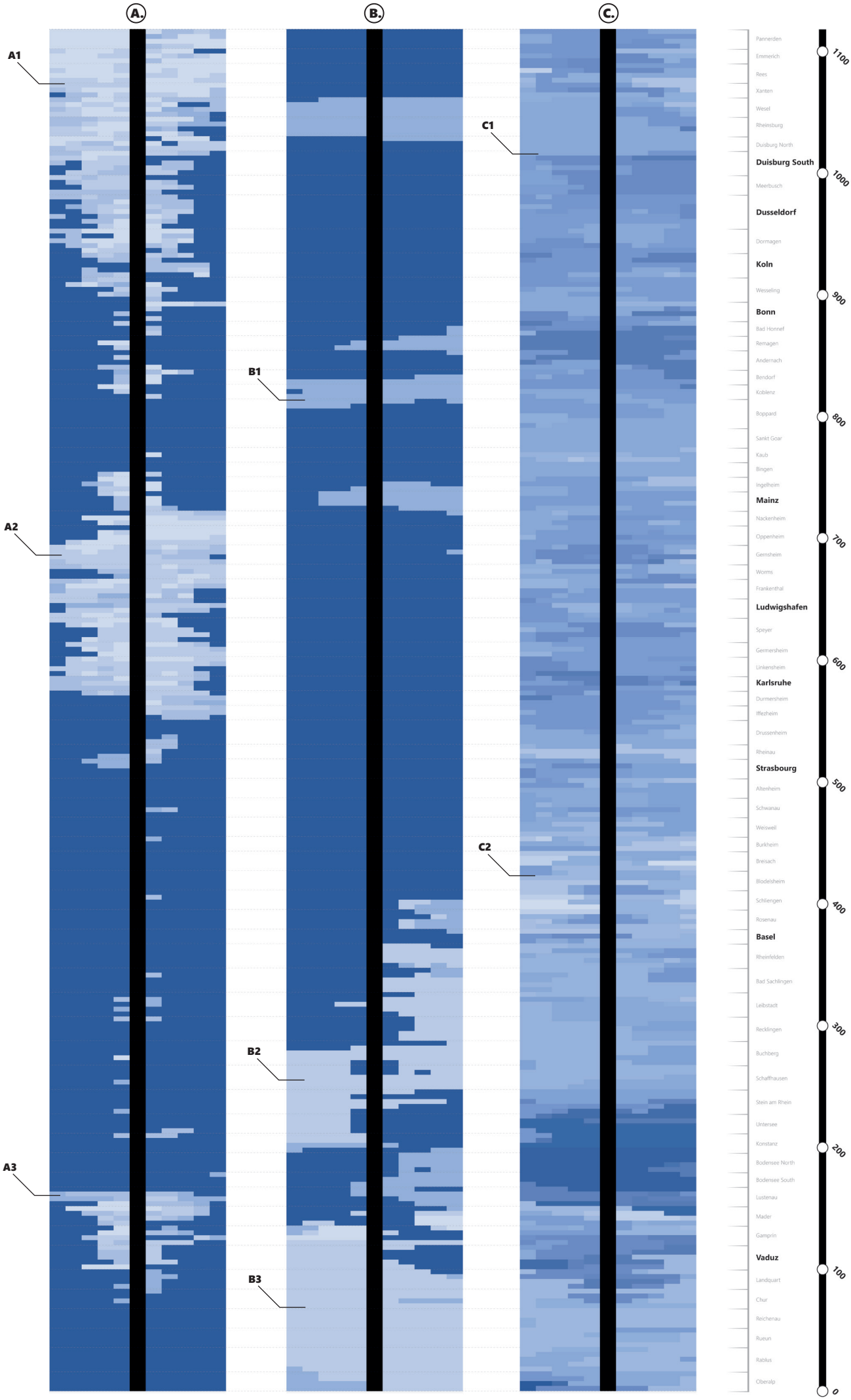
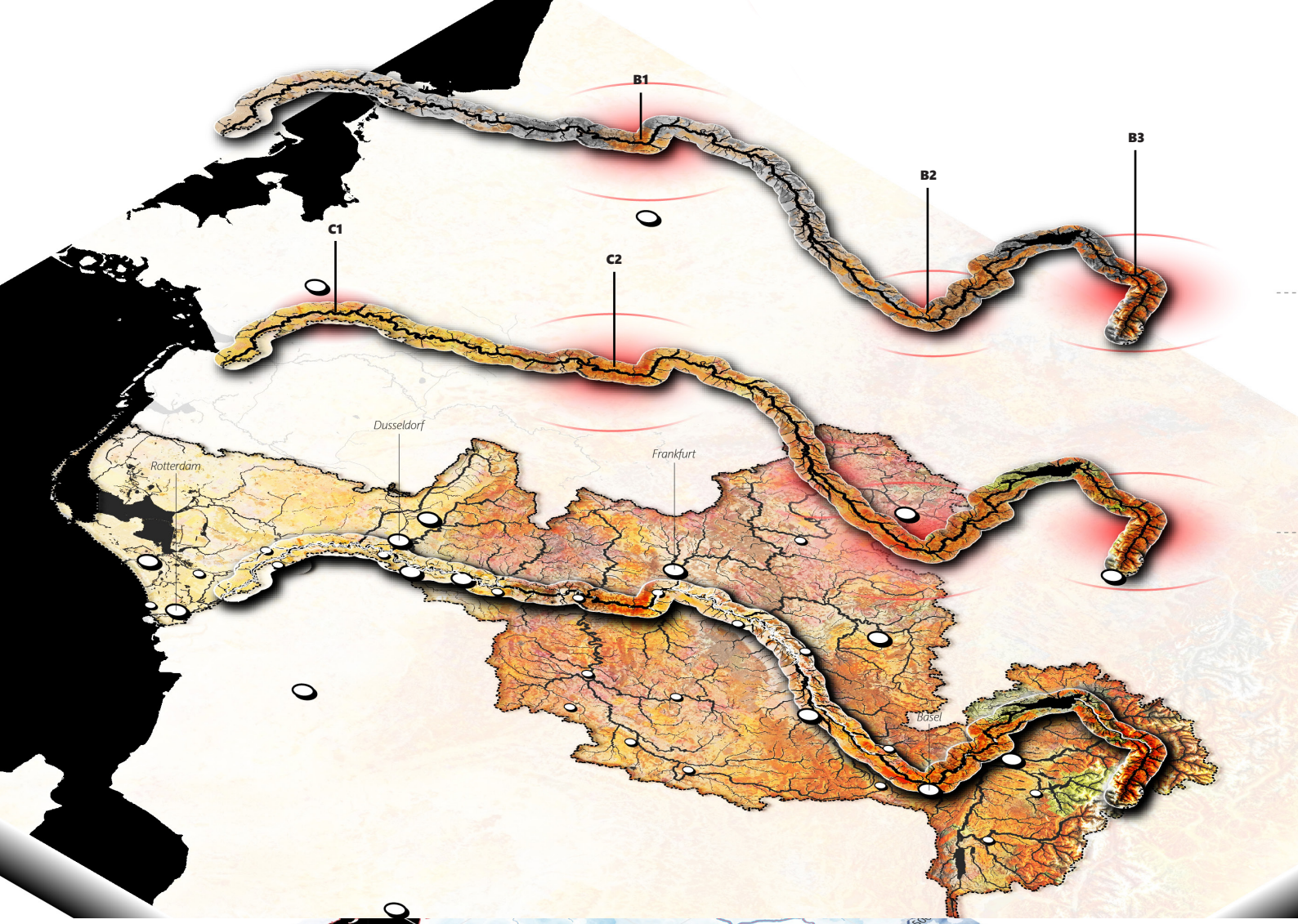


Figure 115: Spatialization of the Rhine Line regarding Autonomy based on existing Flooding & Drought occurrences. (Author, 2023)



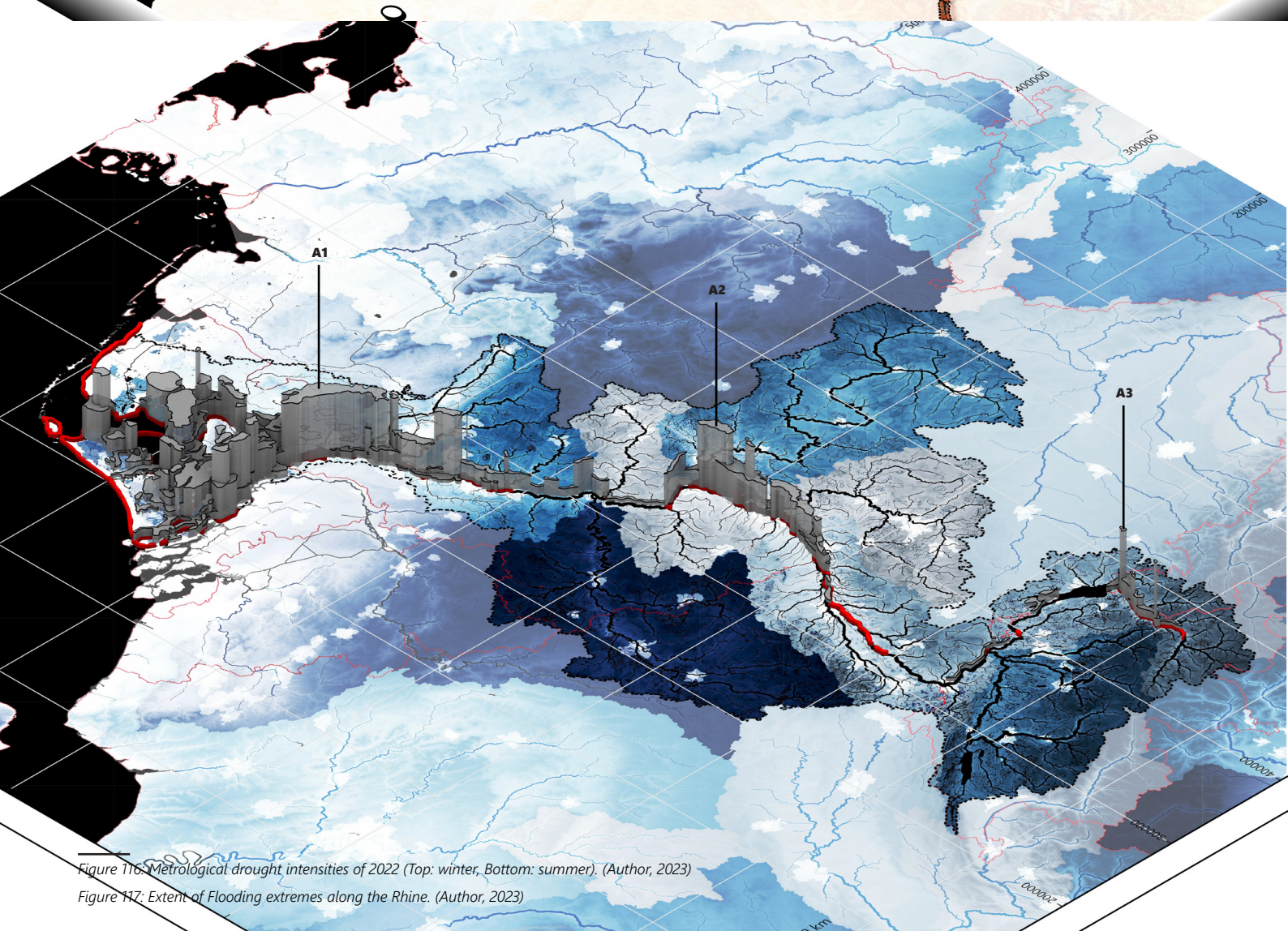


Figure 116: Metrological drought intensities of 2022 (Top: winter, Bottom: summer). (Author, 2023)

Figure 117: Extent of Flooding extremes along the Rhine. (Author, 2023)

Flooding & Drought

2.0

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the impact created by flooding and/or drought, the lower the possibilities for local autonomy"

Low risk — High risk

Scalar Interpretation

Rhine Basin

Translation of Data

Calculation:

2.0(Extreme flooding scenario) + 1.25*(Hydrological drought summer) + 1.0*(Hydrological drought winter) / 4.25*

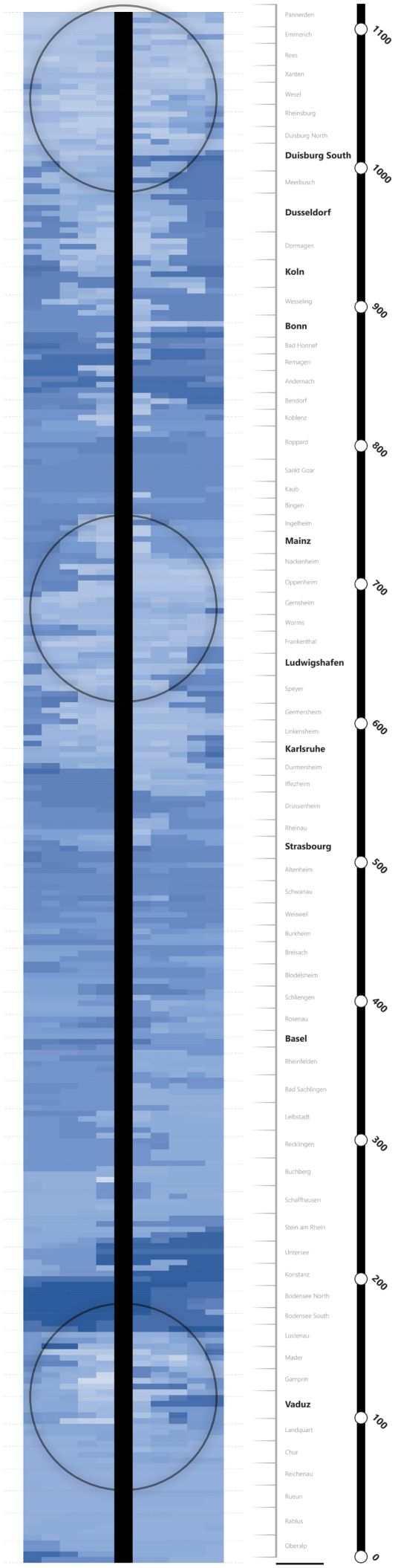
Weighting of the Indicators

The final sub-calculation assesses the pressures created by increasing sensitivity to flood (2.0) and drought events (2.25). Drought is assigned a higher weight because dikes are typically constructed to withstand floods, with less focus on managing large dry spells.

Extreme Flooding (2.0):
Due to more extreme climate scenarios, rivers are more prone to large floods, which stresses existing and future dike lines. Dikes need to withstand large volumes of water during high-flow periods, warranting a weight of 2.0. These most extreme areas are located at the Rhine valleys (A1, A2, A3), where natural features, such as the sea or mountains, enhance blockages of river flow.

Metrological Winter (1.0):
Winter metrological droughts receive a weight of 1.0, as the majority of the Rhine experiences high flow during the hydrological winter due to precipitation. However, regions near the glaciers of the Alpine ridge (B3), which rely more on glacial water than rainwater (B2), may experience hydrological droughts.

Metrological Summer (1.25):
For most of the Rhine, drought primarily occurs during the summer when precipitation is lower. This is particularly true in regions where water cannot be well-infiltrated due to the underlying soil and constructed bottlenecks (dams and weirs) in the river's course (C2).



Legend

Elevation Profile in relation to Rhine River Subbasins — High

Water Exploitation Index (Overlay of 4 seasons) — High

Metrological Drough 2022 (Hydro Summer + Winter) — High

Rhine River System
National Administrative Borders
Rhine River Basin
River Systems of Europe
Drinking Water Protection Area
Urban areas
Rhine River Dyke System

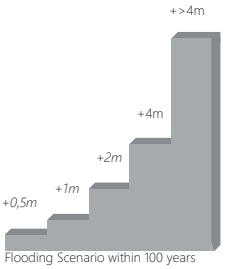
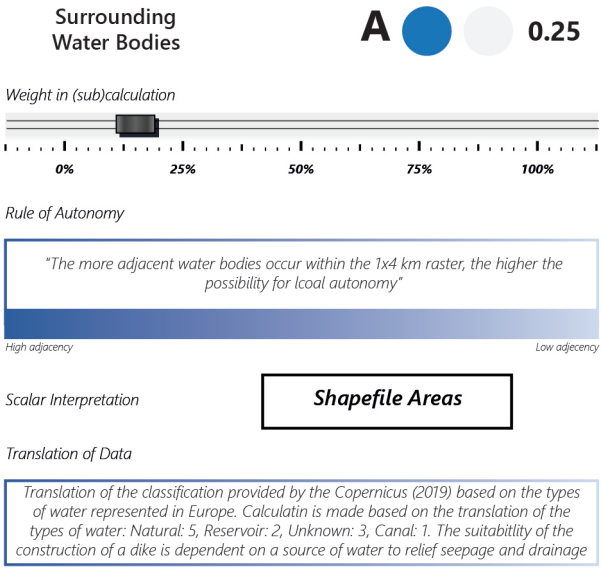


Figure 118: Spatialization of the Rhine Line regarding Autonomy based on Flooding & Drought. (Author, 2023)

Additional Conditions

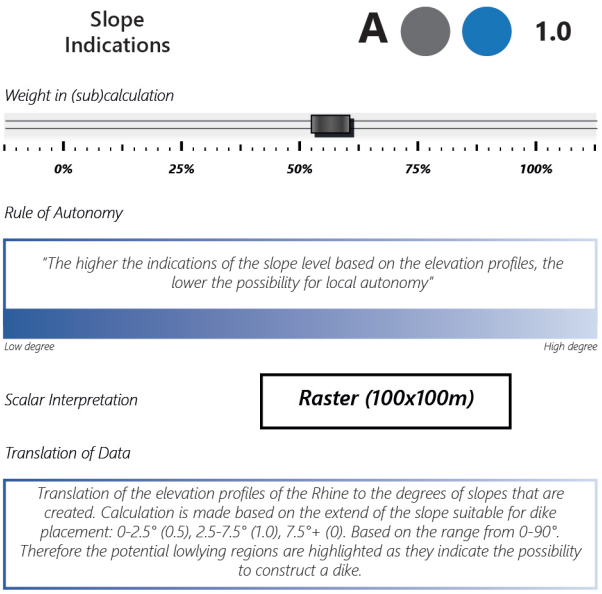
A. *Surrounding Water Bodies*

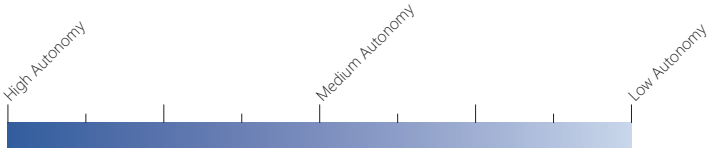
The proximity of a dike to surrounding water bodies increases local dike management. It provides a constant water source for relieving water pressures within the dike. These regions are primarily located where water has more space, such as the lower Rhine regions with their sediment industries (A1) and the wetlands of the Upper Rhine (A2).



B. *Slope Indications*

Dikes are typically constructed on relatively flat surfaces. Surfaces with significant elevation differences are less prone to floods, making dike construction unnecessary. However, locations with little elevation differences can function as dikes in relatively low-lying areas, allowing for more possibilities for dike construction. This is evident in flatter regions such as the Dutch-German border (B1) and the Upper Rhine Valley (B2).





C. *Effective Precipitation*

Effective precipitation, like Groundwater Recharge mentioned in the previous calculation, indicates the soil's suitability for water infiltration. Here the additional component of precipitation is added. In relatively urbanized regions (C1-C3), effective precipitation tends to be lower.

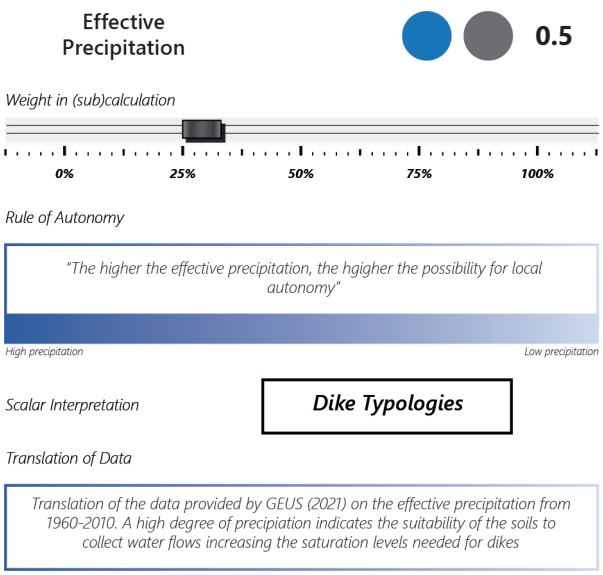


Figure 119: Translation of autonomy indicators of the Additional suitability conditions. (Author, 2023)

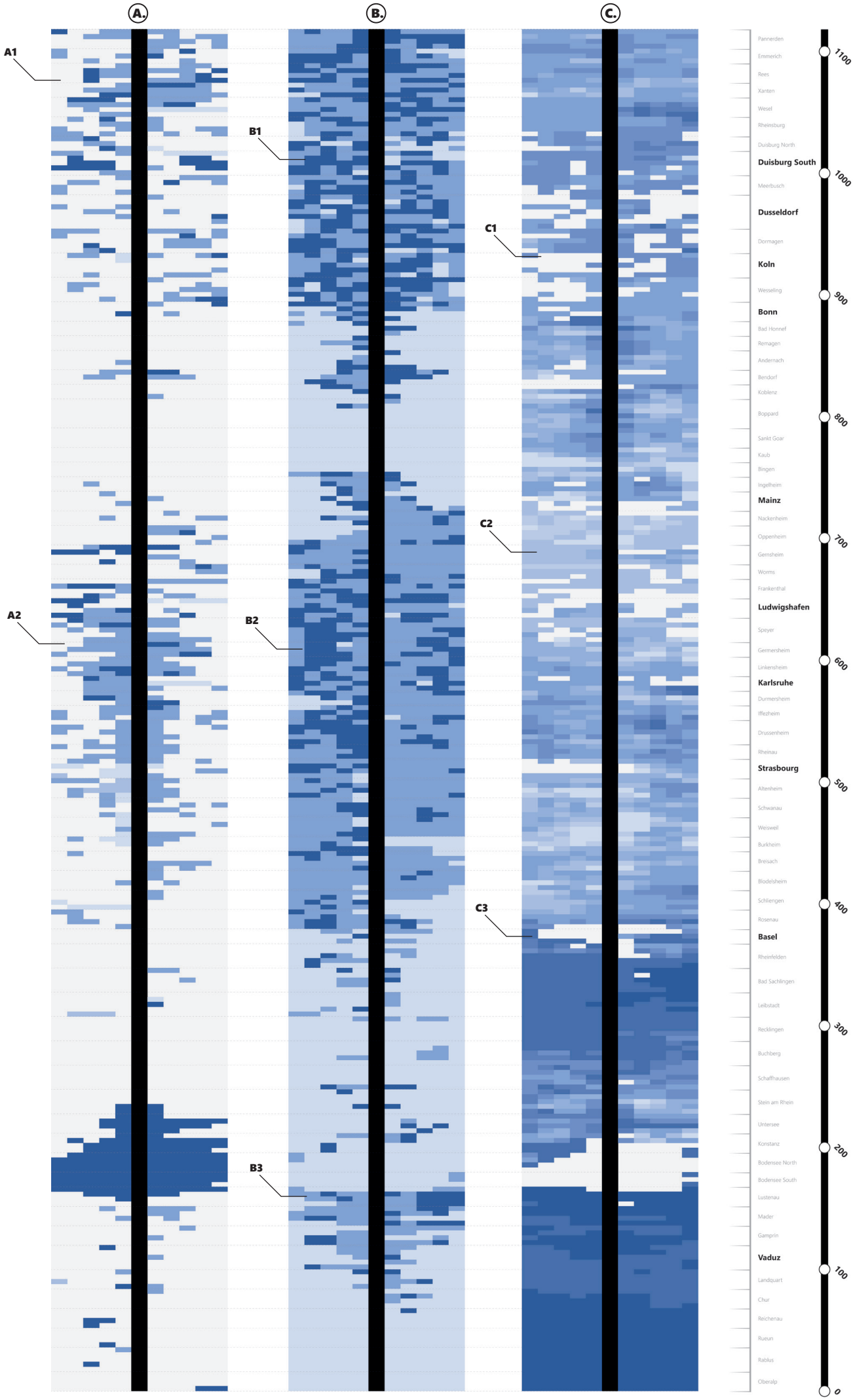


Figure 120: Spatialization of the Rhine Line regarding Autonomy based on additional suitability conditions. (Author, 2023)

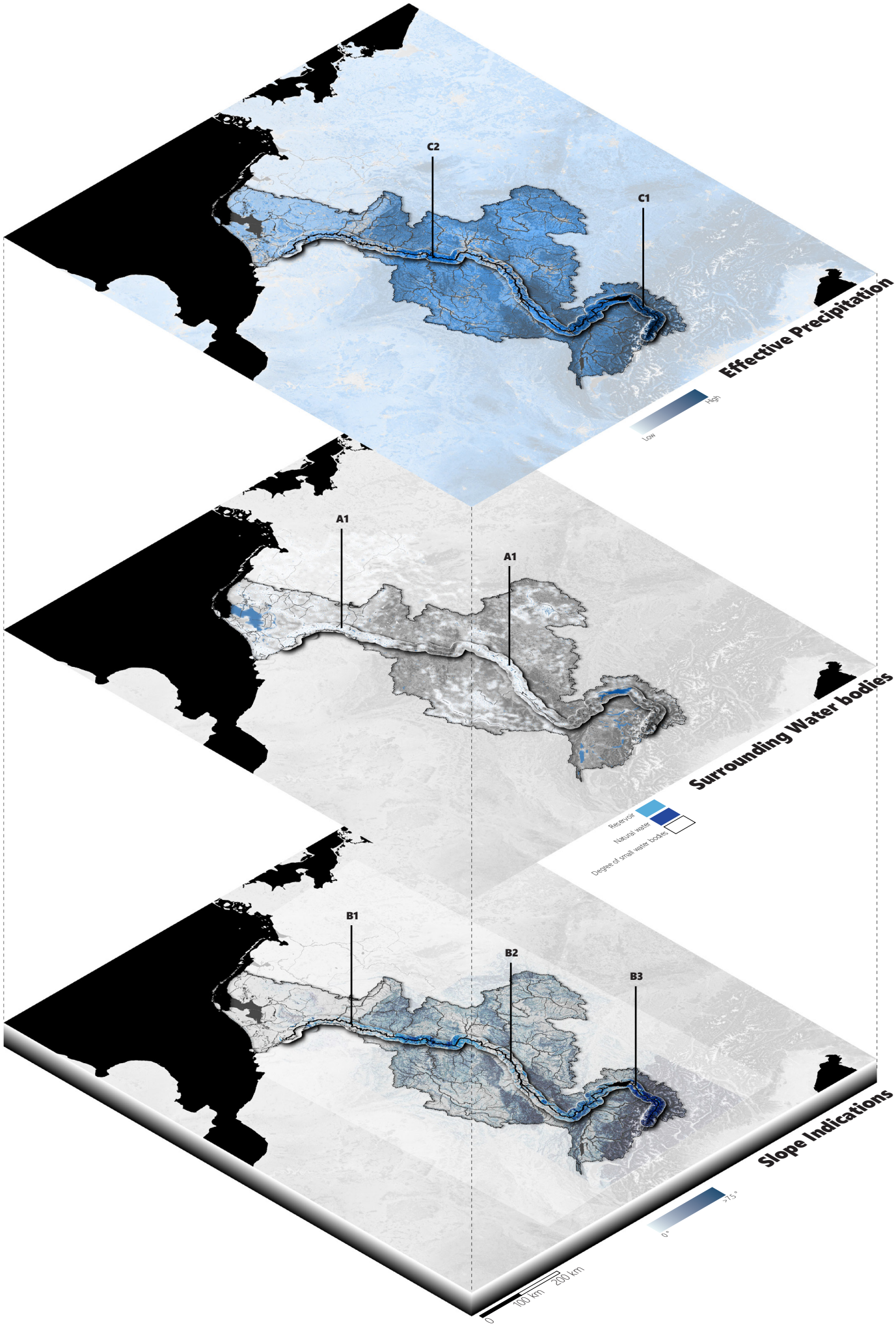
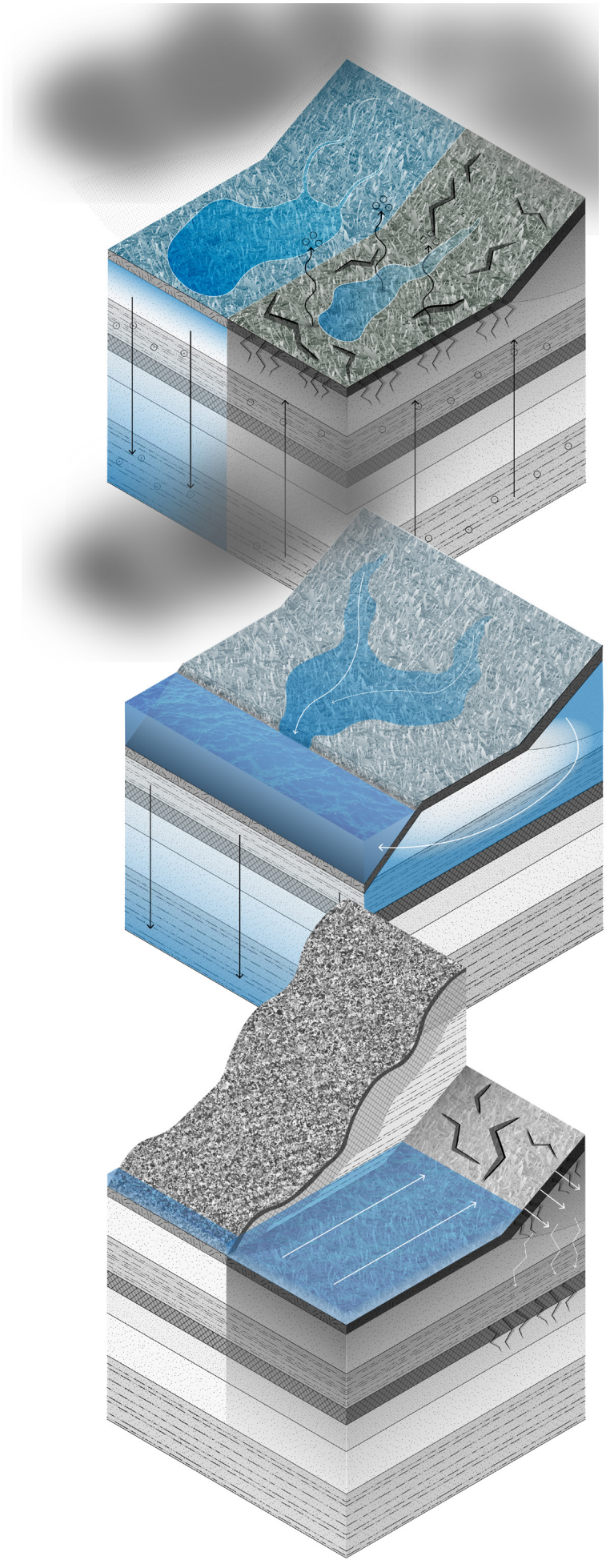
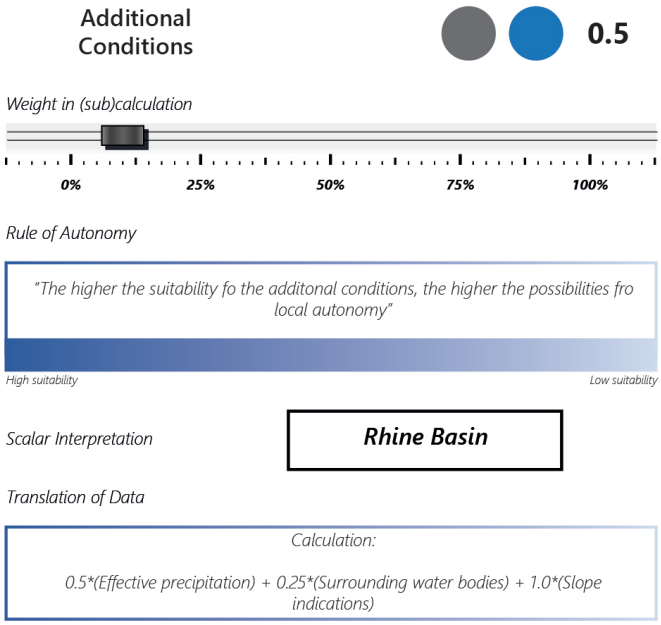


Figure 121: Existing soil conditions of the Rhine regarding, Effective Precipitation, Surrounding Water Bodies and Slope Indications. (Author, 2023)





Weighting of the Indicators

In addition to the main sub-calculation of soil conditions, three indicators are added to enhance dike autonomy and indicate the requirements from the surroundings for dike construction.

Effective Precipitation (0.5):
As the Rhine River becomes more dependent on rainwater in the future rather than glacial water (Stahl et al., 2022), the amount of rainwater infiltration is vital to keep existing dike lines saturated and connected to the underlying groundwater system. Primarily, higher effective precipitation levels can be found in the more natural areas of the Rhine Gorge (C2) and the Alpine areas (C1).

Surrounding Water Bodies (+0.25):
To ensure the technical functionality of a dike, a secondary waterway is needed to redirect seepage and groundwater away from the dike (Barends, 2003). Dike placement is more viable in areas where water bodies are present, such as the lower valleys (A1, A2) of the Rhine, where sediment practices and wetlands can be found.

Slope Indications (+1.0):
Dikes are found in lower-lying areas of the Rhine valleys, rather than areas with significant elevation differences. To focus the research on areas along the Rhine, a stable elevation must be provided (B1-B3) to allow local stakeholders to alter the existing system. Although certain areas with slightly lower elevation differences (between 2.5-7.5 degrees) can be used as a starting point for a new dike line, other soil conditions must be understood to determine the possibility of constructing a dike.

Figure 122: Effect of Additional conditions on dike stability. Top: Effective Precipitation, Middle: Surrounding Water Bodies, Bottom: Slope Indications. (Author, 2023)

Figure 123: Spatialization of the Rhine Line regarding Autonomy based on additional suitability conditions. (Author, 2023)

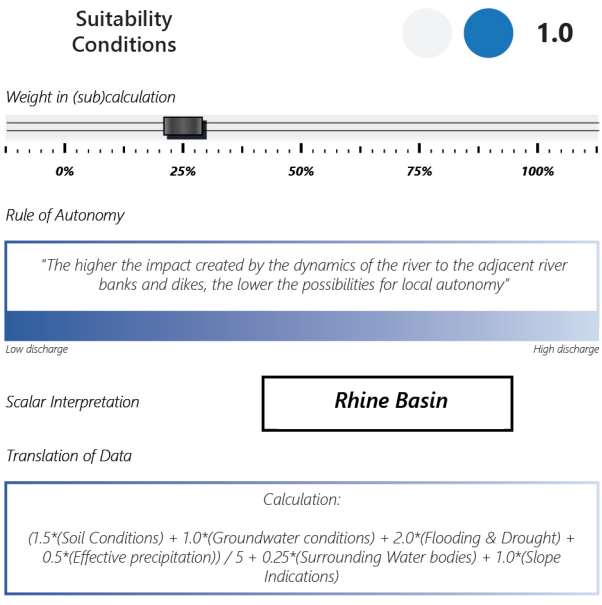
Suitability Conditions

The calculation of suitability conditions provides insight into the necessary conditions for dike placement at specific locations. This is crucial for achieving local autonomy since suitable conditions reduce the need for maintenance and safety regulations, allowing more freedom to the local conditions. Based on soil (1.5), groundwater (1.0), and flood & drought (2.0) conditions, three potential areas become apparent:

(A). *Urbanized low Rhine (Bonn-Duisburg)*
The urbanized lower Rhine region is suitable for dike construction due to favourable underlying soil and groundwater conditions. Additionally, because this area comes after the narrowing of the Rhine gorge, the river's speed is relatively high, making floods more severe downstream. The relatively flat terrain and the amount of water bodies near the river make dike construction technically sound.

(B). *Upper Rhine Valley (Strasbourg-Karlsruhe)*
This area follows the canalized steps of the French Rhine. Therefore, the river's speed is relatively high, leading to more downstream floods. Additionally, the location in the Upper Rhine Valley benefits from stable soil conditions for dike construction. However, spells of drought, particularly in the summer, could still pose a risk to these dike lines. Furthermore, Germany's dedication to establishing a more natural wetland in the area (IKSR, 2020) enhances the technical application of a dike. Besides, the risks of aquifer flooding are relatively low.

(C). *Alpine Rhine Valley-Bodensee border*
The final location suitable for local dike construction is the area between the Alpine Rhine Valley and the Bodensee. This area is relatively flat, with excellent groundwater conditions, allowing for a robust water system between the ground and the dike. However, vulnerabilities related to flooding and drought should not be overlooked.



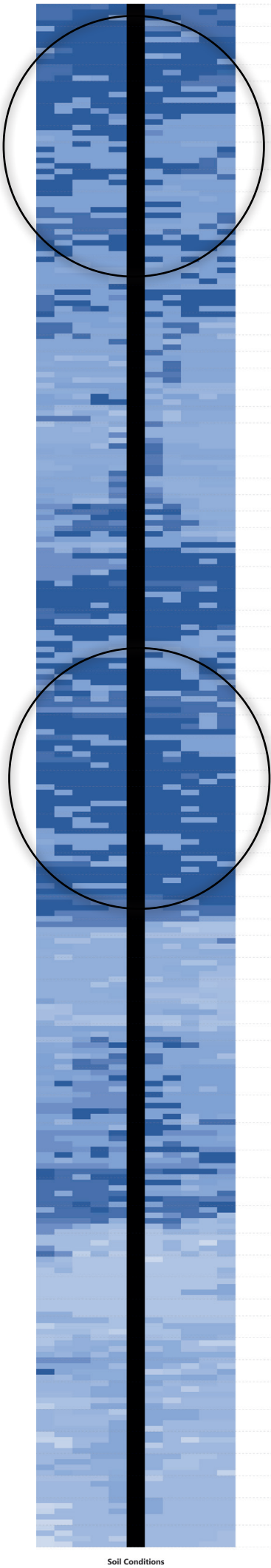
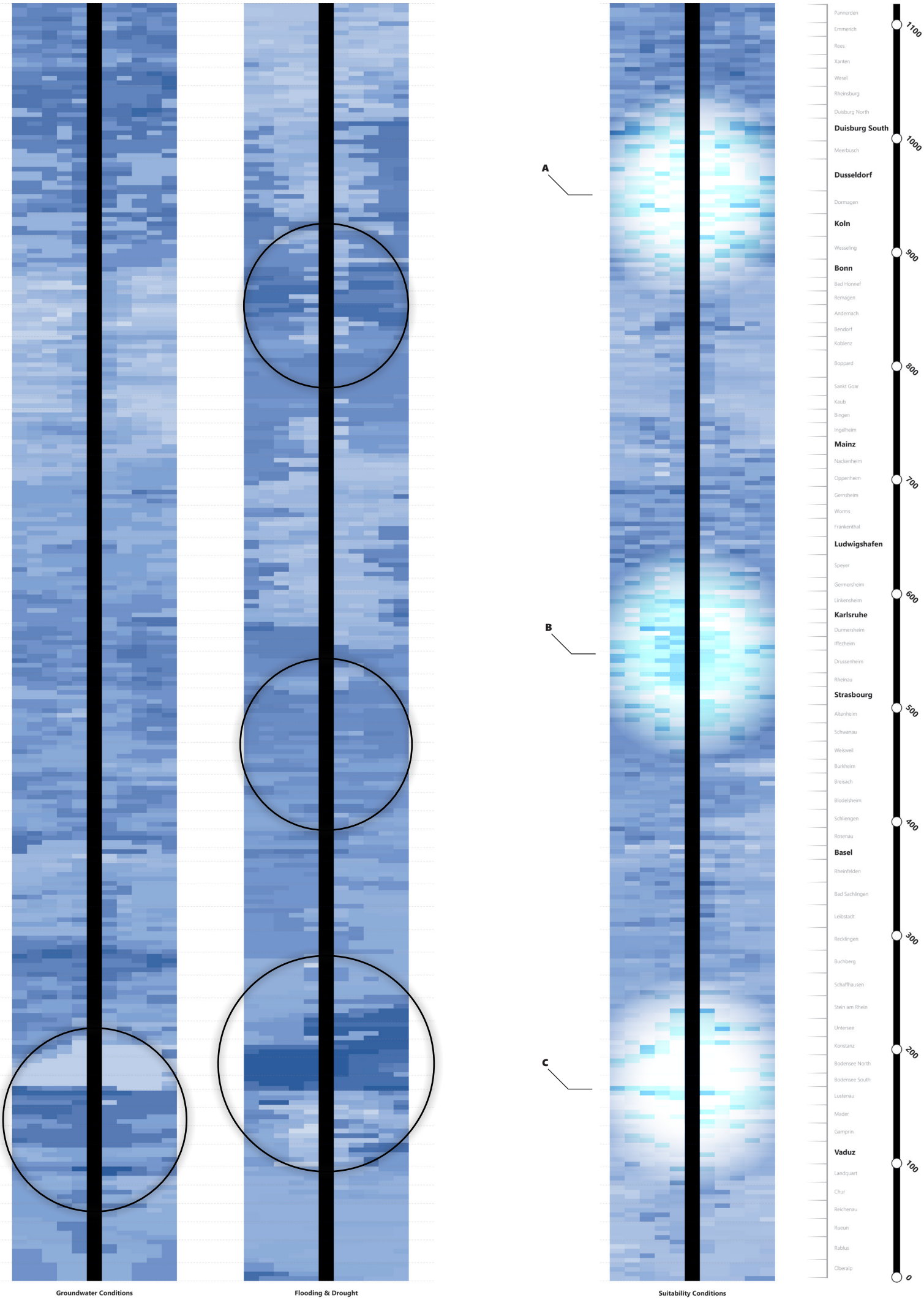


Figure 124: Spatialization of the Rhine Line regarding the autonomy of the Suitability Conditions and the sub-calculations. (Author, 2023)


A
B
C
Pannerden
Emmerich
Rees
Xanten
Wesel
Rheinsburg
Duisburg North
Duisburg South
Meerbusch
Dusseldorf
Dormagen
Koln
Wesseling
Bonn
Bad Honnef
Remagen
Andernach
Bendorf
Koblenz
Boppard
Sankt Goar
Kaub
Bingen
Ingelheim
Mainz
Nackenheim
Oppenheim
Gernsheim
Worms
Frankenthal
Ludwigshafen
Speyer
Germersheim
Linkensheim
Karlsruhe
Durmersheim
Iffezheim
Drussenheim
Rheinau
Strasbourg
Altenheim
Schwanau
Weiswel
Burkheim
Breisach
Blodelsheim
Schliengen
Rosenau
Basel
Rheinfelden
Bad Sachlingen
Leibstadt
Recklingen
Buchberg
Schaffhausen
Stein am Rhein
Untersee
Konstanz
Bodensee North
Bodensee South
Lustenau
Mader
Gamprin
Vaduz
Landquart
Chur
Reichenau
Rueun
Rablus
Oberalp
1100
1000
900
800
700
600
500
400
300
200
100
0
Groundwater Conditions
Flooding & Drought
Suitability Conditions

10.4

Decision Making Autonomy

Main Calculation

This sub-calculation is directed at Decision Making Autonomy. Based on existing regulations, rules, and management schemes, the self-organizing capacity of local stakeholders can be analyzed. This sub-calculation, therefore, addresses the main conclusion: the higher the capacity for making decisions regarding dike management at the local scale, the greater the autonomy of that area becomes. To illustrate the various indicators considered in this sub-calculation, this report categorizes the main indicator groups as follows:

(1). *Flood Safety regions*, as the primary indicator for dike construction regulations.

(2). *Decision Making Autonomy* is based on the capacity of land use classified areas to make decisions freely.

(3). *Autonomy of the Administration* is the main indicator to show current management relations and political power structures.

(4). *Water Use Distribution* is the main indicator to illustrate the interdependency of certain regions regarding water usage of the Rhine.

Sub Calculations

Flood Safety Regions

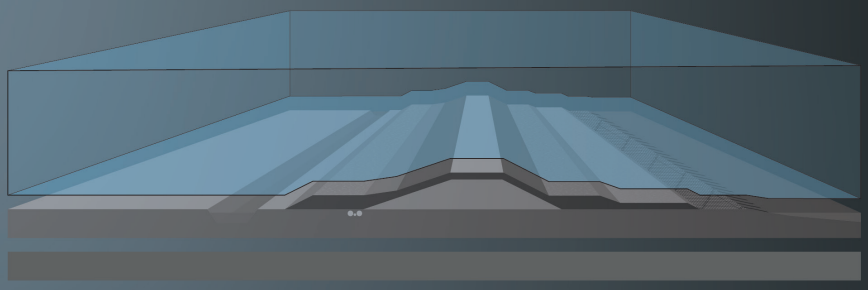
Flood safety measures are related to the potential for catastrophic dike breaches. Based on existing and future safety levels, different regions along the Rhine implement varying regulations. Thus, the lower the safety regulation, the less likely a catastrophic event will occur. Consequently, dikes with higher safety measurements are more controlled and managed by public authorities, leaving less room for localized dike management. To highlight the uncertainties of future regulations, two main flood risk scenarios are translated: a moderate scenario (1.0) and an extreme scenario (1.0) (Linde et al., 2011).

Decision Making Autonomy

To understand the primary decision-making powers of specific regions, this report addresses the key indicators necessary to assess the potential for self-organizing capacity in dike management. The indicators used are as follows:

Available knowledge (2.0)
Available funds (1.75)
Available space (1.5)
Authority in water management (1.0)
Stakeholder involvement (0.75)
Dealing with uncertainties (0.5)

The six indicators are divided based on Spatial, Procedural and Knowledge conditions to address the different conditions that were researched.



Authorative Regions

Indicates the potential to self-govern within the decision-making process of dike management

MAIN CALCULATION

SUB-CALCULATION

INDICATORS

(Flood) Safety Regions

Chance of Flooding as to future projections (moderate + extreme)

1.0

- Future Prediction (Moderate) — 1.0
- Future Prediction (Extreme) — 1.0

Decision Making Autonomy

Available IWM qualities according to existing landuse classification

2.0

- Available Knowledge — 2.0
- Available Funds — 1.75
- Available Space — 1.5
- Self-Organizing Capacity — 1.0
- Total Stakeholder Involvement — 0.75
- Dealing with Uncertainties — 0.5

A

- Existing Projects IKSR — 0.75
- Spread of Project Influence — 0.5

Autonomy of the Adminstration

Administrative layers of complexity that (dis)allow autonomy

1.5

- *Socio-Economic Conditions* — 1.75
  - GDP as per purchasing power standard — 1.0
  - Urbanized Regions — 0.75
- *Political Landscape* — 4.5
  - Water Management Powers — 1.0
  - Dike Management Powers — 1.5
  - Trust in Governance — 0.25
  - Trends in Adaptiveness — 0.5
  - Trends in Citizen Engagement — 0.5
  - Water Management Integration — 0.5
  - Spatial Planning Discourse — 0.25

Water Use Distribution

Autonomy as based on the Efficiency of Water Use per land use classification

1.25

- *Economic Water Use Efficiency* — 1.5
  - Water Use — 0.75
  - Water Efficiency — 0.25
- *Quantitative Water Use* — 0.25

A

- Power Plant Water Use — 1.5
- Waste Water Points — 1.0

Water Dependent Regions — 2.0

Relation to Created Autonomy · Relation to Dike Suitability · Weight given in subcalculation · Used as an Addition to Autonomy

A

Positive · Negative · Neutral

Figure 125: Authoritative autonomy indicators. (Author, 2023)

Additionally, this research states that knowledge is the most critical indicator for determining self-organizing capacity. As dike management is not commonly associated with local stakeholders, the provision and availability of knowledge are essential for establishing a knowledge network. Therefore, this sub-calculation is supplemented with the indicator of existing projects (0.75), known to the IKSR, related to water management (BAFG, 2015). Based on the latter, the additional indicator of the area of project influence is added (0.5).

The scale used to determine the area of self-organization is provided by the different land use classifications in the Corine Land Cover data (Copernicus, 2018). This is done as no direct spatial translation of the stakeholder can be created, besides the use of land use classifications.

Autonomy of the Administration

The third sub-calculation focuses on autonomy that can be established based on the existing political landscapes of the Rhine. Here, two main categories are defined:

(1). *Socio-economic conditions (1.75):* Indicates the possibility of self-organizing capacity based on economic capacity to initiate change in localized dike autonomy.

(2). Current relationships within the *political landscape (4.5)* of the Rhine nations: Determines the possibility of local stakeholder groups to self-organize within the decision-making process of public authorities.

Socio-Economic Conditions

The socio-economic conditions of the Rhine indicate the potential for local stakeholders to initiate change based on the current GDP levels (1.0) and the classification of urbanized regions (0.75). The assumption is that if a single stakeholder can initiate change at any moment, their autonomy within the decision-making process is enhanced. Therefore, the GDP at current market prices by Eurostat (2018) indicates a stakeholder's ability to provide their financial means to initiate change. Furthermore, the classification of urbanized regions indicates freedom in the decision-making process, following the idea that initiated change in urbanized regions impacts more potential activities, making change less 'free' compared to rural regions where the impact is relatively lower.

Political Landscape

Without understanding the current political landscape of decision-making, opportunities to initiate change towards local autonomy cannot be established. To comprehend the possibilities of making independent decisions, the nature of the political landscape must be understood. This sub-calculation defines two indicators that depict the political landscape for dike management:

(1). *Water Management Powers (1.0)*
(2). *Dike Management Powers (1.5)*

Additionally, five other indicators are used to describe the landscape of territorial governance and spatial planning systems of the six Rhine nations, based on the COMPASS report of 2018. These indicators are:

Trends in Adaptiveness (0.5)
Trends in Citizen Engagement (0.5)
Water Management Integration Policies (0.5)
Spatial Planning Discourse (0.25)
Trust in Governance (0.25)

Water Use Distribution

The final sub-calculation involves a quantitative analysis of water usage. Dike management is an integral part of water management, as dikes are used to regulate the flow of water. Dikes also protect certain industries within the water management sector, as the water from the Rhine cannot be mixed with drinking water facilities or industrial production water. Therefore, this sub-calculation is divided into three main categories:

(1). *Economic Water Use Efficiency (1.5)*
(2). *Quantitative water use (+0.25)*
(3). *Water-dependent regions (1.75)*

Economic Water Use Efficiency

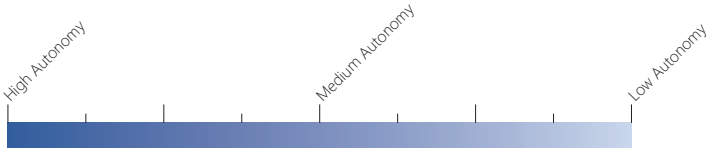
To assess the water use of the Rhine River, this sub-calculation again uses the primary land use classification provided by Corine Land Cover. The data on water use per sector, provided by the European Environmental Agency (2023), facilitates the indication of the amount and efficiency of water use for the main sectors: Agriculture, Electricity Cooling (industrial), Mining and quarrying, Public Water Supply, and manufacturing (industrial). Autonomy is adjusted based on differences among Rhine nations. High extent of water use is indicative for potential stress on adjacent dikes to manage this usage, leading to reduced autonomy on location.

Quantatative Water Use

The second sub-calculation on water use is based on the central points of water use, as determined from existing data from industrial plants (Global Energy Observatory et al. 2019) and wastewater facilities (Ehalt Macedo et al. 2021). As it identifies local spatial points where water use is most common, the need for a dike to manage these water flows increases significantly. Since these power plants and wastewater facilities are self-organized private associations, they can self-govern their local dikes. From this perspective, the central notion followed is that when a water use node is identified, the potential for a dike to be managed by local stakeholders, without significant issues regarding the facility's importance, increases.

The amount of water used and/or treated is used as an indication of the facility's importance on a broader scale, leading to impact when initiating changes within dike management.

Flood Safety Regions

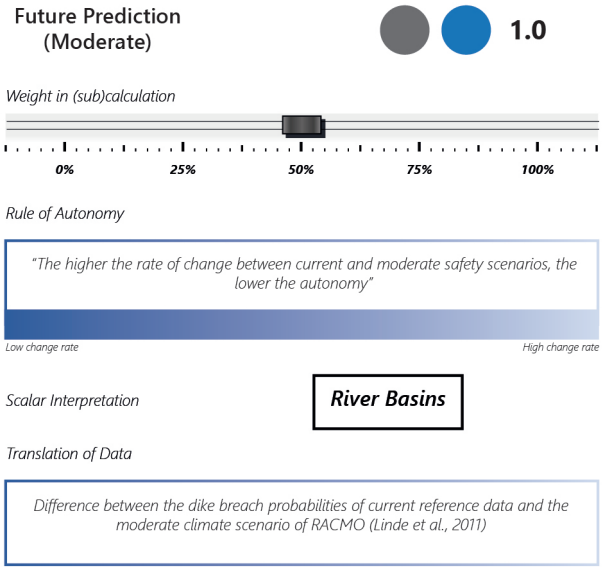


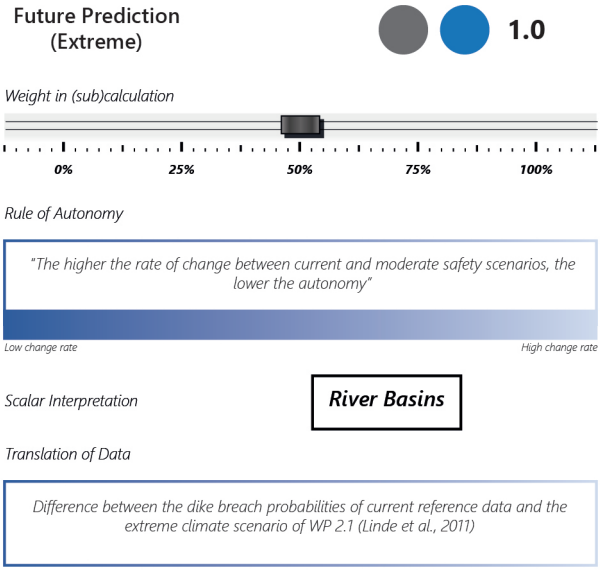
A. *Moderate Scenarios**

Dikes are designed based on the existing flood safety regulations. However, due to climate risks, different scenarios have been developed to show future regulatory change. According to the moderate scenario of IPCC SRES A1B (Linde et al. 2011), safety regulations should be enhanced near the Dutch-German border (A1). The area of the Middle Rhine between Karlsruhe and Bonn (A2) shows a relatively lower increase.

B. *Extreme Scenarios**

Based on the extreme scenario provided by Linde et al. (2011), covering a larger part of the Middle and Lower Rhine between Köln and Düsseldorf (B1), there is considered to be a lower increase in safety compared to other regions. However, the channelized zone of the Rhine between Basel and Karlsruhe (B2) now shows a significant increase.





**The safety regulations based on both scenarios show an increase along the whole Rhine (te Linde, et al. 2011). The difference in the line is made based on their respective changes to each other.*

Figure 126: Translation of autonomy indicators of the Flood safety regions. (Author, 2023)

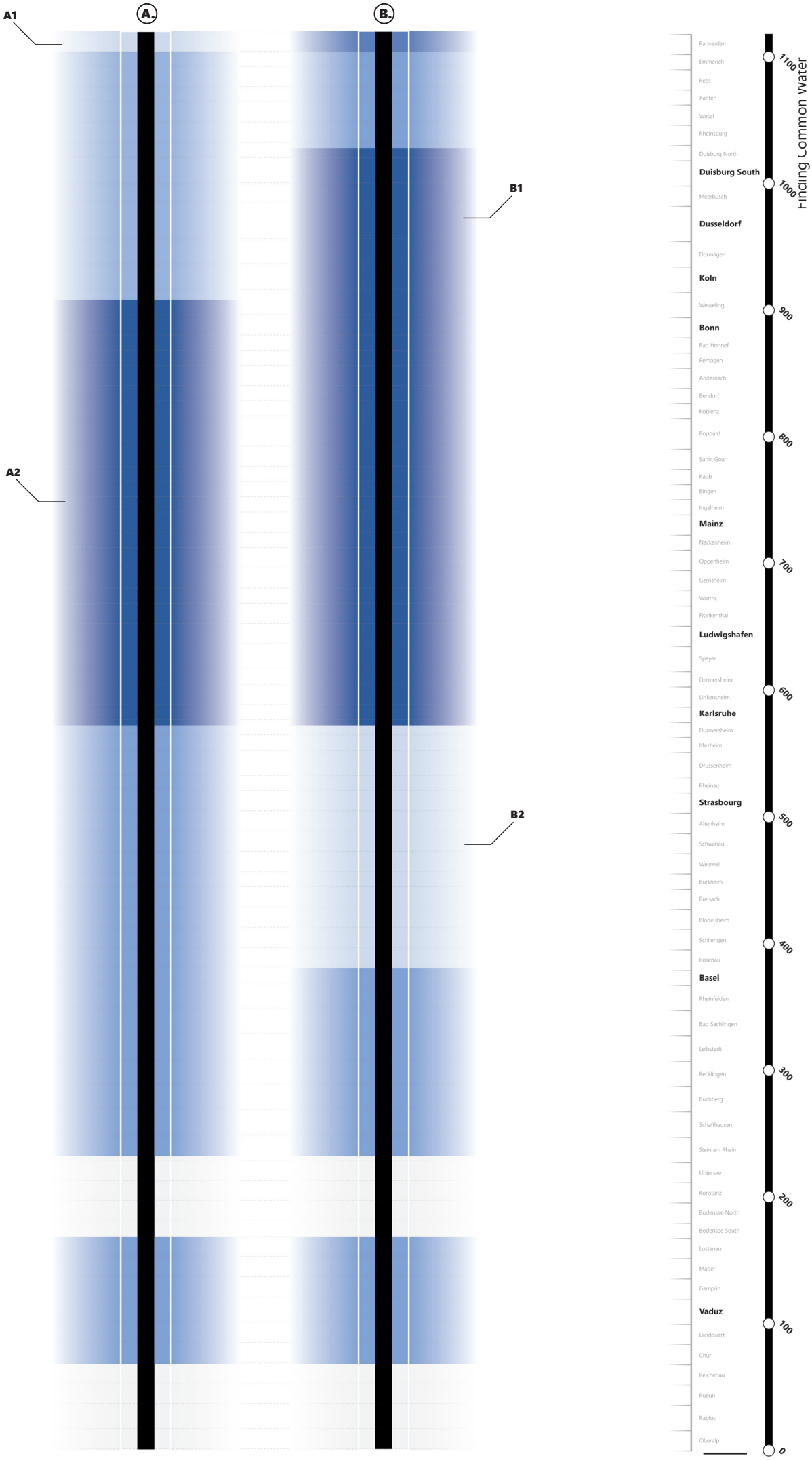


Figure 127: Spatialization of the Rhine Line regarding Autonomy based on flood safety regions. (Author, 2023)

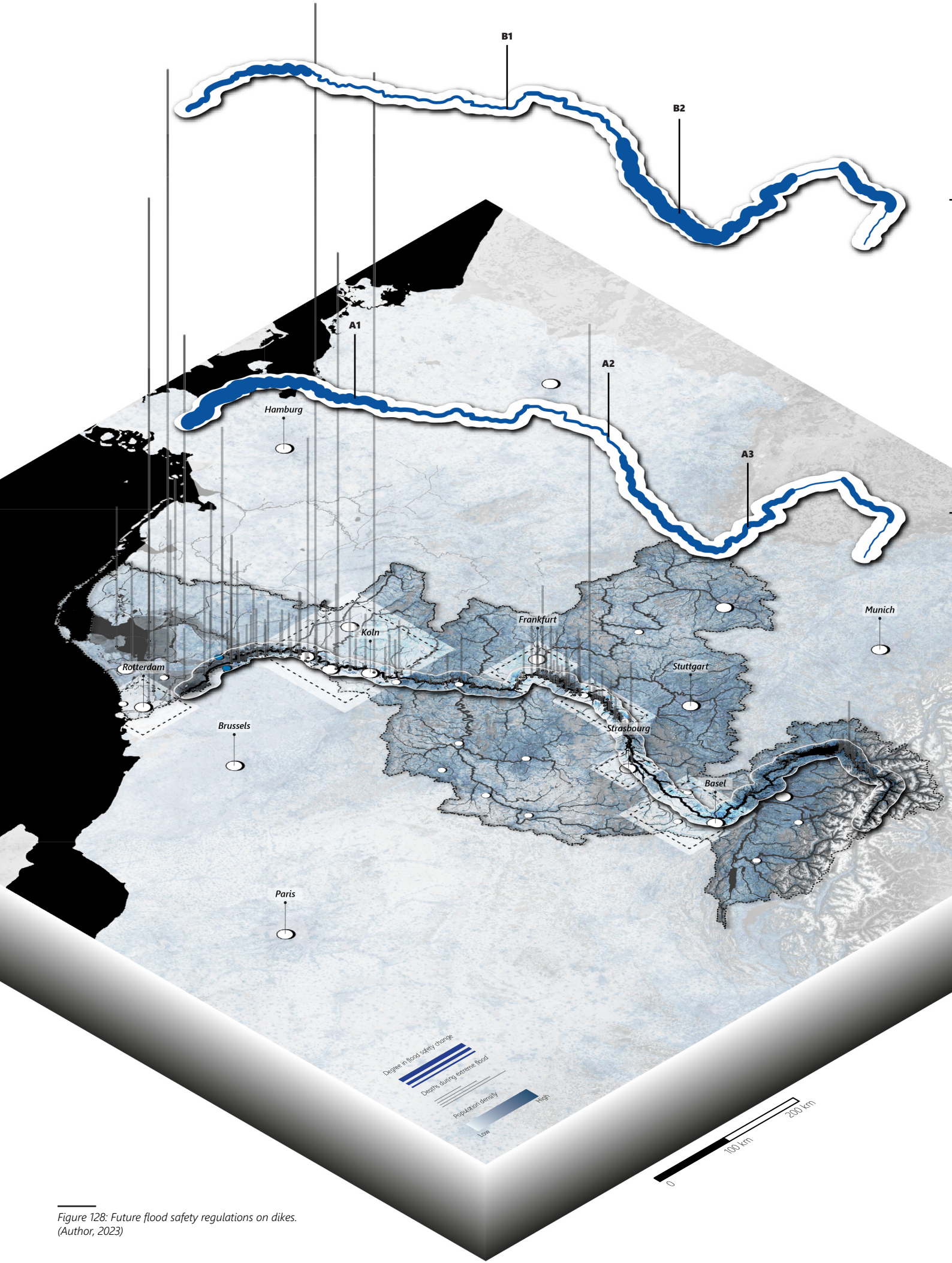


Figure 128: Future flood safety regulations on dikes. (Author, 2023)

Flood Safety Regions

1.0

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the rate of change between current and future flood safety regulations, the lower the possibilities for local autonomy"

Low rate *High rate*

Scalar Interpretation ***River Basins***

Translation of Data

Calculation:

1.0(Future flood safety: Moderate) + 2.0*(Future flood safety: Extreme) / 4.25*

Weighting of the Indicators

The first sub-calculation is based on the existing and future flood safety regulations. This sub-calculation compares scenarios based on research by Linde et al. (2011), where the reference and future scenarios are analysed on comparative change. Therefore, it doesn't show the specific safety regulations but rather the extent of the increase between scenario's. This approach is necessary because different administrative regions handle different regulations. Therefore, the comparative analysis concludes the change in flood safety regulation.

Moderate Scenario (1.0)
The moderate scenario of IPCC SRES A1B reveals two major areas where an increase in safety regulations is measured to be around 150% (Linde et al., 2011): the lower Rhine between Bonn and the Dutch-German border (A1) and the Alpine Rhine from Basel to Chur (A3). The middle and upper Rhine areas from Karlsruhe to Bonn show the lowest increase rate at 125% (Linde et al., 2011), and therefore is comparative more prominent for local autonomy.

Extreme Scenario (1.0)
Based on the extreme climate scenario along the Rhine, the largest increase can be found near the canalized section of the Upper Rhine between Basel and Karlsruhe (B2), where safety regulations rise by almost 400% (Linde et al., 2011). Again, based on the probability of a dike breach, the Middle Rhine near Mainz shows the lowest increase.

Based on these conclusions, the lowest change in safety regulation is found between the Upper and Middle Rhine from Karlsruhe to Bonn. According to the research by Linde et al. (2011), a dike breach is still possible in this area. However, when considering localized autonomy based on the change rate of safety regulations, there is more freedom available for local stakeholders in this part of the Rhine than in other locations.

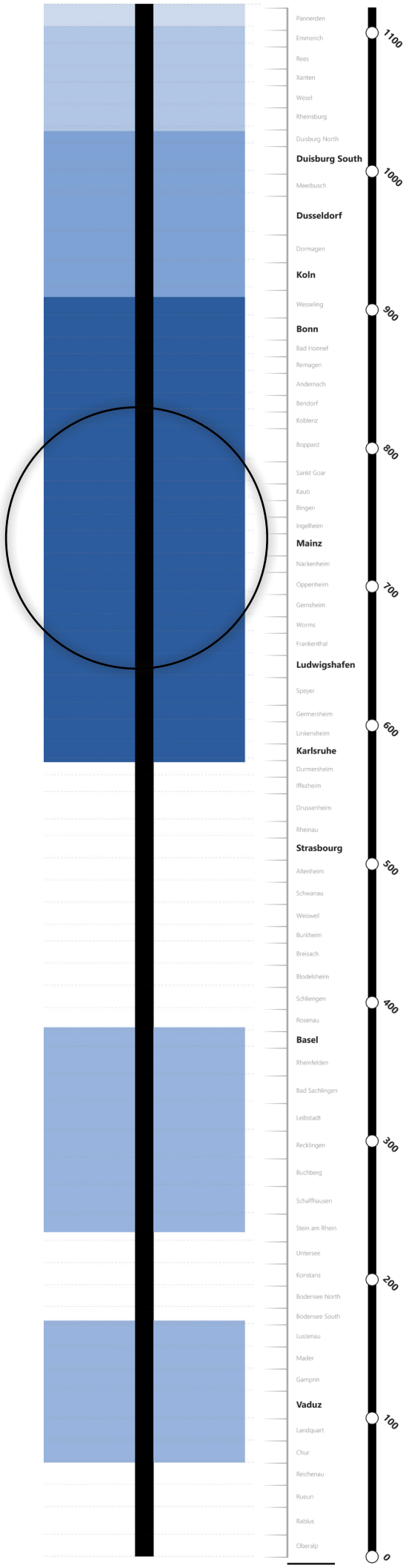
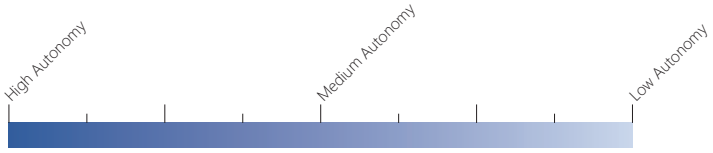


Figure 129: Spatialization of the Rhine Line regarding Autonomy based on Future flood safety regulations. (Author, 2023)

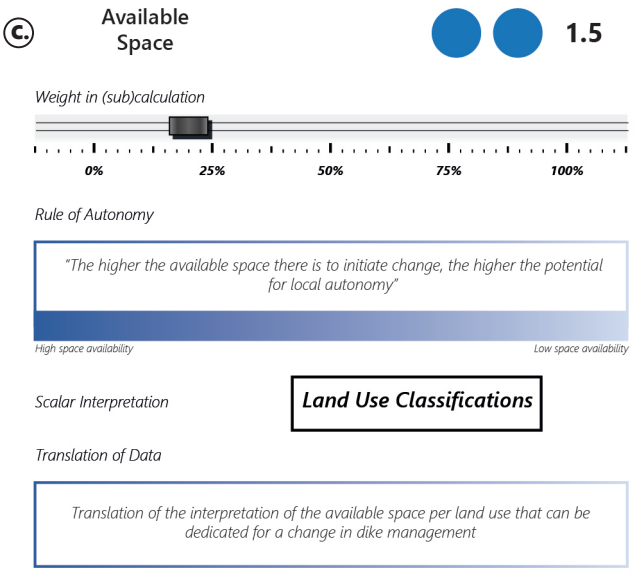


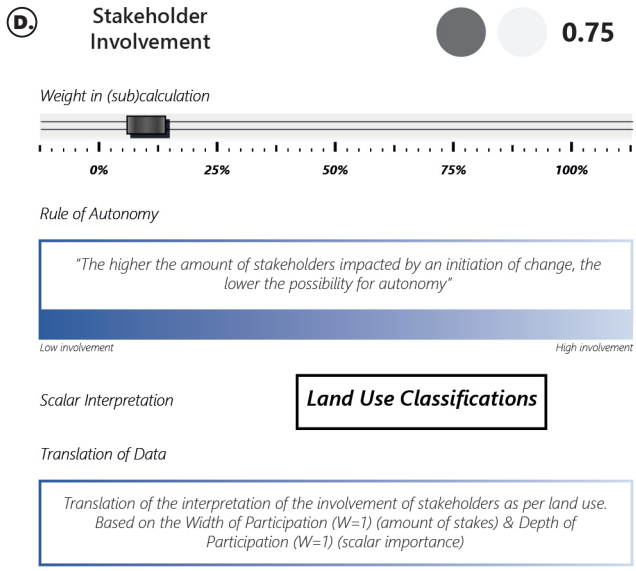
Desicion-making Autonomy

Spatial Conditions

For local dike change to be facilitated, the need of space arises. Primarily, the agricultural and natural regions of the pasture lands of the Dutch-German polders (C1) and the wetland and agricultural zones between Ludwigshafen and Mainz (C2) facility useable space for dike change, as the urbanization rate is considered to be low.

Change in one location can impact direct surroundings. Therefore, when considering an initiative, the impact and the involvement of other stakeholders affects the potential for local autonomy. This impact can be seen both in terms of width and depth of involvement. It is particularly relevant in urbanized regions (D1 & D2), where higher potential impacted stakeholders are located.

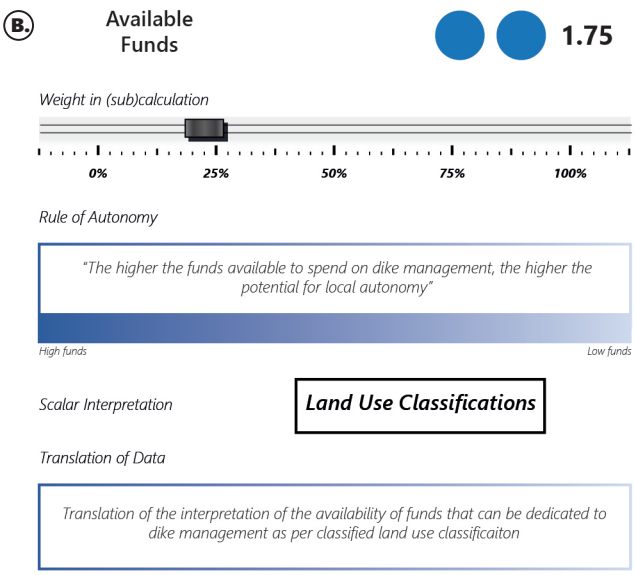




Procedural Conditions

Financial requirements are essential if local change is initiated. Especially for the construction of dikes (CTCN, n.d; Waterschap Riverland, 2023), a substantial financial burden is present. Due to the high urbanization rate of the industrial regions of Ruhr (B1), Ludwigshafen (B2), and Basel (B3), higher interest is dedicated to protection. Which eventually leads to larger funds to be allocated to dike management projects.

When initiating change, alternatives of existing practices have to be established. The willingness of change and the alternatives practices differ per stakeholder groups. Certain practices, such as the industrial sectors, which are dependent on a constant source of water (Düsseldorf: E1, Mainz: E2 & Mannheim: E3), have limited consideration of alternatives.



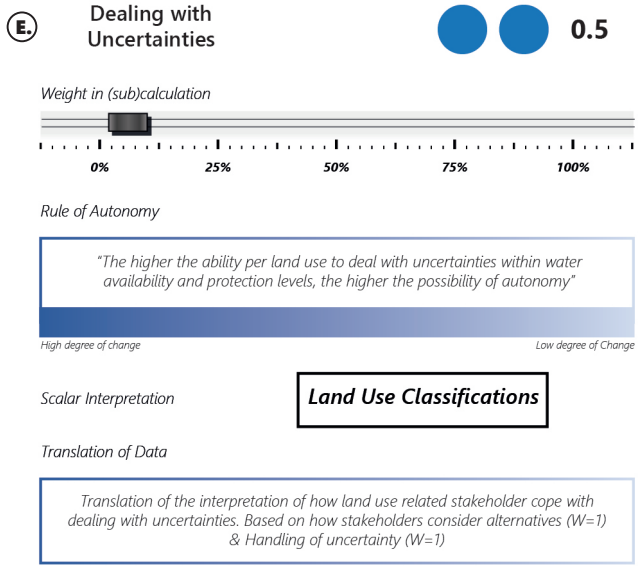
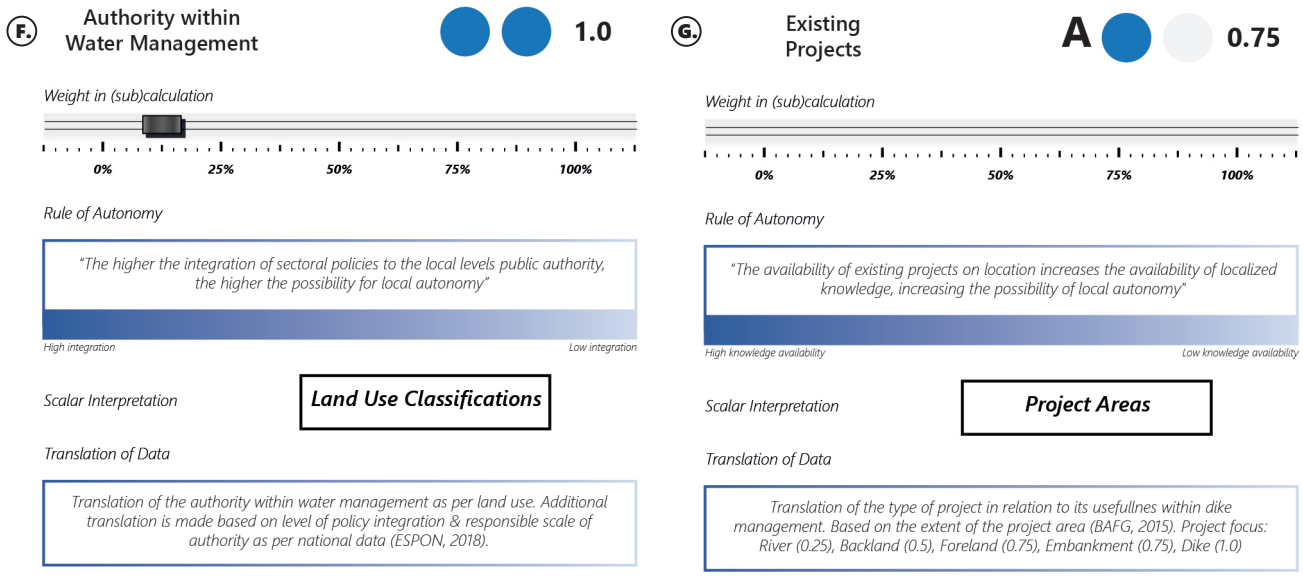


Figure 130: Translation of autonomy indicators of the Decision-making conditions. (Author, 2023)

Based on the authority that different land uses have in the decision-making process of their respective nation-states (ESPON, 2018), existing urban land uses of the Rhine have a higher authority in water management. However, the integration of land use-related policies also impacts the rate of autonomy. For example, there is a low integration of agricultural policies in the Netherlands, Germany, and Austria (F1 & F3) and a high integration of environmental policies in Germany and Switzerland (F2 & F4) (ESPON, 2018). This alters the rate of autonomy for the respective agricultural and natural land-uses of the Rhine.

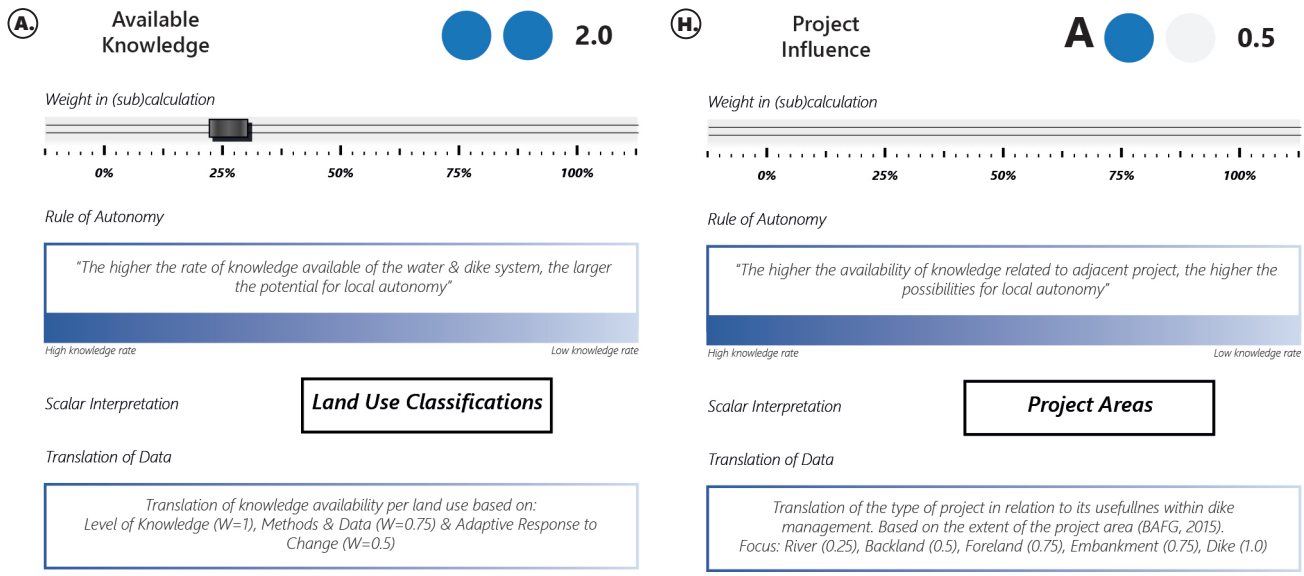
Available knowledge can also be created through adjacent projects by the IKSR (BAFG, 2015). The availability of ongoing projects in the vicinity of future autonomous regions has a positive impact on the possibilities for local actors to initiate changes. The availability of local resources, knowledge, and communication from these ongoing projects could lead to new possibilities for local actors to use available resources while retaining their autonomy within the decision-making process. The existing projects where ranked based on the relation to dike management.

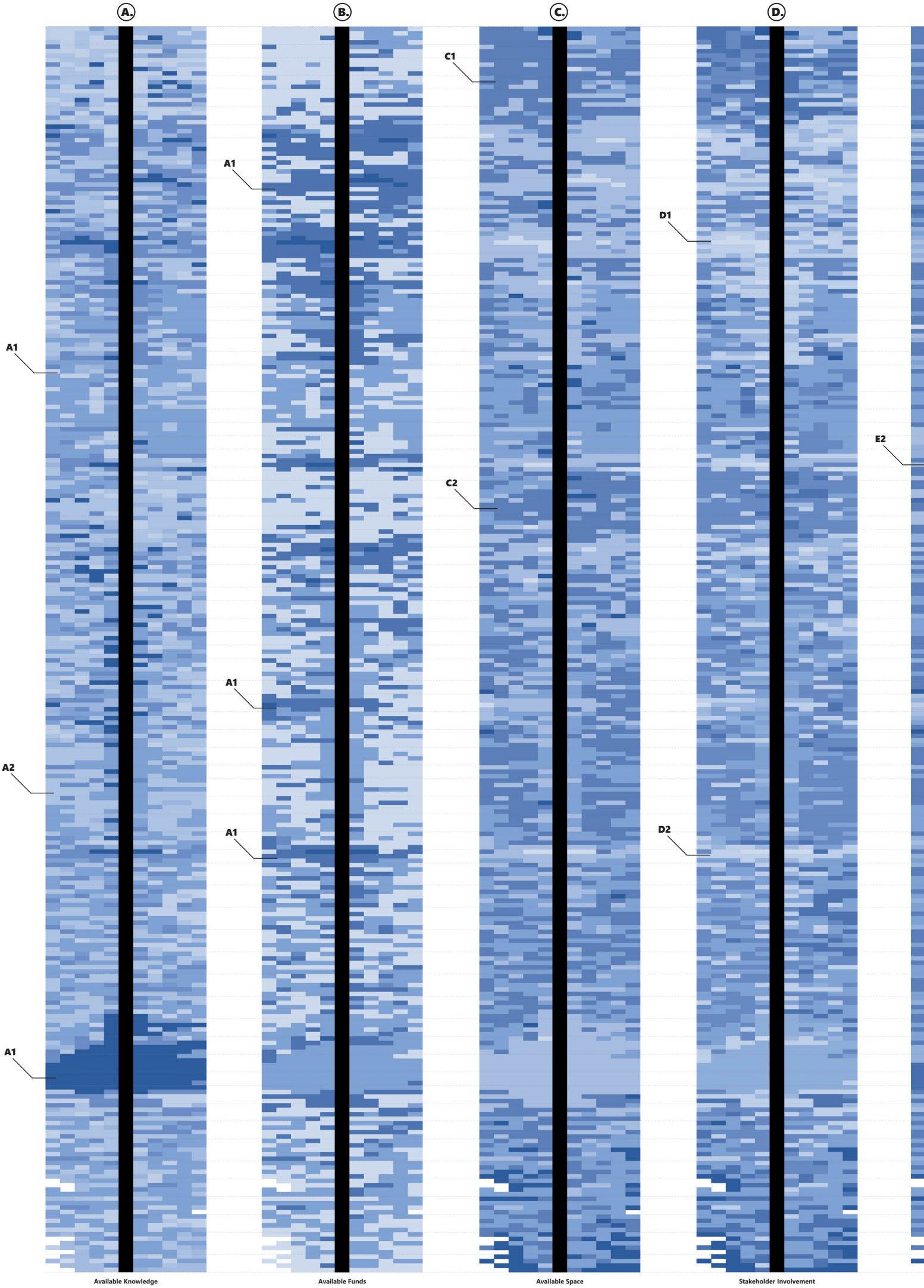


Knowledge Conditions

The level of knowledge present per land use explains the possibility of successfully initiating change. This is based on the indicators of current relations to water, the ability to gather information from the surroundings, and the ability to respond in times of need. For example, agricultural practices have a high level of knowledge but are less practical in response (A2), while natural areas are more capable of responding (A1).

In addition to the availability of nearby project locations, the influence of knowledge can alos be facilitated through communicative channels. Therefore, authorities related to dike and/or water management could have additional knowledge available, making it easier for local initiatives to encouraged. Here, the areas of H1, H2 (Kreise), and H3 (Canton) have a wide range of influence based on the size of the respective administrative regions.




A.
B.
C.
D.
A1
A2
A1
A1
A1
C1
C2
D1
D2
E2
Available Knowledge
Available Funds
Available Space
Stakeholder Involvement

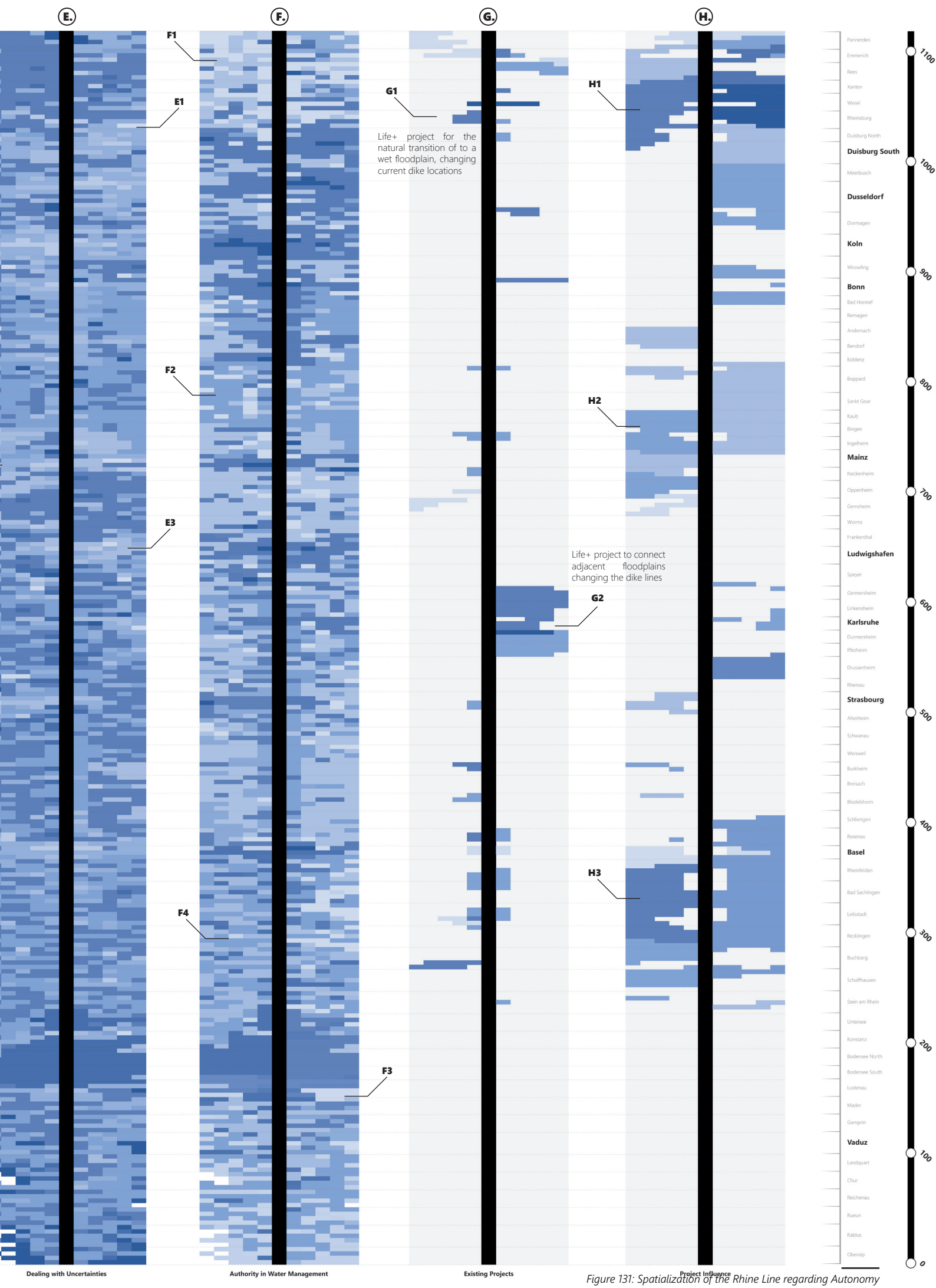


Figure 131: Spatialization of the Rhine Line regarding Autonomy based the decision making autonomy of stakeholders. (Author, 2023)

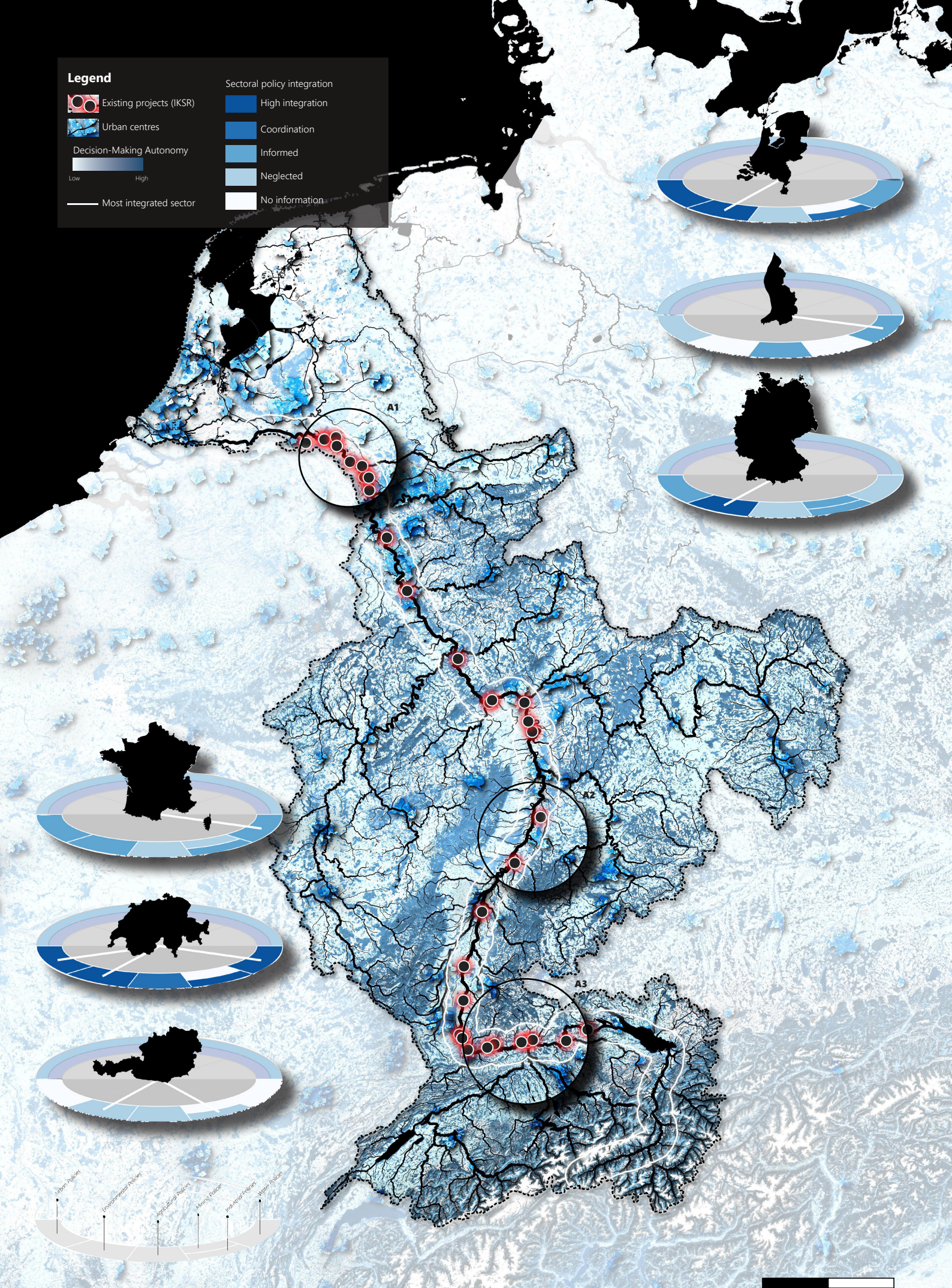


Figure 132: Decision-making autonomy of dike management along the Rhine. (Author, 2023)

Decision Making Autonomy

2.0

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the potential to allocate the decision making process to the local scales, the higher the possibilities for local autonomy"

High potential *Low potential*

Scalar Interpretation

Land Use Classifications

Translation of Data

Calculation:

(2.0(Available knowledge) + 1.75*(Available funds) + 1.5*(Available space) + 1.0*(Self-organizing capacity) + 0.75*(Stakeholder involvement) + 0.5*(Dealing with uncertainties) / 7.5) + 0.75*(Existing projects) + 0.5*(Project influence)*

Weighting of the Indicators

The second sub-calculation aims to understand the position of local stakeholders in making decisions for themselves. Based on the spatial, procedural, and knowledge conditions from the previous sections, an indication is made where dike autonomy is seen as advantageous.

(A1). *Agricultural Lands of the Lower Rhine*
The agricultural lands of the border regions between the Netherlands and Germany offer an abundance of space for the initiation of change, as there are no large urban areas present. This also minimizes the potential impact on additional stakeholders in the surroundings. Moreover, the availability of existing projects in the area, provides a wealth of knowledge that can be exploited and used by local stakeholders. Additionally, German and Dutch water management integration in policy making is seen as relatively beneficial.

(A2). *Areas of Karslruhe*
The areas surrounding Karlsruhe are vital for local decision-making because a balance of large urban cores with industrial facilities, in combination with open agricultural and wetland zones, provides not only the availability of funding nearby but also the necessary space for change to be initiated. Furthermore, the availability of knowledge in two projects related to naturalizing floodplains provides an additional incentive for local dike autonomy to gain foothold.

(A3). *Pasture lands of the High Rhine*
Swiss integration of policies to local levels of authority is seen as extremely high (ESPON, 2018), making the initiation of local change more fruitful. Furthermore, the area from Basel to the Bodensee is primarily characterized by open grassland and agricultural pasture lands, facilitating less impacts to surrounding stakeholders. The presence of projects related to the naturalization of river embankments (BAFG, 2015) in the region makes the possibility of initiating local dike autonomy interesting.

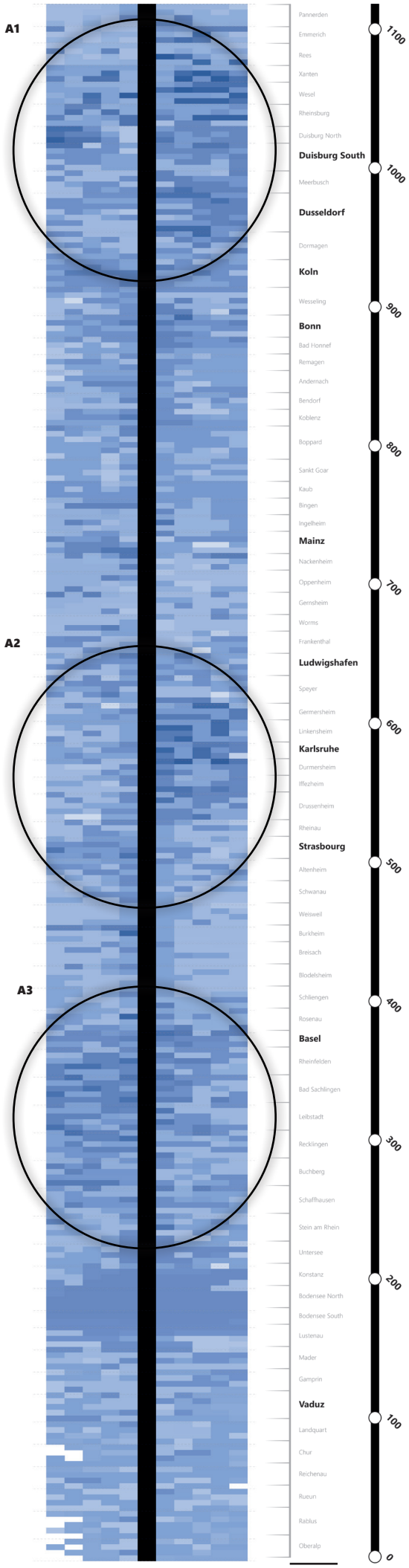
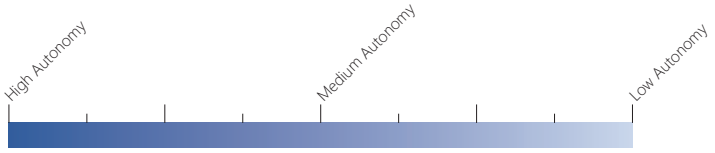


Figure 133: Spatialization of the Rhine Line regarding Autonomy based on the decision-making autonomy. (Author, 2023)



Autonomy of the Administration

Socio Economic Conditions

To establish complete autonomy, local stakeholders must fund the initiative for change. Based on the comparative GDP calculation per inhabitant of NUTS 2 regions of the Rhine, two regions show potential for initiating change: the region of Darmstadt (DE) and the canton of Zurich (CH) (A1 & A2).

A. GDP as per purchasing power standard — **1.0**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the translation of the GDP as per purchasing power standards is, the higher the potential for local autonomy"

High GDP — Low GDP

Scalar Interpretation **NUTS 2 (Regional)**

Translation of Data

Translation of the GDP purchasing power standard per NUTS 2 Regions along the Rhine river (Eurostat, 2023). Translated based on: GDP as per EU Average (W=0.25), GDP as per Rhine Average (W=1.0) & GDP as per National Average (W=1.25)

Here, the focus is on an individual's ability to initiate change without intervention from others, translated conform the urbanization rates of Eurostat (2016). In line with the concept of stakeholder involvement discussed in the previous sub-calculation, a higher degree of urbanization leads to a higher impact on lowering local autonomy. Higher autonomy is created in regions classified as rural as is the case for the agricultural lands of France (B2). Interestingly, due to the higher degree of urbanization in German agricultural areas (B1), a lower potential of autonomy results.

B. Urbanized Regions — **0.75**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the degree of urbanization, the higher the impact that is created when change is initiated, the lower the potential for local autonomy"

Low degree of Urbanization — High degree of Urbanization

Scalar Interpretation **Municipal Regions**

Translation of Data

Translation of the interpretation on Urban (W=1), Semi-Urban (W=3), Water (W=4) and Open/Rural (W=5) degree of urbanization (Eurostat, 2016). Based on the central notion that a high rate of urbanization creates an higher impact on the direct surroundings when change in dike management is initiated.

Political Landscape

Water management power relations are defined by two major components: the total number of administrative bodies and the responsibilities held by these administrative bodies. Surprisingly, Germany (C1) shows signs of low local autonomy because of the significant responsibilities in water management at the national and state levels of government (ECR, n.d).

C. Water Management Powers — **1.0**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the responsibilities and integration of water management is conducted on local levels of government, the higher the potential for autonomy"

High integration — Low integration

Scalar Interpretation **NUTS Regions 1-3**

Translation of Data

Translation of the institutional thickness of responsible authorities as per national, regional and local government levels + the translation of the responsibilities of these governments within the sector of water management (ECR, n.d.; IKSR, 2021).

Similar relations can be observed in the dike management sector. Interestingly, due to French and German (D2) laws that require individuals who may be affected by floods to take action themselves (Surminski et al., 2020; Republique Française, 2016), dike management is decentralized. On the contrary, due to the high national security risks in the Netherlands, the dike management sector there is highly centralized at the national and regional levels (D1).

D. Dike Management Powers — **1.5**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the responsibilities of dike management rely on local governements + the integration of programs related to Flood Protection, the higher the autonomy"

High integration — Low integration

Scalar Interpretation **NUTS Regions 1-3 + Owners**

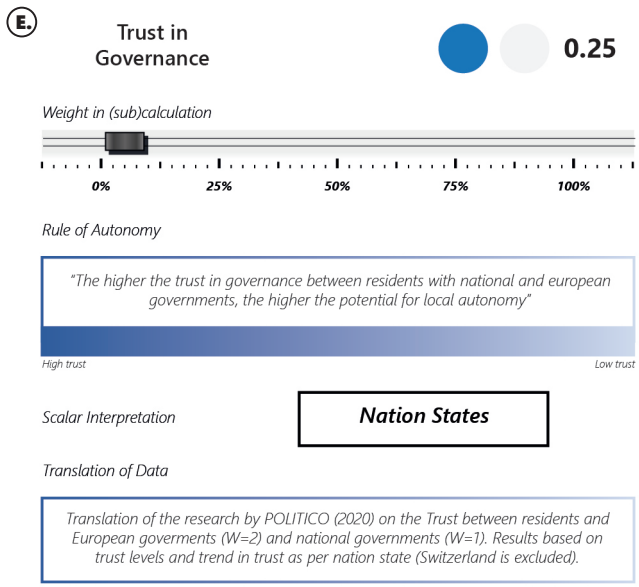
Translation of Data

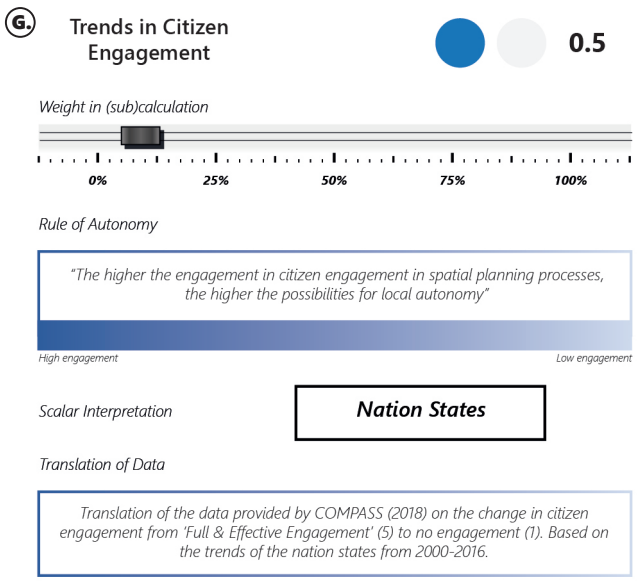
Translation of the responsibilities of the national, regional, local and owner levels of government + Integration of the current programs in relation to the Internationl Flood risk management plan for the Interational River Basin District "Rhine" (ECR, n.d.; IKSR, 2021).

Figure 134: Translation of autonomy indicators of the socio-economic conditions and political landscapes of the Rhine. (Author, 2023)

Real change cannot occur without trust in existing governance. Based on research by Politico (Sugue, 2020), trust levels for residents in National and European Politics are measured. Given that this report follows the notion of active subsidiarity, a higher increase in European trust is considered beneficial. This is particularly evident in Germany (E1) and France (E2), which are actively engaged in EU politics. However, a higher degree of national trust in France negatively impacts the calculation.

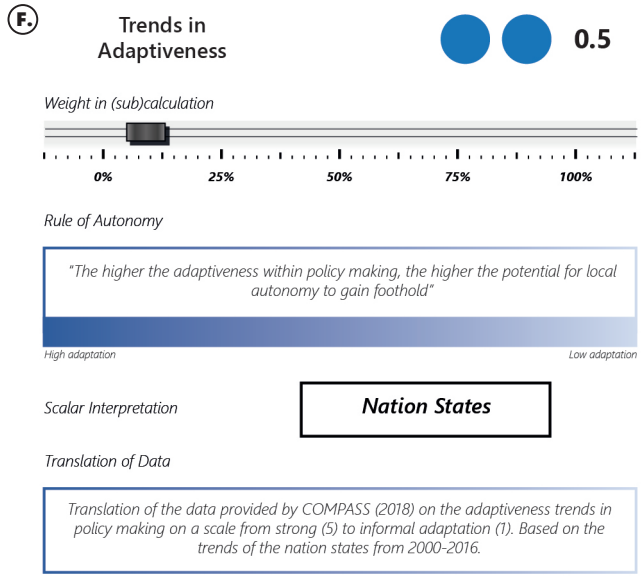
Citizen engagement in policymaking is essential to enable local stakeholders to have the freedom to implement policies at the local level. This not only creates a feedback loop between government levels but also allows for local autonomy in the decision-making process. Overall, citizen engagement is well represented in the national policymaking of the Netherlands and Switzerland (G1), which demonstrates a more integrated form than the weaker engagement in Austria (G2).

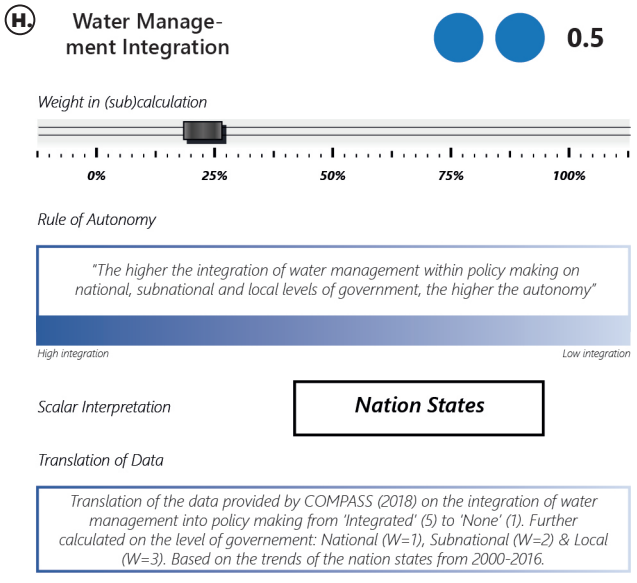




In the face of increasing uncertainties in societal discourse, existing policies must allow flexibility and adaptability. This involves establishing a framework of rules and regulations without overly specific regulations that may interfere with local initiatives. Therefore, high adaptiveness in policy making in France (F1), Austria (F2), and Switzerland (F3) is seen as beneficial.

As dike and water management are crucial components in determining the possibilities for local autonomy in dike construction and maintenance, integrating the right information and statistics into policymaking is essential to share information with local conditions. Based on the three different scale levels (Local, sub-national & national), water management is more strongly integrated in Switzerland (H3) and the Netherlands (H1) (ESPON, 2018). Due to the high integration of local water management into policies, France (H2) also ranks high.





The spatial planning discourse explains where spatial decisions are made based on the different levels of government. The more local the administration of spatial planning practice becomes, the better local conditions are taken into account within decision-making. However, the inclusion of (sub)national layers of government in the same discourse makes institutional thickness more likely. Therefore, Germany and France are ranked relatively lower than Austria (ESPON, 2018).

I. **Spatial Planning Discourse** **0.25**

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

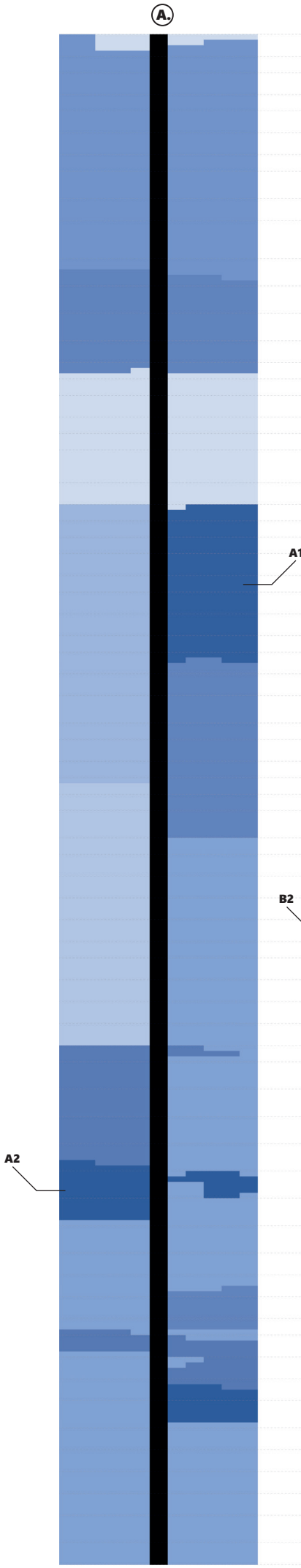
"The higher the integration of spatial planning on national, regional and lcoal levels of government, the higher the potential for local autonomy"

Low involvement *High involvement*

Scalar Interpretation ***Land Use Classifications***

Translation of Data

Translation of the data provided by COMPASS (2018) on integration of spatial planning within the scales of government. Based on the trends of the nation states from 2000-2016.



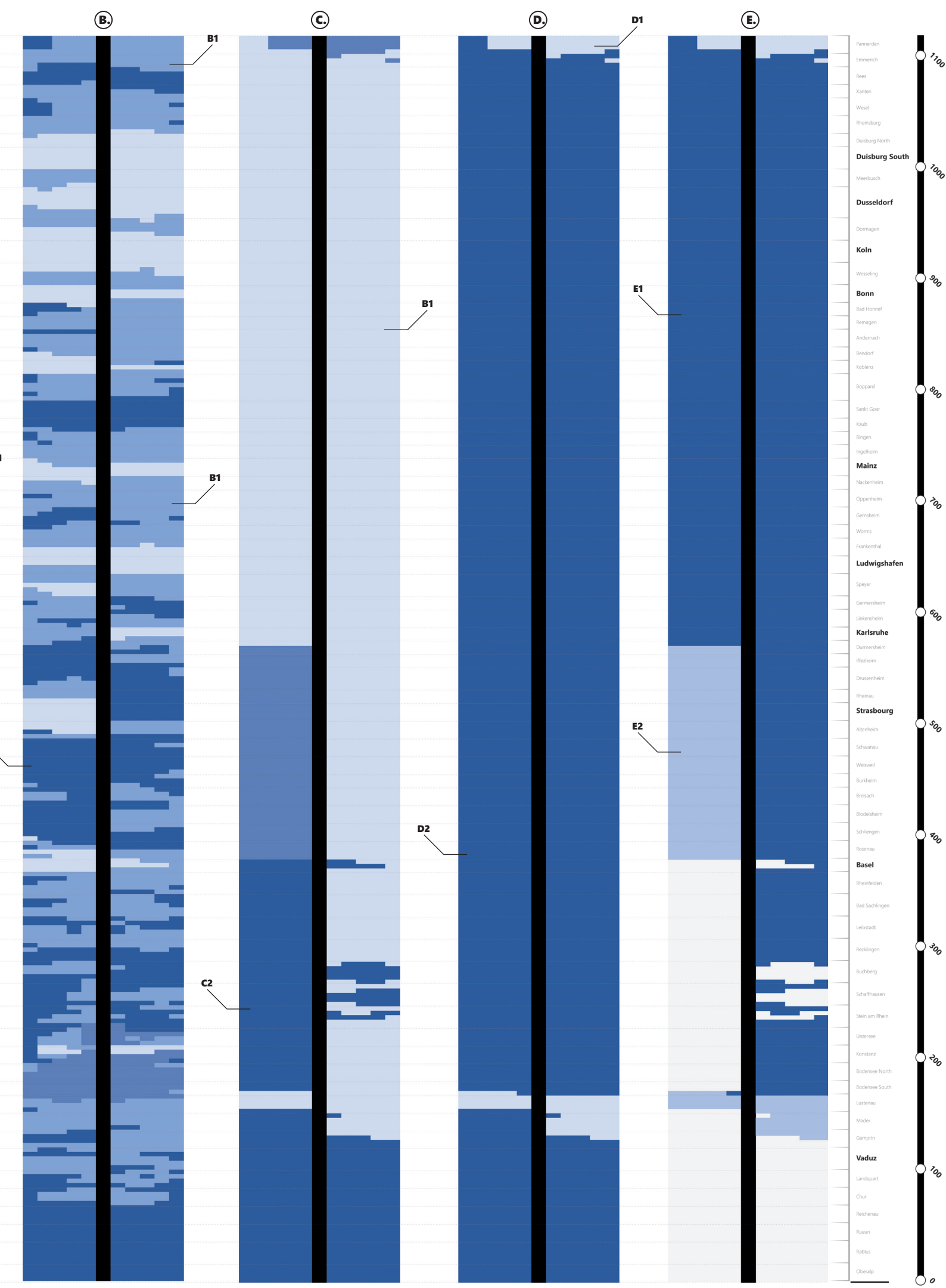


Figure 135: Spatialization of the Rhine Line regarding Autonomy based the socio-economic and political landscape indicators. (Author, 2023)

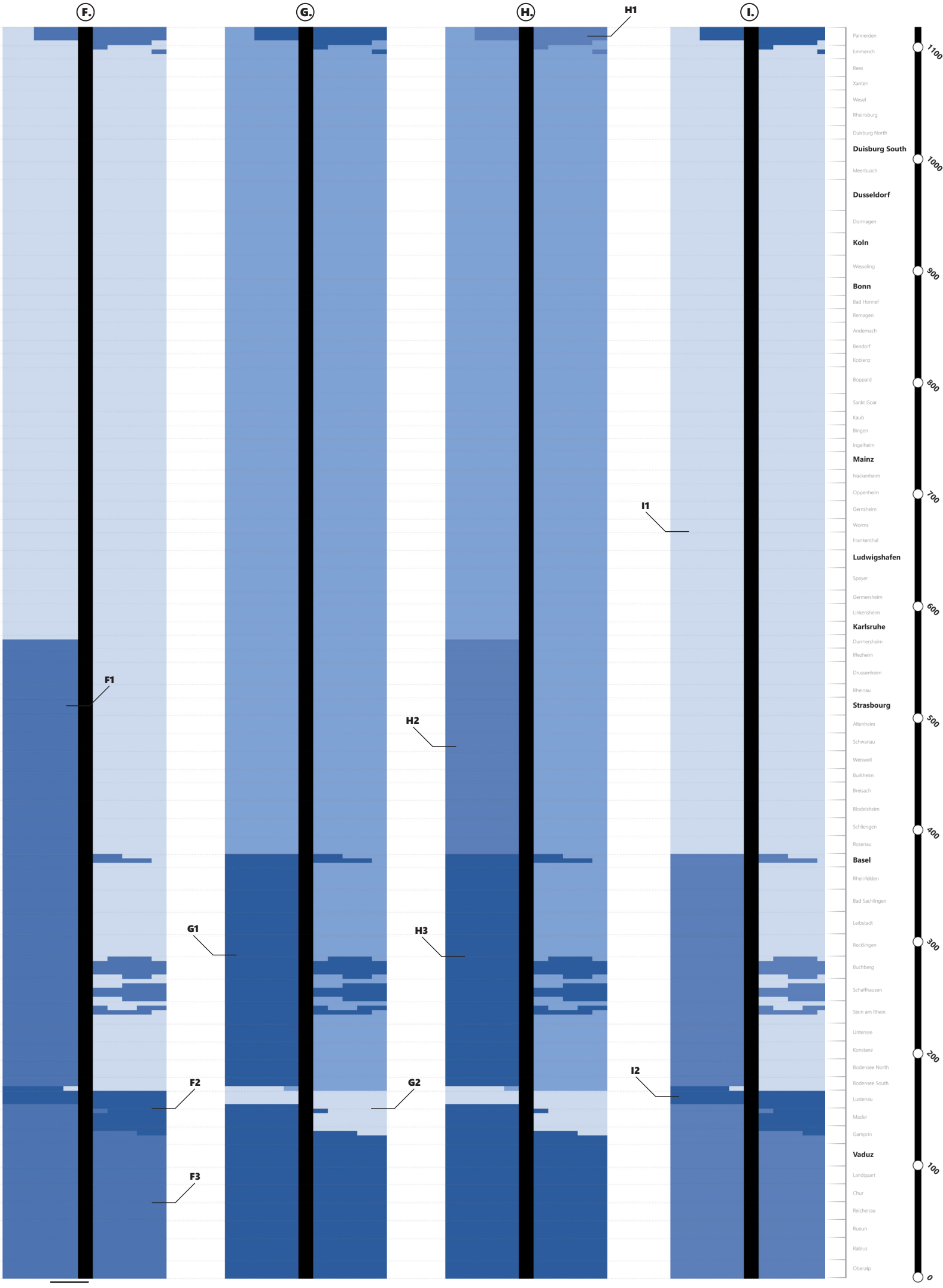


Figure 67: Spatialization of the Rhine Line regarding Autonomy based the socio-economic and political landscape indicators. (Author, 2023)

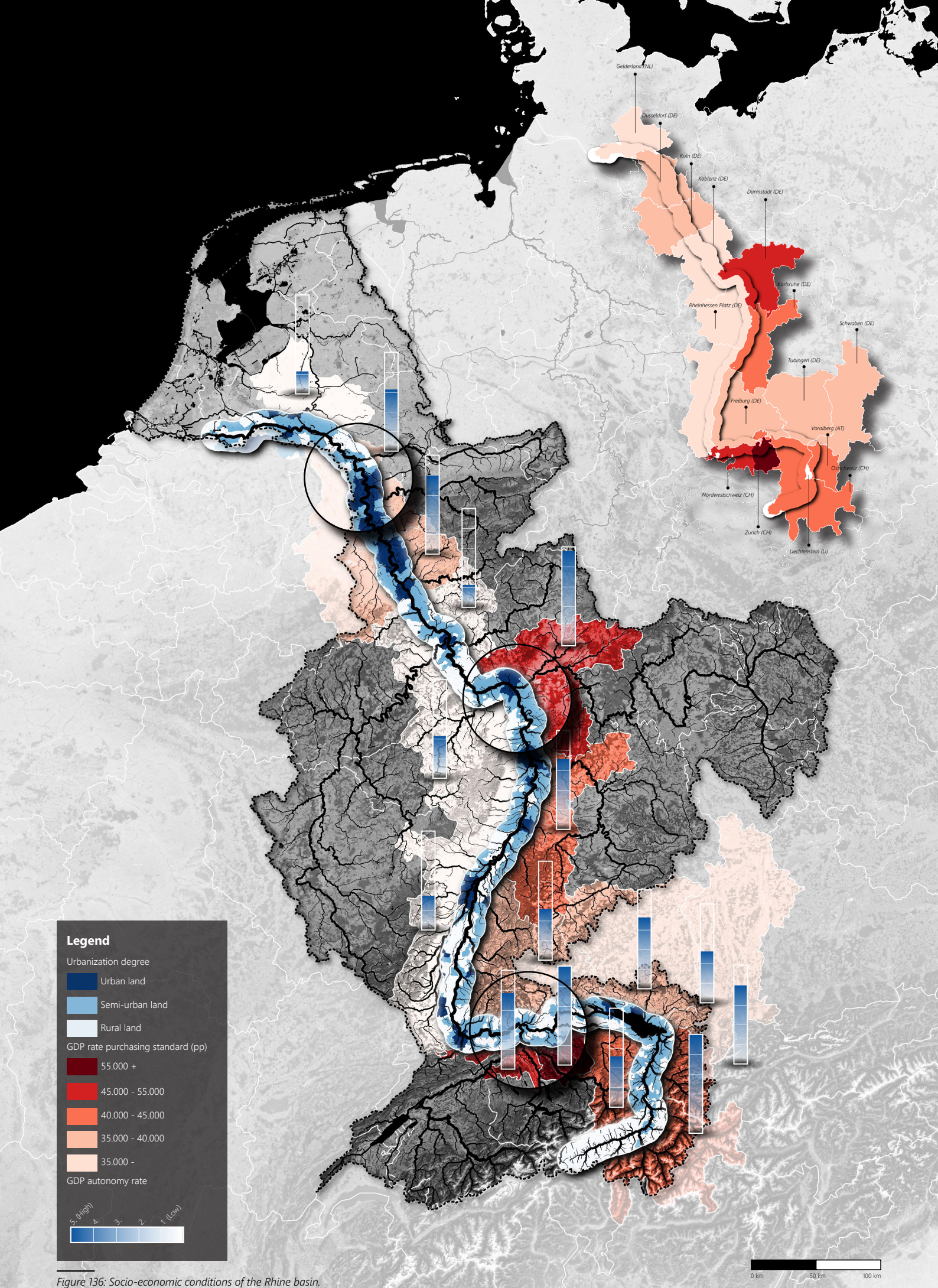


Figure 136: Socio-economic conditions of the Rhine basin. (Author, 2023)

Socio Economic Conditions

1.75

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the socio-economic conditions of a primarily unurbanized area becomes, the higher the possibility for local autonomy to gain foothold"

High conditions *Low conditions*

Scalar Interpretation

NUTS Regions (2 & 3)

Translation of Data

Calculation of the indicators of 'GDP' & 'Urbanized Regions'.

Weighting of the Indicators

To identify potential locations for local autonomy within the decision-making process based on the financial impacts of change initiation, socio-economic conditions are considered. Based on the urbanization degree (0.75) and GDP rate (1.0), three main locations are highlighted. Considering the expenses associated with dike construction (CTCN, n.d), financial benefits (GDP) take precedence over the impact created on the location (urbanization degree).

(A1). *Benefits of Ruhr Industries*
Once again, the agricultural border regions between Germany and the Netherlands are a promising location for local dike autonomy. This area, part of the Kreise of Dusseldorf, boasts a higher GDP rate (Eurostat, 2018). The balance between open rural lands and the urbanized regions of the Ruhr results in less impact when initiating change.

(A2). *Economic regions near Mainz*
With a GDP rate of 47,500 per capita (Eurostat, 2023), it is the second-highest among all the Rhine territories. Besides the large availability of rural land near the major cities of Mainz and Wiesbaden, there is space for change initiation. Although these agricultural areas are predominantly dedicated to vineyards, the potential is still present.

(A3). *Pasture lands of the High Rhine*
Financial benefits from the cantonal areas of Zurich and Aargau facilitate the financial means to initiate change. Furthermore, the area is primarily dedicated to agricultural and natural land, allowing for greater freedom within the initiation of change. This makes it a promising location for localized dike management.

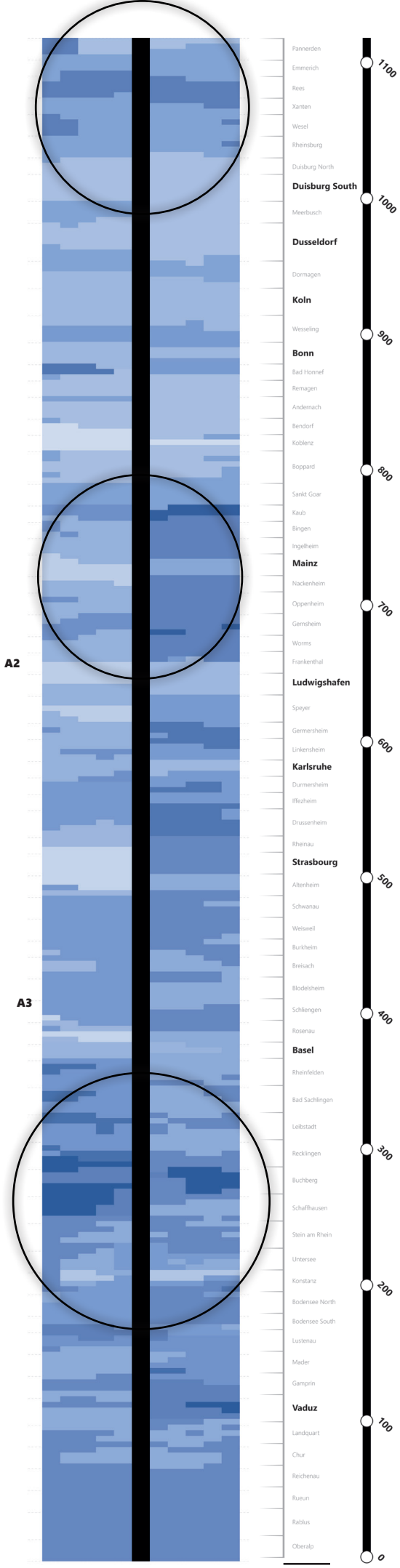


Figure 137: Spatialization of the Rhine Line regarding Autonomy based on socio-economic condition indicators. (Author, 2023)

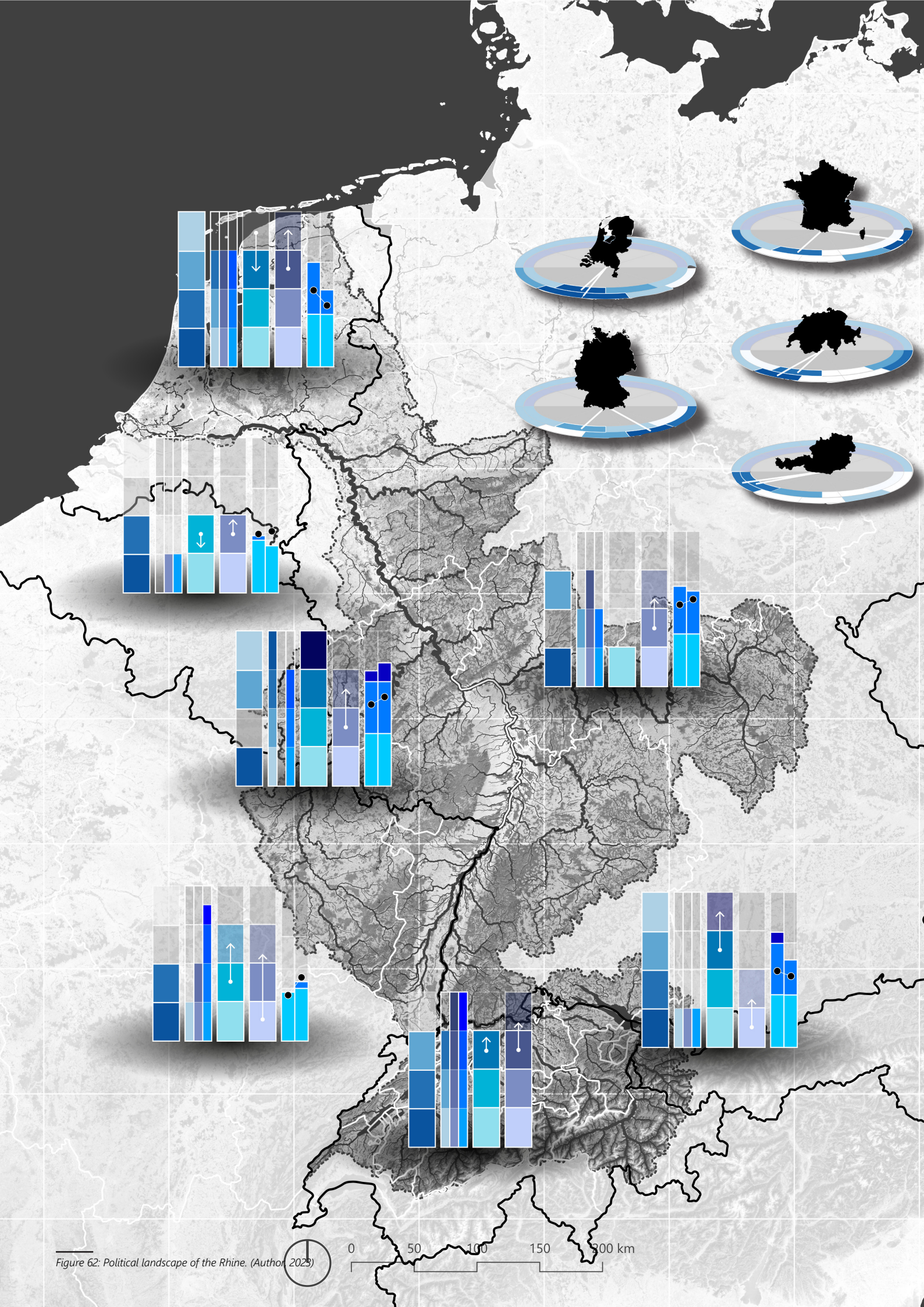


Figure 62: Political landscape of the Rhine. (Author, 2023)

Political Landscape

4.5

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the integration of water management in the spatial planning on local levels of goverment, the higher the possibility for local autonomy"

High integration *Low integration*

Scalar Interpretation **Nation States**

Translation of Data

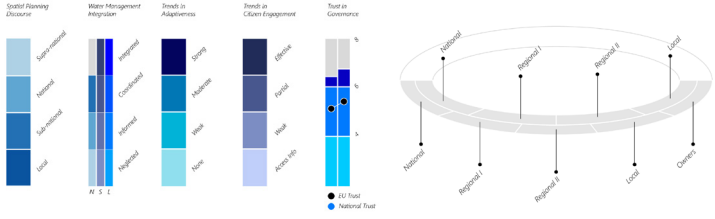
Calculation of the indicators of 'Water Management Powers', 'Dike Management Powers', 'Trust in Governance', 'Adaptiveness in Policy Making', 'Citizen Engagement', 'Water Management Integration' & 'Spatial Planning Discourse'

Weighting of the Indicators

To determine potential locations for local autonomy within the decision-making process, freedom within the political landscape has been researched. The political landscape is the primary factor that influences the degree of autonomy and can gain a foothold in existing management systems.

(A1). *The Netherlands*
The Dutch political landscape offers plenty of possibilities for residents to be integrated into policy-making decisions. The delegation of water management integration to regional and local authorities (ECR, n.d.) increases local autonomy. Additionally, the high integration of citizen engagement and adaptiveness in policy-making enhances the potential for citizen initiatives (ESPON, 2018).

(A2). *Germany*
The German political landscape, particularly in dike management, is highly localized. The creation of dike associations by local stakeholders already paves the way for local autonomy. Furthermore, the high trust in European governance (Sugue, 2020) increases the potential for active subsidiarity to be integrated into new dike management schemes. However, the rest of the German political landscape is less open to citizen participation as German politics are considered to be less flexible (ESPON, 2018).



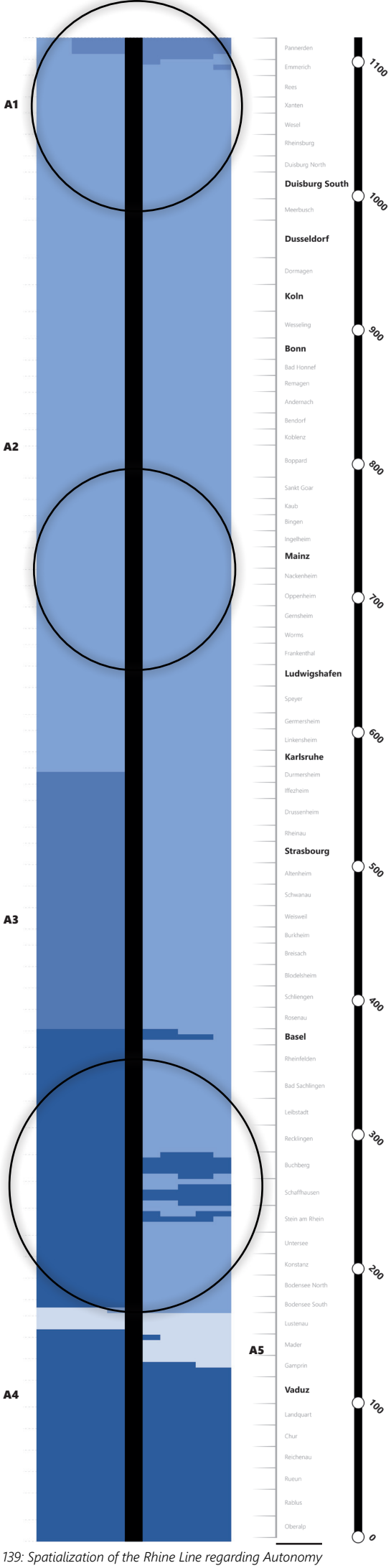


Figure 139: Spatialization of the Rhine Line regarding Autonomy based on the political landscape along the Rhine. (Author, 2023)

(A3). *France*
The French political landscape is characterized by a high degree of national political decision-making and local implementation. As a result, local autonomy is more challenging to achieve in water and dike management (ECR, n.d.; Article 1242 of the Civil Code). A relatively powerful national government makes active subsidiarity more difficult. However, trends in the adaptiveness of policymaking could positively influence bottom-up approaches on local levels.

(A4). *Switzerland & Liechtenstein*
The political landscape of Switzerland and Liechtenstein is considered to be the same. The Swiss political landscape operates around significant responsibilities placed on cantonal regions, making decision-making directly based on local conditions (ECR, n.d). This is reflected in the high autonomy rankings of the previous indicator.

(A5). *Austria*
The political landscape of Switzerland and Liechtenstein is considered to be the same. The Swiss political landscape operates around significant responsibilities placed on cantonal regions, making decision-making directly based on local conditions (ECR, n.d). This is reflected in the high autonomy rankings of the previous indicator.

Autonomy of Administration

1.5

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the polticial landscape is integrated to the local levels of authority, the higher the possibilities of local autonomy"

High integration *Low integration*

Scalar Interpretation **NUTS Areas**

Translation of Data

Calculation:

1.75(Socio-economic conditions) + 4.5*(Political landscape) / 6.25*

Weighting of the Indicators

Based on the two sub-calculations provided in the previous pages, the total autonomy of the administrative regions of the Rhine nations is illustrated. Four regions are highlighted. The indicators used in both calculations are considered equal in weight, reflecting the focus on establishing autonomy within the current political landscape (4.5) in favour of economic rates based on GDP (1.75).

(A). *North Ruhr regions with a Dutch twist*
The area north of the Ruhr region is identified as a potential location for autonomy. The large agricultural lands and relatively high GDP rates provide incentives for localized dike autonomy. The high degree of dike and water management integration at local levels, based on Dutch and German politics, further enhances the potential for local autonomy in initiating dike changes.

(B). *French-German rural lands*
The rural and natural regions along the canalized Rhine at the French-German border facilitate less impact when local change is initiated. The local dike management cultures on both sides of the border create favourable conditions for local dike autonomy. The adjacency of large urban cores of Strasbourg and Karlsruhe further enhances potential financial incentives for initiating change.

(C). *Swiss High Rhine*
The high degree of integration of Swiss political decision-making at the local level, combined with additional financial benefits from the cantons of Zurich and Aargau, creates conditions where local autonomy could thrive. The high degree of freedom within local decision-making establishes a hotspot for localized dike management.

(D). *Alpine Rhine Valley*
Despite the relatively low GDP rate within the Alpine Rhine Valley, the political landscape of Switzerland has changed a lot, making the Alpine Rhine Valley a promising location for local autonomy to take root. However, care has to be considered when initiating change due to the high urbanization rate of the area.

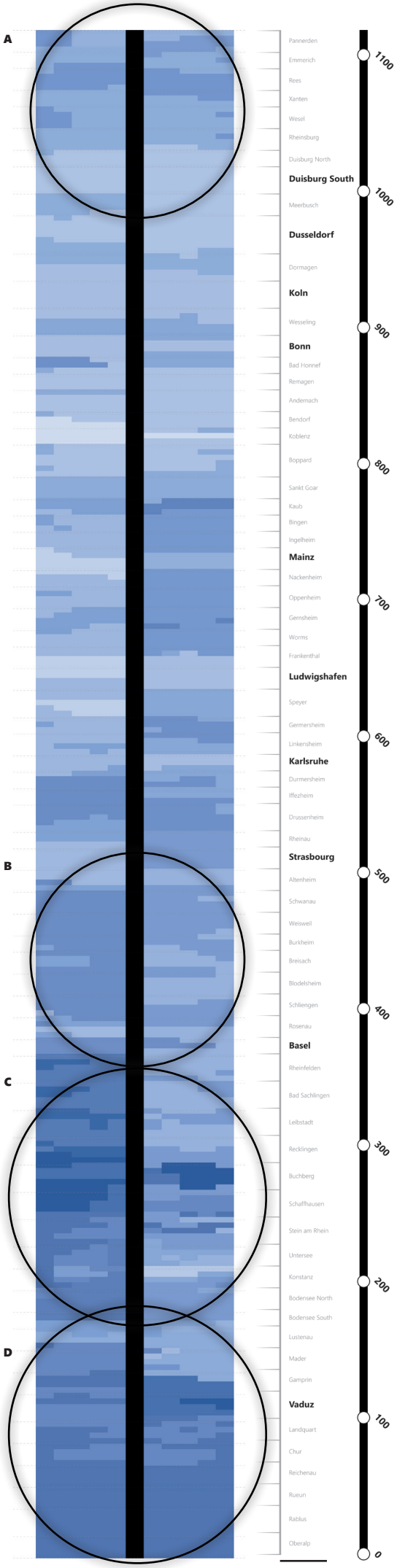
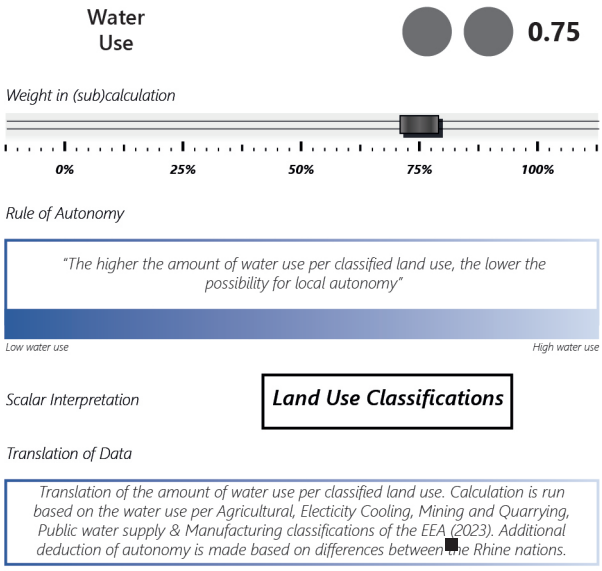


Figure 140: Spatialization of the Rhine Line regarding Autonomy based on the existing Administration. (Author, 2023)

Water Use Distribution

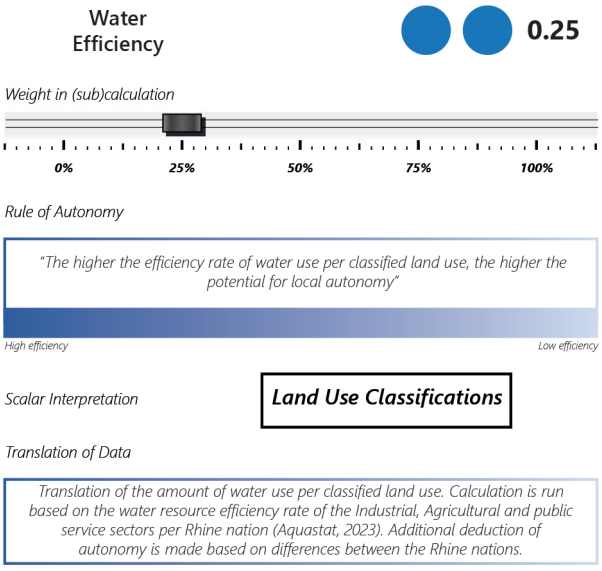
A. *Water Use Autonomy*

The amount of water used per land use classification emphasizes the sector's interdependency on a stable water source. The industrial sector consumes the most water, followed by the public and agricultural sectors (Aquastat, 2023; EEA, 2023). Data from the EEA (2023) regarding national statistics, categorized by sectors, reveals variations in water use across different countries. It is evident that natural areas (A2) and agricultural lands in Germany (A1 & A3) exhibit low water consumption. In contrast, French water use in the agricultural sector (A4) is notably higher, and Swiss public water use (A5) exceeds that of other nations by a significant margin.



B. *Water Use Efficiency*

Water use efficiency refers to the adaptability of the designated land uses in terms of water resource dependency. According to information provided by Aquastat (2023), the efficiency rates differ from one nation to another. For example, the French agricultural sector (B2) demonstrates high efficiency compared to Germany (B1). Although Germany's public and industrial water use is substantial, it is relatively more efficient than Austrian and Dutch practices.



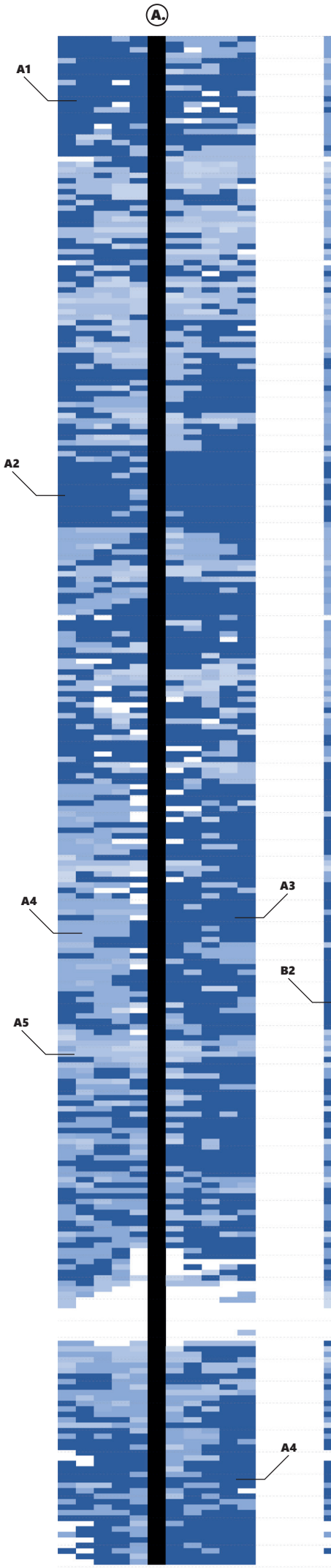


Figure 142: Translation of autonomy indicators of Water use distribution. (Author, 2023)

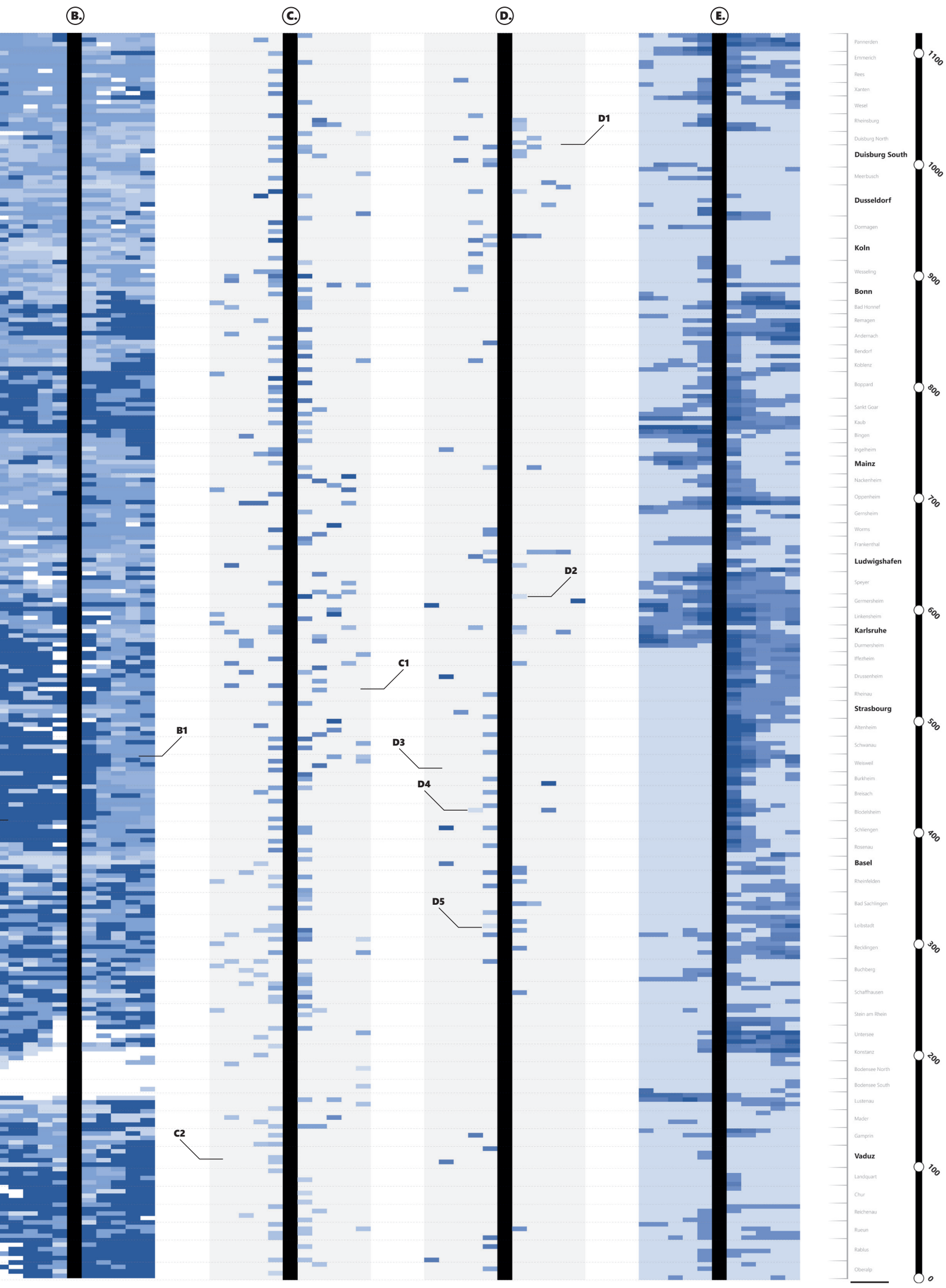
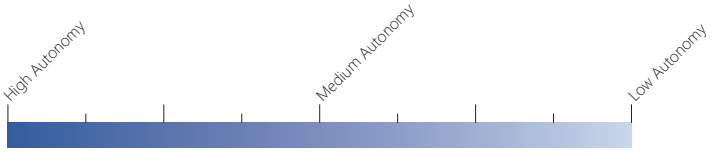
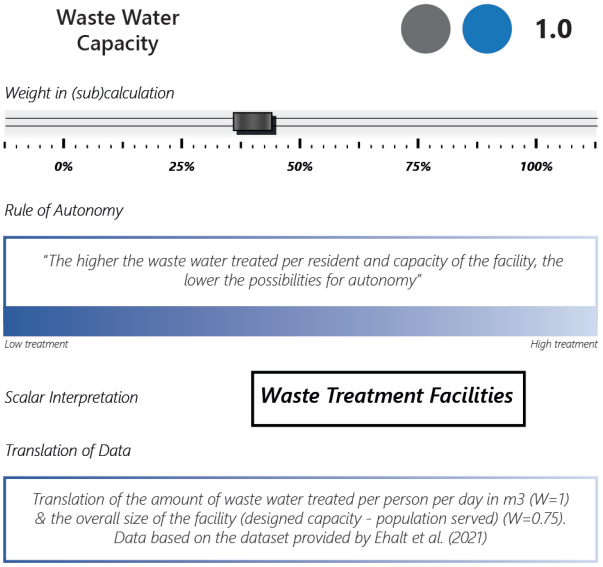


Figure 143: Spatialization of the Rhine Line regarding Autonomy based on existing water use distribution. (Author, 2023)



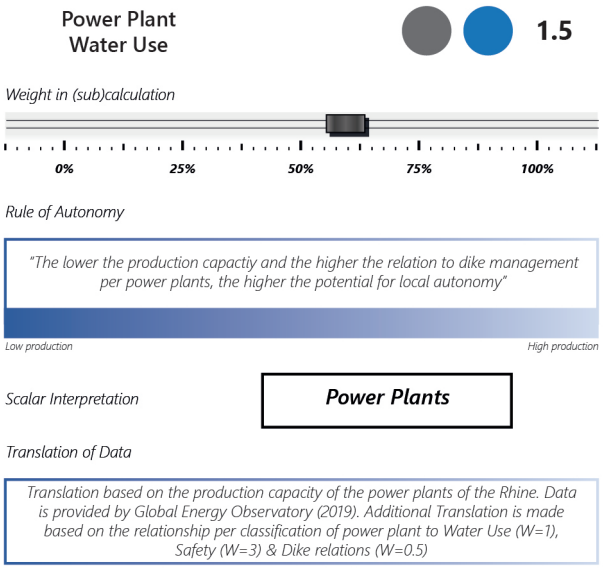
C. *Waste water capacity*

Wastewater facilities are often situated in proximity to rivers or bodies of water and are protected by local dike structures in case of high water levels that could disrupt water distribution mechanisms. The level of autonomy is determined by the size and production capacity of these treatment facilities. Data from Ehalt Macedo et al. (2021) in the Hydrosheds project reveals differences between countries. Notably, Swiss water facilities (C2) are less autonomous due to the relatively larger size of their plants compared to other areas along the Rhine. In contrast, smaller facilities spread out between Breisach and Mainz (C1) have more potential for local autonomy but are heavily regulated by channelized dams upstream of Strasbourg.



D. *Power plant water use*

Energy production is one of the largest consumers of water in the Rhine River system with energy generation being a crucial aspect of the region's economy (Wantzen et al., 2009). The hydroelectric power plants in France (D3) and the energy facilities associated with German coal and gas industries (D1) rely significantly on this water source. As Germany moves away from nuclear power installations, leaving France as one of the few nations heavily invested in nuclear energy, the demand for water for energy production is expected to increase. The location of these power plants is vital in the context of local dike autonomy, especially concerning nuclear power plants. Due to the high safety risks associated with nuclear energy, the potential for local autonomy (D2, D4, D5) is reduced.



E. *Water dependent regions*

Based on datasets from the IKSR (BAFG, 2015), water-dependent regions, often natural retention zones or Natura 2000 areas, require a constant water supply for survival. Dikes can redirect water flows to support these regions, enhancing natural infiltration and saturation rates while providing water buffers during periods of irregular water flow. Therefore these areas support the construction of dikes to distribute water flows.

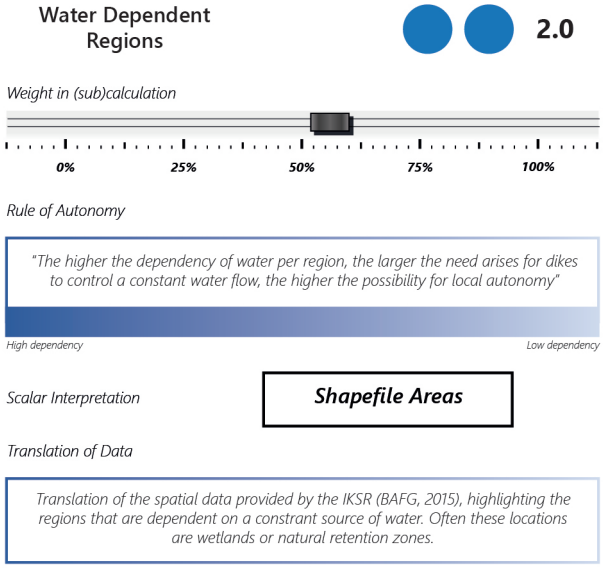


Figure 144: Translation of autonomy indicators of Water use distribution. (Author, 2023)

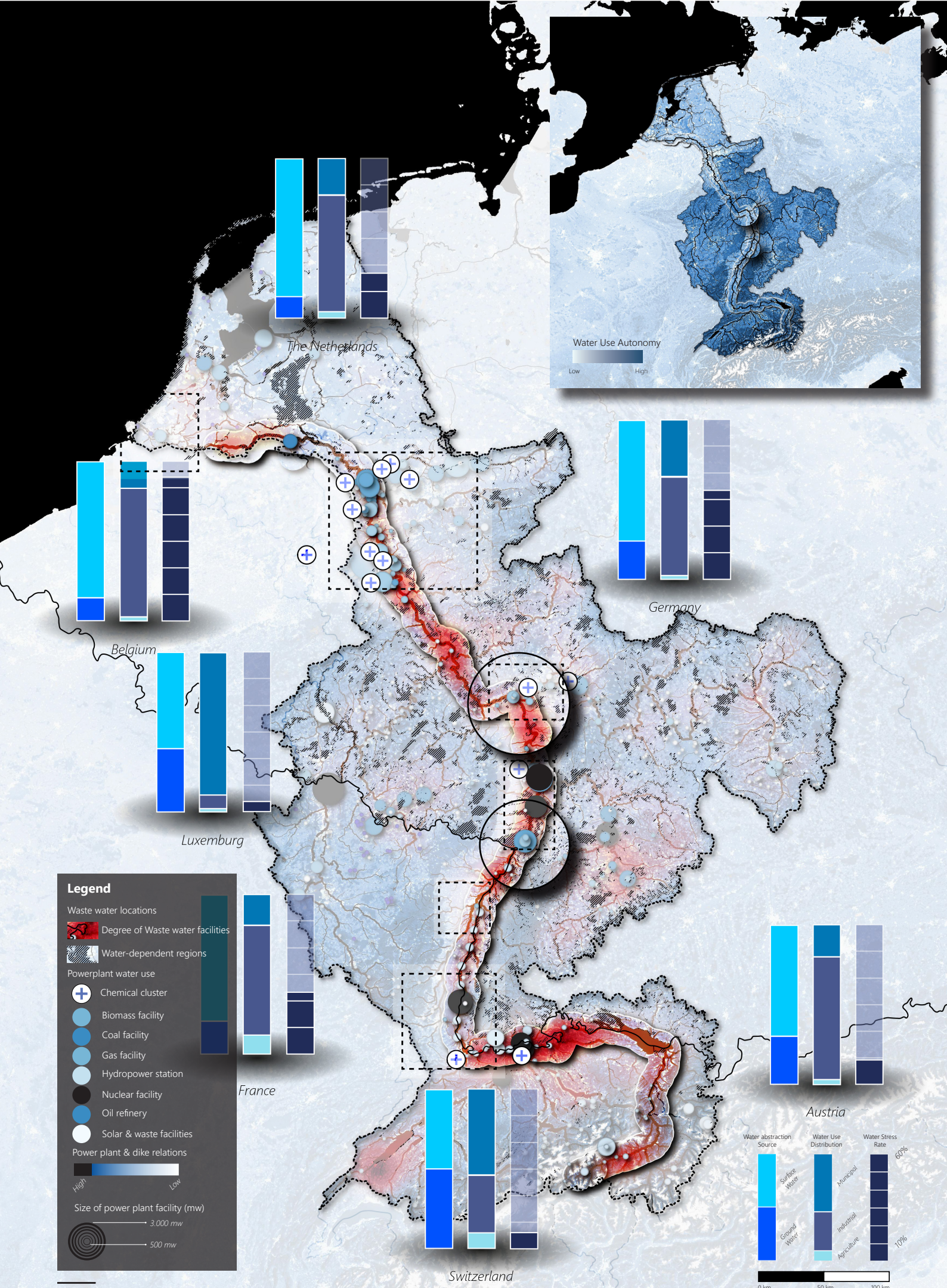


Figure 145: Autonomy of existing water use autonomy based on classified land use typologies. (Author, 2023)

Figure 146: Autonomy of existing water use distribution along the Rhine. (Author, 2023)

Water Use Distribution

1.25

Weight in (sub)calculation

0% 25% 50% 75% 100%

Rule of Autonomy

"The higher the amount of water used within a specific region, the lower the possibilities for local autonomy"

Low water use *High water use*

Scalar Interpretation **Point data**

Translation of Data

Calculation:

(1.5(Economic water use efficiency) + 1.75*(Water dependent regions) / 3.25) + 0.25*(Quantitative water use)*

Weighting of the Indicators

The final calculation focuses on current water usage to assess the dependency of land uses on the Rhine's water resources. Therefore, the autonomy of land use classifications (1.5) along the Rhine is given greater weight than the specific water use points of power plants and wastewater sectors (+0.25). The highest weight is assigned to water-dependent regions (2.0) (BAFG, 2015), as these areas rely on a continuous water supply. Hence, in anticipation of future flooding and drought scenarios, adjustments to dikes are essential. Based on these three indicators, two main areas of focus emerge.

(A). *Water regions surrounding Mainz*
The city of Mainz is surrounded by agricultural and natural wetlands that require a constant water supply (BAFG, 2015). A high number of small wastewater plants contributes to higher autonomy, primarily due to the limited number of power plants in comparison to other German port cities. With efficient German water treatment facilities, a high level of local autonomy can be achieved. This allows for the creation of local water distribution networks, catering to the region's high projection of flooding and river discharge, thus forming a potential water network based on localized dike structures.

(B). *Wetlands of Karlsruhe*
The area around Karlsruhe comprises regions classified as water-dependent. These areas exhibit relatively low water use for the surrounding land uses as most of the area is either agriculture or nature. The main challenge lies in the presence of large power plants and low water efficiency in the region. Localizing dike management here could lead to extensive water storage for both industrial and natural activities.

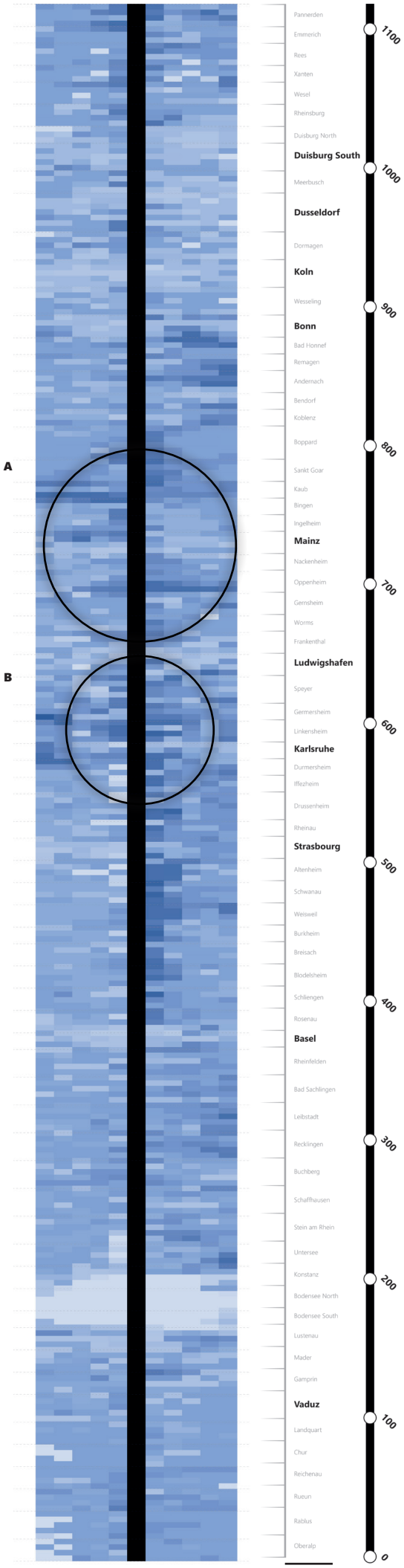


Figure 147: Spatialization of the Rhine Line regarding Autonomy based on the existing water use distribution along the Rhine. (Author, 2023)

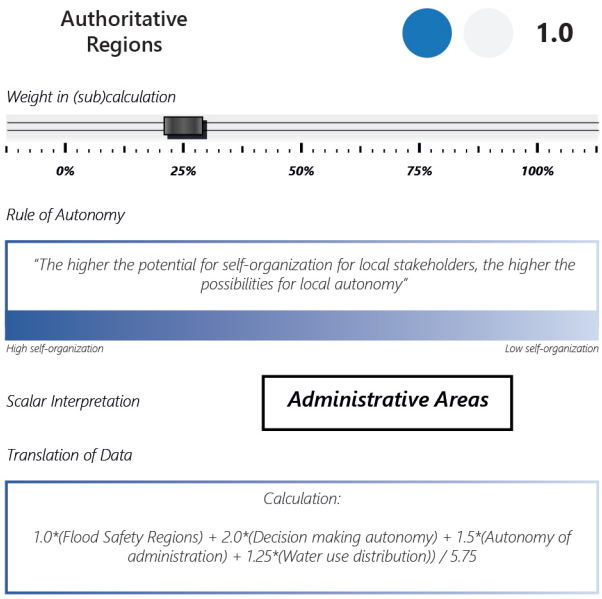
Authoritative Autonomy

The calculation of the self-organizing capacity of land use stakeholders indicates where opportunities for localized autonomy are most promising. The autonomy generated by water use, future safety regulations, and the stakeholder's ability in the decision-making process are influenced by the existing political landscapes. Three major regions are highlighted, showing a higher potential for local dike autonomy:

(A). *Rhine Gorge surrounding Koblenz*
Situated in a low-lying area, the city of Koblenz and the surrounding region benefit from a relatively high degree of autonomy due to the efficient use of water resources.

(B). *Wetlands of Southern Mainz*
This area, located just after the canalized sections of the French Rhine, is well-positioned for dike management. It considers a high degree of freedom within the decision-making process and also builds on the efficient use of water resources of German practice.

(C). *Swiss High Rhine*
The flat terrain between the Alpine Rhine valley and Lake Constance (Bodensee) allows for the creation of a robust water system. The favourable political landscape of Switzerland and a high degree of decision-making autonomy based on the open landscapes increase local autonomy.



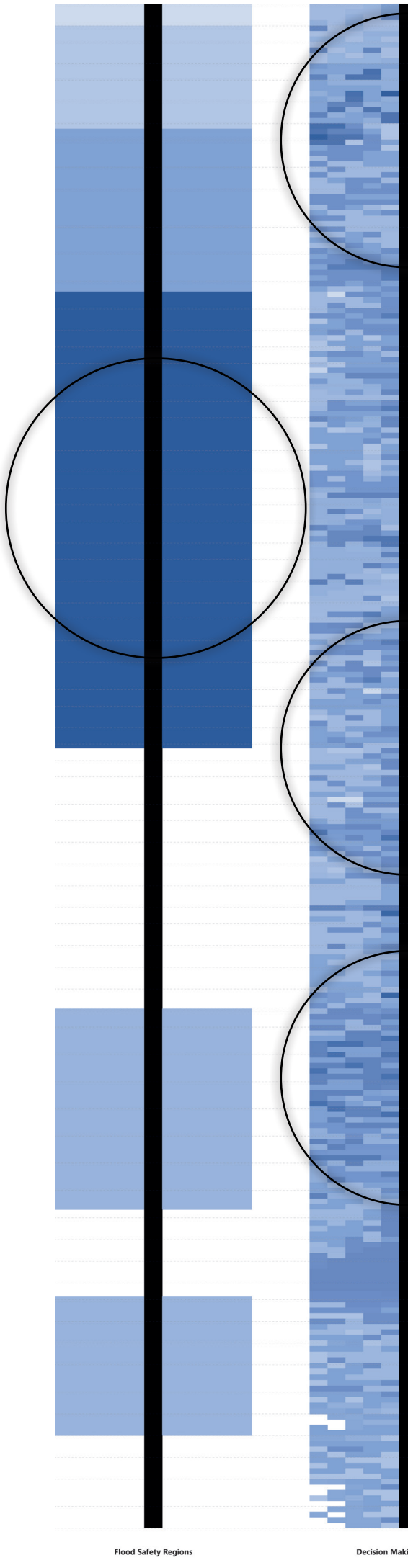
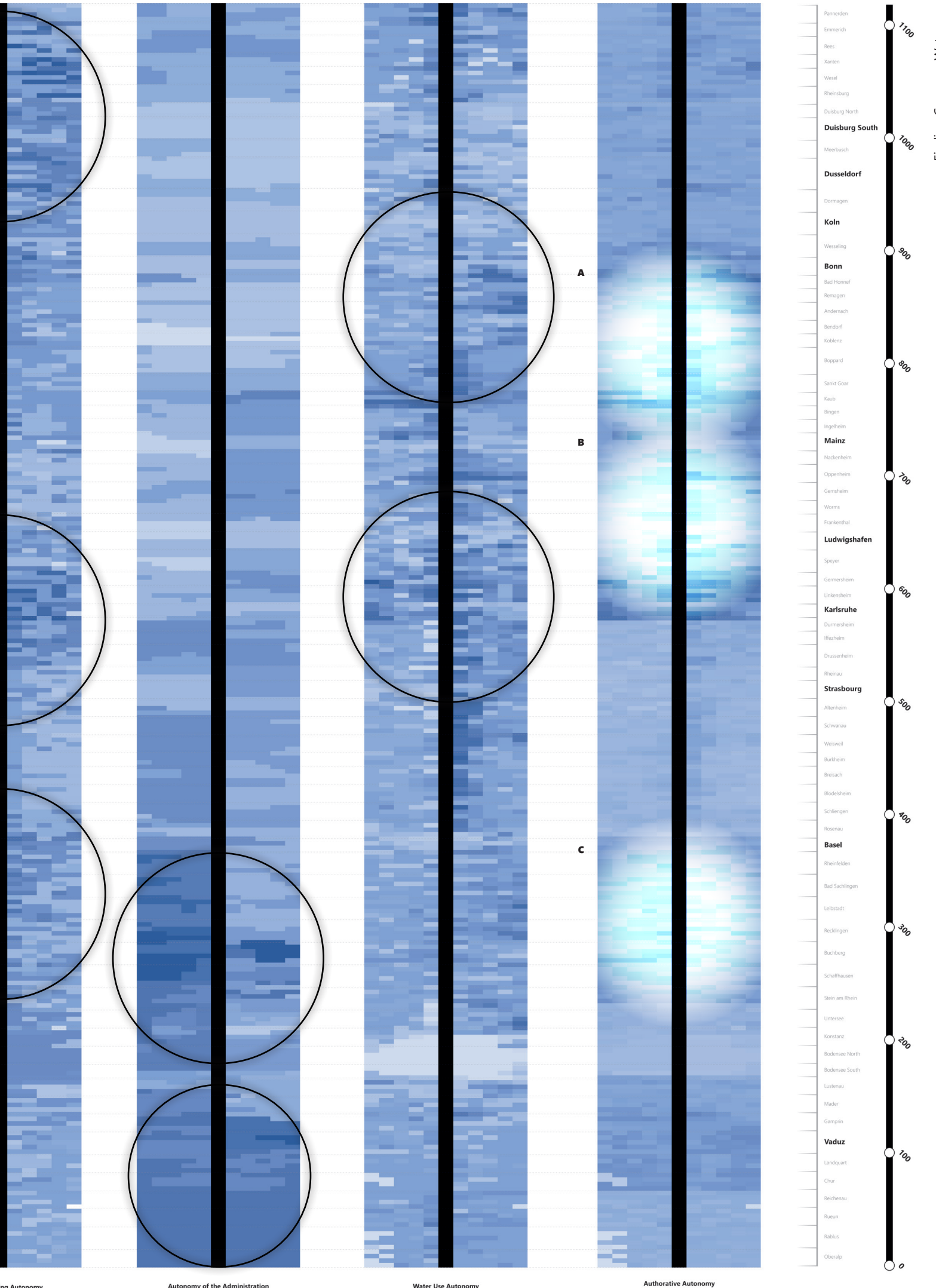
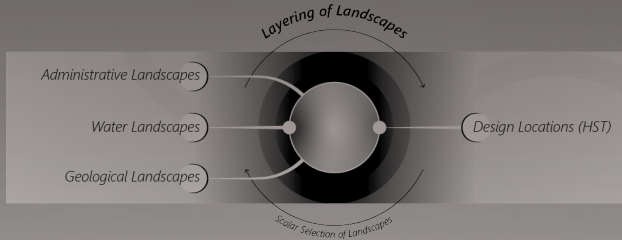


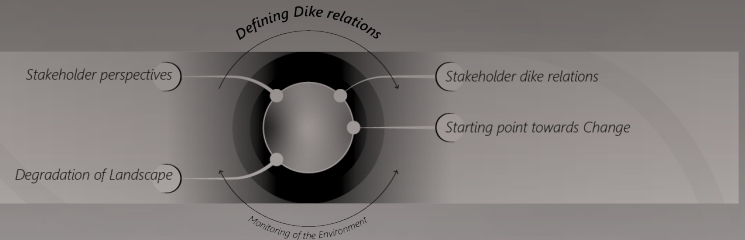
Figure 148: Spatialization of the Rhine Line regarding the autonomy of the Authorative regions and the sub-calculations. (Author, 2023)


A
B
C
Pannerden
Emmerich
Rees
Xanten
Wesel
Rheinsburg
Duisburg North
Duisburg South
Meerbusch
Dusseldorf
Dormagen
Koln
Wesseling
Bonn
Bad Honnef
Remagen
Andernach
Bendorf
Koblenz
Boppard
Sankt Goar
Kaub
Bingen
Ingelheim
Mainz
Nackenheim
Oppenheim
Gernsheim
Worms
Frankenthal
Ludwigshafen
Speyer
Germersheim
Linkensheim
Karlsruhe
Durmersheim
Iffezheim
Drussenheim
Rheinau
Strasbourg
Altenheim
Schwanau
Weisweil
Burkheim
Breisach
Blodelsheim
Schliengen
Rosenau
Basel
Rheinfelden
Bad Sachlingen
Leibstadt
Recklingen
Buchberg
Schaffhausen
Stein am Rhein
Untersee
Konstanz
Bodensee North
Bodensee South
Lustenau
Mader
Gamprin
Vaduz
Landquart
Chur
Reichenau
Rueun
Rablus
Oberalp
1100
1000
900
800
700
600
500
400
300
200
100
0
Finding Common Water
ng Autonomy
Autonomy of the Administration
Water Use Autonomy
Authorative Autonomy

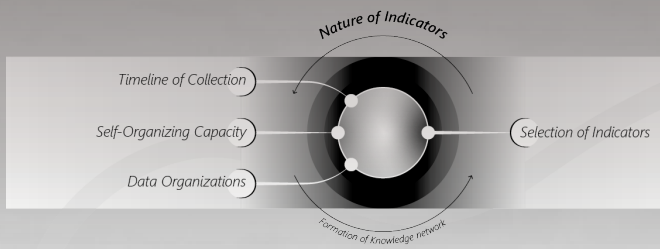
Step 1: *Design Locations (HST)*



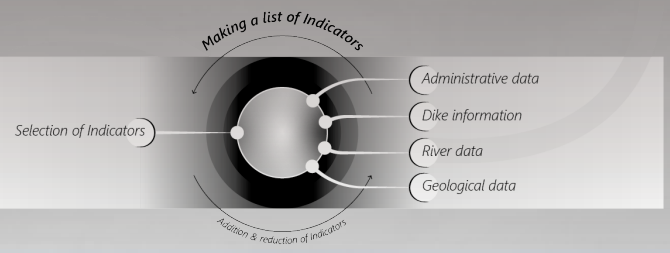
Step 2: *Urgencies*



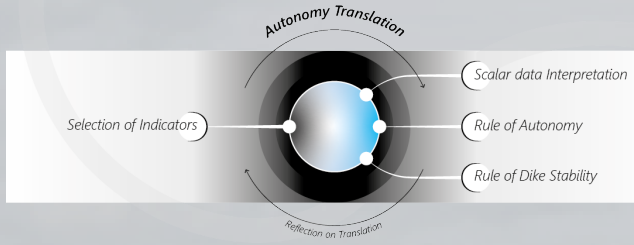
Step 4: *Knowledge Provision*



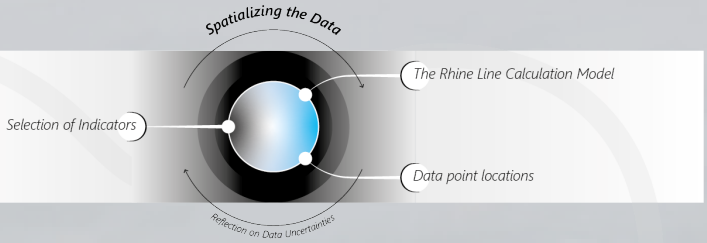
Step 3: *Indicators of Autonomy*



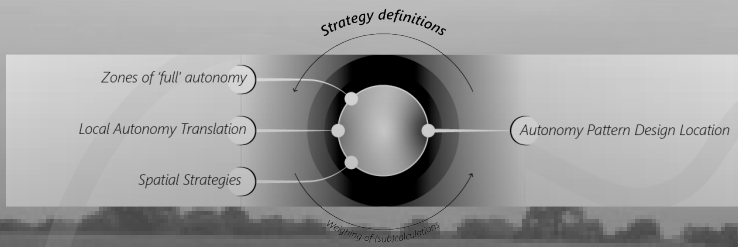
Step 5: *Translation of Indicators*



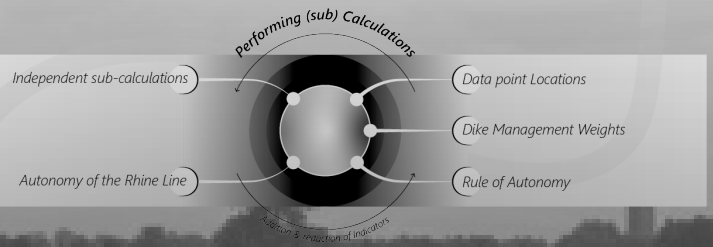
Step 5.1: *Spatialization Model*



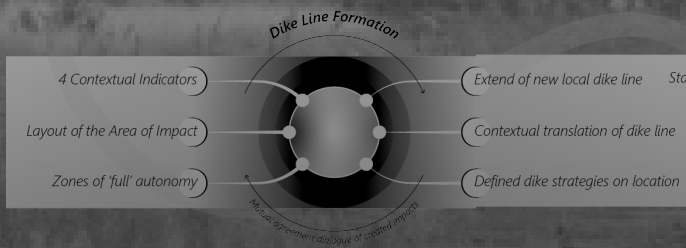
Step 7: *Defining Strategies*



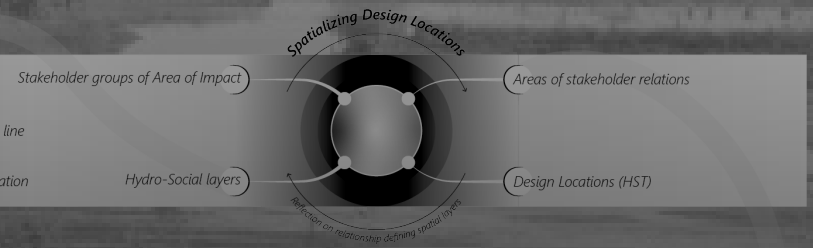
Step 6: *Calculation*



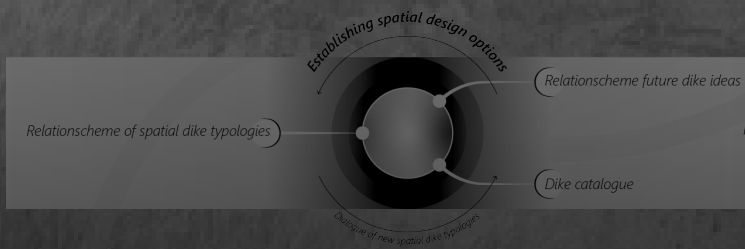
Step 8: *Dike Line Formation*



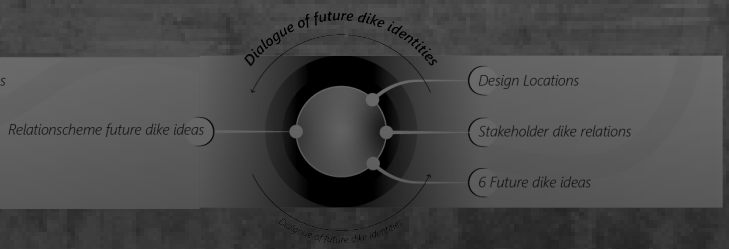
Step 8.1: *Design Locations (HST)*



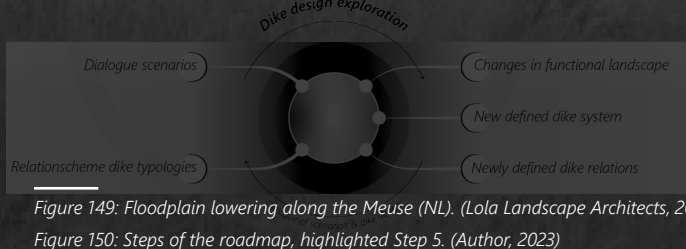
Step 10: *Spatial Dike Formation*



Step 9: *Future Dike Exploration*



Step 11: *Dike Systems*



Step 12: *Dike placement*

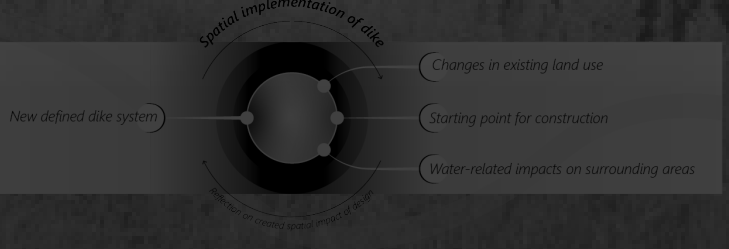


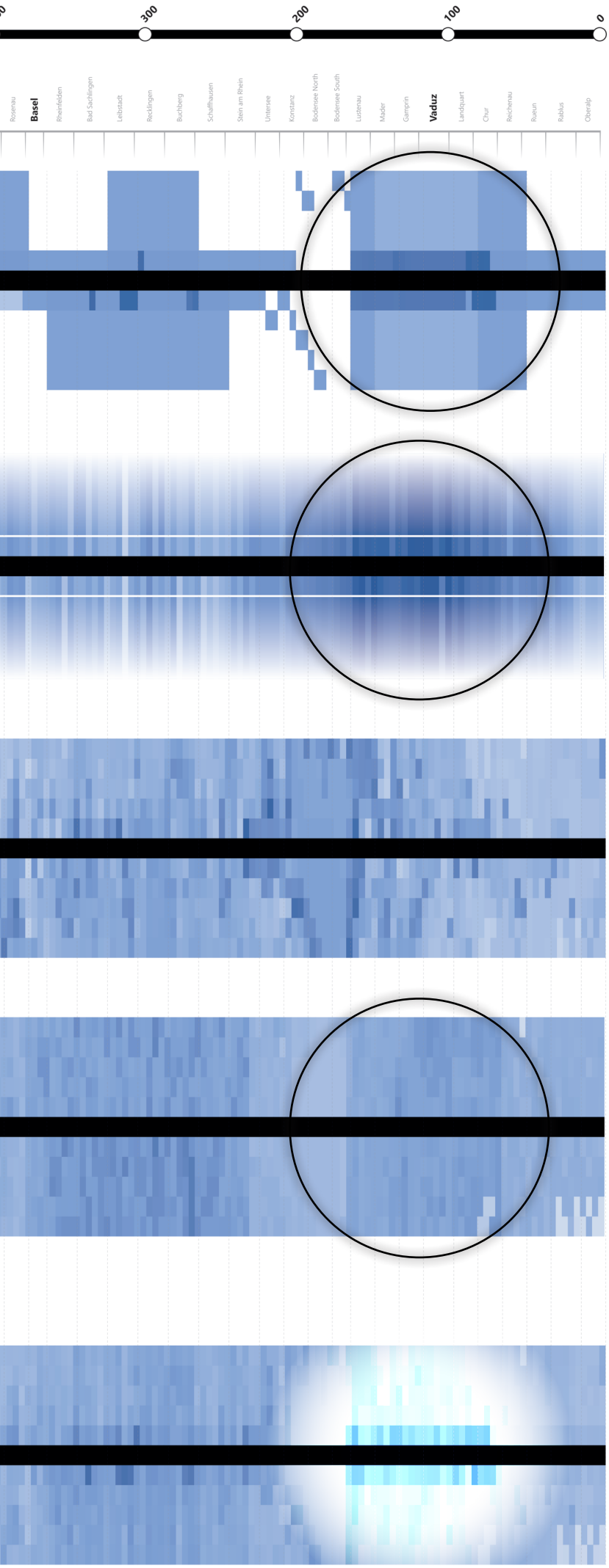
Figure 149: Floodplain lowering along the Meuse (NL). (Lola Landscape Architects, 2014)

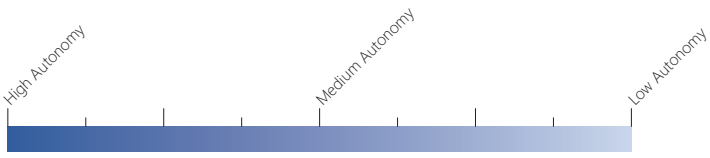
Figure 150: Steps of the roadmap, highlighted Step 5. (Author, 2023)

11

Performing the Calculations

1100
1000
900
800
700
600
500
400
Papenrden
Emmerich
Rees
Xanten
Wesel
Rheinsburg
Duisburg North
Duisburg South
Meerbusch
Dusseldorf
Dormagen
Koln
Wesseling
Bonn
Bad Honnef
Remagen
Andernach
Bendorf
Koblenz
Boppard
Sankt Goar
Kaub
Bingen
Ingelheim
Mainz
Nackenheim
Oppenheim
Gernsheim
Worms
Frankenthal
Ludwigshafen
Speyer
Germersheim
Linkenheim
Karlsruhe
Durmersheim
Iffezheim
Drussenheim
Rheinau
Strasbourg
Altenheim
Schwanau
Weisweil
Burkheim
Breisach
Blodelsheim
Schliengen





Autonomy of the Dikes of the Rhine

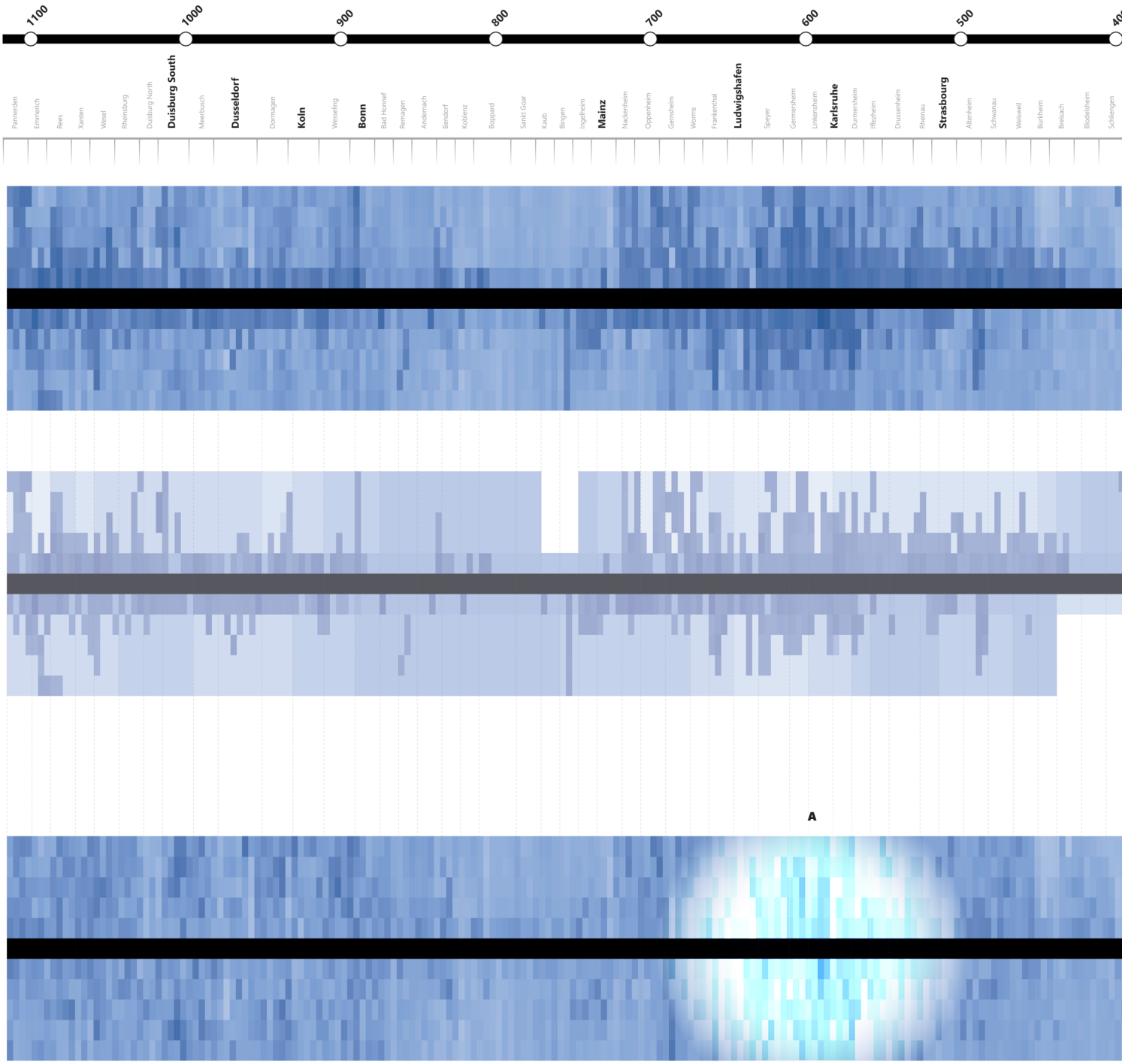
Autonomy of the River Dynamics

Autonomy of Dike Suitability

Autonomy of Self-Organization

Localized Dike Autonomy of the Rhine

Figure 151: Calculation results of the translated autonomy rates of the 4 indicators groups (Author, 2023)



Main Result of the Calculation:

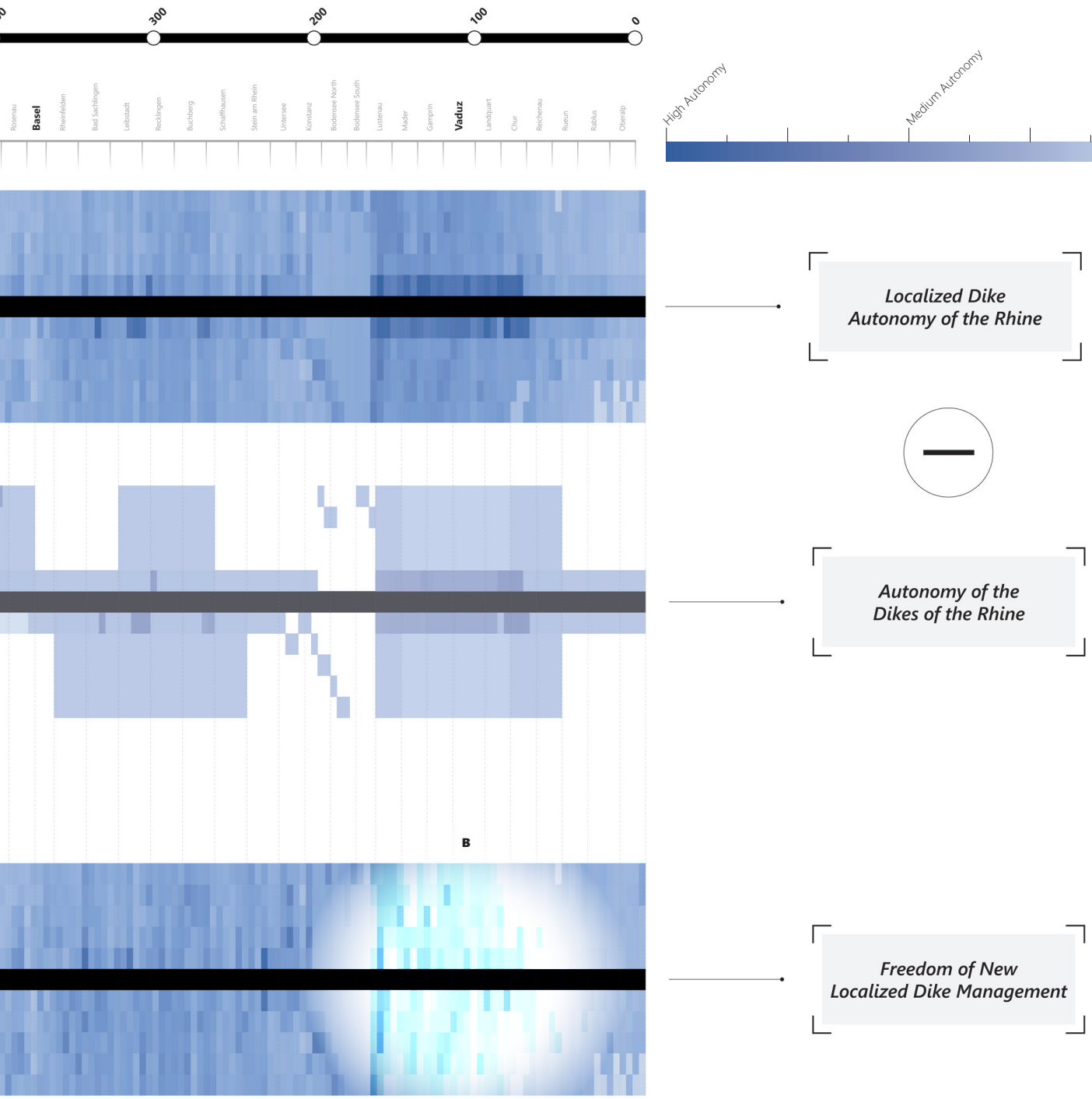
Based on the calculations involving the dikes, river dynamics, suitability conditions, and authoritative regions, the final calculations determine the areas where local dike autonomy is considered prominent. Since each of the classified sub-calculations is based on a different layer of dike management, all indicators are considered equal in the final calculation.

Note: It does not indicate where local autonomy can take place. The results shown are based on a comparative analysis of the results and only indicate the difference in autonomy of the data locations.

Rhine without Dikes:

To establish a baseline for initiating change towards local dike design in subsequent chapters, a different calculation has been performed without using the indicators provided by the existing dikes of the Rhine. This allows the area to be calculated based on the potential for the future suitability of dike management, rather than focusing solely on existing conditions. The calculations of local dike autonomy have resulted in the identification of two regions where the potential for local dike autonomy is higher than in other regions within the calculation.

(A). *Wetlands of Karlsruhe:*
The area near Karlsruhe is defined by the two large countries of France and Germany, where the Rhine serves as a border between these nations. The location of the area at the end of the canalized Rhine zone of France has its benefits. The control of water upstream results in higher autonomy concerning river dynamics, although flooding and drought potentials can still cause



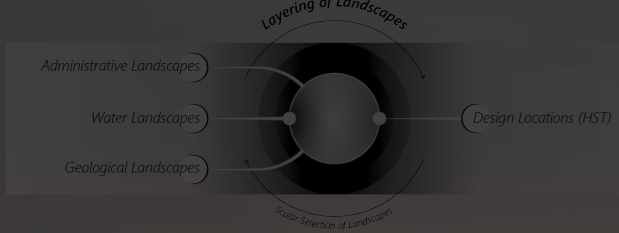
problems in the future. Additionally, due to the high groundwater recharge numbers of the natural wetlands that have been constructed on old sediment extraction locations, and the high soil conditions of the sediment deposits at the base of the Upper Rhine Valley, high dike suitability is established. The region is characterized by a large natural wetland and agricultural areas, leading to a higher decision-making autonomy to be reached as less impact is created. Additionally, the large projects residing over wetland formation of the water-dependent regions, facilitate an additional incentive for available knowledge.

(B). *Alpine Rhine Valley:*
The area of the Alpine Rhine is defined by the borders of three nations: Switzerland, Austria, and Liechtenstein. The Rhine is considered heavily modified, as the course of the river is relatively straight. This enhances autonomy based on river dynamics, as the forces of the river are not directed at a particular area. Besides the high sedimentation rate of the river, due to its location before the Bodensee where all sediments of the Alps are deposited (Preussser, 2007), further enhances autonomy. Besides, the suitability conditions and authoritative autonomy are considered to be relatively moderate. The high degree of urbanization in the region increases the impact created when change is initiated. However, this is countered by the fact that a large part of the region resides in Switzerland, where local decision-making potential is highest among the Rhine nations.

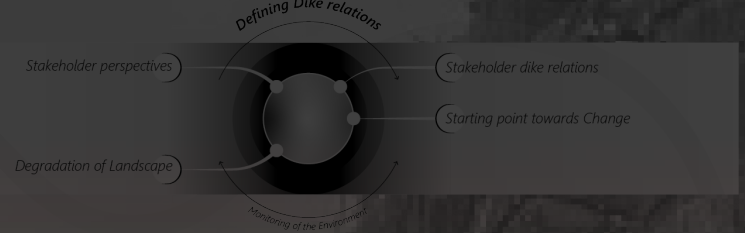
For the next stages of the report, the test case of the Alpine Rhine is further explored, showing the possible new dike designs that can be created when following the final steps of the roadmap.

Figure 152: Calculation results of the translated autonomy rates for future dike change. (Author, 2023)

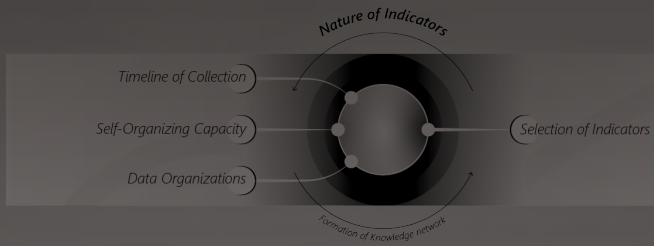
Step 1: *Design Locations (HST)*



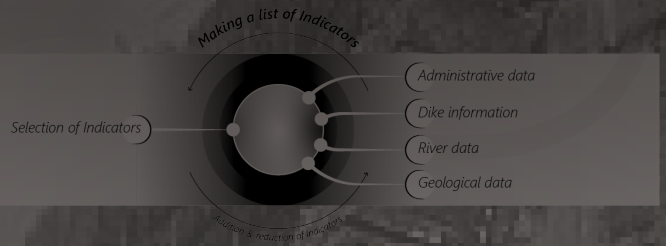
Step 2: *Urgencies*



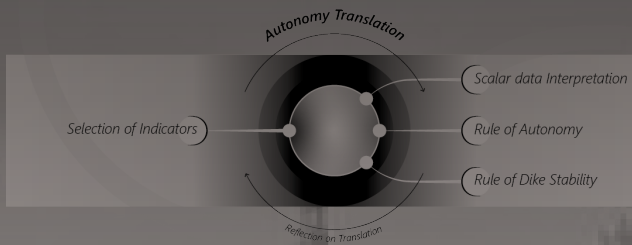
Step 4: *Knowledge Provision*



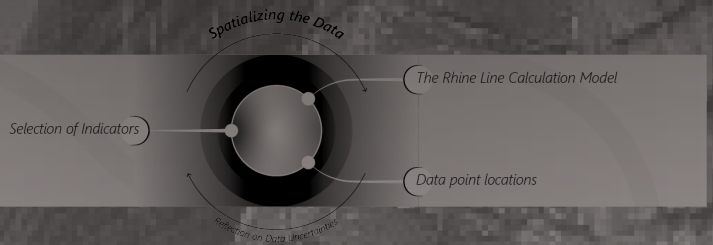
Step 3: *Indicators of Autonomy*



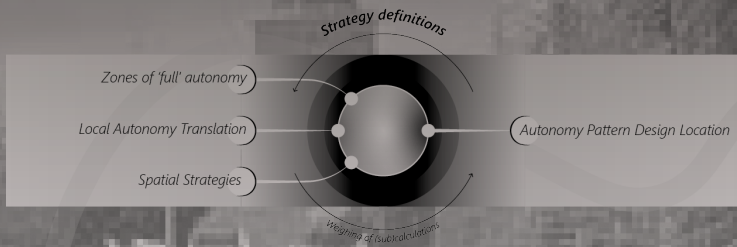
Step 5: *Translation of Indicators*



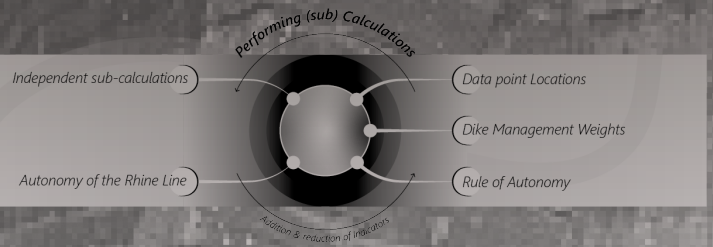
Step 5.1: *Spatialization Model*



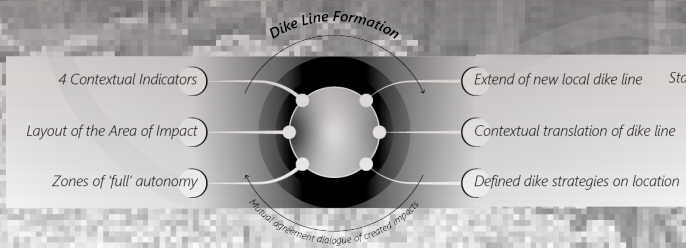
Step 7: *Defining Strategies*



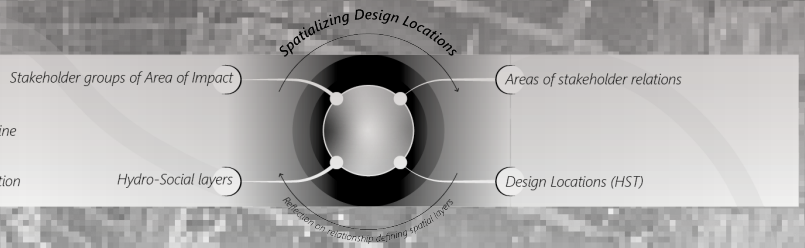
Step 6: *Calculation*



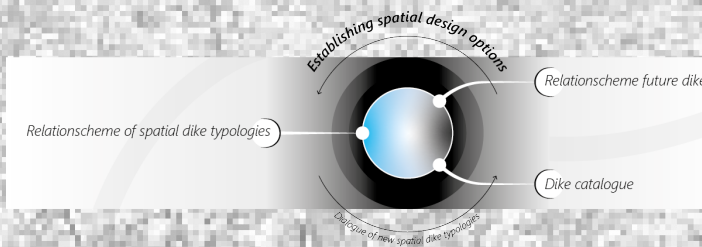
Step 8: *Dike Line Formation*



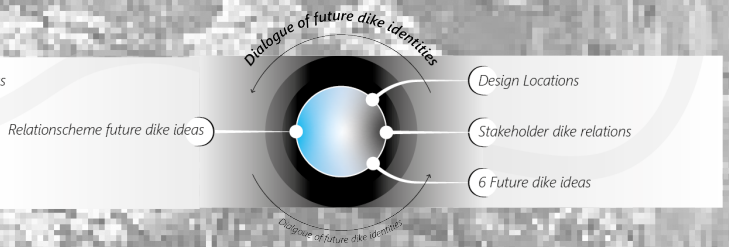
Step 8.1: *Design Locations (HST)*



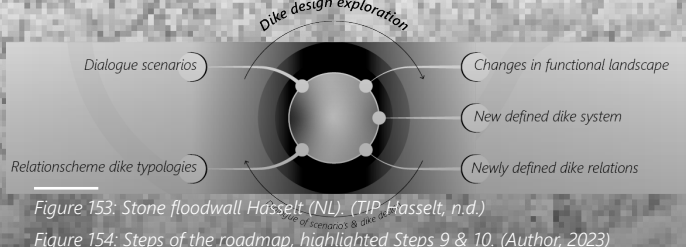
Step 10: *Spatial Dike Formation*



Step 9: *Future Dike Exploration*



Step 11: *Dike Systems*



Step 12: *Dike placement*

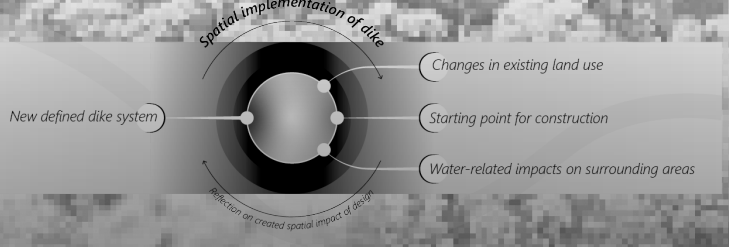


Figure 153: Stone floodwall Hasselt (NL). (TIP Hasselt, n.d.)

Figure 154: Steps of the roadmap, highlighted Steps 9 & 10. (Author, 2023)

12

Exploration of Future Dikes Ideologies

The Ideologies of the Dike

Dike as the Protector
Dike as the Distributor
Dike as a Source of Life
Dike as a Historical Landscape Element
Dike as a Multifunctional Element
Dike as an Autonomous Body

The Ideologies of the Dike

To lay the groundwork for establishing new identities for dikes, this report initially presents radical directions that dikes can potentially take. This allows stakeholders to reimagine the concept of a dike and determine what suits their needs best. There are numerous possibilities for transforming a dike, making it nearly impossible to identify the extremes in dike management. Therefore, a division has been made into six distinct extreme scenarios of dike management, each characterized in the same way as the existing dikes of the Rhine, and the stakeholder preferences have been described.

(1). *Dike as a Protector:* Indicates the dangers of the water for man, seeing the dike as a border

(2). *Dike as a Distributor:* Indicates the possibility of water as a resource for urban activity.

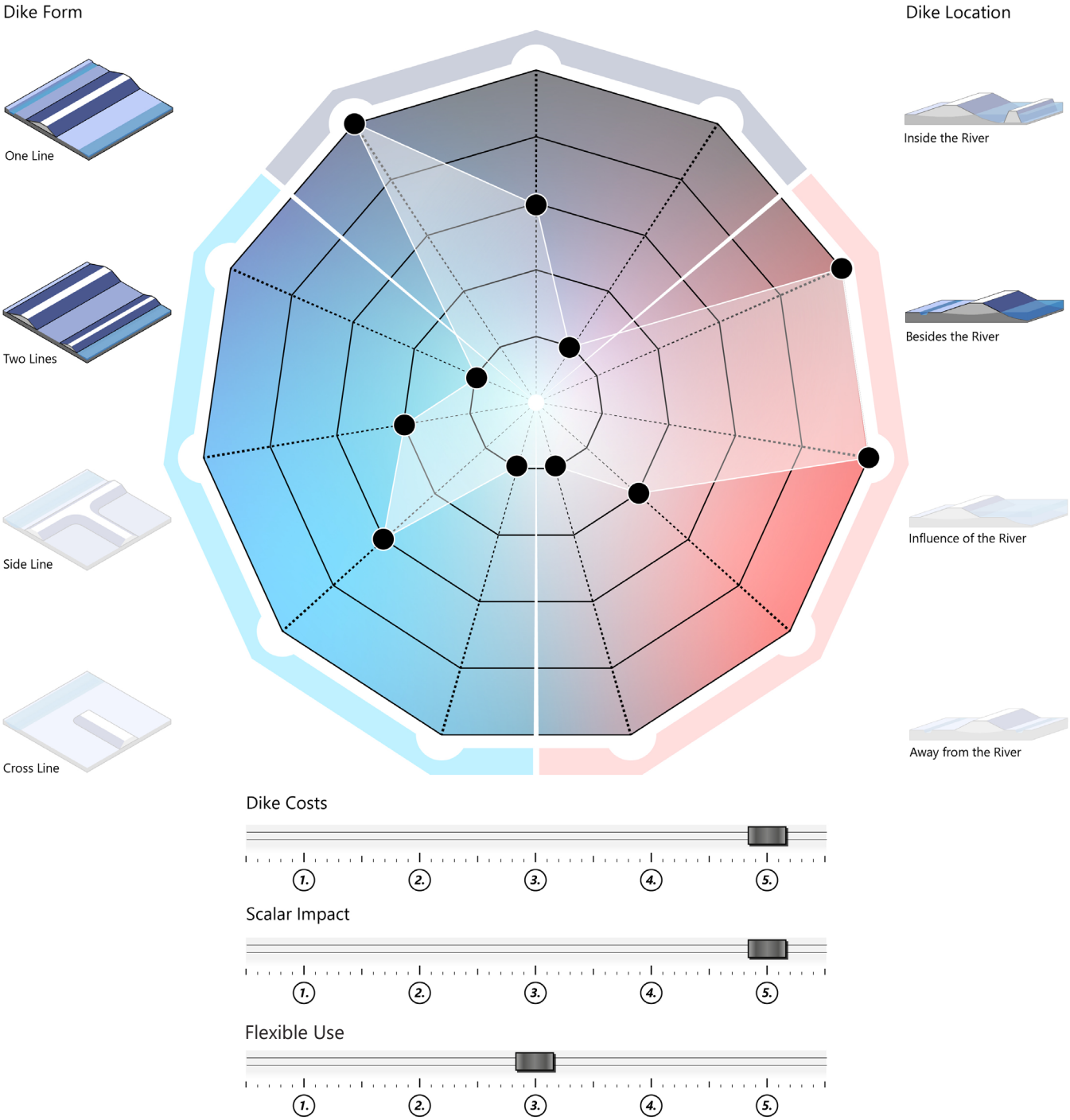
(3). *Dike as a Natural retention zone:* Enhances the story of water being the source of life.

(4). *Dike as a Landscape Element:* Indicates the ancient relationship creating a place for water and man

(5). *Dike as a Multifunctional Element:* Uses the dike to extend the urban activity

(6). *Dike as an Autonomous Body:* Seeks to strike a balance between the forces of the natural system and the opportunities it offers.

Protection *As based on their current and potential relationship to dikes*



Dike as the Protector

In this scenario, the dike amplifies its traditional role in flood and water management. It stands as a prominent fixture in the landscape, solely dedicated to retaining the Rhine's water. To cope with climate change and the rising variations in high and low water levels, the dike requires regular maintenance and reinforcement, significantly impacting its spatial presence in the landscape. Additional elements that can be seen near this dike are breakwaters, revetments, and seepage screens that protect the structural integrity of the dike.

Figure 155: Classification scheme of 'protective' dike characteristics. (Author, 2023)

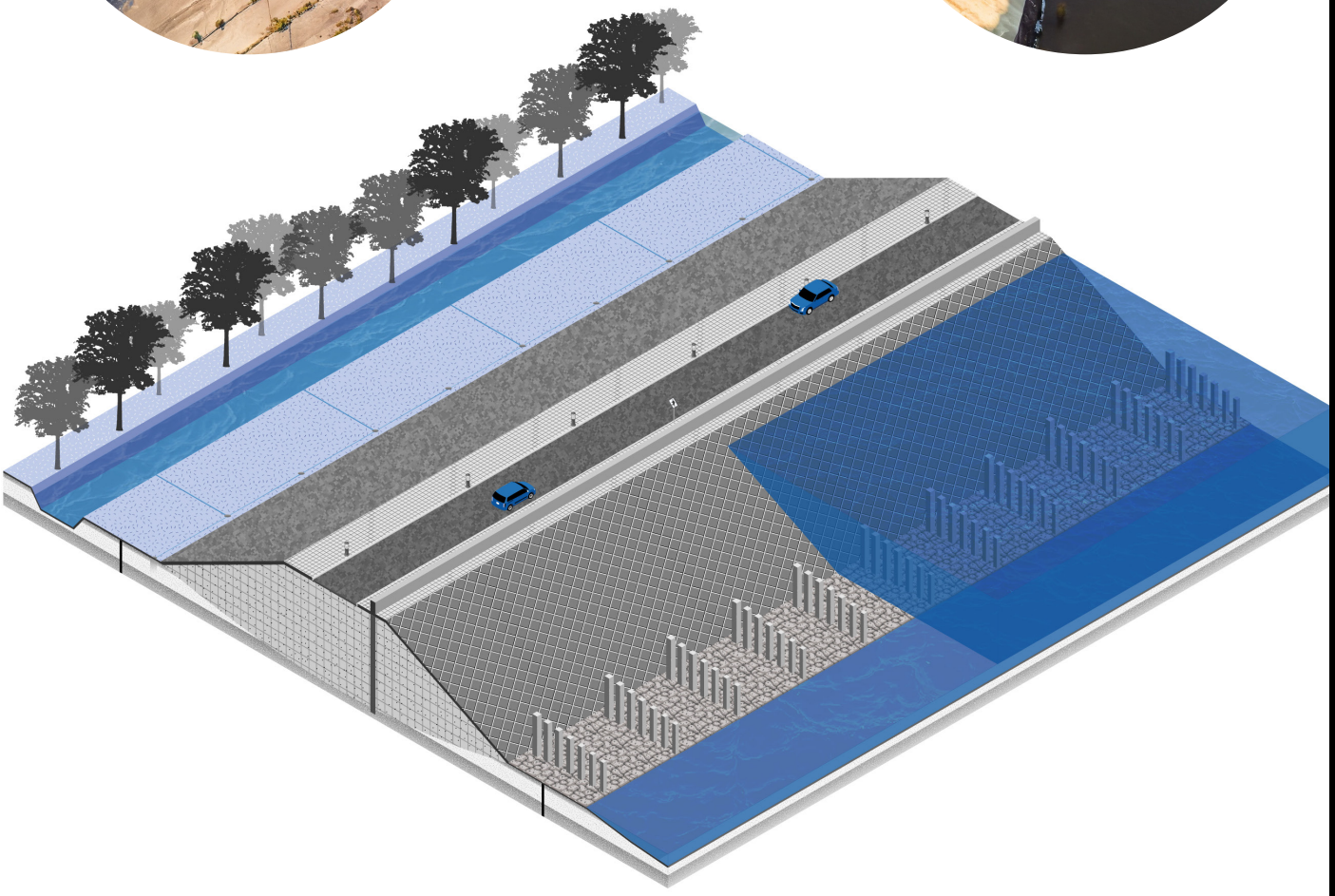
Figure 156: Visualisation of future dike identity of the 'Protective' dike. (Author, 2023)

Generated Visualisations



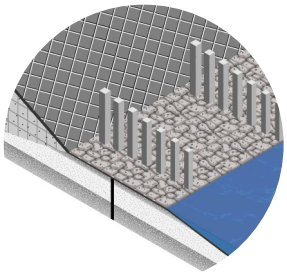


Spatial dike typology



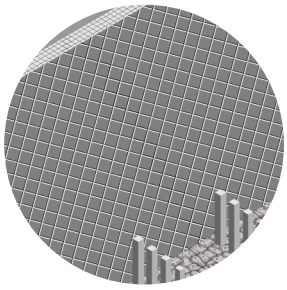
Dike Features

Breakwaters



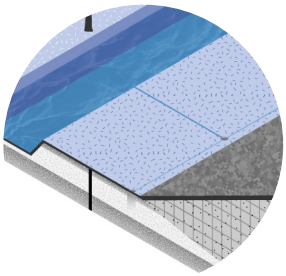
Placing breakwaters infront of the dike creates a first line of defence, where a concrete pole structure impacts the first blow of the incoming waves of the river.

Revetments



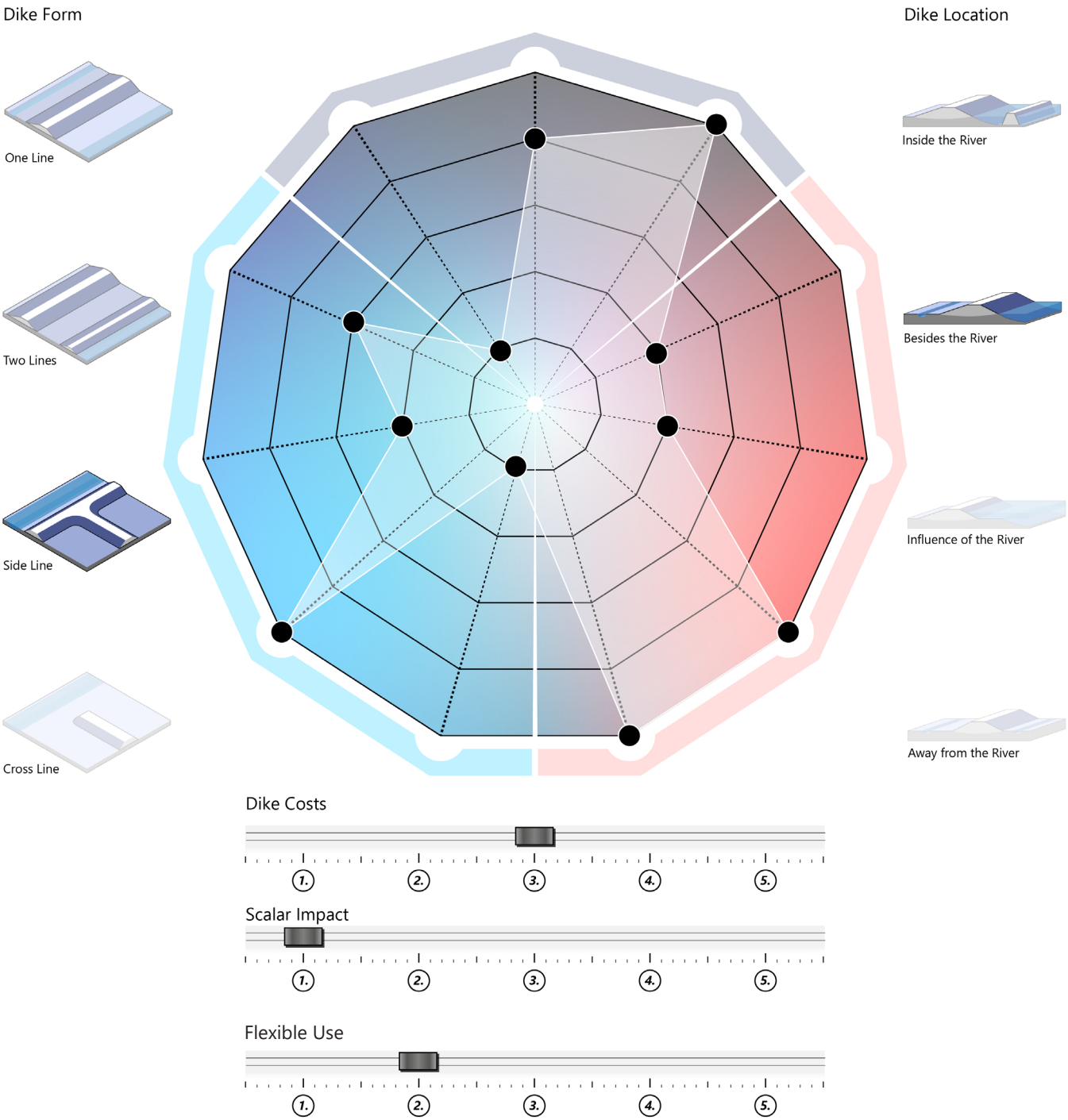
By placing revetments as the main cladding material for the dike, the dike is protected from the forces of the river and its incoming waves. Futhermore by interlocking the revetments in place enhances the structural integrity of the dike.

Seepage Screens



One of the main problems in relation to dikes is seepage. By placing a steel screens on one or both sides of the dike line, the possibility of seepage decreases making sure the ground underneath the dike can not be swept away by the water.

Distributor *As based on their current and potential relationship to dikes*



Dike as the Distributor

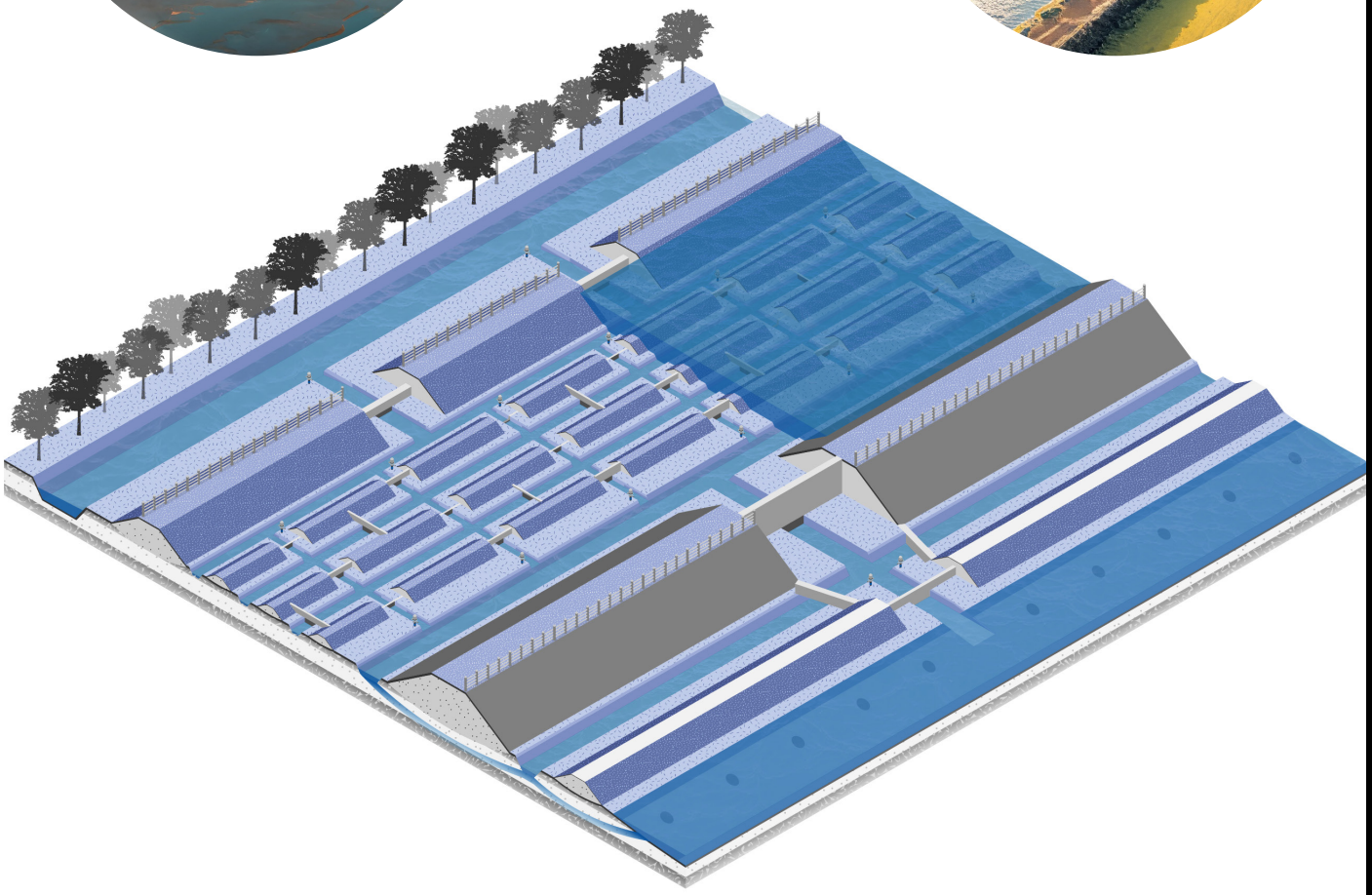
Here, the dike transforms into an integral component of the water management system, functioning as a distributor of water resources to various locations. While it still serves as a water retention structure, its primary role shifts to efficiently distribute water where needed (e.g., users, storage, natural retention). The dike's identity changes from a single, strong line to a network of interconnected lines following the landscape's slope profile. These smaller dike lines can potentially be maintained at the local level, although it requires varying levels of knowledge among stakeholders. Power dynamics within the dike management system should be considered, as major private corporations and government entities can influence water allocation. Dike placement closely aligns with the river's natural dynamics, maximizing water collection and distribution. Additional features of seepage holes and sluice networks allow dike users to control the in and outflow of water.

Figure 157: Classification scheme of 'distributive' dike characteristics. (Author, 2023)

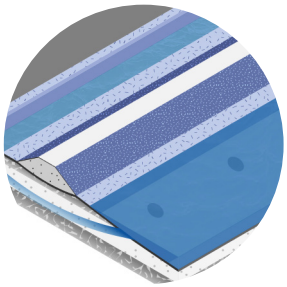
Figure 158: Visualisation of future dike identity of the 'Distributive' dike. (Author, 2023)





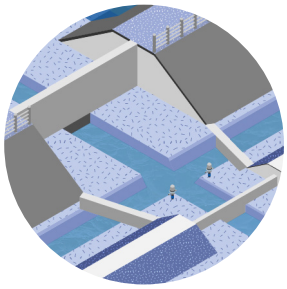


Seepage holes



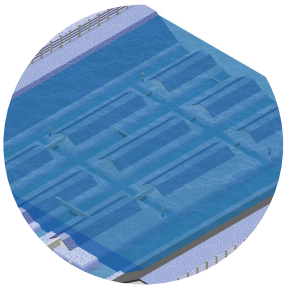
The integration of seepage holes near the feet of the dikes increases the distributive effect of seepage between the water inside the dike lines and the river. Therefore a mutual flow is created between the two water systems.

Sluice network



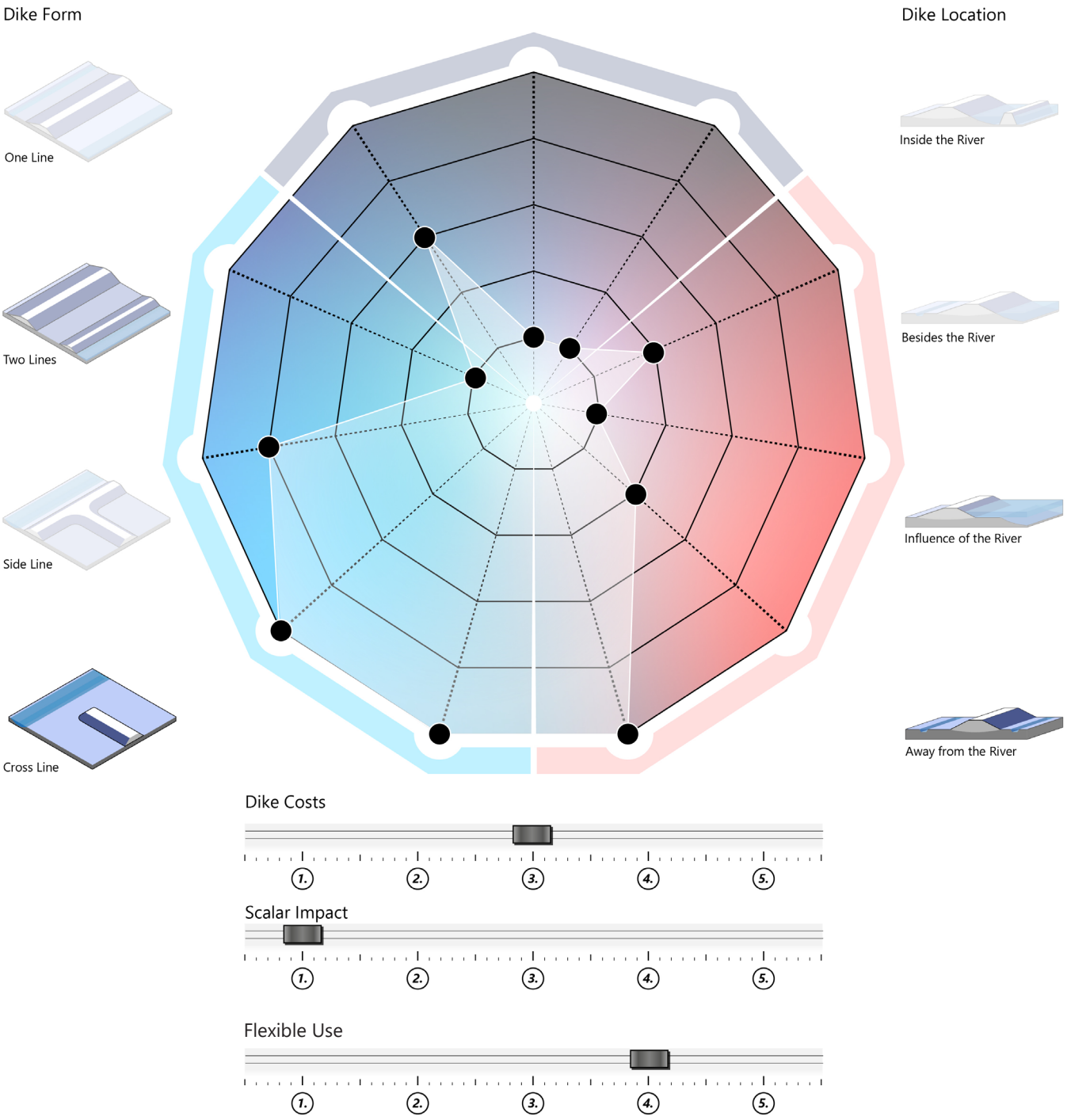
The integration of a sluice network within the dike construction increases the possibility for water to be distributed towards and from the river inlands. As these sluice systems form a part of nearby local practices, autonomy within the region is increased.

Small dike system



In order to retain the new distributive functionality of the dike line, the placement of different size dikes increases the distributive character. These different size dikes operate based on different water levels, therefore distribution can be guaranteed.

Natural Retention *As based on their current and potential relationship to dikes*



Dike as a Source of Life

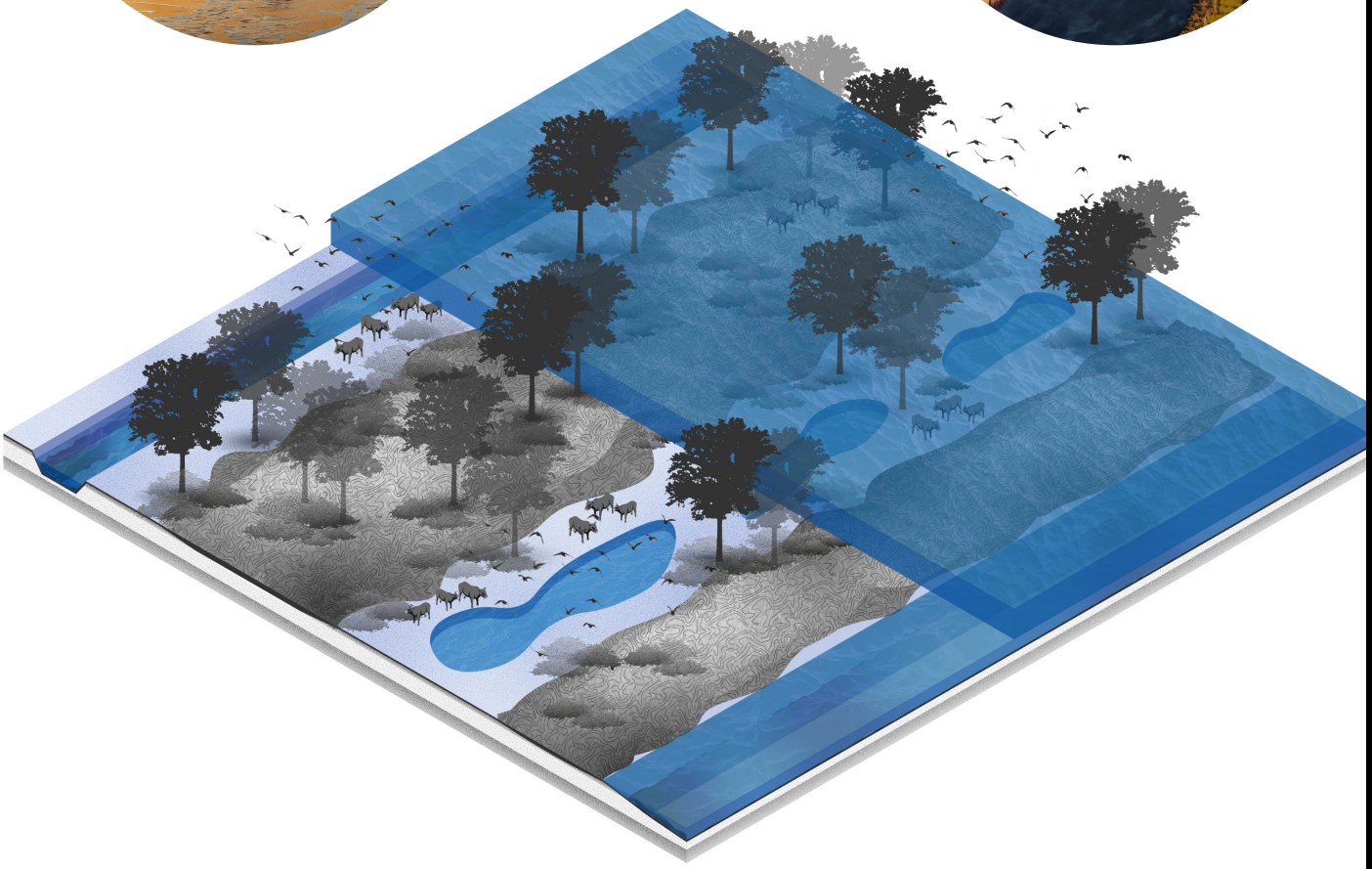
In this scenario, the dike integrates with the natural river system, resembling a gentle hill in the landscape subject to direct influences from the river's sedimentation and erosion patterns. It renounces its primary defense role, resulting in reduced spatial visibility. The main expenses are made when altering the surrounding landscape in direct connection with the dike. Changes are closely tied to existing land uses around the river, necessitating adaptations to manage increased flood and drought possibilities. These dikes do not serve as major protective barriers, requiring local stakeholders to accept the likelihood of flooding and drought. However, over time, as the dike has adapted to the dynamics of the river, the intensity of floods and droughts will become less extensive. In cases where stakeholders cannot adapt their existing practices, their only option is to accept the changes or relocate.

Figure 159: Classification scheme of 'natural retention' dike characteristics. (Author, 2023)

Figure 160: Visualisation of future dike identity of the 'Natural Retention' dike. (Author, 2023)





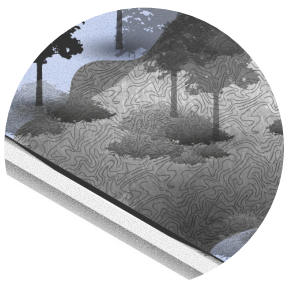


Farm animals



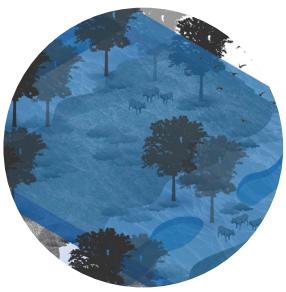
As the whole region transforms to a natural retention zone, possibilities for local farm animals and other wildlife can be integrated. Although caution should be taken when considering the low protective character of this dike against the water, integration of wildlife decreases maintenance.

Natural sediment

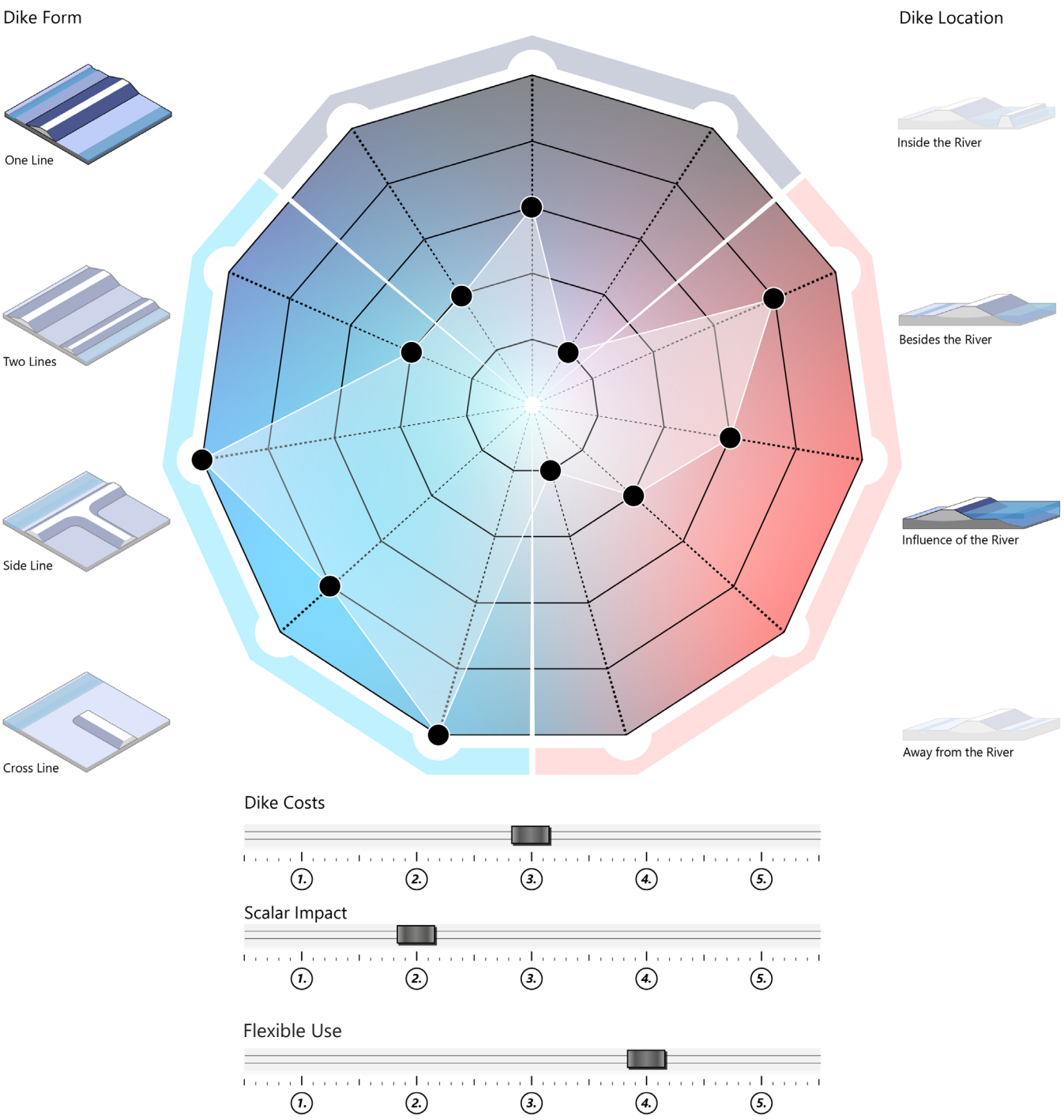


The placement of sediment poles and trees, increases the sedimentation process during high flow. Therefore the placement of the new dike line can be managed. Although this increases the natural dynamics of the river, the time on which the dike element is created has to be taken into account.

Natural overflow



As the low water retaining function of the dike line is accepted, the possibilities for longer and more frequent periods of flooding should be taken seriously. Although available dike lines can decrease the reach of the floodings, they should not be seen as protective elements.



Dike as a Historic Landscape Element

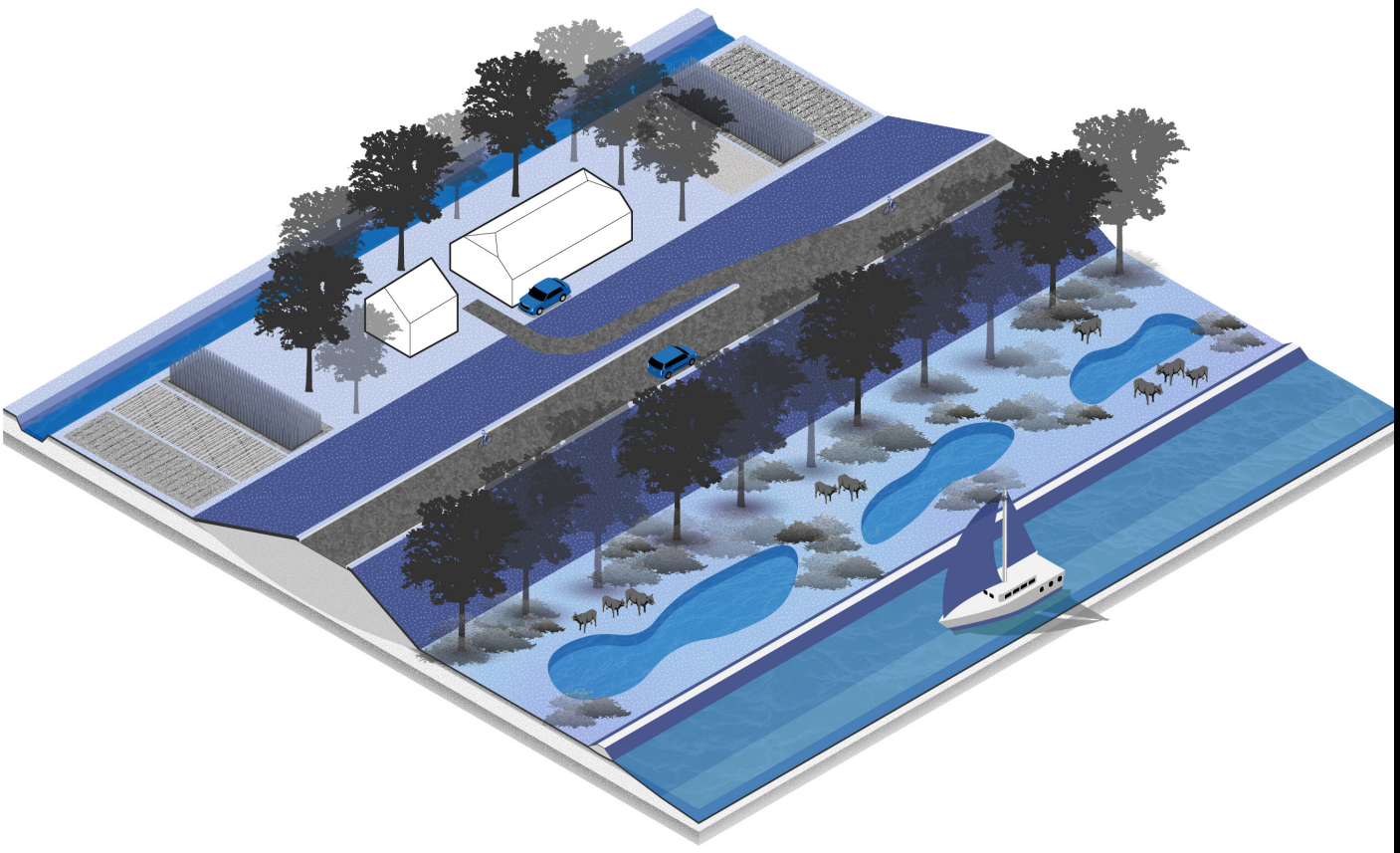
Here, dikes become integral spatial elements in the landscape, enhancing the beauty of the Rhine River landscape. While still functioning as a river barrier, the dike's relationship with its surroundings fosters biodiversity and societal connections. Increasing floods and droughts become part of raising awareness about flood and drought management. The primary concept of this dike is to maintain its original position and preserve its heritage value as a spatial element. Management shifts to a larger administrative level to protect its heritage qualities. More recreational and natural elements are integrated into the dike and its surroundings.

Figure 161: Classification scheme of 'Landscape' dike characteristics. (Author, 2023)

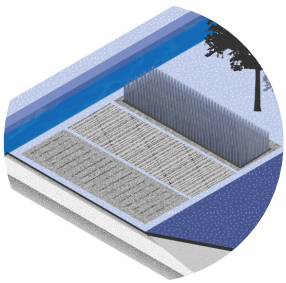
Figure 162: Visualisation of future dike identity of the 'Landscape' dike. (Author, 2023)







Agricultural practices



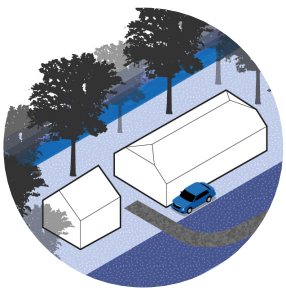
Due to the placement of the dike in relative closeness onto old river embankments the soil composition near the dike is often good for fruit and wheat production. Additionally high groundwater levels adjacent to the dike increases the source for agricultural production

Natural floodplains

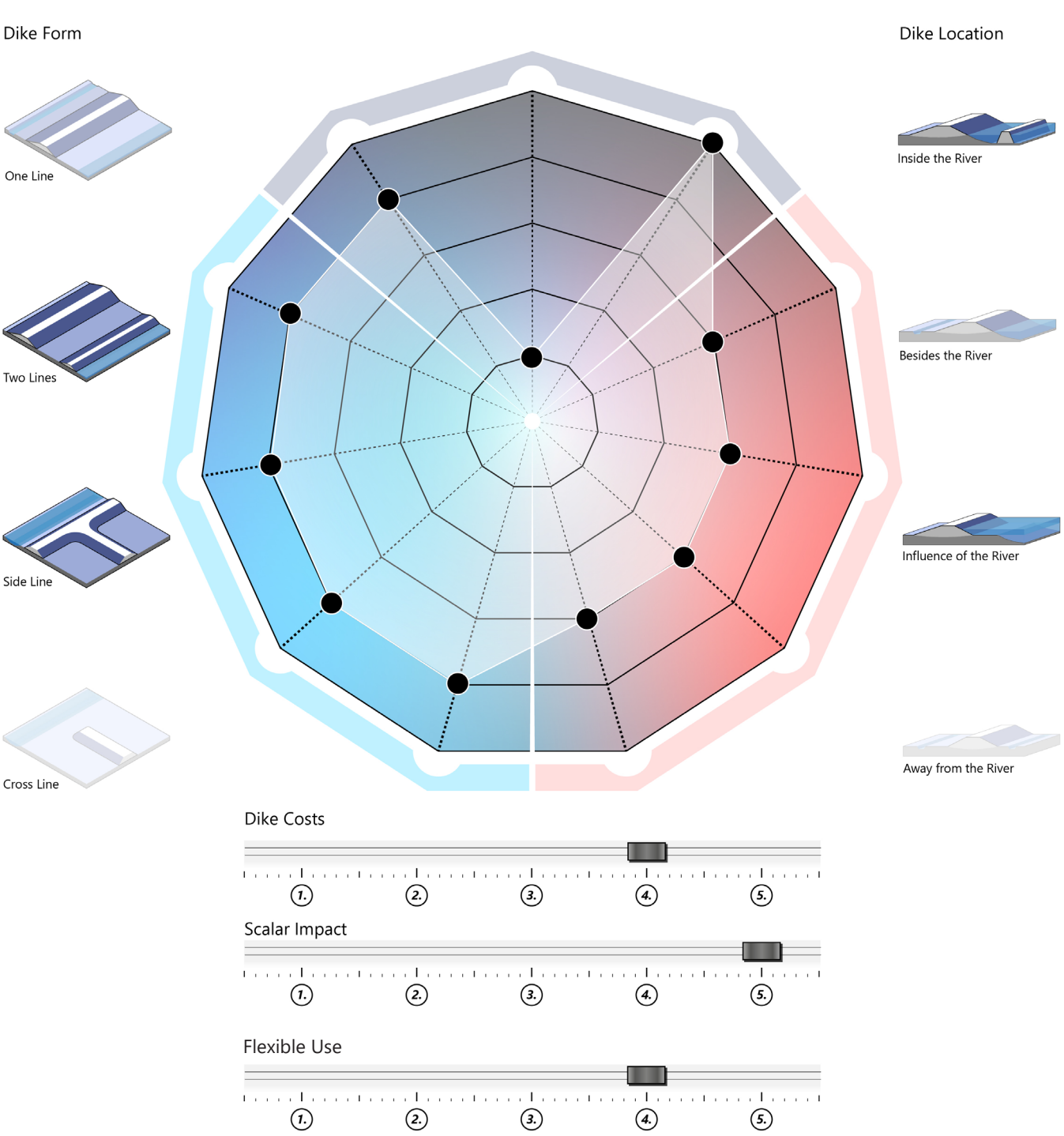


The common feature of the riverlands are the floodplains that are based between the dike lines of the summer and winter dikes. These areas form a natural water retention zone where cattle and recreation can find a place.

Farm life



The orginal owners of the dikes of the Rhine river, where related to local farmers. Re-introducing the old bond between the agricultural practices and the adjacent river, increases the nostalgic factor of the Rhine riverlands.



Dike as a Multifunctional Element

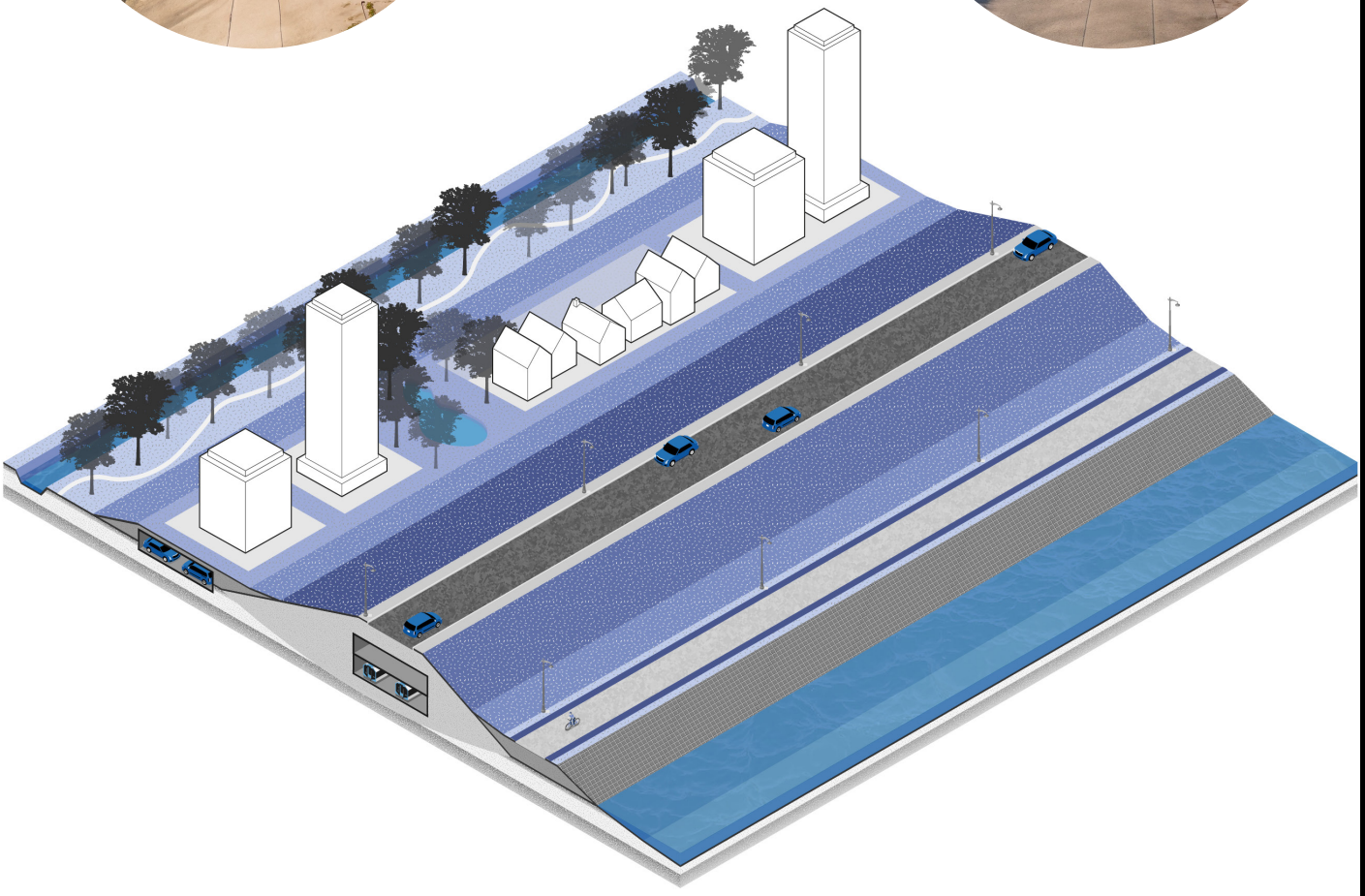
In this scenario, existing dikes acquire new features. With the growing potential for floods and droughts, these dikes are adapted to include infrastructural, urban, and energy-related developments, forming rather urbanized islands than dikes. Implementing these changes necessitates costly developments, expanding the dike's scale significantly to incorporate various functions. They become landmarks in the river landscape due to their substantial spatial presence. While multifunctional, these dikes continue to serve the roles of water distribution and river protection at the same standard level.

Figure 163: Classification scheme of 'multifunctional' dike characteristics. (Author, 2023)

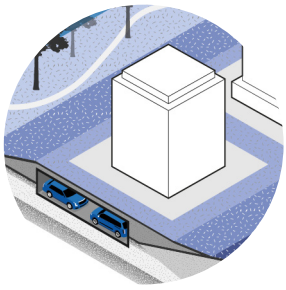
Figure 164: Visualisation of future dike identity of the 'Multifunctional' dike. (Author, 2023)





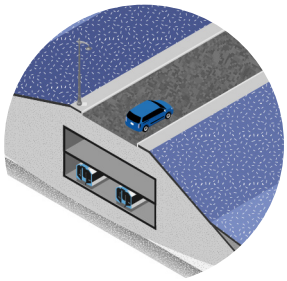


Urban integration



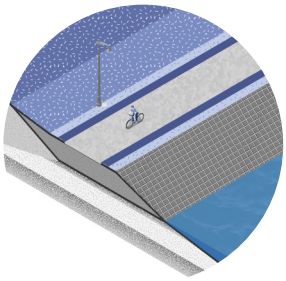
The size of the dike line creates new opportunities to integrate urban programs onto and inside of the dike.

Multifunctional Infra

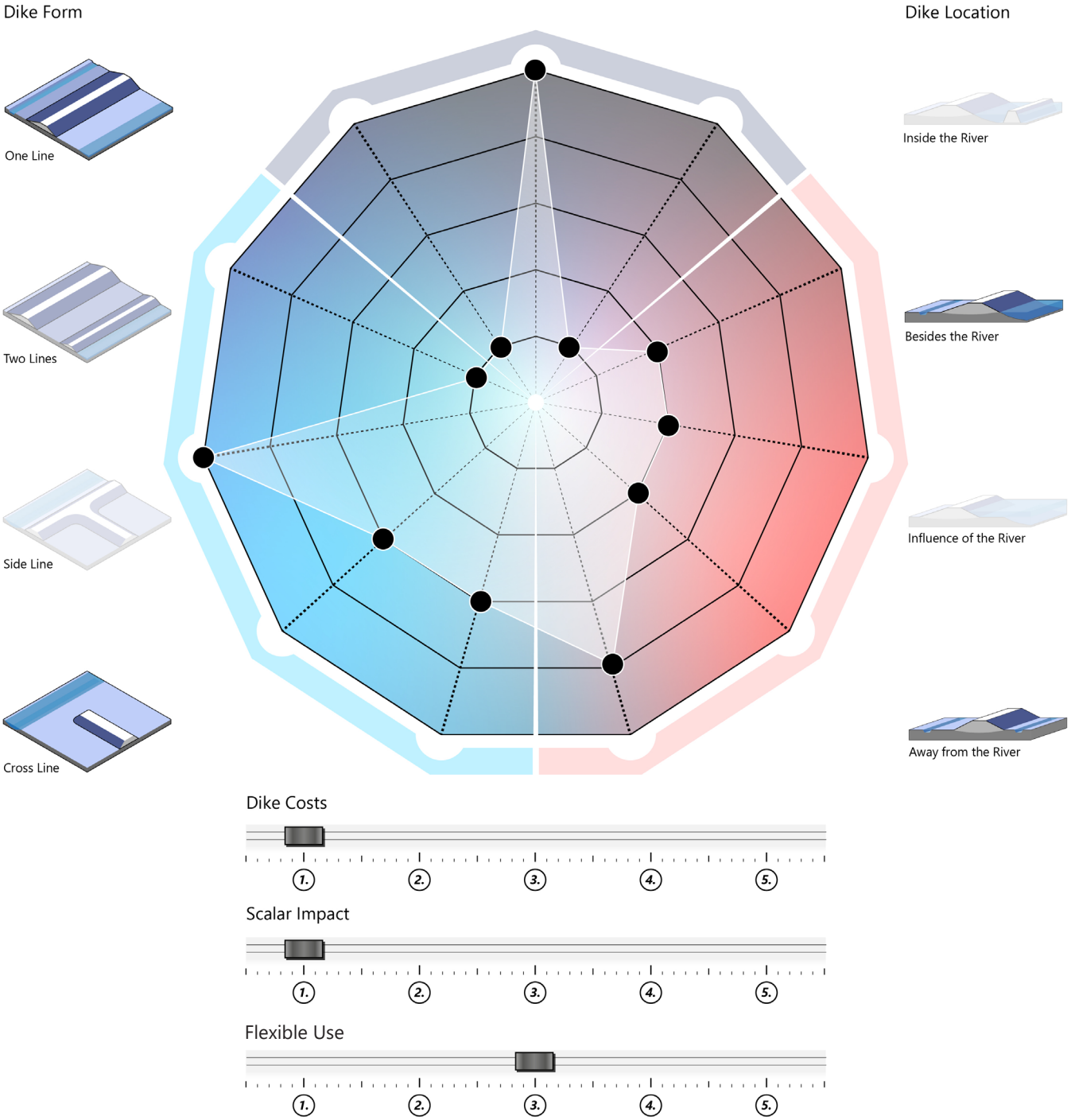


To enhance on of the old features of a dike as a transportation element in periods of flooding, new infrastructural networks can be integrated into the dike line. Although it enhances the regional connectivity of the dike, large investments are needed.

Local networks



Besides the larger regional network capabilities, also localized transportation can be enhanced.The size of the dike in combination with the different slope platforms increases the functional use of the dike for urban and natural systems.



Dike as an Autonomous Body

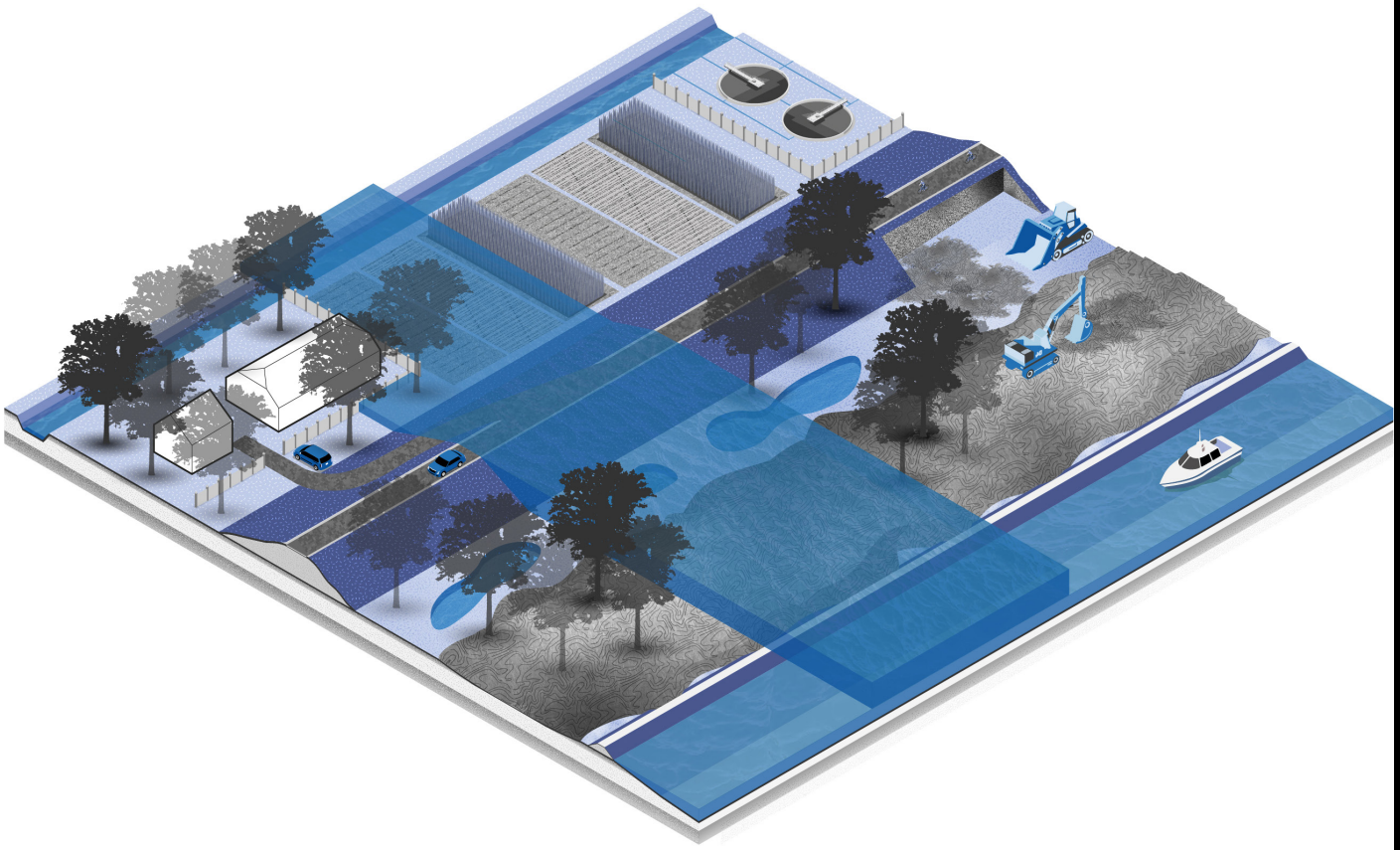
In the final scenario, the Rhine's dikes are once again integrated into local communities, with residents responsible for their maintenance and construction. The traditional water-retaining function diminishes, as safety measures are interpreted flexibly based on the type of stakeholder overseeing the local dike line. Floods and droughts will have a substantial impact on the dike structures, but they are considered part of a stakeholder's responsibility. The dikes can take various forms and become more integrated into the existing land use practices along the Rhine. The area surrounding the dike will be dedicated to large water management practices as these are the ideal nodes for local water distribution. Integration of local floodwalls and sedimentation zones provides additional protection as a base of material for dike construction and maintenance.

Figure 165: Classification scheme of 'locally managed' dike characteristics. (Author, 2023)

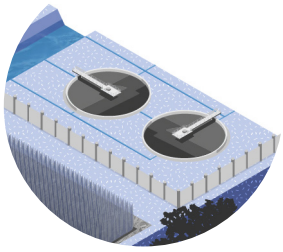
Figure 166: Visualisation of future dike identity of the 'Locally managed' dike. (Author, 2023)





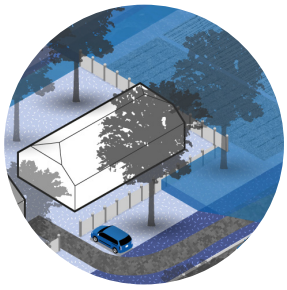


Local sanitation



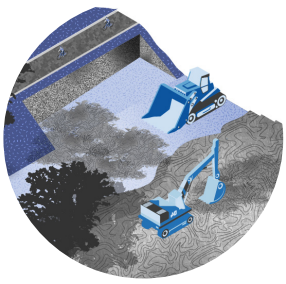
The local responsibility of dike management also increases the potential for localized water management. As the integration with the water is enhanced, local water use is subdued by the natural water system. To make sure a constant body of water can be used, local sanitation plants are vital.

Local floodwalls



As the main responsibility of dike management is placed on the local contexts, water retaining measurements have to be easily placed, maintained and used. Therefore the integration of localized floodwalls increases protection of the urban fabric without large loss of space.

Local construction

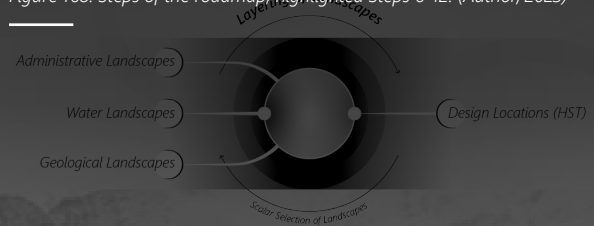


To create a water retaining line, adjacent sediment can be used to construct the dike line. As the dike is reliant on local stakeholders to maintain and monitor the dike line, maintenance is increased.

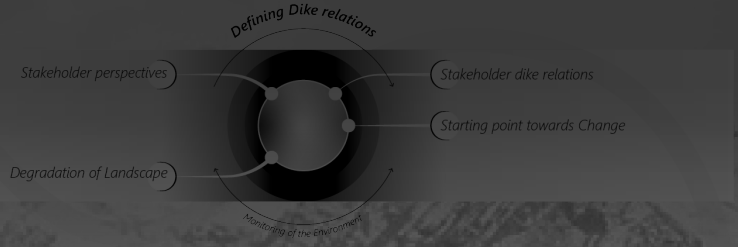
Figure 167: Grande-Dixence Dam, in Valais (CH). (Toma, J., 2019)

Figure 168: Steps of the roadmap, highlighted Steps 6-12. (Author, 2023)

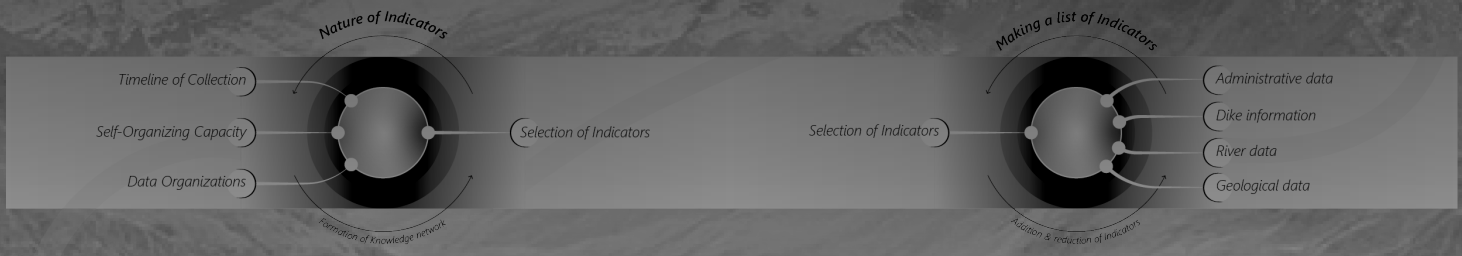
Step 1: *Design Locations (HST)*



Step 2: *Urgencies*

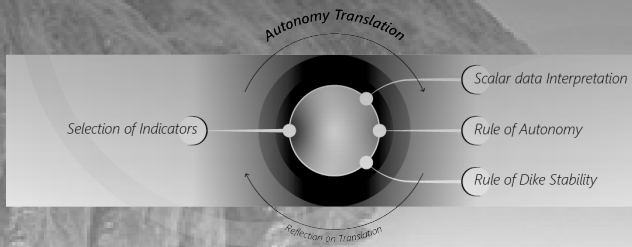


Step 4: *Knowledge Provision*

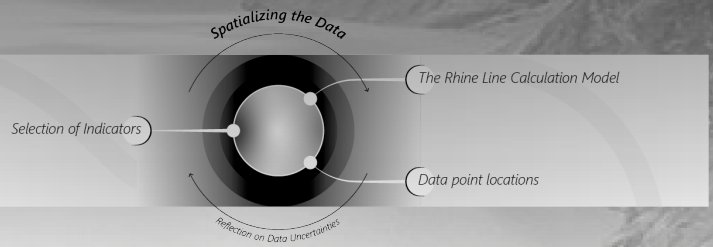


Step 3: *Indicators of Autonomy*

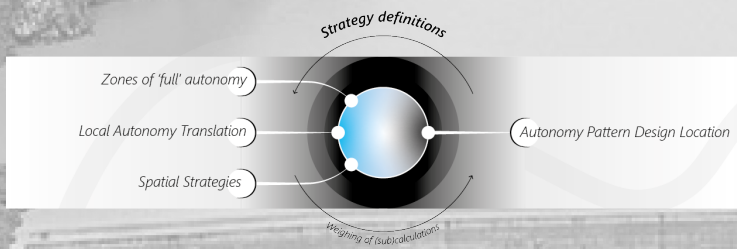
Step 5: *Translation of Indicators*



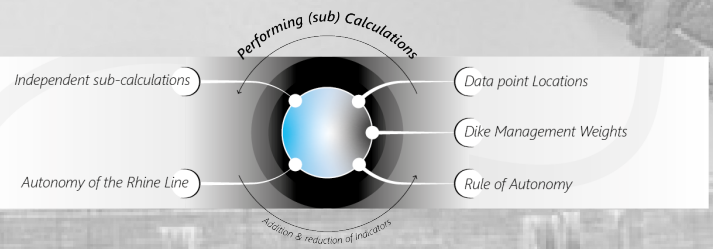
Step 5.1: *Spatialization Model*



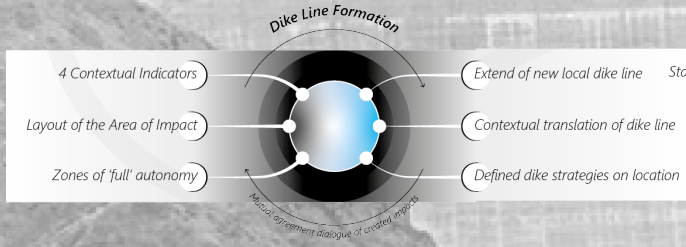
Step 7: *Defining Strategies*



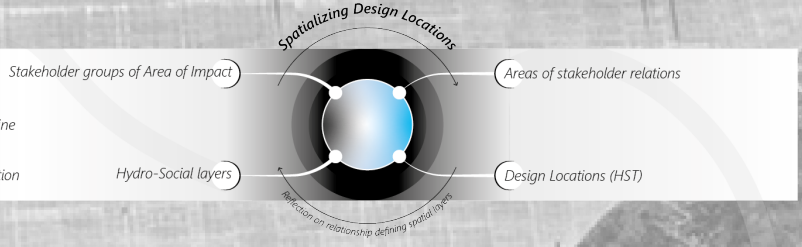
Step 6: *Calculation*



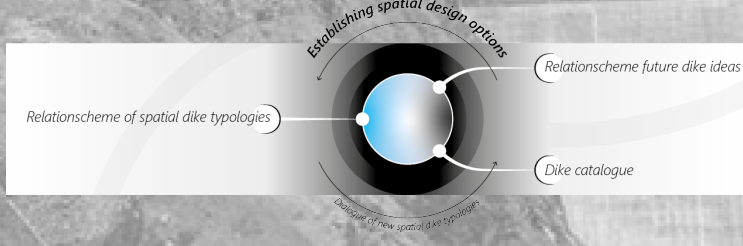
Step 8: *Dike Line Formation*



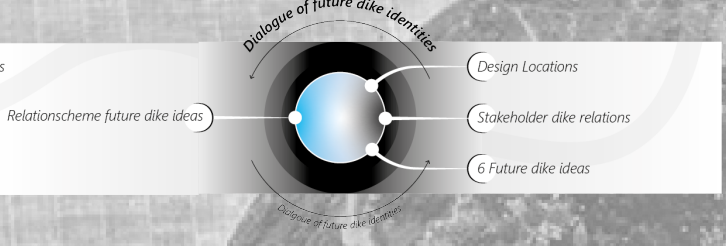
Step 8.1: *Design Locations (HST)*



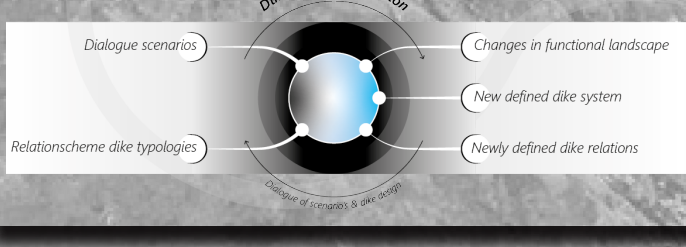
Step 10: *Spatial Dike Formation*



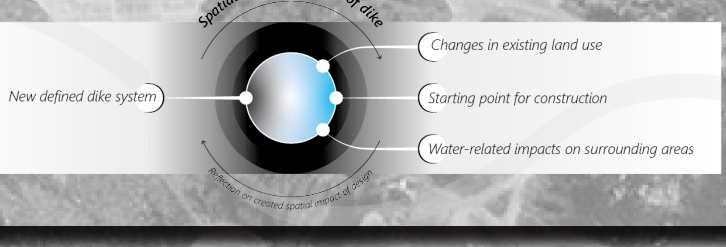
Step 9: *Future Dike Exploration*



Step 11: *Dike Systems*



Step 12: *Dike placement*



13

Lustenau
Vaduz

13.1 The Alpine Rhine

The Alpine Rhine
Hydro-Social Territories of the Alpine Rhine
Calculation Results

13.2 Strategizing a Dike Line

Choose a Strategy
Indicators of the Location
Creating a New Dike Line

13.3 Design Dialogues

Choosing a New Dike
Hydro-Social Territories
A New Meaning of Dikes
Creation of a New Dike System

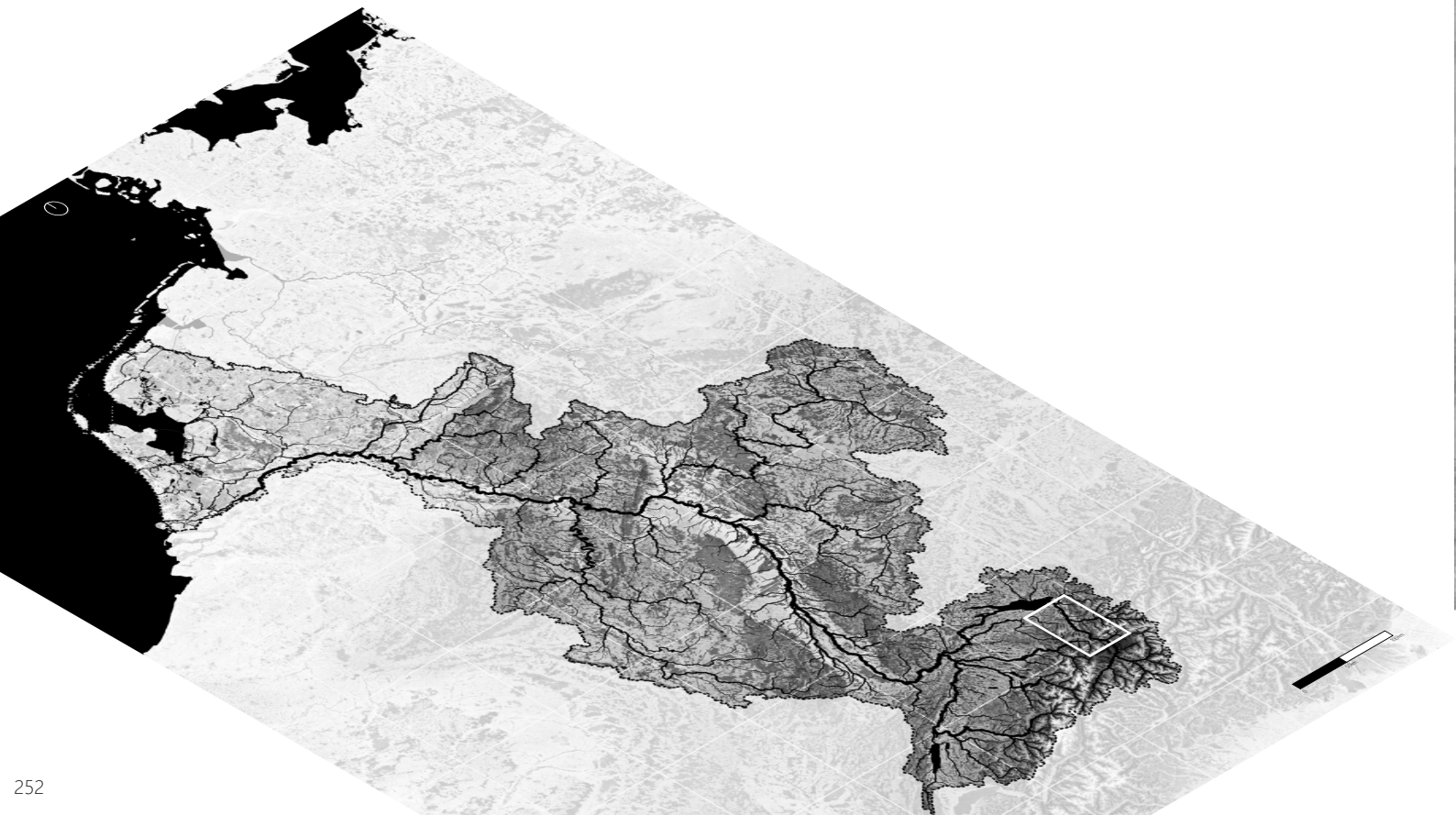
12.4 Spatial Dike Scenarios

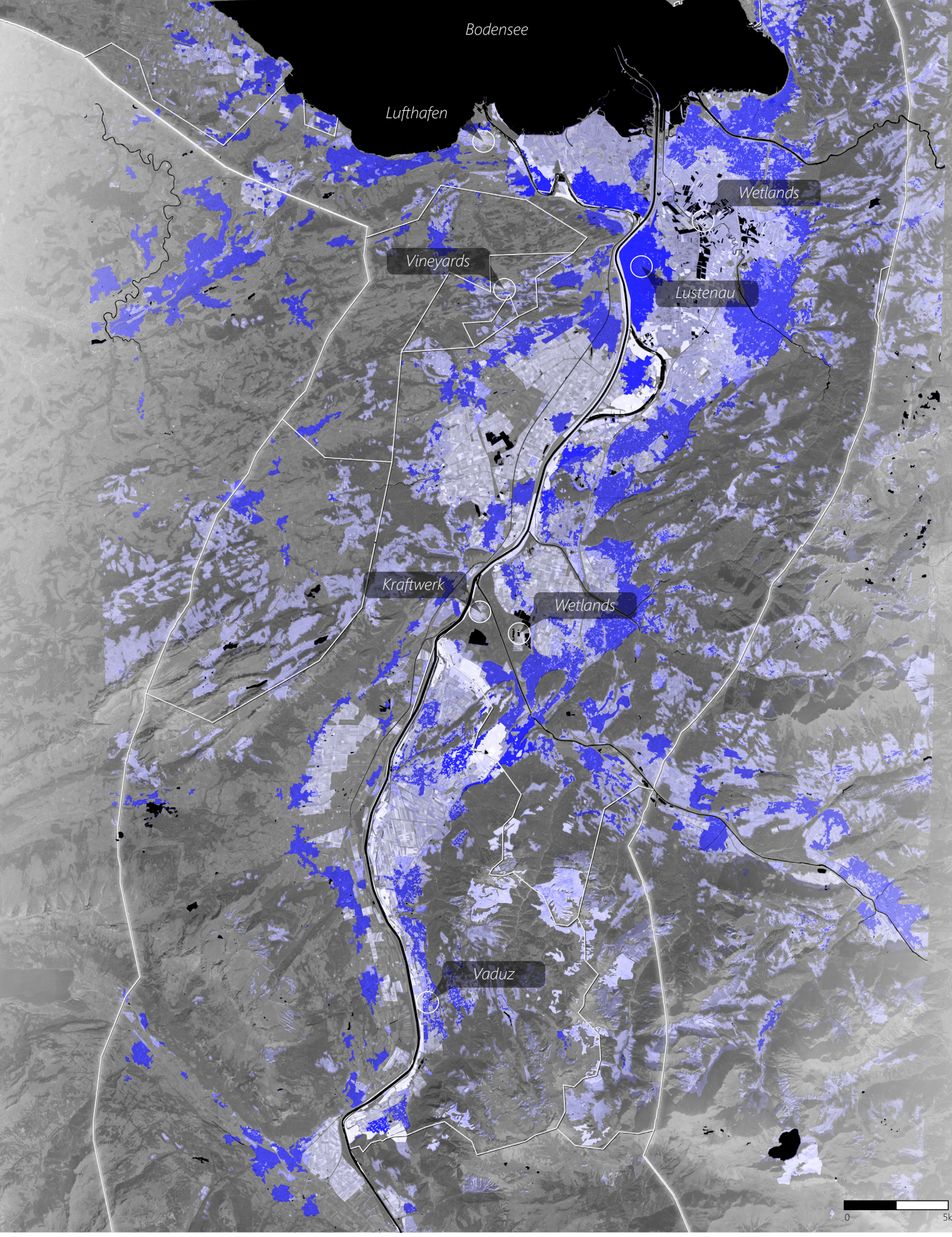
Design Location
Going for the Safe Option
Going for the Radical Option
Going for the Moderate Option

13.1 The Alpine Rhine Valley

The Alpine Rhine area is situated along the border regions of Austria, Switzerland, and Liechtenstein. It is renowned for its strategic position at the foot of the Alps and encompasses major urban centers such as Lustenau, Feldkirch, and the capital of Liechtenstein, Vaduz. Moreover, the area is significant for its sediment industries using the sediment of the Rhine as a base for concrete and stone production. A series of dike breaches in the 18th century led to the canalization of the Rhine in 1862 as part of the Rhine Correction project (SOURCE). Consequently, the Rhine is characterized as a relatively small yet highly regulated river.

The water management sector plays a vital role in sustaining water use and environmental preservation in this ecologically sensitive region. The area is primarily susceptible to droughts due to extensive glacial melt in the Alps. However, more intense rainfall periods in the Alps could cause unexpected floods. Thus, a reconsideration of the Rhine's configuration is crucial in establishing a water-resilient region.





Water bodies
Urban areas
Industrial zones (commericial & quarries)
Agricultural land
Natural grassland
Forests
Administrative regions (Nuts)
Elevation

Figure 169: The Alpine Rhine Valley in Switzerland. (Author, 2023)

Hydro-Social Territories of the Alpine Rhine

This report introduces Hydro-Social Territories to indicate new territorial units for local dike management. HSTs have been developed to reestablish the relationship between the river and humans through a change in dike management practices. These territories are defined based on Geological, Water, and Administrative Landscapes. Stakeholder locations have been spatially allocated according to the conditions set by these three main Hydro-Social identifiers, resulting in the creation of 117 unique HSTs in the Alpine Rhine Valley. Below for each landscape layer, the new territories are shown, where each black dot indicates a potential HST. These newly defined territories form the areas in which local dike management will take place.

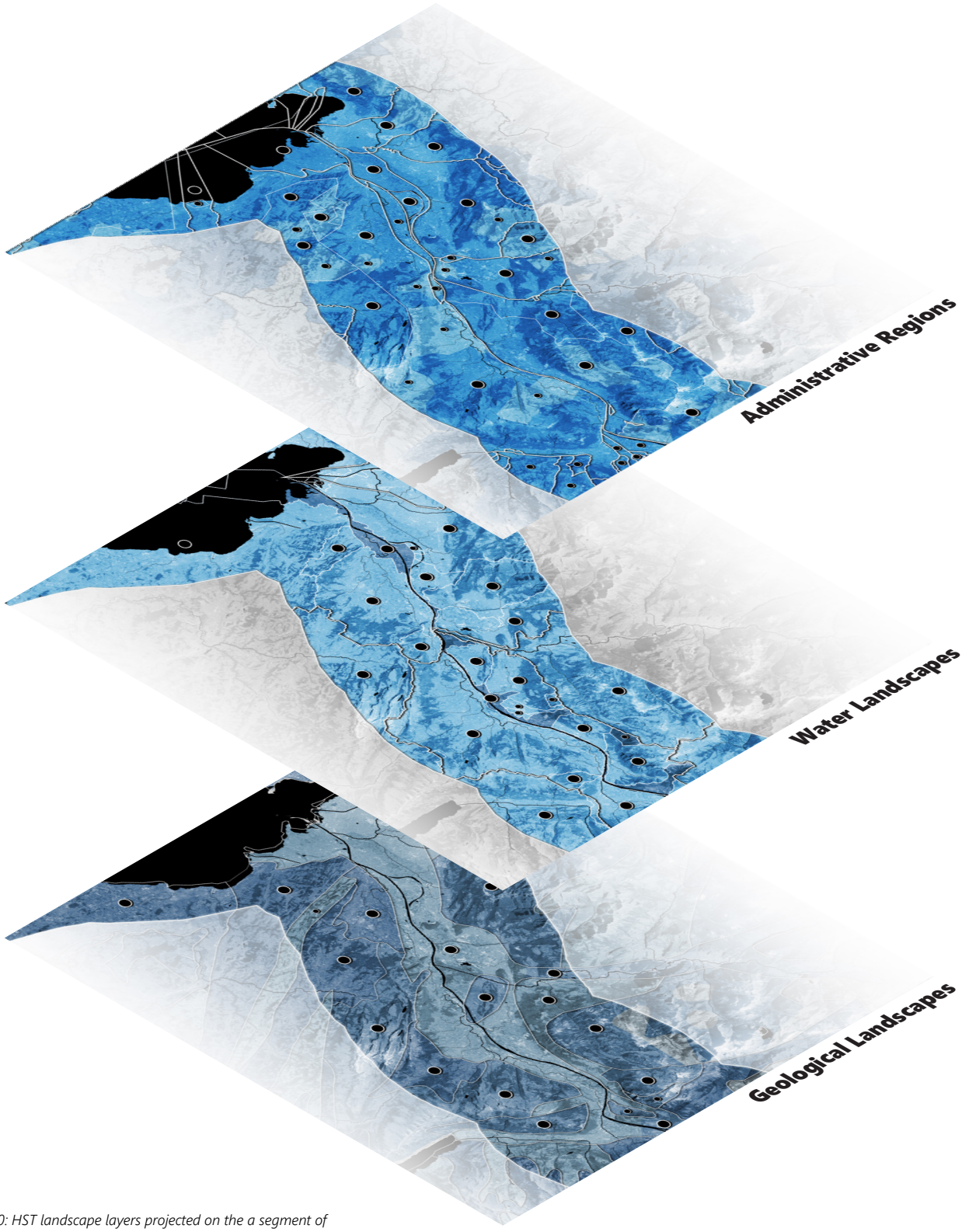


Figure 170: HST landscape layers projected on the a segment of the Alpine Rhine (Author, 2023)

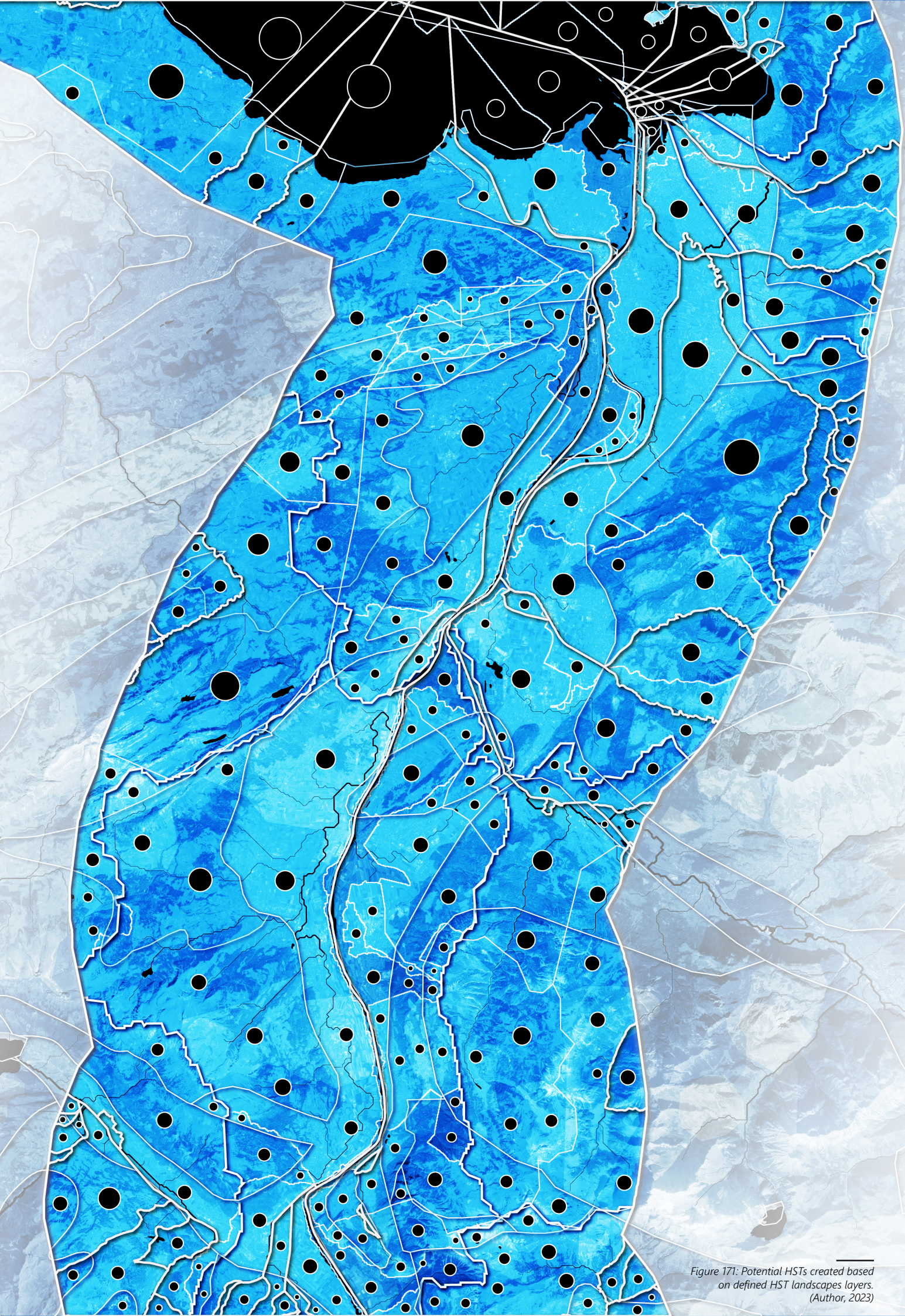


Figure 171: Potential HSTs created based on defined HST landscapes layers. (Author, 2023)

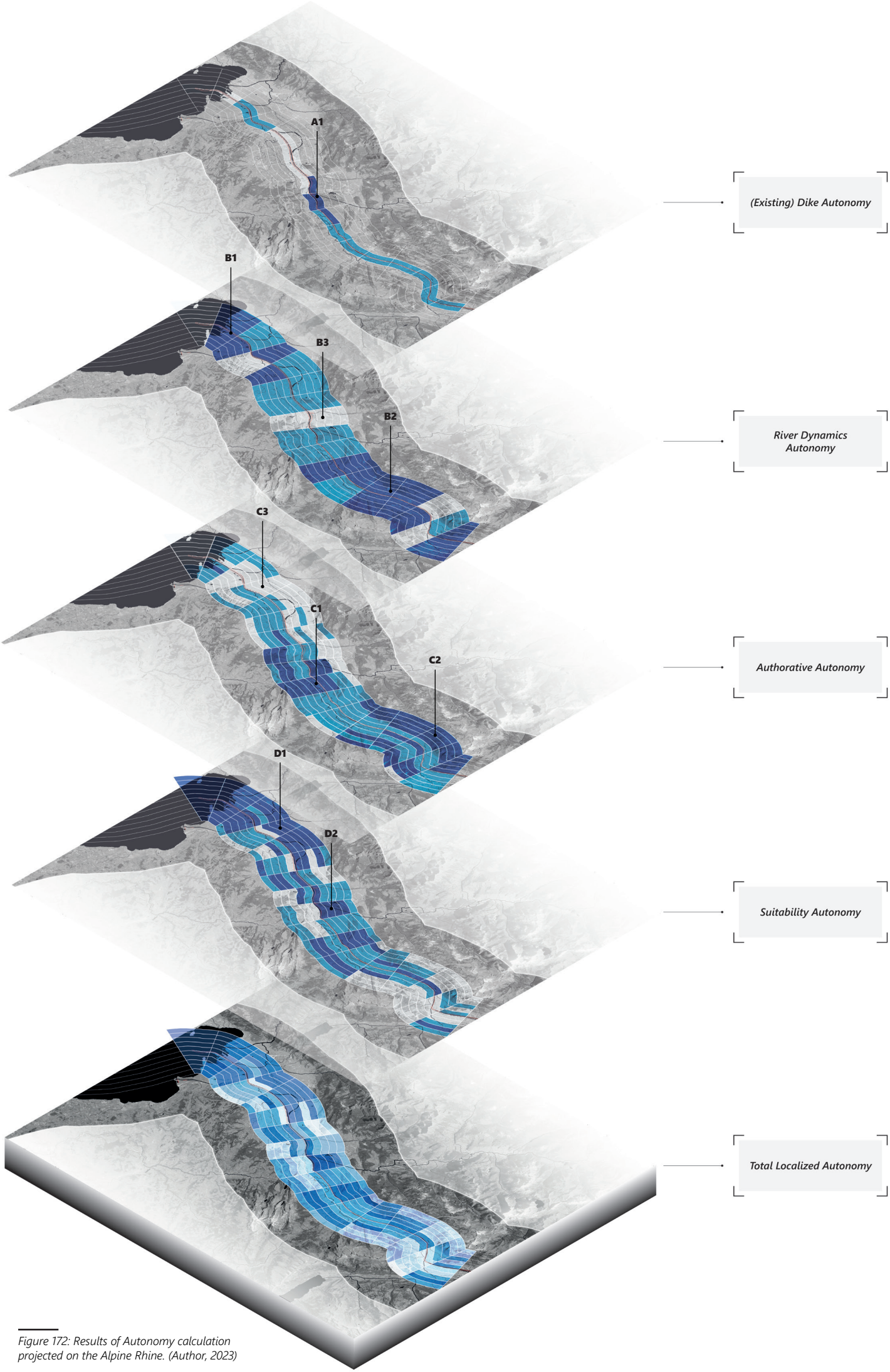


Figure 172: Results of Autonomy calculation projected on the Alpine Rhine. (Author, 2023)

Calculation Results

The calculation results from Chapter 10 are highlighted to show the differences in the context of the Alpine Rhine. Note that the indicative blue gradient colors of the calculation results are based on a comparative translation and indicate the areas with a higher autonomy based on the included data locations.

Dike Autonomy
Following the Rhine Correction measures of 1862, the Alpine Rhine transformed into a canalized river, consisting of extended sections of canalized structures with two primary dike lines intersecting the river. The locations near A1, while still in proximity to the river, indicate the highest potential of local autonomy of the area, averaging between 2.5 and 3.0 out of 5.0. This is primarily because the area is less prone to flooding (C1), and the existing dikes offer more space to the river as the tributary of the Ill streams into the Rhine. The further upstream you travel, the greater the local autonomy, although the differences in elevation become more pronounced, inducing dike construction unnecessary in certain areas.

River Dynamics
Due to the relatively consistent discharge and substantial sediment deposition, a high degree of autonomy can be achieved based on existing and future river dynamics. Locations B1 and B2, characterized by a low degree of meandering and minimal dike system interruptions, exhibit immense potential for local dike autonomy. The only exception is location B3, where the confluence of the Ill from Austria with the Rhine results in lower autonomy due to the presence of hydrological dams and energy plants in the cross-border region, inducing more pressure on the respective dike lines.

Authoratative Autonomy
While a significant portion of the region falls under Swiss regulatory law, variations in autonomy levels become evident upon closer examination. The highly urbanized areas on the Austrian side (C3) of the border have limited decision-making autonomy due to the impacts that can be generated once a spatial change is initiated. On the contrary, more natural regions like C1 near the city of Gamprin and the mountainous regions of Liechtenstein near C2 have additional capacity to initiate localized change.

Suitability Conditions
The areas with the highest potential for local autonomy are dispersed due to the localized nature of the aquifers in the Alpine Rhine. However, two primary areas stand out as having a relatively higher potential for local autonomy. The region near D1 features lower-lying areas of the Rhine, considered ideal for dike construction. With high groundwater and favorable soil conditions, these locations are prime candidates for dike construction. The more expansive areas near D2 are predominantly characterized by their natural retention function, offering high groundwater and soil conditions. Additionally, being further upstream reduces the threat from flooding.

Zones of Intervention
Considering all the calculations together, three primary areas emerge as prime locations for local dike management. E1 is distinguished by its ideal suitability for dike construction. E2 is well-suited for maintaining existing dike lines due to high levels of Dike and Authoritative autonomy. Finally, E3 is excellently located based on the dynamics of the Rhine. These zones of interventions formulate the input needed for further steps.

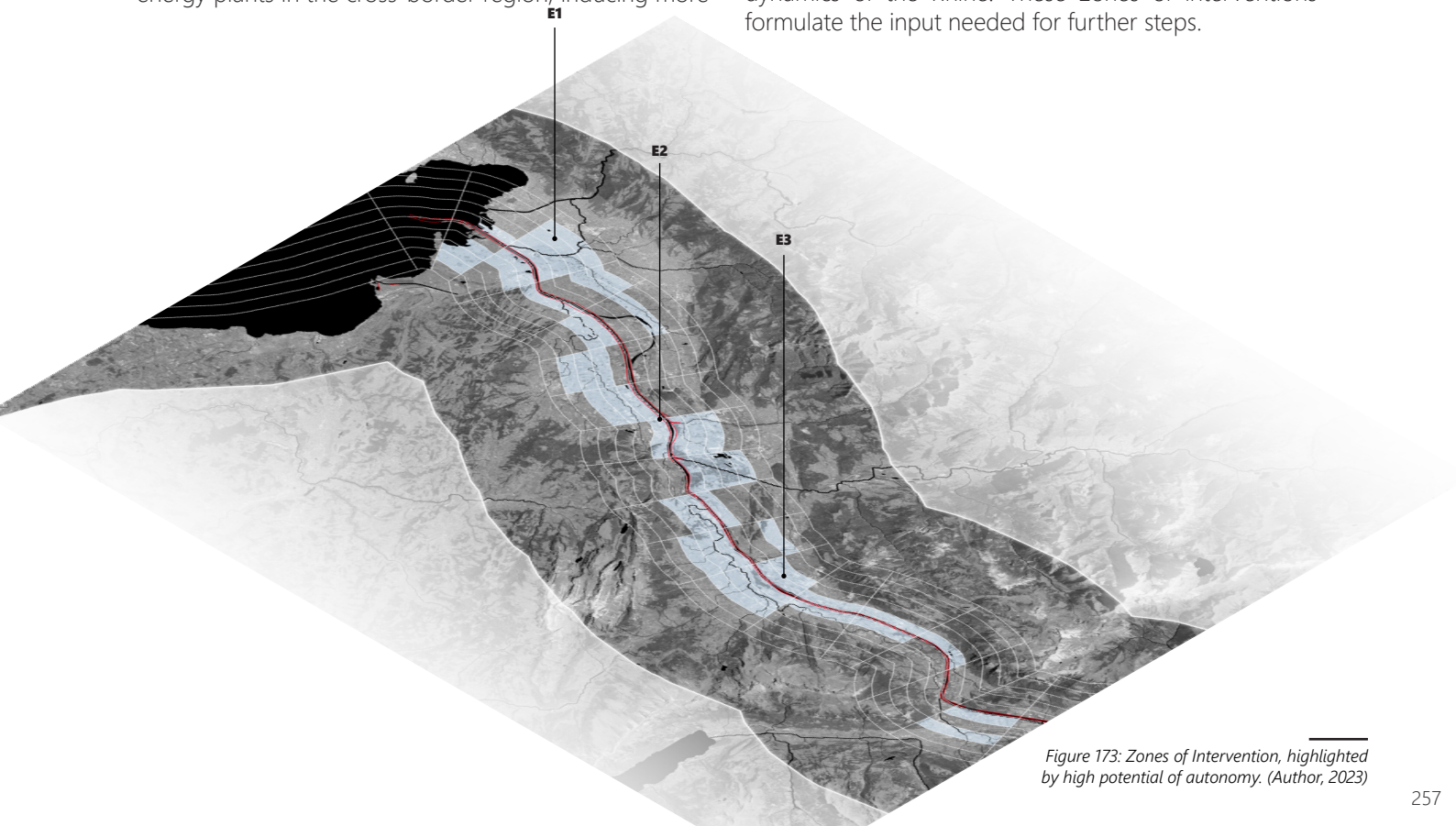


Figure 173: Zones of Intervention, highlighted by high potential of autonomy. (Author, 2023)

13.2 Choose a Strategy

Based on the results from the preceding chapters, we can initiate the initial steps in designing local dikes, introducing various strategies to select from. The choice of dike strategy is directly influenced by the calculation outcomes and is divided among high, medium, and low autonomy areas.

High Autonomy
If the calculations reveal a high potential for localized dike management, there is a considerable opportunity to opt for a Dike Typology change. This strategic choice permits the complete reconfiguration of the existing or newly established dike line as to the location of the dike line. A clean slate is created for dike construction, thus allowing more localized dike management to be introduced.

Medium Autonomy
In regions where autonomy potential is moderate, a significant spatial transformation of the dike line may not be feasible. However, there remains an opportunity to change the location of the dike line without altering its spatial and functional characteristics. As this strategy is not considered the most extreme, the dike (re)location will be discussed in further steps as part of the dike typology change in the area.

Low Autonomy
In cases where autonomy calculations indicate low results, the best course of action is to retain the existing dike structure and location. Due to the limited autonomy potential, changing dike typology at these locations through the intentions of local stakeholder groups is not recommended. This limitation can be attributed to the high flood risk or proximity to heavily urbanized areas. Therefore, the primary recommendation is to consider dike stability changes initiated by larger administrative units. This strategy also included areas having a higher autonomy degree once with no feasible space to change the location and typology of the existing dike line.

As this report centers on establishing complete autonomy, the following chapters will focus on areas with high autonomy for exploring radical dike autonomy options.

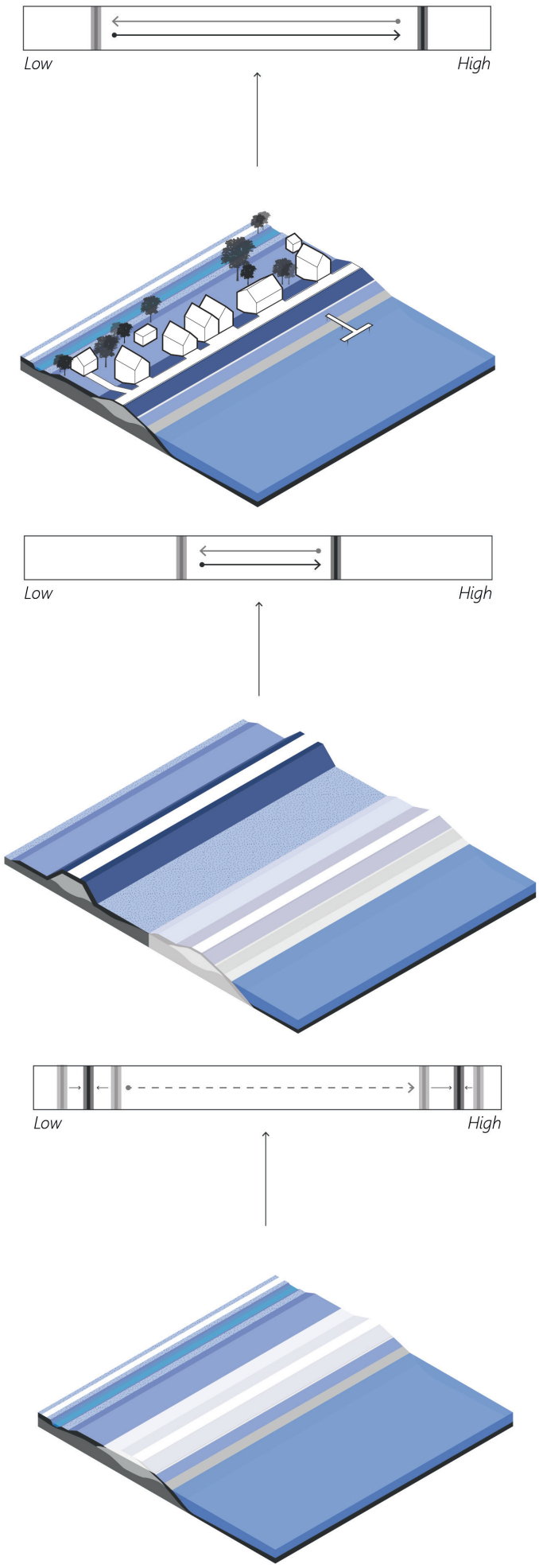


Figure 174: Dike design strategy options. (Author, 2023)

Indicators of the Location

Based on the in-depth explanation of the previous calculation results, we can now proceed to the next steps in the roadmap. To determine whether dikes are suitable for construction, we need to define the freedom of placement using four main categories. These categories narrow down the regions suitable for dikes based on current slope indications, lithological depositions, the extent of the extreme flood line, and the availability of adjacent water bodies. These indicators are essential for ensuring the suitability of the dike's location. Only then a new dike line can be outlined to the areas where the dike is most compatible considering its suitability and ability of local autonomy.

Zones of Potential
The calculation results indicate areas along the Alpine Rhine that are suitable for localized dike management. The intensity of local autonomy can be determined based on the degree of grey as can be seen in the map below. These areas form the initial zones on whether the new dike line is outlined.

Freedom of Placement
To further confine the area of the new dike line to regions where the relationship between the river and the dependent stakeholders can be revised, indicators such as the flood line (blue), current water bodies (white), and slope line (black line) are mapped. Based on these three indicators, the area of the new dike line is considered the ideal location for the construction of dikes.

Extent of the New Local Dike Line
Ultimately, based on the calculation results and the implementation of final dike indicators, a new area can be delineated for the creation of the new dike line along the Alpine Rhine. Between the boundaries of this region, a new dike line can be constructed. This result forms the input of the next step. Based on this outline, a new dike line can be outlined based on the existing context.

Zones of potential

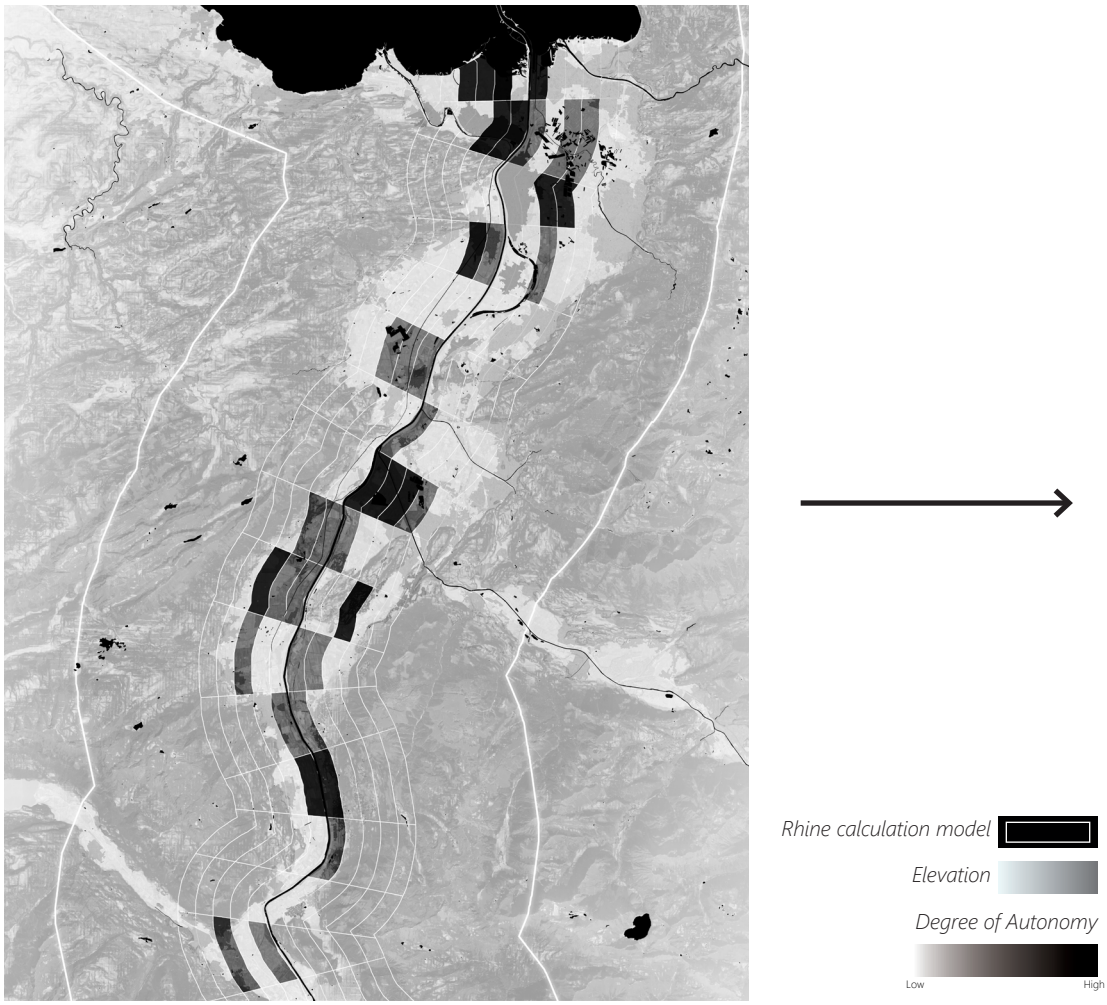
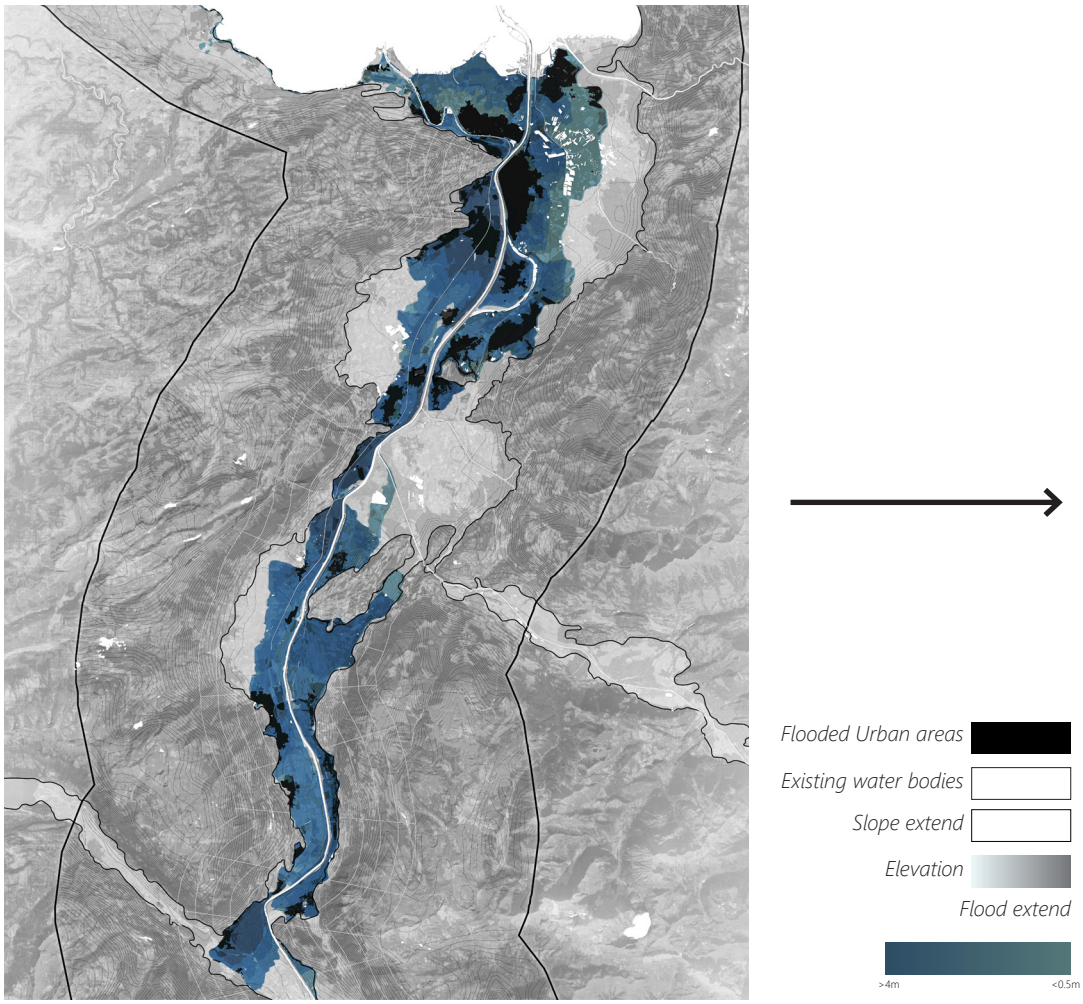


Figure 175: High autonomy locations of the Alpine Rhine (1x4 km). (Author, 2023)

Freedom of Placement Indicators



Extent of the new local dike line

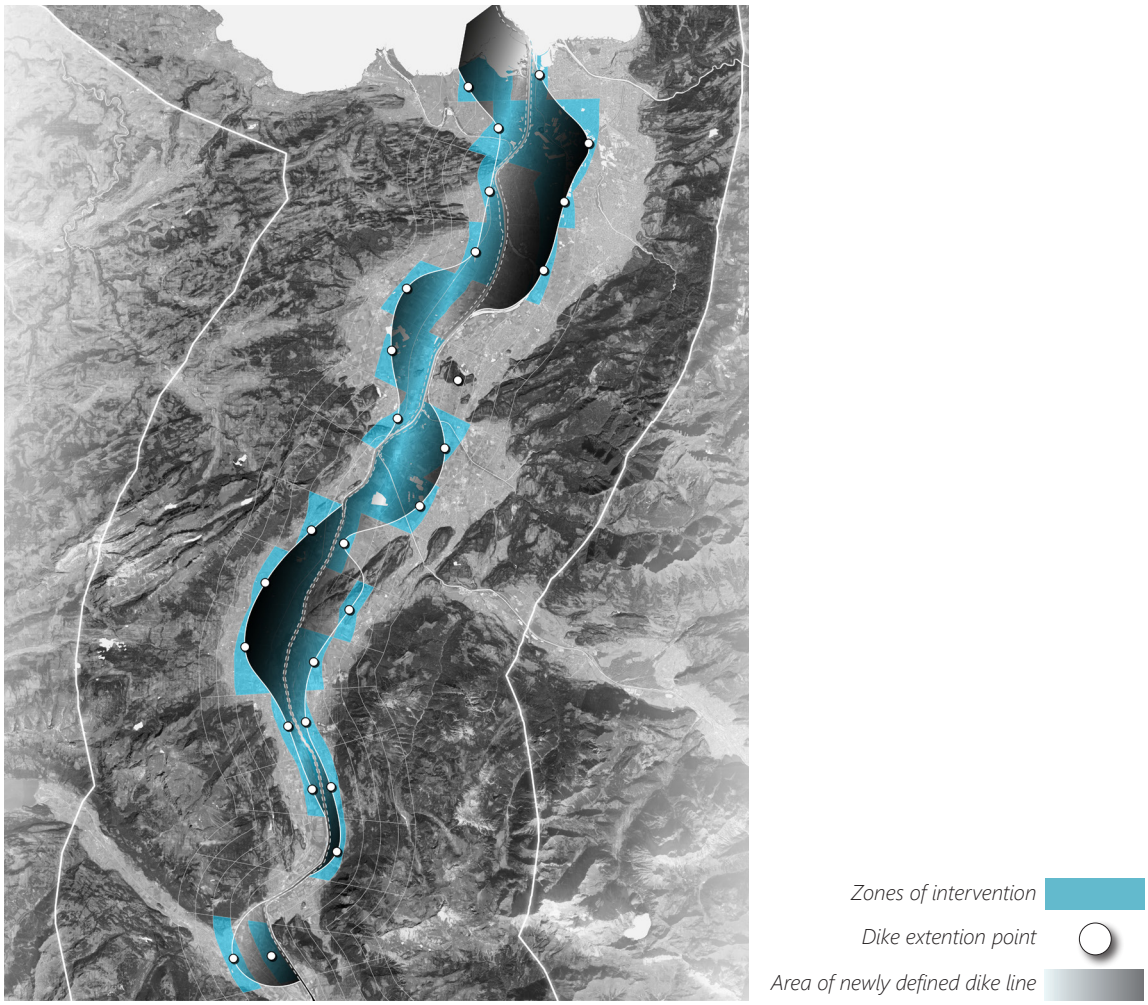


Figure 176: Freedom of placement indicators of the Alpine Rhine. (Author, 2023)

Figure 177: Extent of the new dike line of the Alpine Rhine. (Author, 2023)

Creating a New Dike Line

With the extent of the new local dike line established in the previous steps, the new dike line can be outlined based on the existing spatial context. For the construction of dikes, an open field is recommended, leading to less impact on adjacent urban functions. As the existing water and road infrastructure can be integrated within new dike lines, these networks are considered to form the ideal webs on where a dike can be constructed. Based on these statements new dike lines and waterways are constructed as shown in Figure 179.

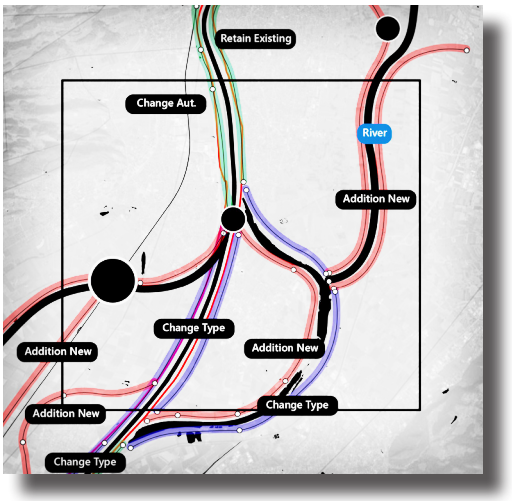
Based on the existing local context, three primary dike line strategies are considered.

(1). The first strategy is the simplest. Based on the area, stakeholders can choose to retain the existing dike line, as exemplified on the left side of map C (Green), where existing energy and urban areas directly border the Rhine on one side and elevated areas on the other, leaving less room for the construction of new dike lines.

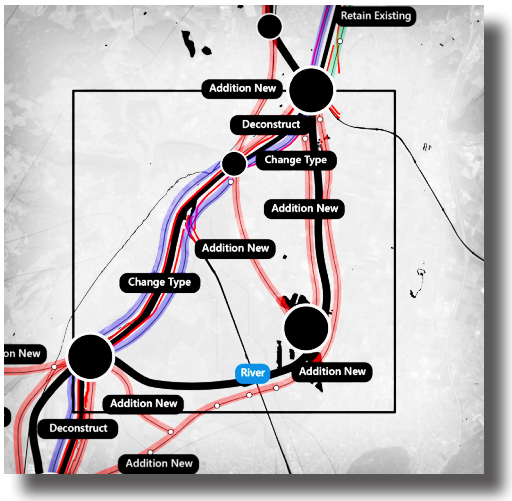
(2). The second option is to change the existing autonomy of the dike while retaining its original location, as shown on the right side of the Rhine in map D (Green), where no other relevant location has been selected since the city of Vaduz directly borders it.

(3). The third option is to add another dike line. The addition of a new dike is seen as possible due to the location of adjacent water or based on the dynamics of the river, as demonstrated on the right side of both maps A and B. In map B, the creation of a new dike line is designed around an existing water retention area, allowing the river to extend further inland. Additionally, this allows the existing dike lines bordering the river to change location (Blue). In map A, an additional dike line is created based on a new distributive character of the river (Red). In times of high flow or increased flood risk, these additional dike lines can help distribute the water away from the urbanized areas around Lustenau to the available wetlands further north.

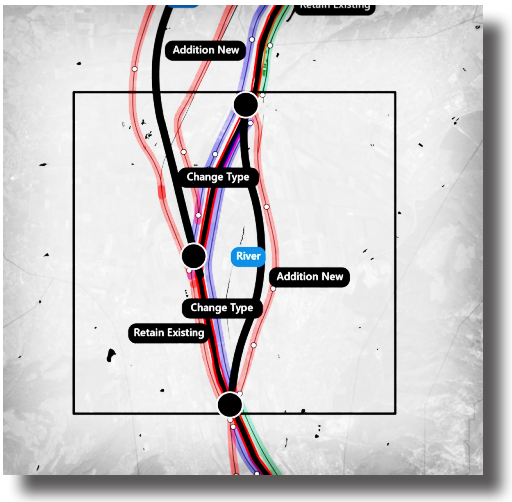
A *New defined river course of the Rhine*



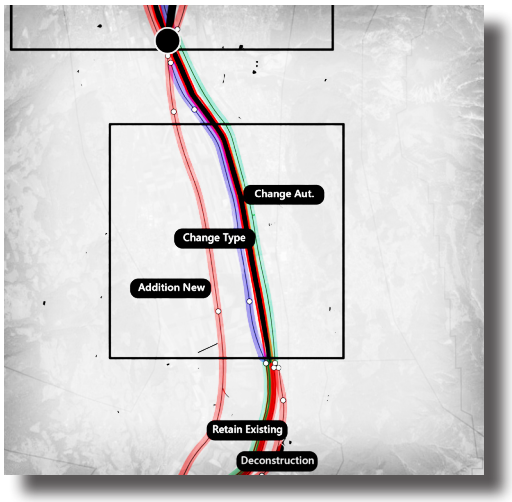
B *Additional side arm*



C *Additional side arm*



D *Additional space for the river*



New dike additions

Addition of new dike

Retain existing dike line

Change existing dike location

Figure 178: New local dike strategies of 4 locaitons along the Alpine Rhine. (Author, 2023)



Figure 179: New dike line along the Alpine Rhine based on highest degree of autonomy. (Author, 2023)

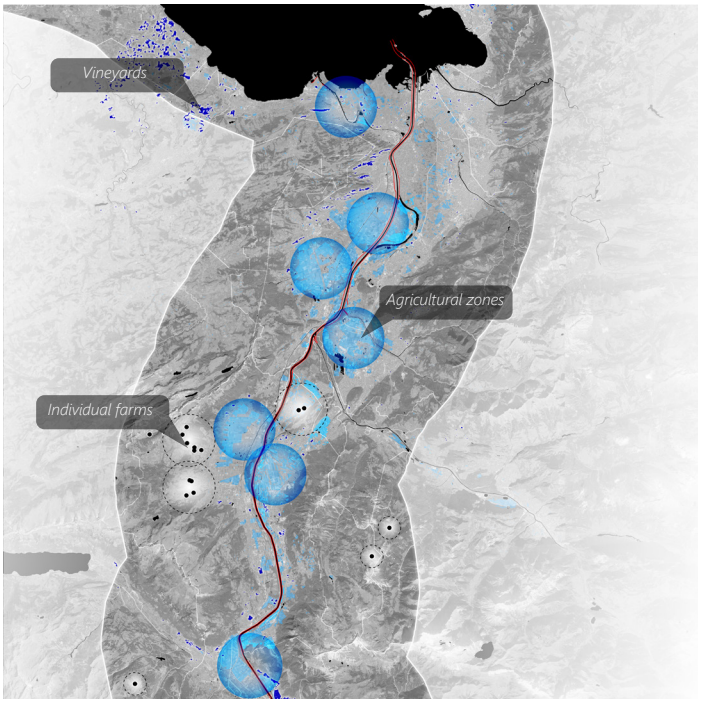
13.3 Choosing a New Dike

The third option is to add another dike line. The addition of a new dike is seen as possible due to the location of adjacent water or based on the dynamics of the river, as demonstrated on the right side of both maps A and B. In map B, the creation of a new dike line is designed around an existing water retention area, allowing the river to extend further inland. Additionally, this allows the existing dike lines bordering the river to change location (Blue). In map A, an additional dike line is created based on a new distributive character of the river (Red). In times of high flow or increased flood risk, these additional dike lines can help distribute the water away from the urbanized areas around Lustenau to the available wetlands further north.

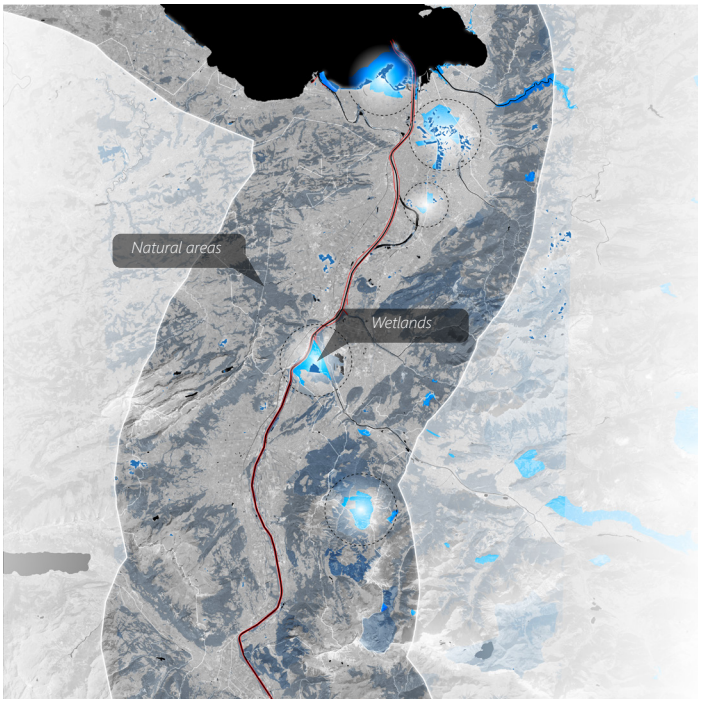
Local Stakeholder Influences

The next step is to assess the regions of the Alpine Rhine represented by the nine major stakeholders, as defined in this report. Understanding the major stakes at hand is crucial in choosing the right dike for the right location where dike lines will be established. The nine major stakeholders are mapped based on their significant interests within the different areas of the Alpine Rhine.

Agricultural Sector



Soil and Water Organizations



The residents

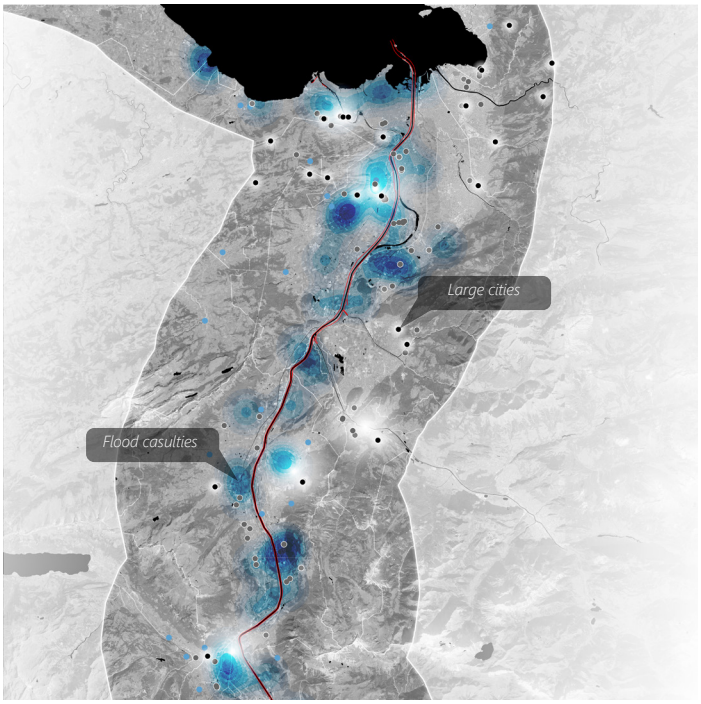
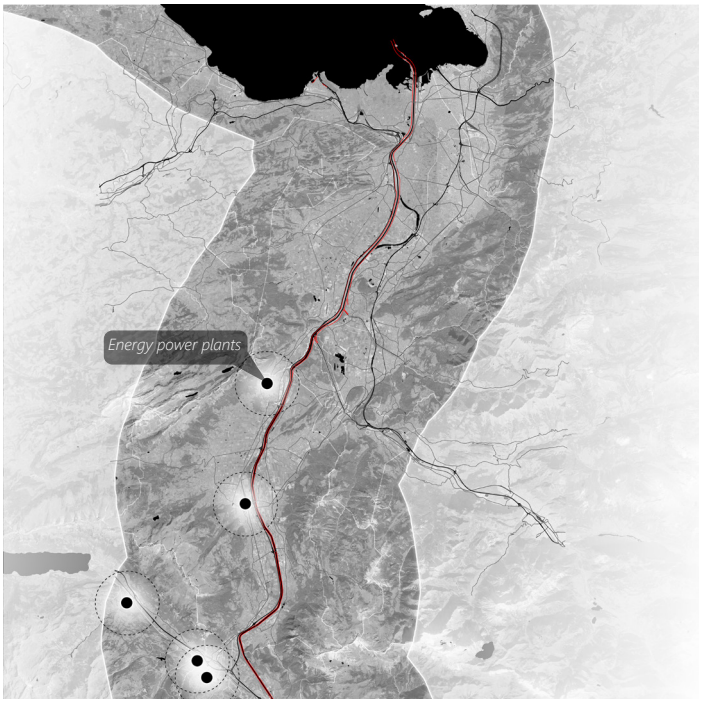
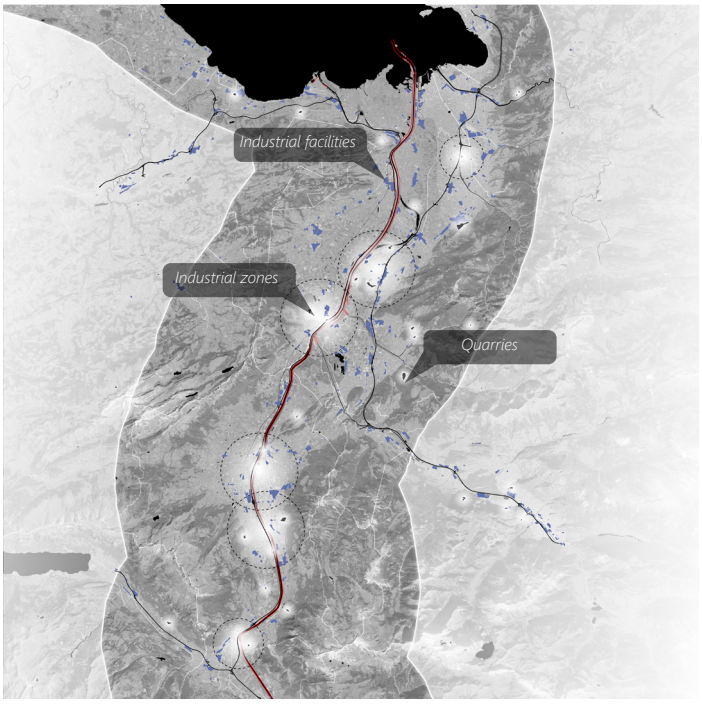


Figure 180: The extent of interest of the nine stakeholder groups of the Alpine Rhine. (Author, 2023)

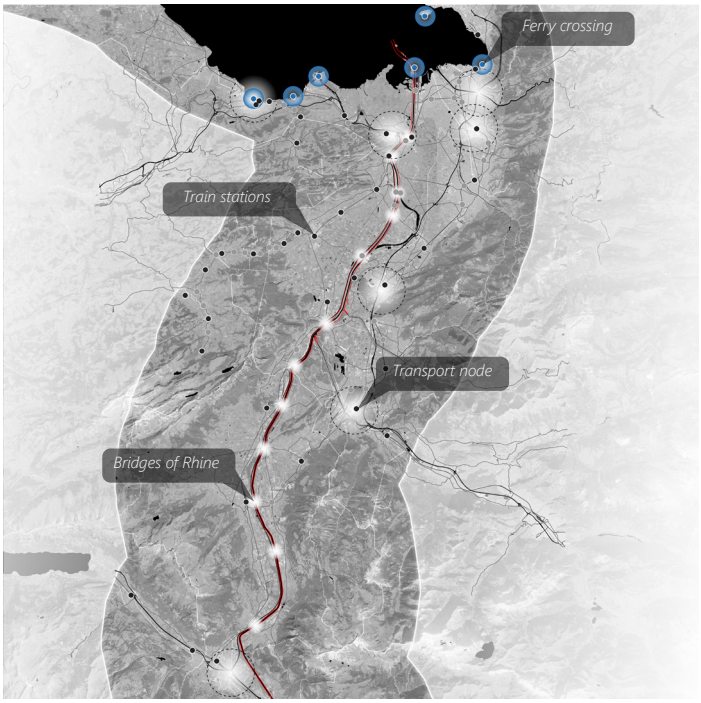
Energy Sector



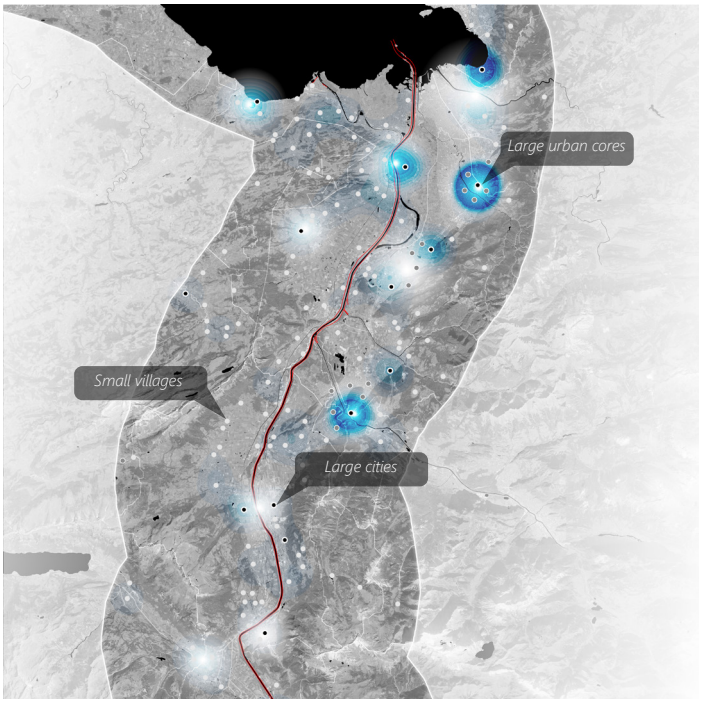
Industrial Sector



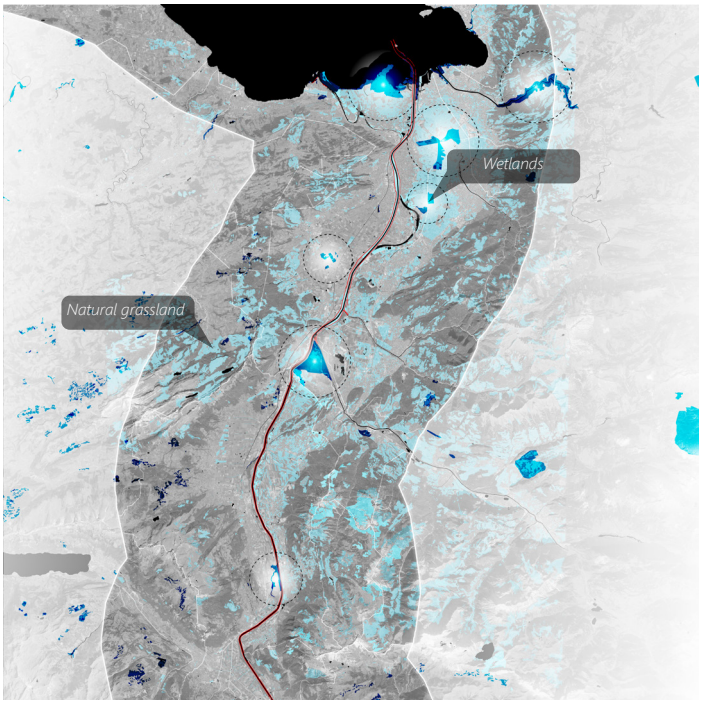
Transporation Sector



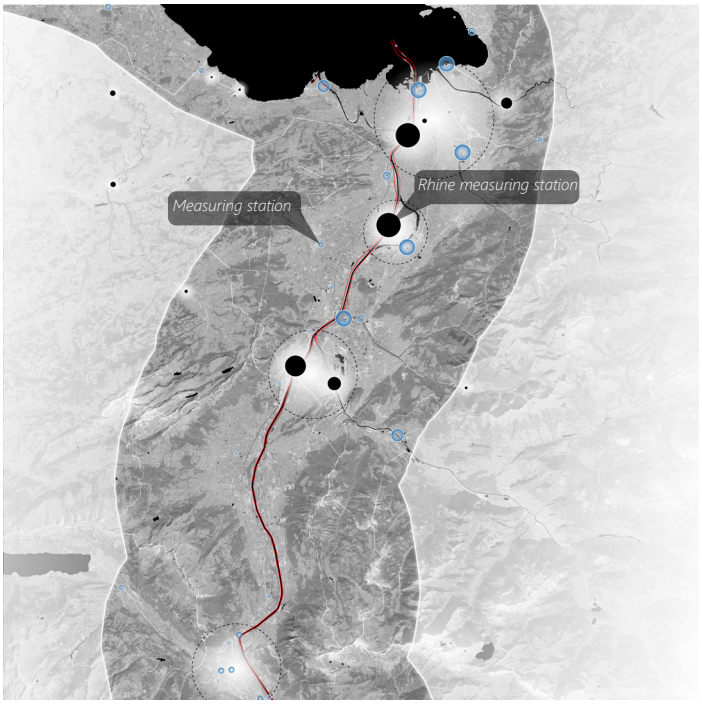
Urban development Sector



Nature and Ecology Organizations



Waterworks Sector



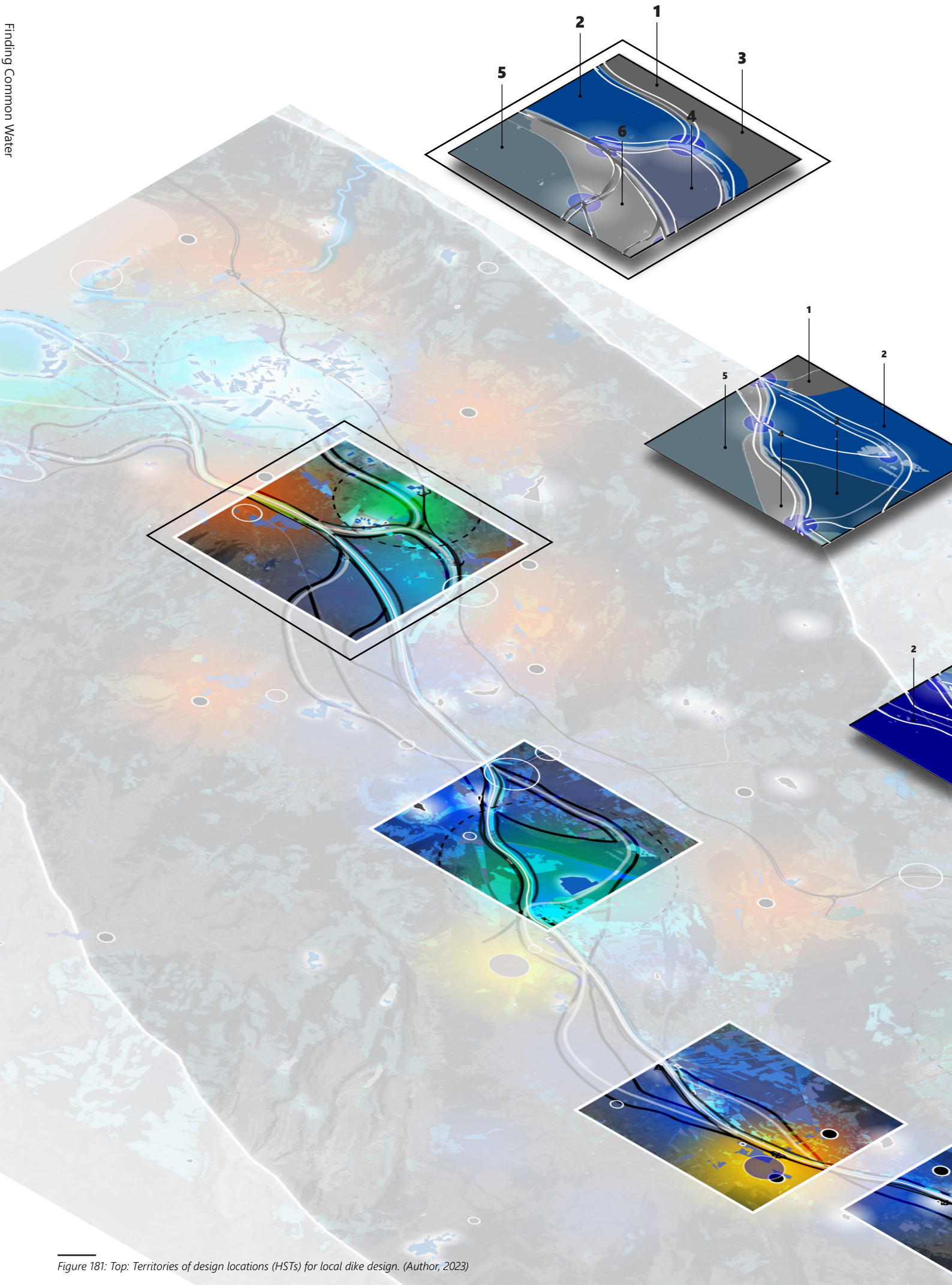


Figure 181: Top: Territories of design locations (HSTs) for local dike design. (Author, 2023)

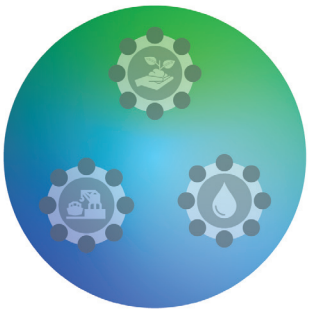
Figure 182: Bottom: Extent of mapped stakeholder interests. (Author, 2023)

5



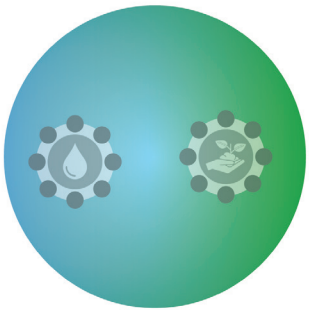
Territory of Transportation, Urban development, waterworks, industrial sectors and local residents

2



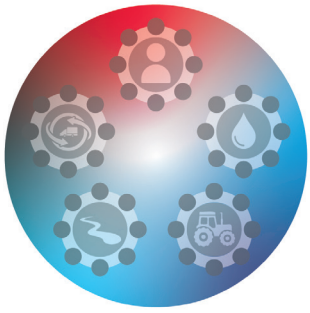
Territory Nature and Ecology, and Soil and Water Organizations with the Industrial sector

1



Territory based on Nature and Ecology, and Soil and Water Organizations

6



Territory of residents, Soil & Water organizations, agricultural, waterworks and transportation sectors

4

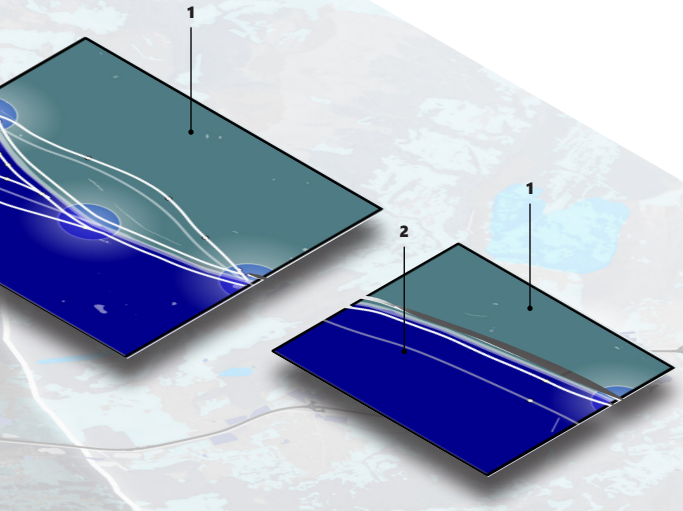


Terriotiry of Nature and Ecology Organizations with transportation, waterworks and agricultural sectors

3



Terriotory of Industrial, waterworks and Urban development sectors



Hydro-Social Territories

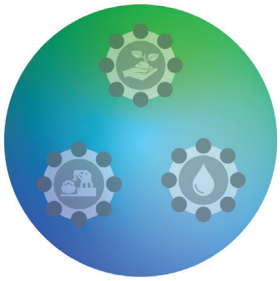
Based on the areas selected for further design steps due to the significant changes taking place, the major representatives of the nine stakeholder groups are linked to the defined Hydro-Social Territories. It is within these territories that the localization of dike management takes spatial form. Location A is highlighted to show the six new design locations that can be defined and which stakeholder groups are represented. We will further examine the interplay between Hydro-Social Territories 2 and 4 on the next pages.

Figure 183: Formation of stakeholder groups per defined HST for later dike design. (Author, 2023)

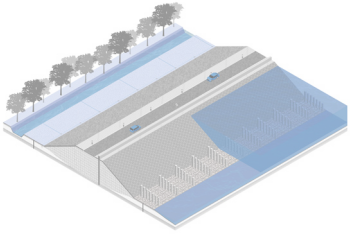
A New Meaning of Dikes

Based on the relationship scheme of the six new dike typologies and the allocated stakeholder groups, we can identify the most mutually accepted dike identities as introduced in Chapter X. The stakeholders from the nature, soil, and industrial sectors combined favor a combination of the natural dike and the distributive dike. The natural dike aligns with the interests of nature and soil organizations and can also serve the industrial sector for water storage and cleaning purposes.

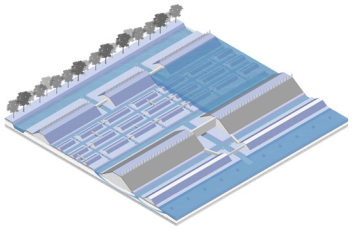
HST 2



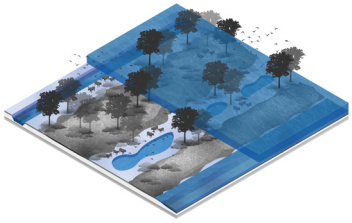
PRO **(16%)**

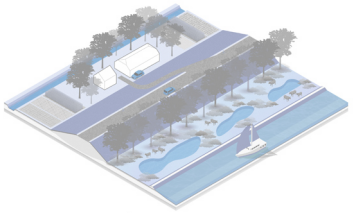


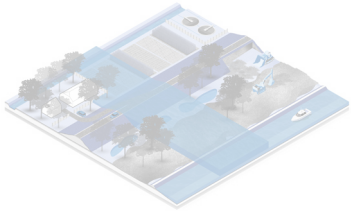
DIS **(19%)**



NAT **(25%)**







LAN **(15%)**

MUL **(11%)**

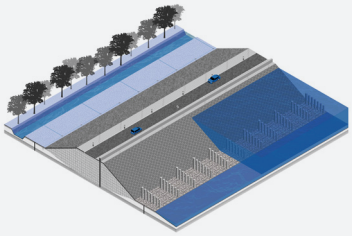
LOC **(13%)**

Based on the relationship scheme of HST 4, a different set of future dikes is mutually agreed upon. In addition to the higher representation of nature-focused stakeholder groups, the protective and landscape dike options also carry value. This is due to the introduction of the stakeholder groups of the agricultural and transport sectors that prefer protection of retention.

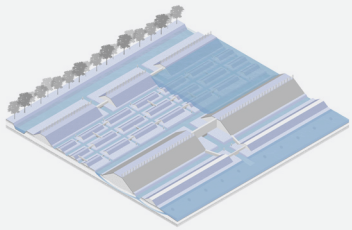
HST 4



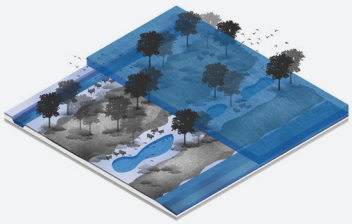
PRO **(21%)**

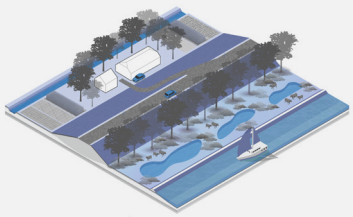


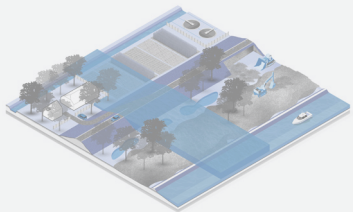
DIS **(15%)**



NAT **(21%)**







LAN **(19%)**

MUL **(10%)**

LOC **(15%)**

Figure 184: Relation scheme between stakeholder groups and the future dike identities. (Author, 2023)

Creation of a New Dike System

Now that the two design locations have defined their preferences, the next step of the creation of a new dike line can be considered. On the following pages, different scenarios are introduced based on the mutually selected dike typologies from the dike catalog. Using input from stakeholders, the dike identities, and the spatial options from the dike catalog, a representation is created of the dike typologies most commonly agreed upon by the HST. To introduce the various options for dike systems, three scenarios are presented on the next page.

Before introducing this step, let's look at the indicators of the impact assessment. As this report defines a complete freedom of interpretation per design location (HST), multiple dike systems can be created. While this enhances local autonomy, it also results in various impacts on the immediate surroundings. Therefore, it is crucial to understand the potential impacts created by the functionality of the dike, river flow, and the possibility of flooding and drought occurrences.

Impact assessment

When the design is adjusted to the context of the design location, the dynamics of the river, dike, and surroundings are impacted. These impacts can either be seen as positive or negative and are considered different according to the impact scale and the impact time scale. In this brief assessment, classifications are made as follows:

(1). *Dike functionality:* Indicates an impact based on the functionality and stability of a dike line.

(2). *River flow:* Indicates the impact that is created on the flow of the water according to speed, sedimentation, and high and low flow water levels.

(3). *Flooding & drought:* Indicates the impact that is created on the occurrences of flooding and drought.

Impact scale:
The impact scale indicates the area that is impacted by the change that has been made during the design process. The different scales used are:

(1). *Underground flows.*
(2). *Direct vicinity.*
(3). *Design location.*
(4). *River segment.*
(5). *Rhine River.*



The impact time indicates how fast a created impact is noticeable. The different times are defined based on the hydrological system. The scales used are:

(1). *Direct impact*
(2). *Monthly (short term)*
(3). *Seasonal (medium term)*
(4). *Multi-seasonal (long term)*

Impact time:

Figure 185: Legends of Impacts, Impact scale and Impact time. (Author, 2023)

13.4 Design Location

For the establishment of a spatial test case following the designated autonomy calculations, location A (see page X) has been selected. This location was chosen based on its extensive border between two adjacent design locations. The area between the two HSTs is characterized by the old meander of the Rhine, which was cut off during the Rhine reconstruction of 1862. Today, the area serves as a natural retention area, forming the border between Switzerland on the left and Austria on the right. Other interesting locations include the existing concrete factory on the Austrian side of the river, which often relies on river sediments for concrete production. Furthermore, residents of the cities of Diepoldsau (CH) and Lustenau (AT) view this region primarily as a recreational zone with a high level of biodiversity.

Scenarios

To understand the different dike possibilities that can be formed as part of the freedom of local dike design, a set of different scenarios has been created based on the mutual carrying capacity of the local stakeholders in different design locations. These scenario's consider:

(1). *Going for the Safe Option:* In this scenario, the most common dike typologies are collected and transformed into a new dike system.

(2). *Going for the Radical Option:* Here, the least common dike typologies are collected and transformed into a new dike system.

(3). *Going for the Moderate Option:* In this scenario, a moderate option is chosen between the radical and safe options to further explore the possibilities.



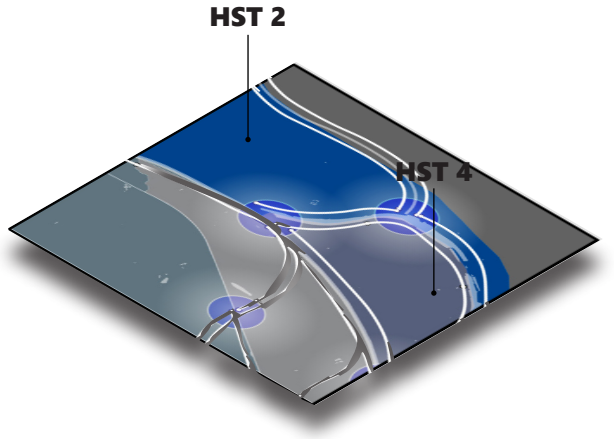
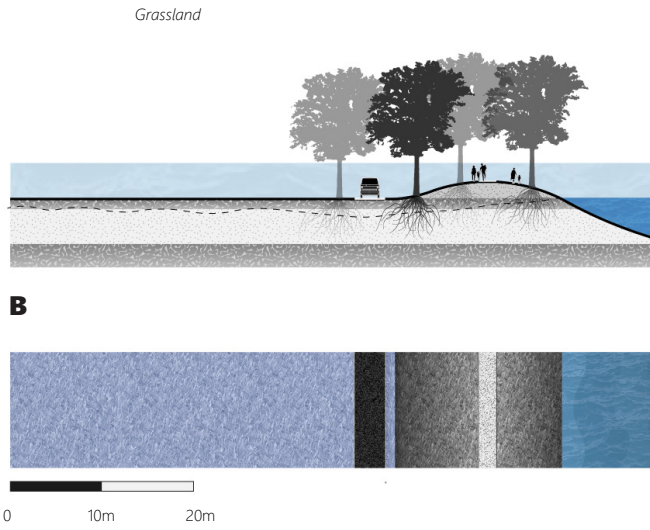
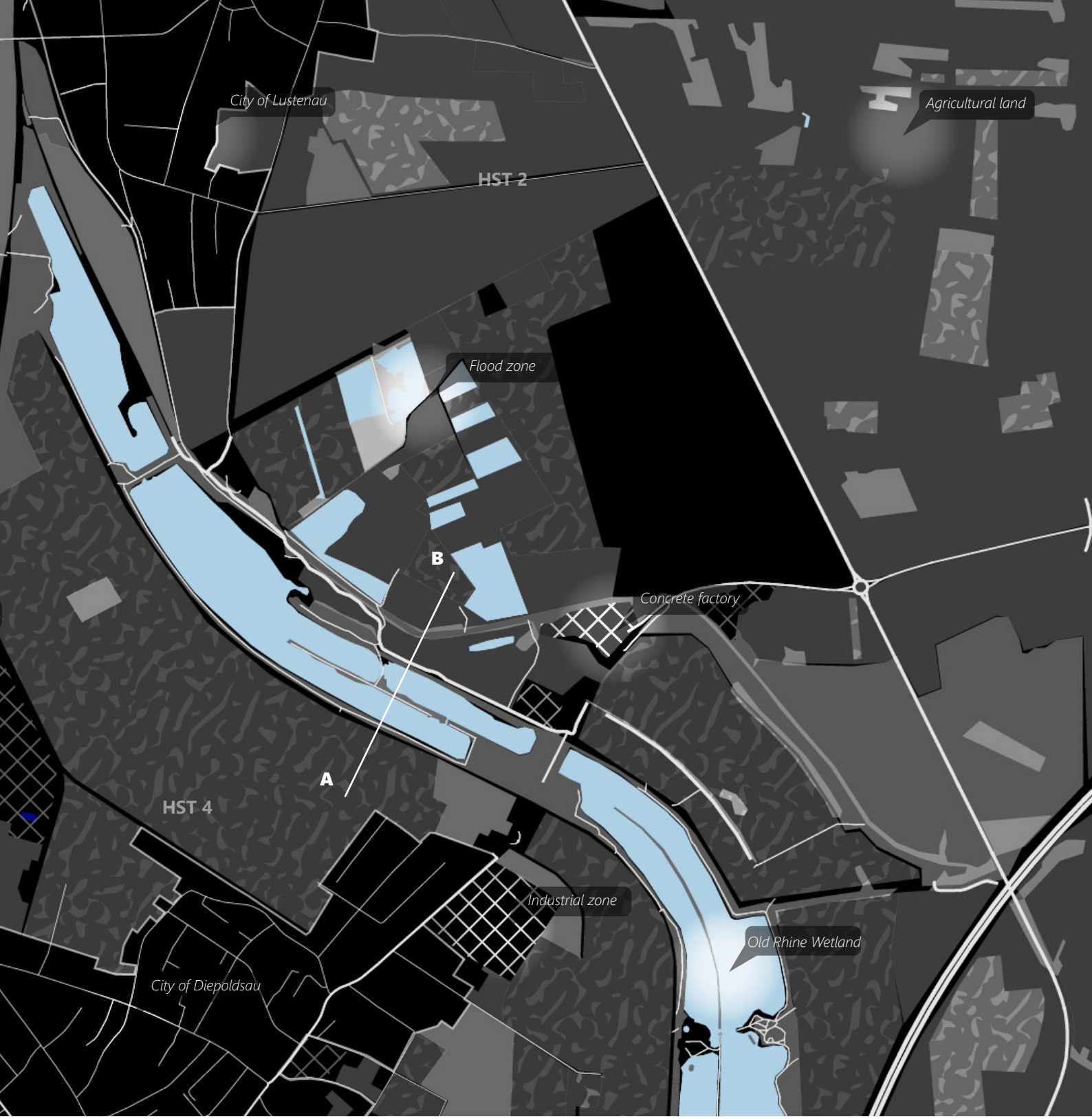


Figure 186: Border region of HSTs 2 & 4 of design location A. (Author, 2023)





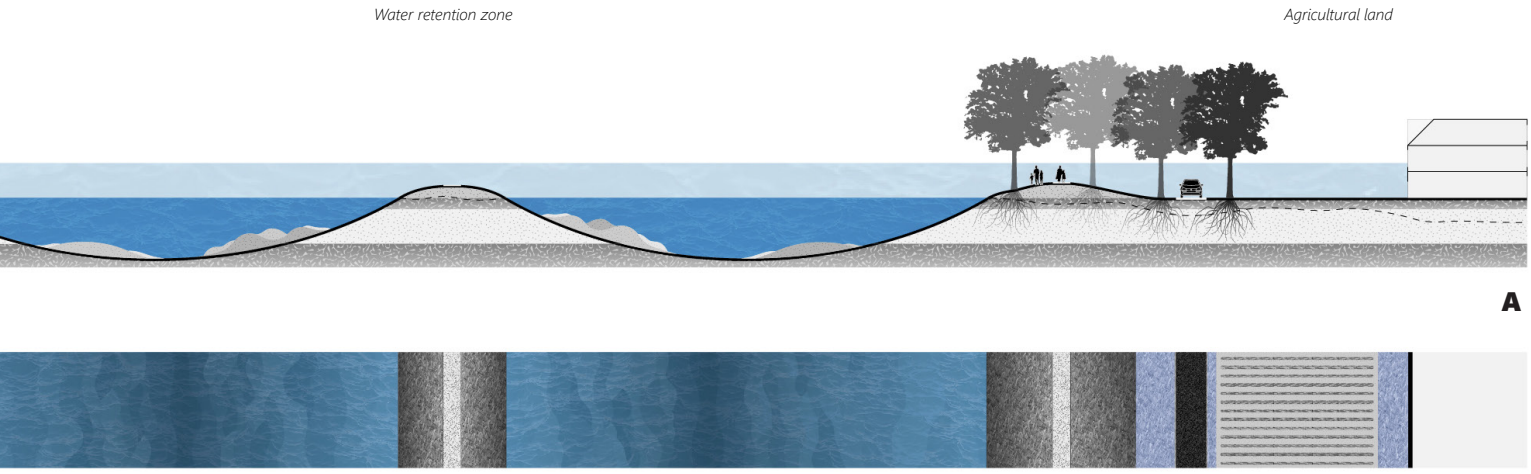


Figure 187: Area of design location A. (Author, 2023)

Figure 188: Existing section and top view of the border regions between HST 2 & 4. (Author, 2023)

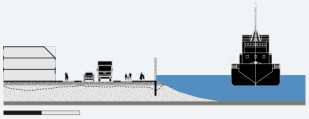
Going for the Safe Option

The first dike design is related to the spatial dikes that are most commonly agreed upon by the stakeholders. A new dike system is defined for HST 2 based on the commonly carried dike typologies in the dike database. Due to the significant industrial presence, a relatively more protective character has been chosen. Although not ideal for nature and water organizations, the choice of a floodwall (30%) in combination with a multifunctional dike (21%) highlights the interests of all stakeholders. The floodwall and bulkhead (22%) combination forms the protective core of the dike, while the rest of the large dike can be allocated to different uses, including the placement of trees on top of the dike line.

HST 2



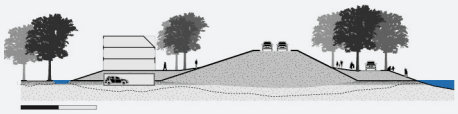
Floodwall **(30%)**



Bulkhead **(22%)**



Multifunctional dike **(21%)**



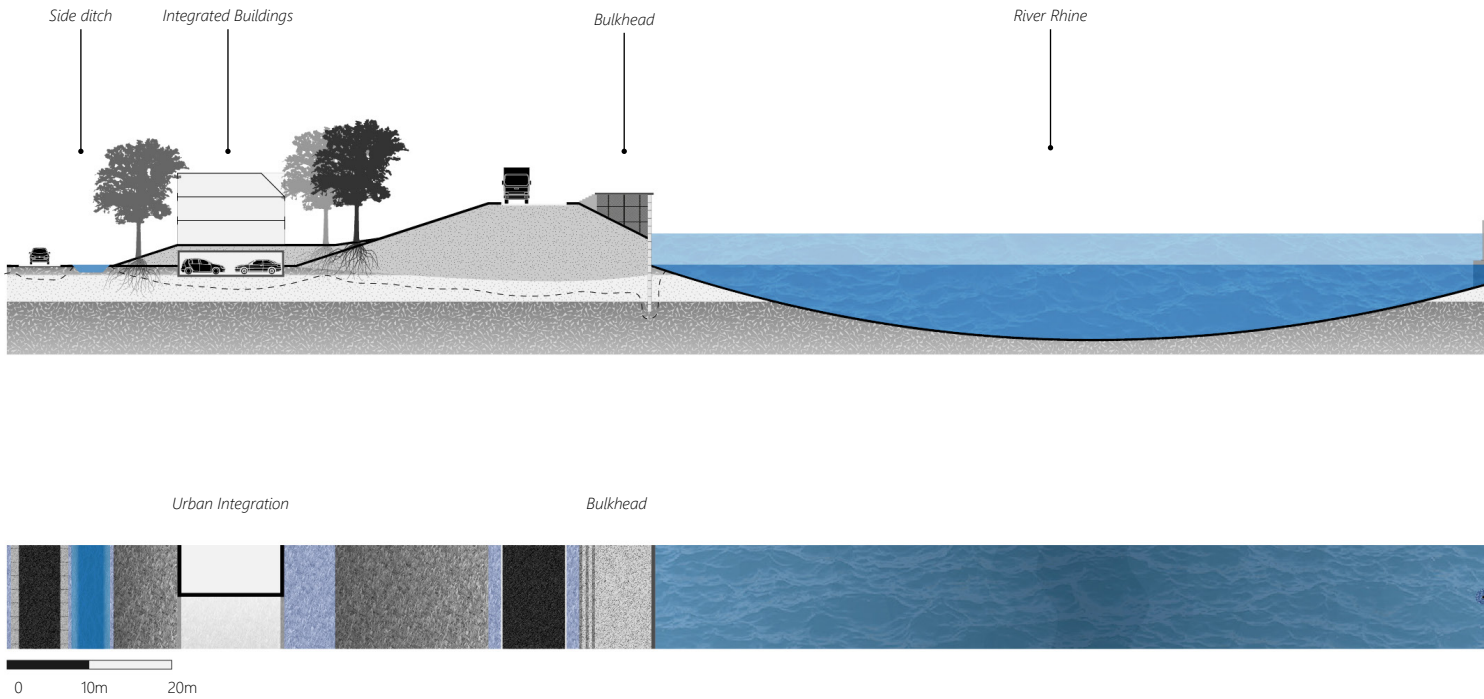
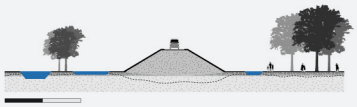


Figure 189: Relation scheme of scenario: "Going for the safe option" for HST 2. (Author, 2023)

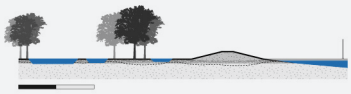
HST 4



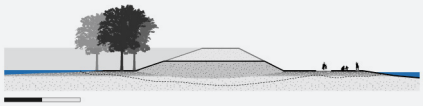
Leading dike **(22%)**



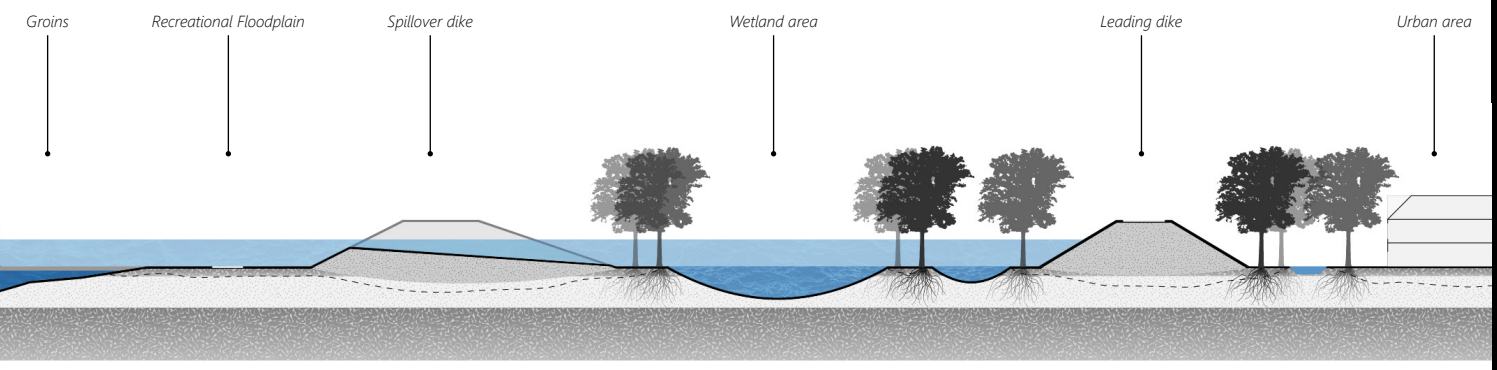
Summer dike **(31%)**



Spillover dike **(30%)**



For HST 4, the collection of dikes was primarily related to facilitating more space for water. Therefore, the dike system is divided into two main parts, divided by a water retention zone in between, which functions as an additional waterway during periods of high flow. Right beside the river, a spillover dike (30%) is placed, creating multiple openings within the dike line for water to be distributed during high flow, extending the infiltration zone of water within the area during drought periods. The integration of groins along the river stabilizes water flow during periods of low flow, preventing bottlenecks in the river flow. On the side closer to the urban areas of Diepoldsau, a leading dike (22%) is placed to protect the area during periods of extreme high flow.



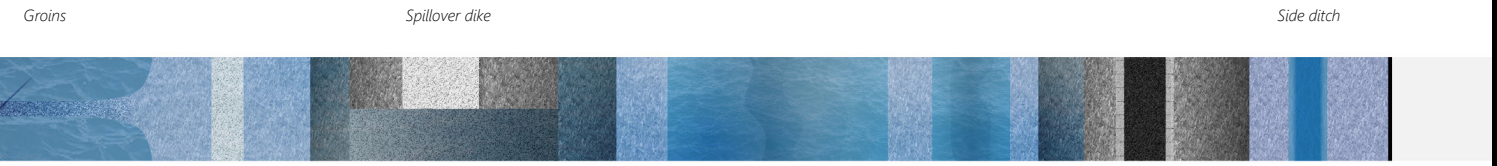


Figure 190: Relation scheme of scenario: "Going for the safe option" for HST 4. (Author, 2023)

Figure 191: Section & Top view of Multifunctional-Spillover dike system. (Author, 2023)

Going for the Safe Option

Impacts

Once the new dike system is placed in the context of the design location, the following new layout of the Rhine River can be created. In this scenario, the re-attached side arm of the Rhine follows the main course of the river. Although a new relationship is created between man and the river, it is vital to understand that changes in dike typologies and placement along the river have implications for the immediate surroundings. Impacts up and downstream are discussed to address the effects that are generated.

Downstream area

Although the integration of a spillover dike in the inner bend of the river enhances the size of the river in periods of high flow, due to the flow of the water near the floodwall of the multifunctional dike, an increase in water speed and flooding can be created. This can lead to the degradation of other dike lines downstream. On the contrary, in periods of low flow, the water can be distributed more efficiently downstream.

Upstream area

While the downstream area could experience increased flooding possibilities, the opposite can be observed in the upstream areas. Although the large flood zone of the wetlands increases the infiltration rate on location it also reduces water levels in upstream areas as there is more space available for the storage of water. This relieves upstream dikes from high water pressures, creating additional autonomy possibilities in those regions. Although flood risks are reduced if the spillover dikes are not adequately maintained, high sedimentation rates between high and low flow periods could lead to potential bottlenecks in the river flow. leading to increased flooding risks upstream.

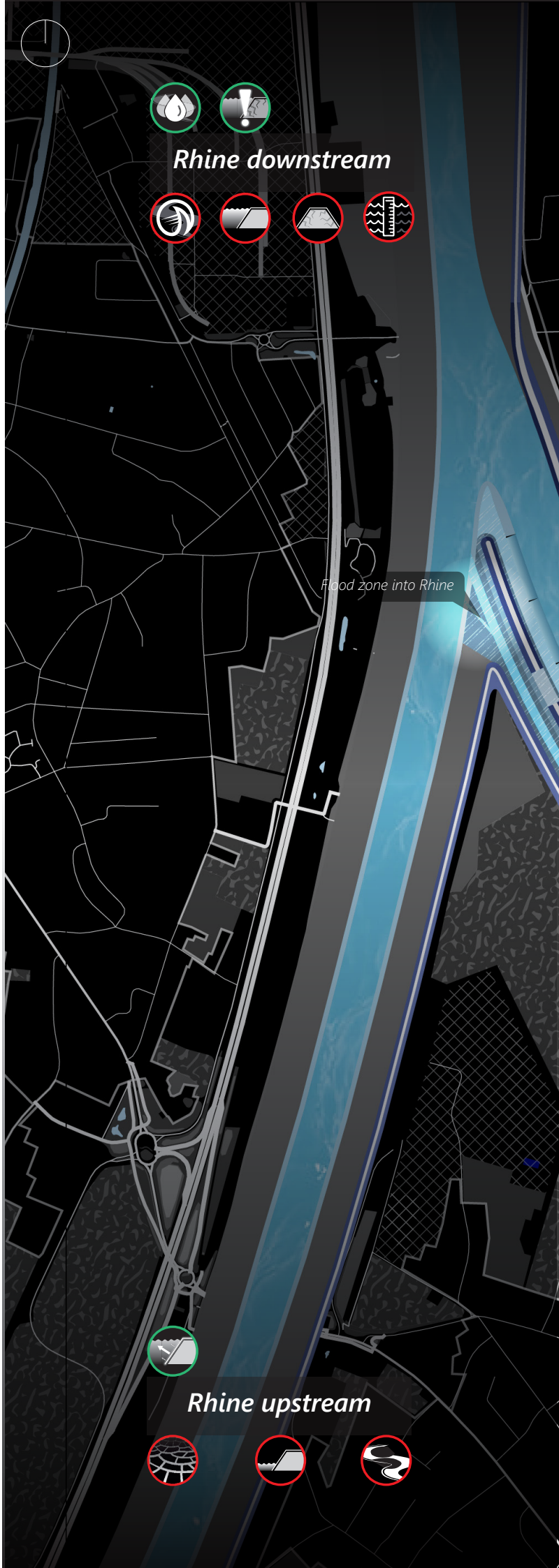


Figure 192: Placement and Impact assessment of new Multifunctional-Spillover dike system. (Author, 2023)


A
HST 2
Spillover dike
B
Multifuntional dike
A
HST 4
Leading dike
Groins
Wetland zone

Figure 193: Visualisation and Perspectives of the Multifunctional dike. (Author, 2023)

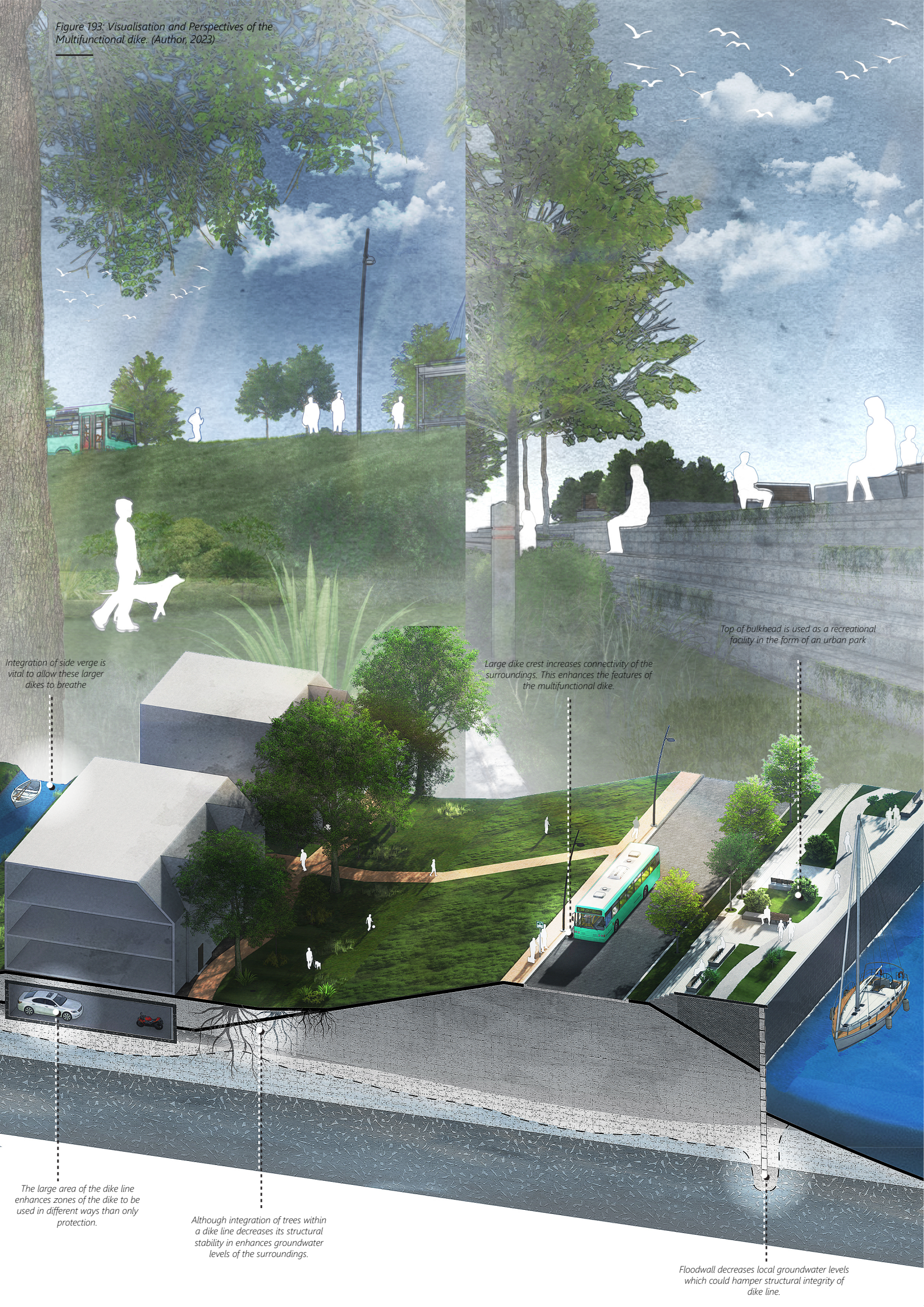


Figure 62: Impacts assessment of the Multifunctional dike. (Author, 2023)

Floodwall

The integration of a floodwall allows the immediate vicinity to be protected from the direct pressures of the river. The combined integration of a floodwall and a bulkhead not only provides a direct protective boundary against the river but also enhances additional urban activities, such as the creation of a riverside park, for example.

Multifunctional dike

The combined integration with the multifunctional dike enhances the urban activity of the dike system. Integrated housing, green spaces, and infrastructural connectivity allow the area to serve a broader purpose beyond being just a dike. This also increases potential infiltration rates and local monitoring of the dike lines, enhancing local autonomy.

Groundwater flows

Although the new dike system enhances urban activity, it's essential to pay attention to the structural integrity of the dike line and groundwater flows. The floodwall's large protective nature and the mass of earth placed by the new dike line can obstruct underground groundwater flows, potentially leading to increased drought risk during low-flow periods. Additionally, the added integration of greenery and underground structures may decrease the structural integrity of the dike line, requiring more intense maintenance and monitoring.

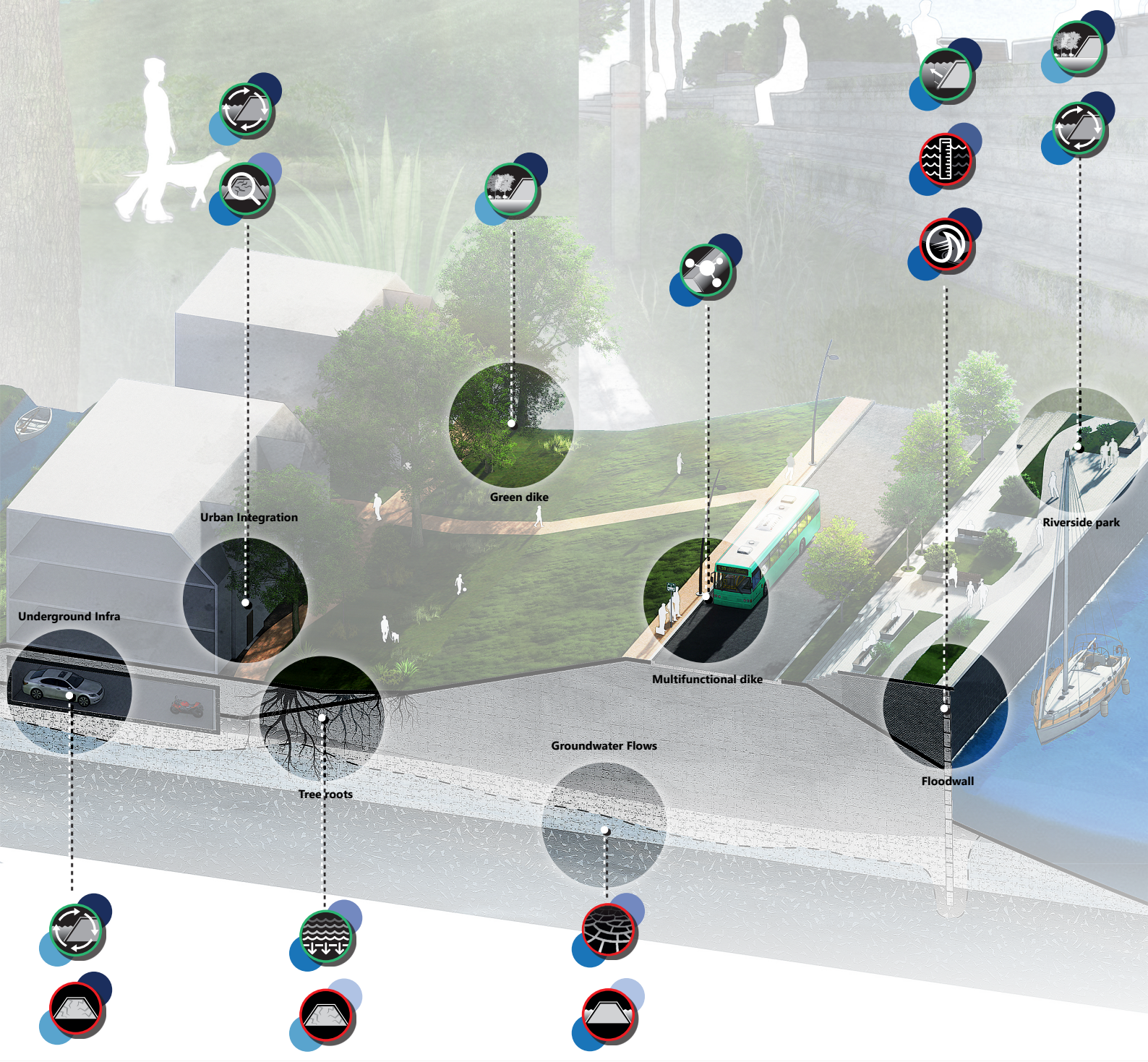


Figure 195: Impacts assessment of the Spillover dike. (Author, 2023)

Spillover dike

The placement of the spillover dike allows the direct dike to serve as a recreational zone, opening up the floodplain for recreational activities during periods of low flow. While this system promotes a higher degree of sedimentation and infiltration processes, the constant changes in water flow can undermine the structure of the dike line, affecting its functionality. Therefore, local maintenance is required. The ability to open the floodplain for grazing animals also allows for some small-scale maintenance.

Groundwater flows

The low protective function of the spillover dike increases the risk of more frequent flooding. Although this is considered 'controlled' flooding to enhance the infiltration rate, flooding of the groundwater levels could oversaturate the dike lines, leading to dike instability. This should be monitored every month.

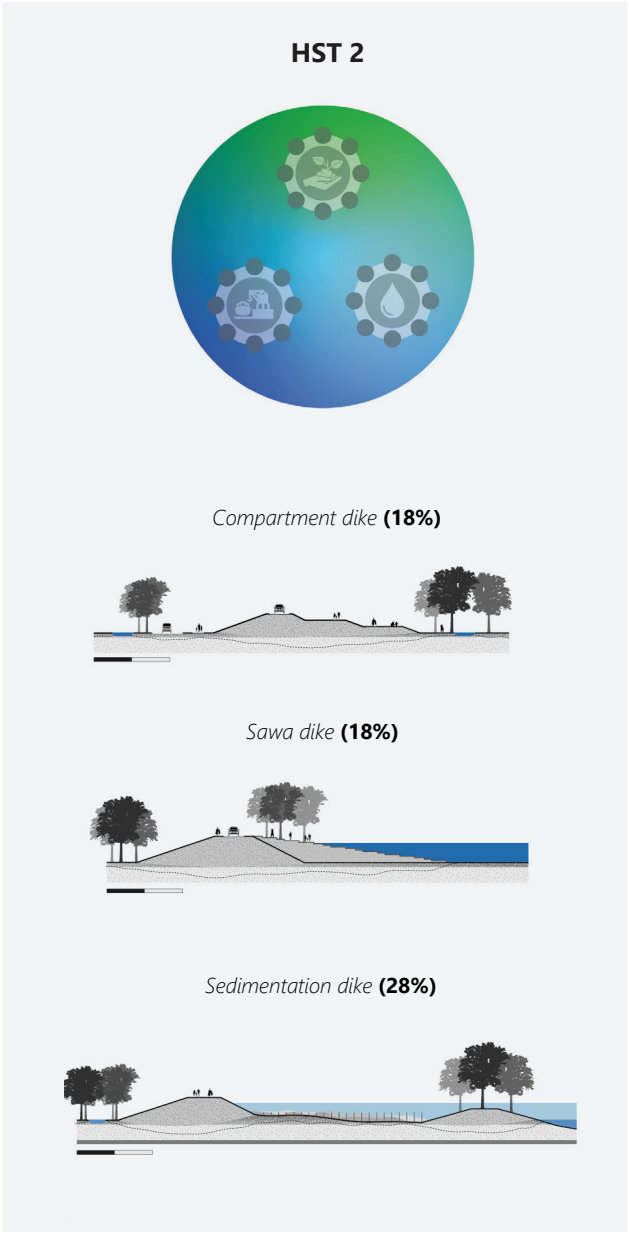




Figure 196: Visualisation and Perspectives of the Spillover dike. (Author, 2023)

Going for the Radical Option

For HST 2, the radical option creates an overall dike system that, although large in spatial scale, can be adapted to the preferences of available stakeholders. This demonstrates that although a radical option may not be directly mutually beneficial, it is worth exploring. The introduction of a sawa dike (18%) in the form of a compartment dike (18%) allows for the generation of an inverted sedimentation dike (28%). Although the water-retaining function of the new dike system lowers its protective character, it offers additional functions. Due to the spatial formation of the sawa dike, the existing recreational character of the area can be enhanced, leading to the creation of a new recreational zone along the river. This area is only considered flood-prone during high-flow periods, which requires local maintenance consideration. The placement of a sedimentation zone behind the sawa dike increases the area where sediment material deposited during high flow can be used for industrial and maintenance purposes. So, although safety regulations are not fully met, the localized character of the dike facilitates the character of the HST.



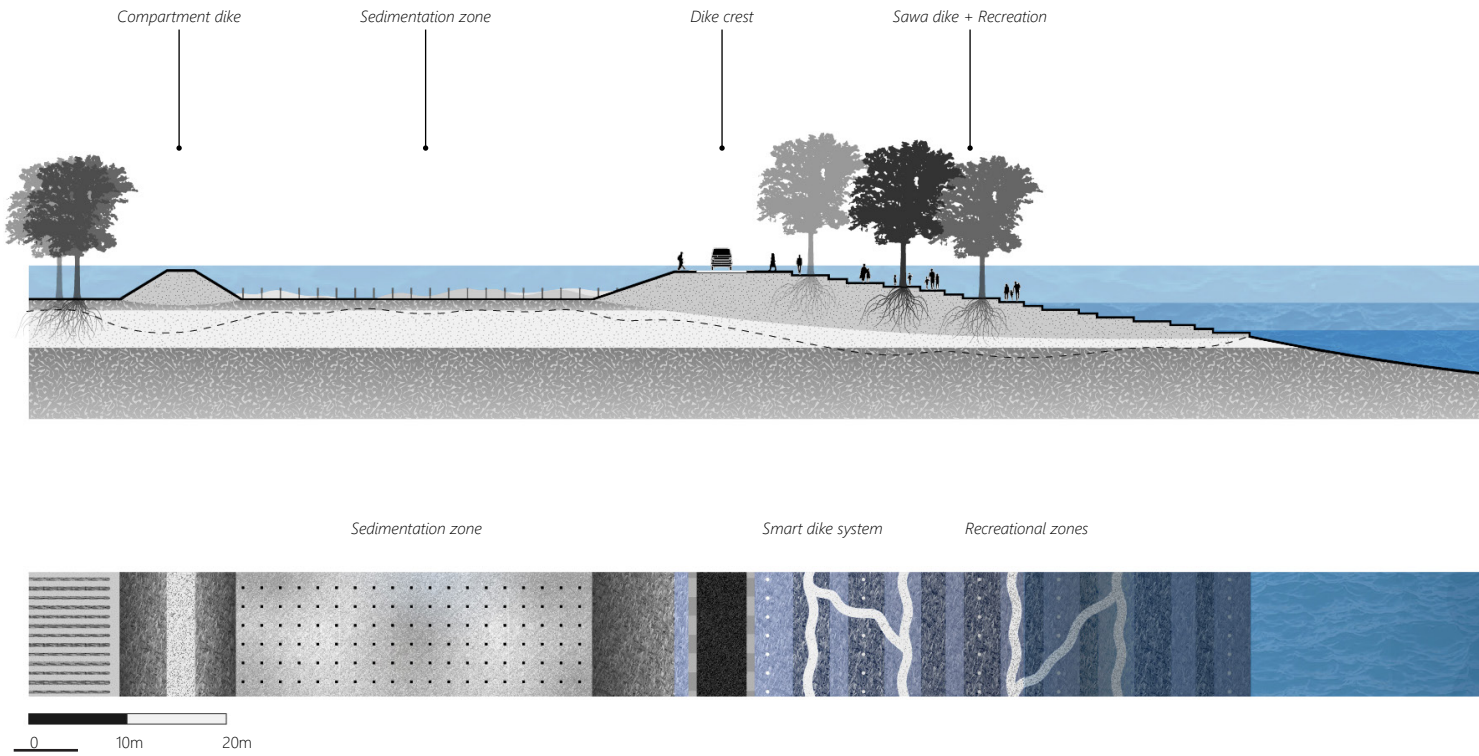
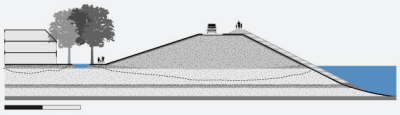


Figure 197: Relation scheme of scenario: "Going for the radical option" for HST 2. (Author, 2023)

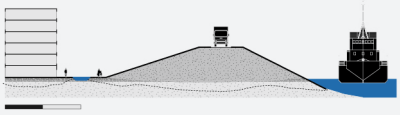
HST 4



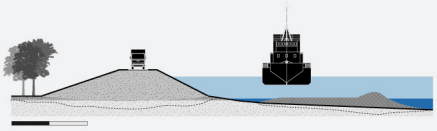
Revetment dike **(24%)**



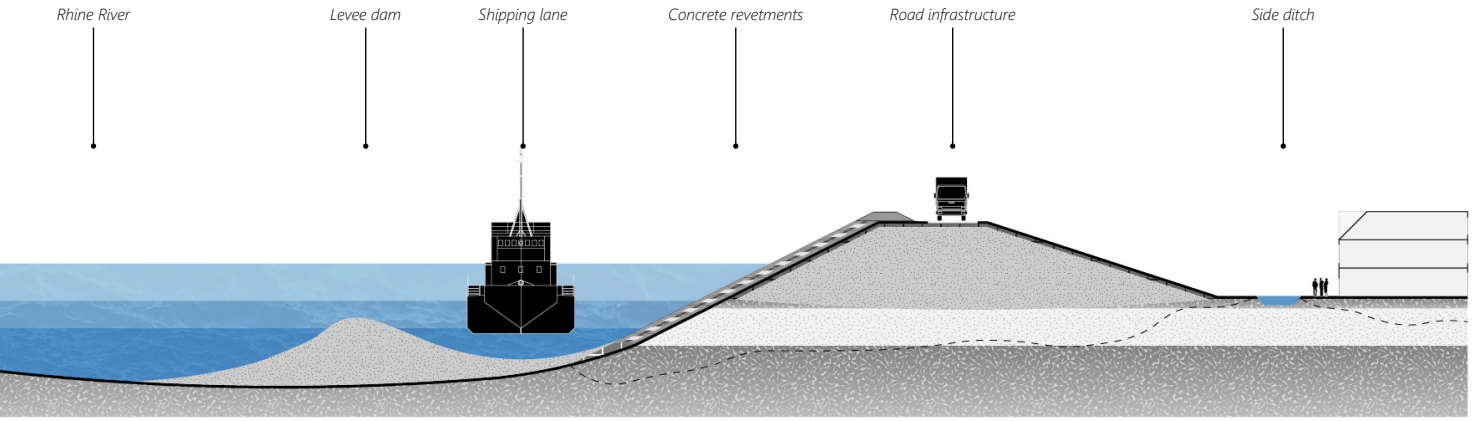
Shear dike **(19%)**



Levee dam **(22%)**



For HST 4, the radical option enhances the protective character of the dike. The introduction of a shear dike (19%) in combination with revetment (24%) reinforcements creates an impenetrable dike line. The addition of a levee dam in the river ensures efficient water distribution away from the river during medium and high-flow periods, creating a navigable waterway, which is beneficial for the transportation sector. This dike system primarily serves the protection needs of the stakeholders in HST 4. Although protection is guaranteed, no additional features are considered beneficial for the stakeholders. Furthermore, due to the high water-retaining function of the dike, maintenance should be allocated to civil engineering companies, as the technical knowledge needed cannot be facilitated by the existing HST stakeholders.



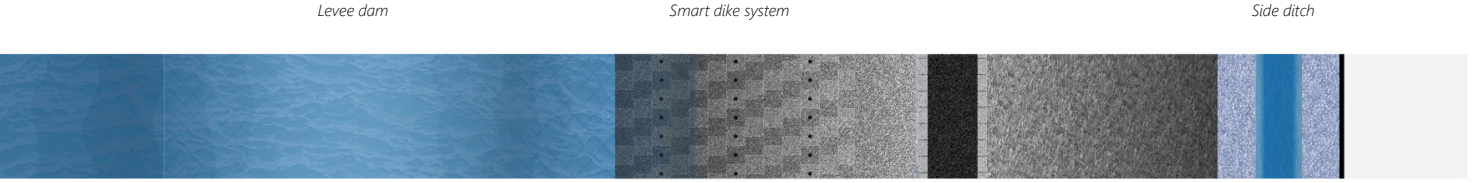


Figure 198: Relation scheme of scenario: "Going for the safe radical' for HST 4. (Author, 2023)

Figure 199: Section & Top view of Sawa-Revetment dike system. (Author, 2023)

Going for the Radical Option

Impacts

Once the new dike system is placed in the context of the design location, the following new layout of the Rhine River can be created. In this scenario, the re-attached side arm of the Rhine follows the main course of the river. The impacts up and downstream are discussed to address the effects that are generated.

Downstream area

The placement of a sawa dike in combination with a sedimentation dike allows water, during periods of high flow, to disperse throughout the immediate area. It's important to note the high risk of backland flooding. Downstream areas experience reduced water pressure during high flow periods due to the integration of the acute angle of the sawa dike, which stabilizes the river. While this reduces flood risk, more intense periods of low flow could lead to increased drought occurrences as the integration of the levee dam inside the river may block the river upstream.

Upstream area

As mentioned in the previous scenarios of 'Going for the safe option,' opposite impacts are created between the areas upstream and downstream. Here, the pressure from the high flow is reduced due to the sawa dike, relieving upstream dike lines from intense water pressures. The integration of a revetment dike and levee dam overall stabilizes the river flow and enhances the water level during periods of low flow. This is primarily caused by the river's blockage due to higher rates of sedimentation within the elevated riverbed of the levee dam.

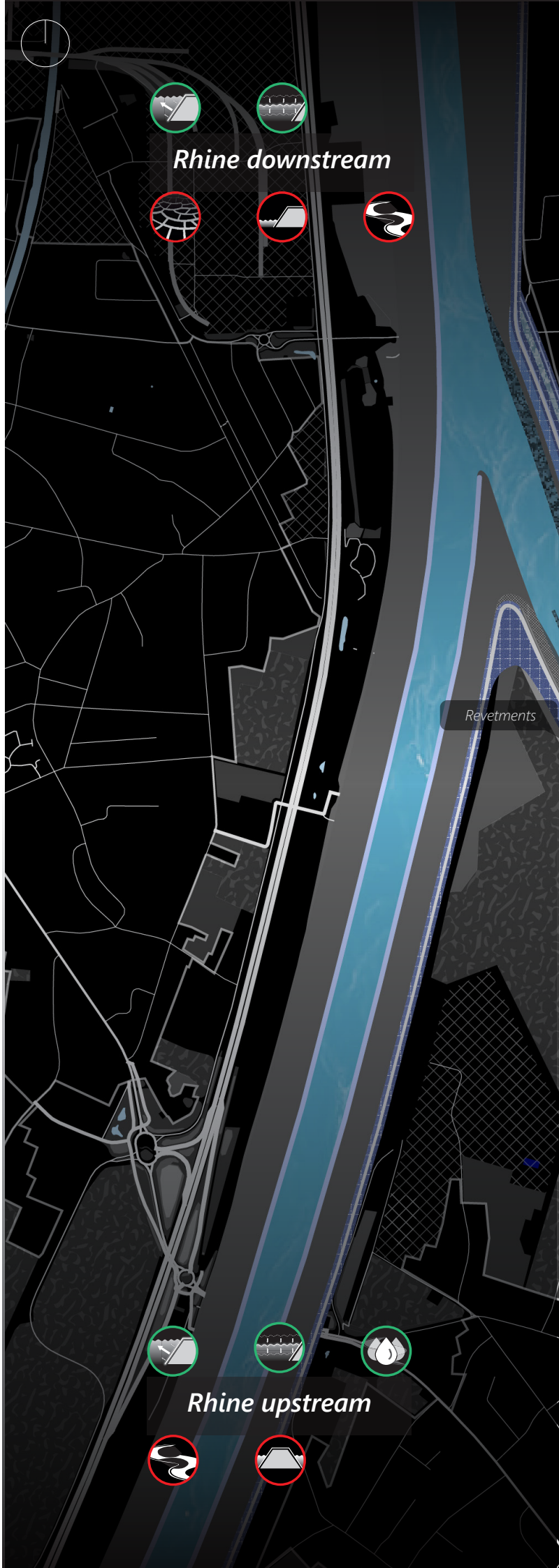


Figure 62: Placement and Impact assessment of new Sawa-Revetment dike system. (Author, 2023)


A
HST 2
Winter dike
B
Levee dam
Sawa dike
A
HST 4
Sedimentation zone
Revetment dike

Figure 201: Visualisation and Perspectives of the Sawa dike. (Author, 2023)



Figure 202: Impacts assessment of the Sawa dike. (Author, 2023)

Sawa dike

The acute slope angle of the sawa dike reduces the impact of the breakwater on the dike line and allows for additional sedimentation. In addition to providing space for recreational activities, green riverbanks, flora integration, and nature reserves, the placement of the sawa dike on the edge of the high-flow water level can serve as a controlled flood zone. This enhances sediment deposits for industrial maintenance and increases awareness of flood risks for local stakeholders.

Groundwater flows

Due to the large width but low elevation of the dike line, the groundwater table is integrated within the dike line. This allows the area to build up some resistance against intense drought occurrences in the future, although they should not be overlooked.

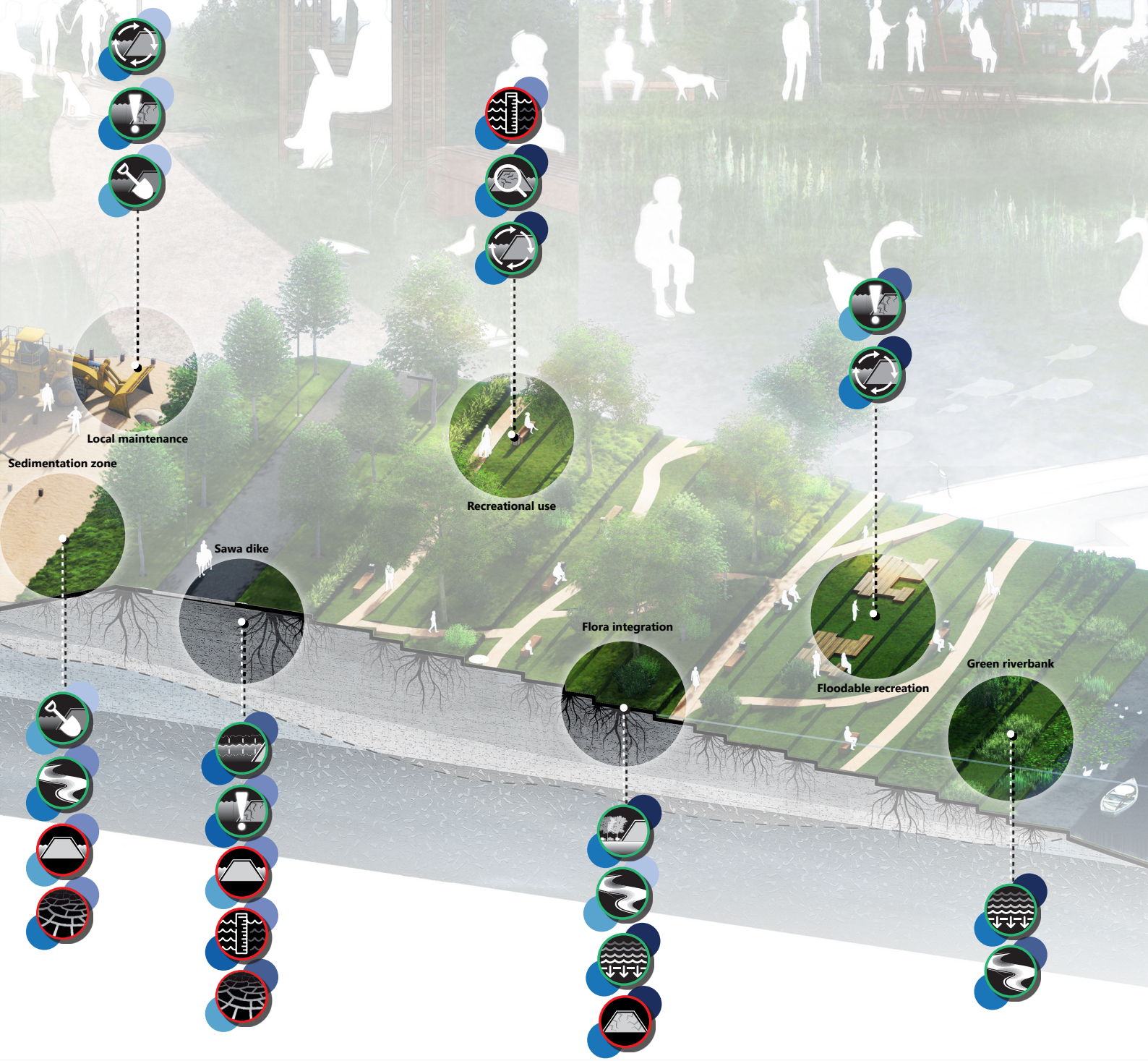


Figure 203: Impacts assessment of the Revetment dike. (Author, 2023)

Revetment dike

By placing a concrete revetment system, both the area behind the dike and the dike itself are protected from large floods. In addition to providing protection, the integration of the revetment system allows the placement of measuring systems within the revetment blocks. This enhances knowledge provision regarding the discharge rates of the river. The high protection rate along the river also allows the other dike slopes to be used by adjacent agricultural stakeholders. The presence of farm animals reduces the need for low maintenance of the dike.

Groundwater flows

Despite providing a high degree of protection on the outside, the dike is vulnerable from the inside. The use of large concrete materials increases the mass of the dike line, leading to a lowering of the groundwater level. Therefore, the integration of a side ditch for groundwater relief is vital. However, this also increases the risk of drought for the dike and the adjacent agricultural lands during periods of low flow. All of these factors increase the complexity of maintenance surrounding the overall dike line, potentially decreasing local autonomy.

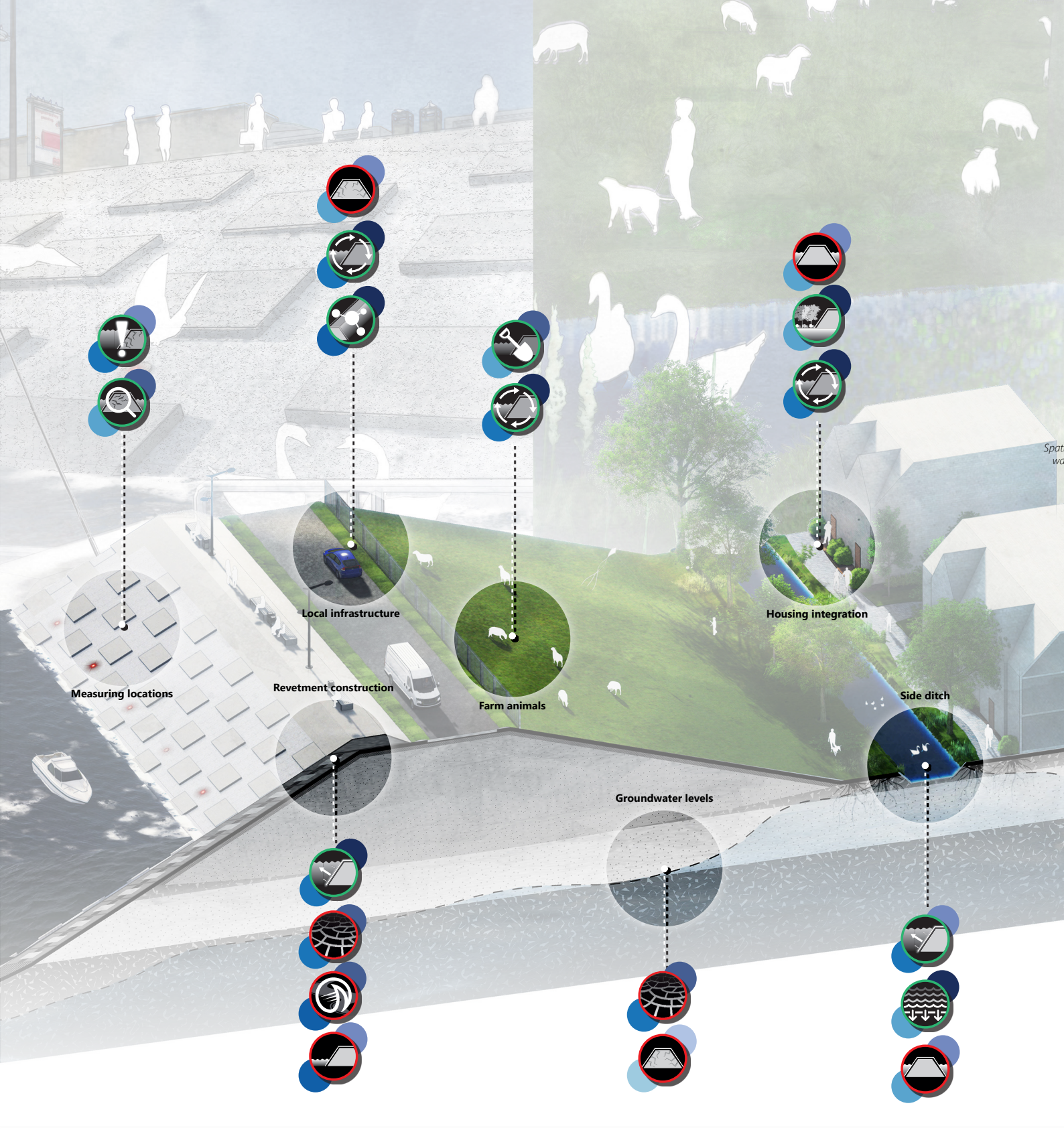
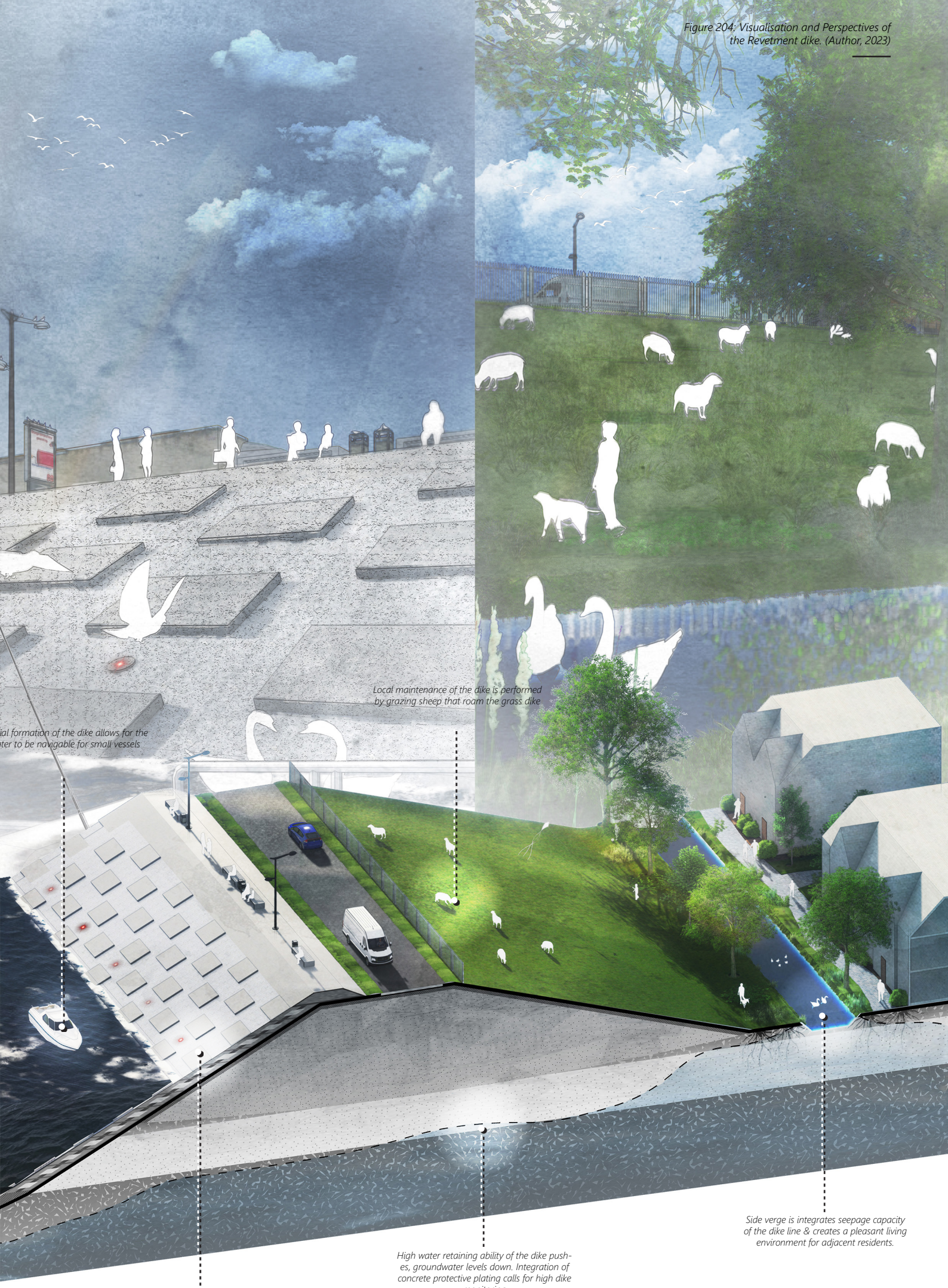
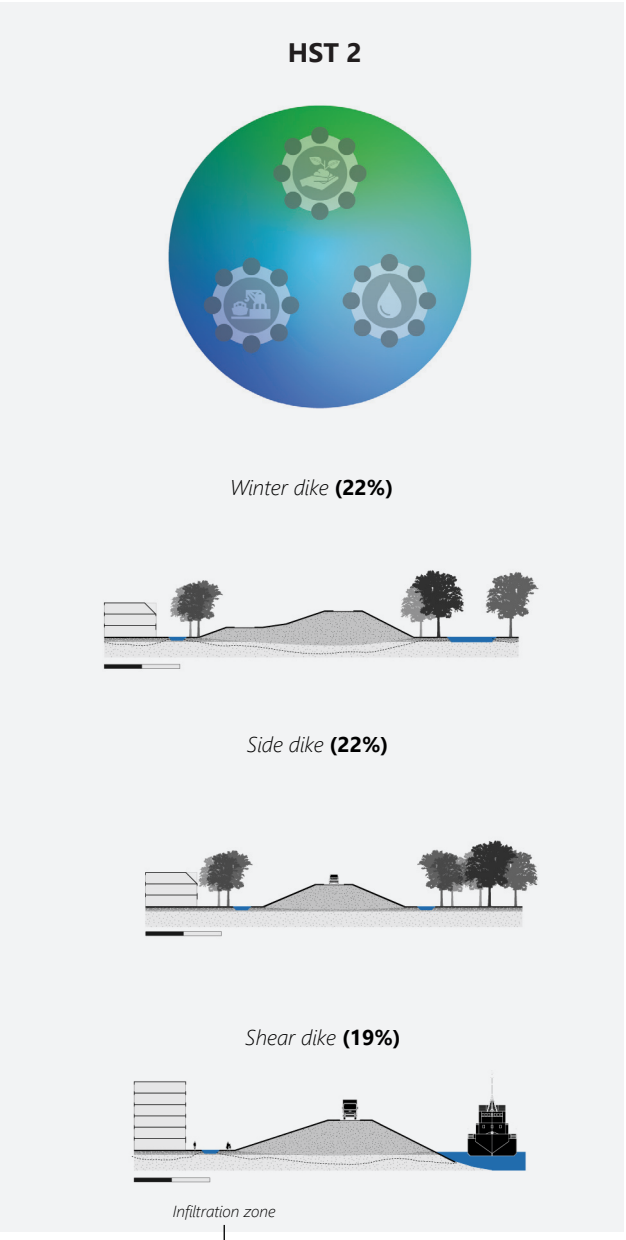


Figure 204: Visualisation and Perspectives of the Revetment dike. (Author, 2023)



Going for the Moderate Option

This dike line aims to enhance its water distributive character, viewing this river course again as a side arm of the Rhine rather than a new course. Based on several moderate preferences, it was chosen to create a new dike as a combination of the shear dike (19%) and the winter dike (22%) as the primary dike line, with a side dike placed in the river as part of a cistern-dike system. The new dike is directly placed along the river, emphasizing its water-distributive character. The choice of a winter dike was predominantly made for its flexible implementation, facilitating easier construction and maintenance. Additionally, the introduction of a cistern-dike system dividing the river into three waterways enhances localized water distribution between the two HSTs, maintaining local autonomy.



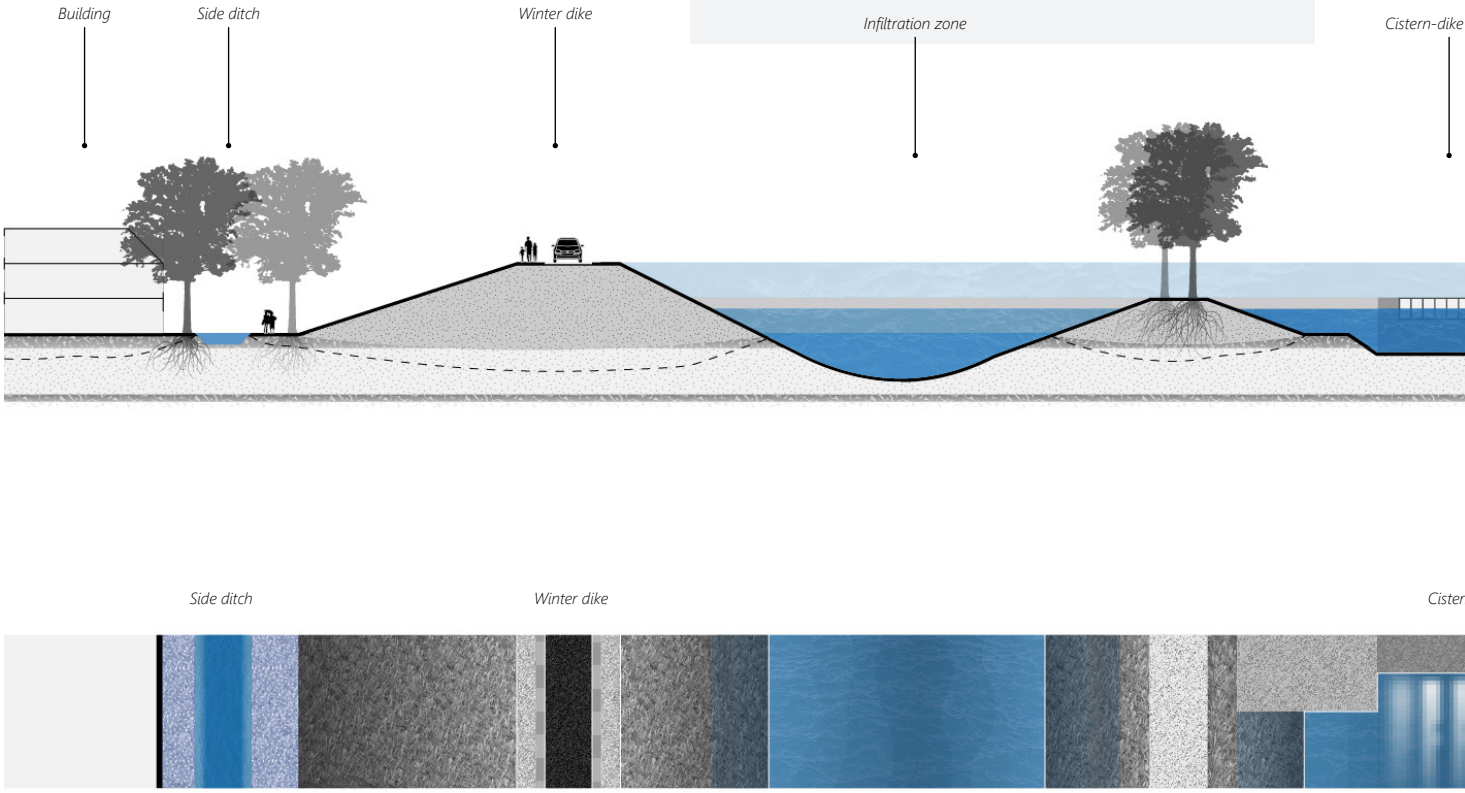
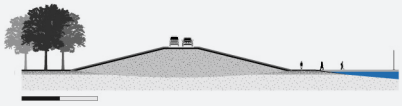


Figure 205: Relation scheme of scenario: "Going for the moderate option" for HST 2. (Author, 2023)

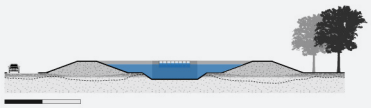
HST 4



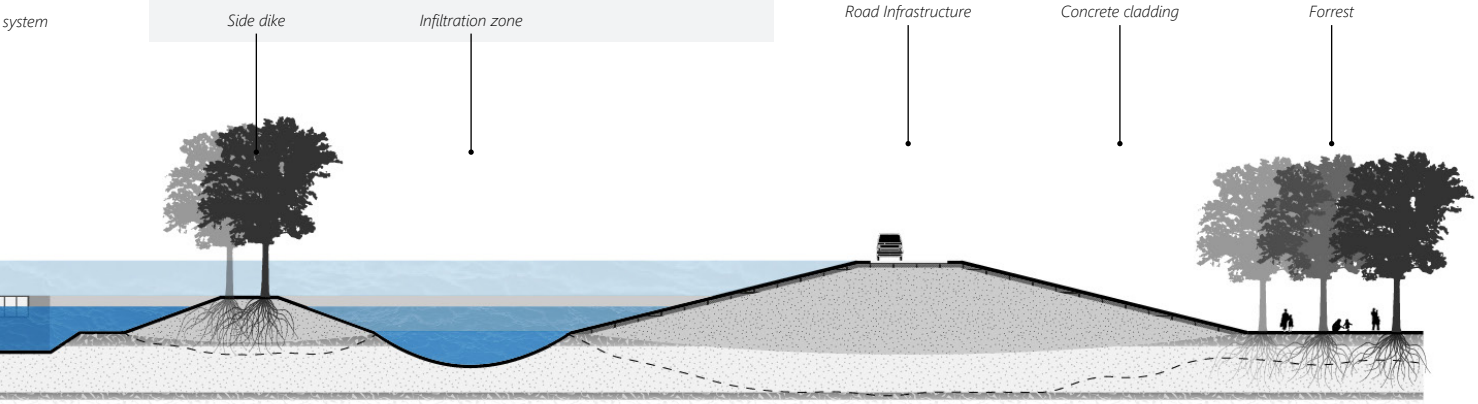
Delta dike **(29%)**



Cistern dike **(20%)**



For HST 4, the moderate option focuses on changing the character of the river to serve a distributive function. The placement of the cistern-dike system alters the layout of both HSTs. The cistern dike allows for the creation of three waterways, where the outer waterways function as small rivers, and the middle waterway allows for the distribution of varying amounts of water to the different areas upstream and downstream. Hence, the autonomy of this system is dedicated to controlling the intake and outflow of water. To establish this, greater importance is placed on the larger scale of the entire Alpine Rhine, as this region relies on water distribution from upstream, which can impact water flow downstream. Additionally, the placement of a delta dike reduces the need for local maintenance, as it ensures the protective character of the dike line remains effective for a longer period.



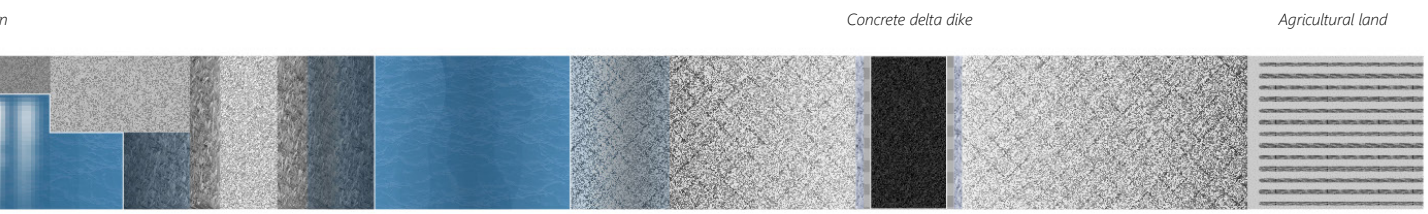


Figure 206: Relation scheme of scenario: "Going for the moderate option" for HST 4. (Author, 2023)

Figure 207: Section & Top view of Winter-Cistern-Delta dike system. (Author, 2023)

Going for the Moderate Option

Impacts

Once the new dike system is placed in the context of the design location, the following new layout of the Rhine River can be created. In this scenario, the existing character of the side arm is adopted. Although the two river segments are connected, the dike system is not directly related to the main course of the Rhine River. The impacts up and downstream are discussed to address the effects that are generated.

Downstream area

The distributive dike system of the cistern-dike allows local stakeholders to control and manage water intake. This reduces the risk of downstream flooding as it stabilizes the river, relieving downstream dikes from additional water pressure. However, it's worth noting that the new waterway doesn't follow the mainstream of the Rhine, and it could enhance drought occurrences downstream by potentially blocking more water from going downstream.

Upstream area

Despite serving as a secondary waterway for the Rhine River to distribute its water, the distributive nature of the dike increases the possibilities of flooding and drought upstream. During periods of high flow, the dike system could create bottlenecks in the water system, leading to higher water levels upstream. The same could be observed during periods of low flow when the distributive character of the dike could increase water intake, drawing water resources from upstream. Therefore, this system favors additional autonomy downstream but may create potential problems upstream. Effective communication of water intake, storage, and outflow is necessary between the cistern-dike area and the areas upstream and downstream.

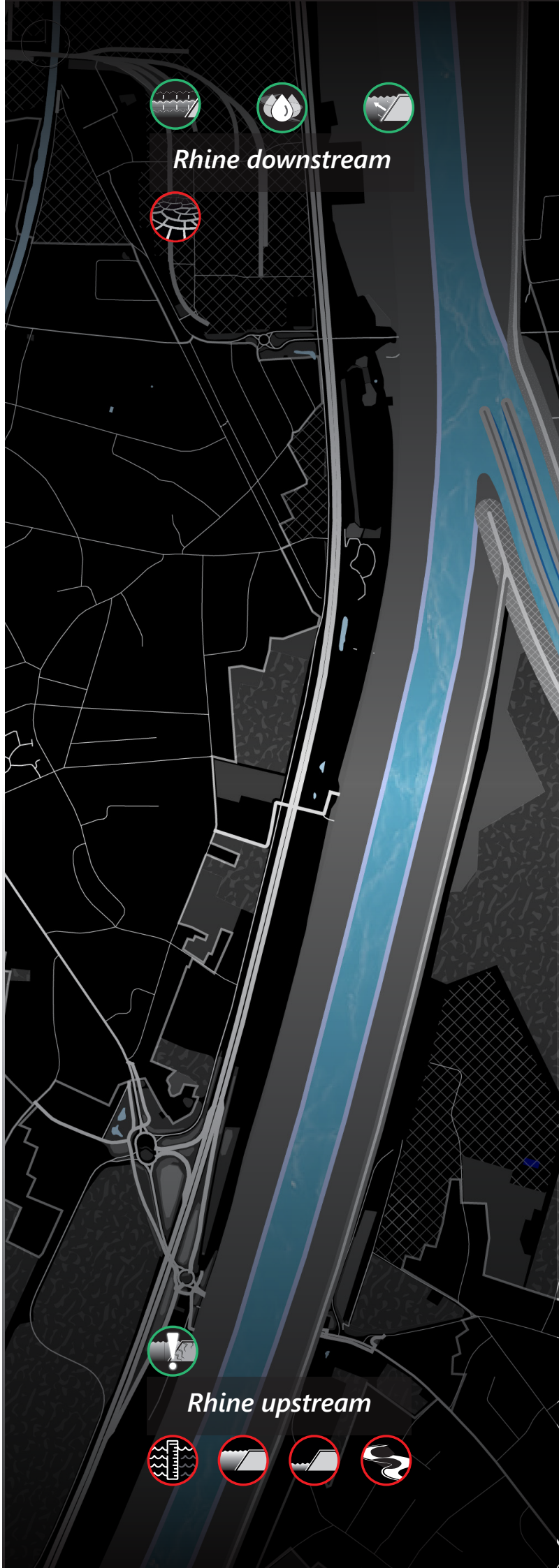


Figure 208: Placement and Impact assessment of new Winter-Cistern-Delta dike system. (Author, 2023)


A
HST 2
Winter dike
Cistern
B
Canal
Local side cisterns
A
HST 4
Floodable floodzones
Delta dike

Figure 209: Visualisation and Perspectives of the Cistern dike. (Author, 2023)

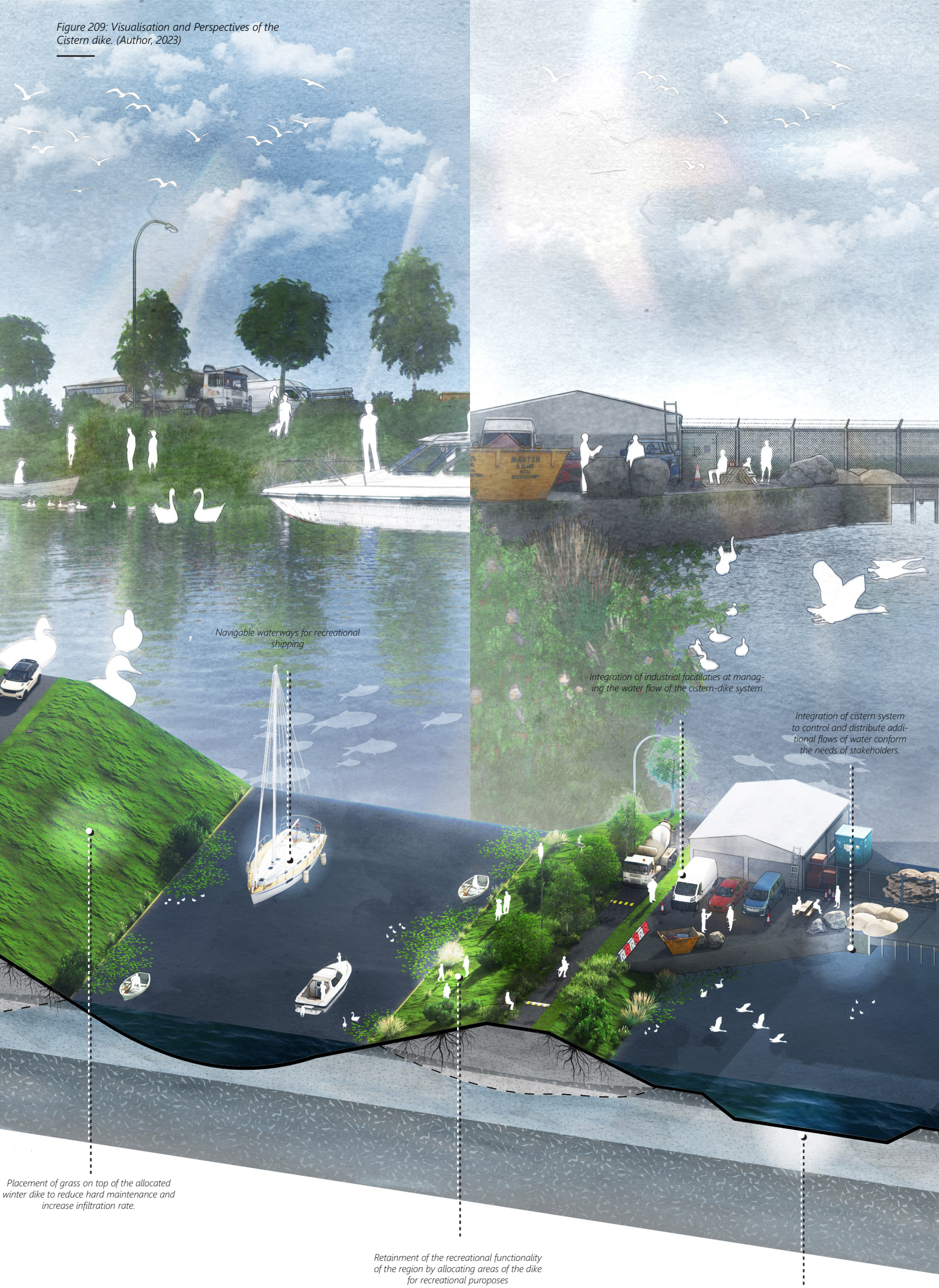


Figure 210: Impacts assessment of the Cistern dike. (Author, 2023)

Cistern system

The integration of the cistern-dike system allows direct stakeholders to control the intake and outflow of water. This increases local responsibility for monitoring and using the water as a source for agricultural, industrial, and natural activities. On the other side of the cistern, a more natural area could be created, allowing groundwater flows between the water channels to form an integrated water system.

Secondary waterway

The integration of a secondary waterway allows available water resources to not be fully controlled by local stakeholders, reducing risks for areas upstream and downstream. Additionally, during periods of high flow, these areas can be used as navigable waterways for pleasure cruising. However, it should be noted that during periods of low flow, the area is at high risk of experiencing heavy sedimentation rates and drought.



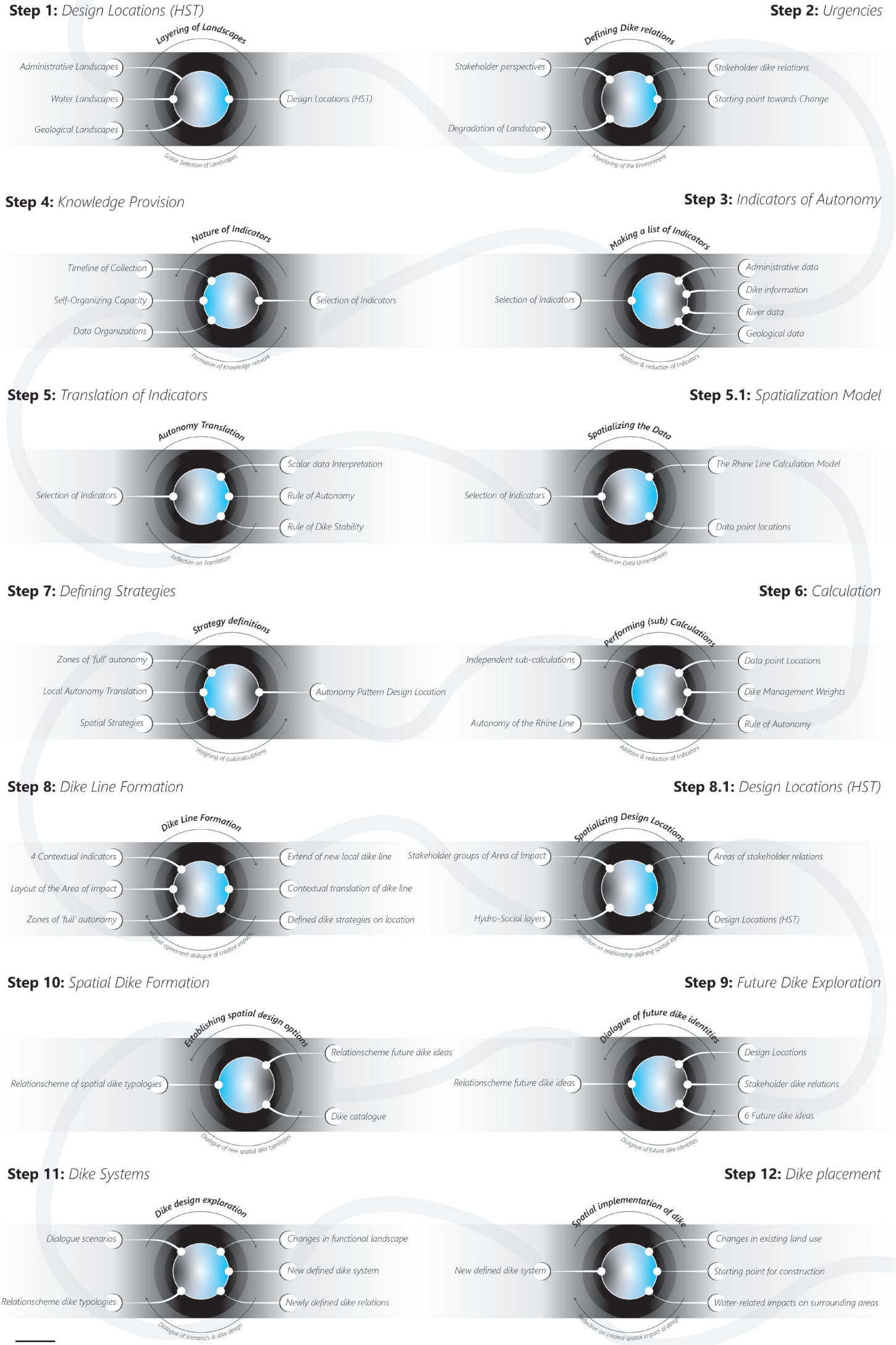


Figure 211: Roadmap steps toward local dike autonomy. (Author, 2023)

14

To Conclude

14.1 Conclusion

Introduction of the project
Methods of the project
Introduction of the Research Question
Creation of the Hydro-Social Territory through Active Subsidiarity
The Indicators of Autonomy
Freedom of Dikes
Limitations
Future research recommendations

14.2 Reflection

Contextual yet Transferable
Methods & Design
Freedom Arising from the Initiation of Change toward Local Autonomy
Relation between Technical & Social Sciences
Relations between Stakeholders and Dikes

14.1

Conclusion

Introduction of the project

This project focused on designing a roadmap towards local dike autonomy, with the primary aim of empowering local stakeholders to initiate change. Given the high vulnerabilities of water in the face of climate change, it is essential to redefine the relationship between the Rhine River and human and natural systems, creating an adaptive river landscape. Building upon the freedom provided by the active subsidiarity principle, this project explored the possibilities and information required for local stakeholders to reshape their relationship with the river, using the spatial element of the 'dike' to make this relationship spatially explicit.

Methods of the project

The project primarily involved an in-depth analysis of data indicators needed to understand the autonomy of existing decision-making systems and dike management. To establish a framework for autonomy within the decision-making process of local stakeholders, the importance of knowledge was highlighted. Thus, the project focused on presenting the necessary information about soil, river dynamics, dike infrastructure, water usage, and the self-organizing capacity of stakeholders. Through quantitative analysis involving translation, weighting, and calculation of these indicators, the degree of autonomy was spatially determined in a newly defined spatial translation model of the Rhine Line.

Introduction of the Research Question

Based on the approach provided in the previous paragraph, the central research question was formulated: "How can Active Subsidiarity empower localized dike management, raising awareness of climate uncertainties regarding the Rhine River?" This question was addressed through a series of sub-research questions, each focusing on a critical step within the roadmap toward local dike autonomy.

The project takes a highly technical approach to explore whether localized dike management is feasible. This approach involves not only quantitative research methods but also provides insight into the practical implementation of strategies and designs based on the existing expertise of stakeholders on location. The project has developed a detailed implementation method that considers geological, hydrological, and administrative characteristics specific to

each location.

Creation of the Hydro-Social Territory through Active Subsidiarity

The theoretical framework adopted in this project was based on studies in adaptive governance, territorial governance, and the subsidiarity principle. The project was inspired by the concept of Moodie et al. (2022) which emphasized the need to establish territorial boundaries within the system of Active Subsidiarity to facilitate change where it is needed. This led to the introduction of the theory of the Hydro-Social Territory by Boelens et al. (2012). By spatializing the mutual relationship between people and the river based on geological, hydrological, and human landscape layers, territorial configurations were established, creating the spatial context necessary for implementing active subsidiarity.

Drawing upon the ongoing struggle between soft planning and territorial governance, the project utilized examples from the Room of the River program to illustrate how local stakeholders can be involved in the decision-making process at the local scale. Therefore, the strategies proposed in this report were designed to be easily interpreted, ensuring that design locations had the freedom to establish their new dike line.

Additionally, to grant local stakeholders the utmost freedom throughout the entire process, from defining their starting point to designing a new dike line, knowledge sharing was considered critically important. The gathering of information revealed that the wide array of data needed was often overwhelming for local stakeholders. Building upon the principles of integrated water management provided by Akamani (2016) and Rietveld et al. (2013), the project advocated the creation of a knowledge network where local stakeholders could gather, share, and generate information to support Active Subsidiarity. That is why the entire spatial calculation model was centered along the Rhine rather than focusing on a particular location.

The Indicators of Autonomy

In the human-controlled environment of the Rhine River, changes in one area can have impacts elsewhere. Similarly, when considering the potential for local dike autonomy, the process must encompass the entire territory in a manner likewise to dike management, given its focus on long stretches of land. This approach aligns with the technical nature of the question at hand. Consequently, a selection of indicators was formulated, drawing from the four main layers of the landscape of dike management: Dikes, The River, The Soil, and The Administration, to establish the foundation for local autonomy. Each of these sub-calculation groups is designed to focus on specific indicators required for constructing a dike line that is suitable for localized management. These indicators highlight the spatial aspects that enable local autonomy while emphasizing the reduced importance of certain technical characteristics of the dike.

(1). *The Dikes of the Rhine*
The first sub-calculation was dedicated to the existing dikes of the Rhine. Research, based on the spatial and managerial characteristics of the dike has indicated the possibility of certain dike typologies not dedicated to protective functionalities, could be locally managed. Although the technical characteristics of a dike are primarily used as the indications of the dike's functionality, giving more importance to the spatial characteristics of the dike, facilitates a new meaning of the dike proposed in this report. To re-establish the bond between man and the river, the technical characteristics of the dike should be understood, but should not weigh higher than other spatial characteristics. Therefore the meaning of the dike as a transitional space becomes more viable making local autonomy more feasible.

(2). *The River*
As the Rhine River is considered to be one of the most controlled river bodies in the world, the establishment of local autonomy is unlikely. Therefore the revitalization of the river

as a natural system has to be undertaken. By weighing the potential of the sedimentation process and the change in discharge rate, viable locations for dike construction that are compatible with the river system can be selected. Therefore, locations that are less vulnerable to degradation of the dikes, have a higher potential of local autonomy. As the increasing uncertainties of flooding and drought projections place pressure on the resources that the river brings, facilitating the dike as a transitional element regenerates the natural formation of the river.

(3). *The Suitability*
One of the key features of local autonomy is to be able to provide a dike that does not need constant maintenance and restructuring. Therefore the underlying conditions form an important part. Based on the suitability indicators that were researched in this report, the areas where the dike line can be seamlessly integrated with the existing water system became a crucial consideration in assessing suitability conditions. By acknowledging the revitalization of the natural river system, an enhancement can be made where the dike becomes an extension of the geological processes rather than a boundary within the landscape.

(4). *The Administration*
While looking at the possibilities for localized autonomy, it is important to understand the current management schemes and relations that allow local decision-making to gain a foothold. The main conclusion taken from the translation of the indicators used in this sub-calculation is that the higher the impact that can be created when a change is initiated within dike management, the lower the possibilities for local autonomy. Therefore often areas with a combination of open land and needed knowledge and financial resources, form an ideal location for local autonomy.

All of the indicators used in the report can be translated into what they mean for dike management and how they impact localized autonomy. This is facilitated through the notion that although the technical applications are important to determine the ideal location for a dike to be constructed, this lowers local autonomy. To explore the potential for local autonomy, these technical applications need to be given reduced significance. Therefore to establish local autonomy, uncertainties in the stability of the dike line must be acknowledged since many stakeholders lack the technical expertise necessary to construct a dike as a civil engineer would. While this approach may not pinpoint the optimal location for dike construction based solely on technical considerations, it does indicate the areas that are implied to have more potential considering localizing certain responsibilities of dike management, increasing the awareness and the relationship between man and the river.

Freedom of Dikes

The second part of the roadmap centers on strategy development. By leveraging examples from the Room of the River program, the project aimed to provide as much freedom for local interpretation as needed. While basic strategies were formulated, they were designed to ensure local dike management and active subsidiarity could be translated spatially. The areas indicated within the calculation model formed the foundation for the construction of a new dike line, which could be divided into a patchwork of localized dike lines within the spatial boundaries of the new design locations. This approach gave stakeholders the freedom to choose their new dike line based on their collective preferences. A secondary calculation model enabled the translation of the six dike ideas into the available spatial dike lines of the dike catalog. By aligning this translation with the relationship between stakeholder groups and dikes, a set of dike systems was calculated, allowing multiple options to be considered, rather than selecting a single, commonly shared option. This enhanced the formation of dialogues between the stakeholders of the HST throughout the design process.

Limitations

As this graduation project was situated within the context of the entire Rhine basin, one of the primary limitations was the level of detail available for the autonomy indicators. The focus on creating a framework for the entire Rhine meant that detailed information, such as soil quality, discharge data, and other indicators, could not be obtained consistently, as it relied on national information, which varied between countries. Given that numerous indicators are based on data statistics published in different years and on different scales, uncertainties in using the information were common. For each indicator, a calculation had to be constructed leading towards their importance on autonomy. Nevertheless, this project aimed to overcome these limitations by translating the information into a newly created dataset, focusing on how the information could be employed for spatial analysis and the decision-making process rather than real-world implementation.

Furthermore, the selection of indicators was limited to those that could be covered within the project's timeframe. Additional indicators could be explored to enhance the accuracy of the autonomy calculation. Due to the lack of knowledge present in the translation of technical data to their impact on local autonomy, additional research is vital in making the spatial model proposed in this report more viable for future calculations.

Future research recommendations

To validate the methods used in this calculation model, future research should focus on a smaller area, potentially in a country like the Netherlands where data is more consistent. By testing the model in a context with reliable and consistent data, the project's validity could be established. Recent projects, such as Room of the River and the HWBP, could be analyzed using the calculation model proposed in this report as a validation tool to assess the underpinnings of decisions made during various Dutch dike programs.

Furthermore, while the project has established a network of autonomous regions along the Rhine through the Rhine Line calculation model, further development of this network could be beneficial for future research. This could involve creating a knowledge platform where similar stakeholder groups along the Rhine can learn from one another's decisions, form mutual agreements based on the impact and autonomy created during the decision-making process, and collaborate effectively.

14.2

Reflection

Contextual yet Transferable

This research has introduced a new method for assessing the possibilities of local dike management on a large scale, particularly in the context of the Rhine River. The project presented a dual focus: the Rhine as a calculation model on one side and the local-scale calculations on the other. The creation of a calculation model is crucial in spatializing available information into a spatial pattern. The chosen contextual situation allows the model to be adapted in various ways, as the roadmap's steps offer a general framework adaptable to a wide range of contexts. As the project focuses on the creation of a roadmap towards local dike autonomy, the translation of the indicators to form a centralized framework where local dike management can be considered became an important feature of this research.

This type of approach, involving methods like mapping, setting up criteria, and translating data into schemes, makes data transferability between all the indicators rather challenging. As this approach attempts to combine technical data such as sedimentation rates, discharge numbers, and GDP rates with conceptual data such as trust in governance levels and dike characteristics into a single model, a simplified ranking system was created to consolidate all the information into one spatial model. Focusing on the Rhine as a straight water entity allows us to translate all the material into a clear scheme. However, we must acknowledge that by translating the spatial analysis in this manner, we lose technical details. This approach, although leading to the loss of certain technical details, contributes to researching the conditions for dike management in a larger portion of the river. As a result, a spatial pattern can emerge, indicating potential locations of dike autonomy along the Rhine.

The translation of the data is confined to two major distinctions: their relation to dike construction and suitability, and local autonomy. Often, these distinctions are opposites. Initial translation of a certain indicator toward autonomy is considered to be difficult, as although it is mentioned in the literature (Gupta et al., 2010), it does not provide a tool that can be used to assess technical data for autonomy. As the translation of the indicators takes place per indicator, compatibility between the different indicators is difficult to formulate. Therefore, a weight is given based on their importance to dike management and dike construction. Besides the use of different scalar data with different timestamps, which additionally results in less compatible outcomes, more attention should be given to making data on water management, in general, more compatible within the river basin. This allows for better coordination between nation-states and increases the viability of the calculation models as proposed in this report.

While the loss of detailed data translation is accepted in this report, it is crucial for everyone who follows this roadmap to understand the calculation translations that take place. So when change is initiated, a reflection can be made on the impacts that could be created at the location, as well as for areas upstream and downstream. Here, a significant role is placed on transnational organizations like CHR, IKSR, and the European Union, to ensure data transfer between local stakeholders, local authorities, and technical sectors becomes a reality. This allows every participant to contribute to a larger picture. In this setup, stakeholders are given the freedom to explore the possibilities of dike management, local authorities are informed about the process and can contribute with financial incentives and data publications,

and the technical sector can assist in translating the new data publications and support the local stakeholder groups in making a clear and informed dike decision.

To facilitate the translation of all these conditions, a new spatial entity, the Rhine Line, was proposed. This entity allows for the creation of a grid along the Rhine where autonomy and conditions can be assigned specific rankings. The development of the Rhine Line offers a means to translate essential information to evaluate local autonomy possibilities, applicable at both the scale of the Rhine and in pinpointing local areas with the highest potential for autonomy. Since the model proposed in this report resulted in the translation of 2,800 data locations along 1,100 km of the Rhine, the transferability of this method to other river contexts should be carefully considered in terms of the level of detail that needs to be portrayed. Depending on the area to be included in the model, different sizes of data locations may emerge. When considering a relatively small location, more detail can be portrayed than in a larger area, given the same amount of time allocated to data translation. Additionally, the level of detail in the model depends on the availability of data. Even if a small area is chosen, without sufficiently detailed data, differences in the calculation can be challenging to observe. Therefore, it is vital to determine beforehand the level of detail needed to assess the local conditions (data locations) and the overall size of the area that needs to be translated.

Given that this project aims to establish criteria for implementing, modifying, and supplementing existing dike systems, it aims to generalize the data used in this report. The translation process, achieved through ranking systems from 1 to 5, treats all data equally. The filled-in data locations are meant to be related to the other data locations within the chosen calculation model, creating a comparative calculation model. This allows for the earlier-mentioned loss of technical details to be accepted. Therefore, depending on the scale of interpretation, the importance of autonomy might vary for different locations.

As the implementation or alteration of dike systems impacts locations upstream and downstream, it must be considered within different scenarios. Since this report heavily addresses the freedom of design, each new design solution creates a different impact on its surroundings. For instance, the effect of location A changing its dike design on locations B and C could vary significantly. Location A may have multiple options to choose from, and this choice will continually affect B and C. An interplay is thus created among locations, which is a key criterion for establishing knowledge networks and implementing active subsidiarity.

Although the creation of the calculation model facilitates translation into other river contexts, direct implementation is not recommended. Conditional differences related to dike history, political contexts, and information availability alter the model's layout for determining local autonomy. Major rivers, often spanning multiple nations, create impacts for numerous countries. These countries have different political landscapes, management schemes, and data availability, making the creation of a comprehensive model challenging. Therefore, the roadmap emphasizes the stakeholders' role in initiating the process, with public authorities primarily focusing on steps after the new dike lines have been 'designed'. Although the translation of information into a river-scale model is not standardized, all steps can still occur. The larger scales become more prominent only when the impact is assessed, and a network is established. While this model has been implemented on the Rhine River, where public institutions provide substantial data, in areas of the Global South, where governmental organizations are less involved, stakeholder groups may face more challenges in initiating change. Although a calculation on a large basin scale may not be feasible, smaller areas can serve as the foundation for the calculation model. Depending on the available knowledge, the same steps can be taken, with adjustments made to the input of dike typologies based on the specific context. The roadmap's primary focus on changing the meaning of the dike allows for the implementation of calculations, even when scalar interpretations differ.

Methods & Design

The initial focus of this project was to address growing concerns related to the increasing prospects of drought in the Rhine region. However, it proved challenging to fully comprehend the impacts of droughts on the urban and natural systems of the Rhine due to the scale of impact being at the Rhine level, which made the translation to local conditions difficult.

Shifting the focus to the dike as a spatial element enabled the translation of impacts to local scales. Consequently, this emphasis on the dike reshaped the project's focus, leading to the development of a roadmap for local dike management as the primary design outcome. This shift highlighted the importance of translating existing conditions related to dike management into local design regions, as opposed to creating a vision for the entire Rhine.

To seamlessly integrate spatial design into the systematic context outlined in the calculation model, the same methods were applied during the design phase. This process relied on relationship schemes between dikes, stakeholders, and future dike identities, intending to calculate the most viable design option based on the defined design location. This approach ensures that the newly created dike systems are not viewed as fixed solutions but rather as starting points for dialogue among stakeholder groups in defining their future dike relations.

Freedom Arising from the Initiation of Change toward Local Autonomy

One of the primary features of this report is to highlight the opportunities that emerge when local stakeholder groups are given "complete" freedom within the decision-making process of dike management. The roadmap serves as a guide for these stakeholder groups to develop their path to autonomy. In the initial stages of the roadmap, which focuses on establishing the spatial pattern of autonomy, a lack of knowledge, data, and willingness may hinder progress. Nevertheless, each step in the process contributes to a learning experience, which extends across multiple design locations along the river. This marks the beginning of a learning process that spans a large number of design locations along the river, with each step reflecting on the viability of the process. In the future, major organizations like IKSR and CHR should concentrate on establishing a framework where the smaller design locations have access to a database containing all the initiatives taking place along the Rhine. This enhances future integration of the design locations, as this new database shows all of the examples of previous autonomy endeavors, making the initial step more comfortable and facilitating data transfer among the local stakeholder groups.

Furthermore, the indicators used to address local autonomy in the decision-making process face another issue that needs to be addressed. The central idea of localizing dike management to local stakeholders themselves has not been previously seen, at least not in heavily urbanized European regions. This makes addressing decision-making autonomy and its implications for dike autonomy a challenging task. Therefore, it was decided to focus on the broader land use classifications as larger stakeholder groups. Based on the relationships between these large stakeholder groups and the dikes, an indication could be made to connect the technical side of the story with the management side.

The creation of the roadmap not only enables the understanding of the necessary steps when stakeholder groups consider localizing the dike line but also reinstates the awareness that the dike should not be perceived as a controlling entity, but rather as a transitional element that collaborates with the river, not opposes it. This concept is integrated into five out of six future dike concepts. This redefined meaning of the dike is not limited to the Rhine but can be applied to any river basin. While the indicators do emphasize the technical aspects required for dike construction, the primary focus of evaluating these indicators is to change the perception of the dike.
By examining the existing technical and organizational aspects associated with dike management, we can formulate potential outcomes for newly designed dike systems and create new territorial configurations that foster a shared identity toward water management. These new territorial configurations are based on the theory of Hydro-Social Territories (Boelens et al., 2016) and can be perceived differently at various scales, given that each territory is defined by the layering of multiple "landscapes." Therefore, different regions can emerge by considering different layers of the landscape, although they should always consider the three integral layers of geology, water, and humans, as these three layers form the basis for constructing and perceiving existing water relations.

Once the design locations (HST) are established, a representation is created by larger stakeholder groups. Due to the scale of the Rhine, stakeholders have been confined to their respective groups, as represented by Meyer et al. (2014). As these groups define the future spatial outlook of the dike, power imbalances often emerge. Power imbalances between industrial and urban regions in comparison with agricultural and residential groups can be substantial. To address this issue, the design process focuses on the translation of stakeholder relations, future dikes, and existing dike typologies, following the same systematic approach as the autonomy calculation model. This allows each stakeholder to have one "vote" within the process, irrespective of the size and importance of the stakeholder groups. Although this does not precisely replicate real-life conditions, it is acceptable because the design solution is not fixed but rather an exploratory effort, resulting in a relational scheme of preferred dike typologies. This allows for the establishment of multiple sessions of dialogue where rather only a new dike system is created, it is also built upon the relation of the stakeholder with the dike.

Relation between Technical & Social Sciences

Numerous studies have focused on the impact of climate change on global river systems and the integration of EU policies into citizen engagement and participation strategies. However, the concept of active subsidiarity in EU decision-making and citizen participation strategies still requires local spatial planning implementations to be effectively rooted in local contexts (Moodie et al., 2022). These spatial implementations, aimed at mitigating the risks posed by increasingly uncertain weather phenomena, will significantly affect the areas where such risks are most apparent. While impact assessments of flooding are widely practiced in Western contexts, the reintegration of human and natural systems through the use of dikes remains relatively uncharted territory.
The primary objective of this graduation project is to coordinate the existing dike management practices of the Rhine nations, establishing an adaptive and robust roadmap for localizing dike management. This roadmap places a strong emphasis on comprehending both the natural systems of the Rhine's hydrological network and the water and dike management sector, extending from European governance arrangements to local ownership. This research adopts a systematic approach that involves calculations to determine ideal locations for

local autonomy. Technical data related to existing dikes, river dynamics, geological conditions, and management arrangements are translated into a newly defined spatial model, depicting the extent of autonomy along the Rhine River.
The blend of spatial analysis and management strategies is a crucial aspect of what urbanism should prioritize. Only through an understanding of the relationship between humans and nature can we identify effective solutions. Since the existing sciences of dike management are rooted in the technical foundation of civil engineering, this report challenges the traditional perception of dikes, facilitating a dialogue about how dikes are characterized. It conceives the dike as a transitional element, contributing to the discourse on the required extent of flood protection, especially in the face of extreme climate change scenarios.

Here, the dike is seen as a bridge between the fields of urbanism and civil engineering. While dikes remain essential for managing the increasing risks of flooding and drought, it's crucial to retain their technical functionality. However, to make them relevant to local contexts, a secondary spatial role should be assigned, enabling the translation of additional benefits to local stakeholders who may lack technical expertise. The adaptable and historical nature of dikes makes it possible to merge their technical applications for construction and maintenance while also providing opportunities for integrating additional functions within the landscape. This shift also serves as a tool to raise awareness of flood and drought risks among local stakeholders, as dikes become integral components of spatial planning.

Relations between Stakeholders and Dikes

In the course of this research, the relationship between stakeholders and dikes was explored from historical, current, and future perspectives. These relationships predominantly revolve around the risk factors associated with dikes. As limited research on the social relations between dikes and humans is primarily based on flooding events, little research has been provided on what a dike means for stakeholders.

Additionally, as the relationship between a stakeholder and the dike, differs per location, the analysis provided in this report tries to underline the main distinction between the dike and the stakeholder group. Therefore, different local relations have to be considered when this roadmap is to be followed. To alter stakeholders' perception of dikes, it would be beneficial to incorporate social science research, offering additional insights and inputs into the model proposed in this report.

One of the primary objectives of this project is to raise awareness about society's vulnerability to natural forces. By directly involving local stakeholders in dike management, a different perspective on dikes is introduced. While dikes should still retain their protective function against water, their spatial aspects can help obtain the existing relationship into a tangible spatial element. This, however, requires concessions regarding their structural stability. If these concessions are accepted, it will pave the way for revitalizing local responsibility for natural river systems. Allowing the dike to not be as extremely protective as technical sectors want it to be, enhances the dynamism of river systems, bringing water closer to society. This can lead to a better understanding of the river's forces during extreme weather scenarios, fostering increased awareness of flooding and drought occurrences.

Though incorporating this concept can be challenging, given the technical sector's primary focus on controlling water inflow and outflow, projects in the Netherlands have demonstrated the ability to combine technical guidelines with local stakeholder involvement, allowing stakeholders to have a say in designing the spatial plan (De Bruijn et al., 2015).



Figure 212: Dike near Westerschelde. (NIOZ, 2018)

15

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Literature List

Figure List

Literature List

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Figure 213: Dike near Westerschelde. (NIOZ, 2018)



Figure 213: The Grande-Dixence Dam, in Valais, Switzerland. (Jeremy Toma, 2019)

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Appendix

16.1 Roadmap Appendix

16.2 Dikes of the Rhine

16.3 River dynamics

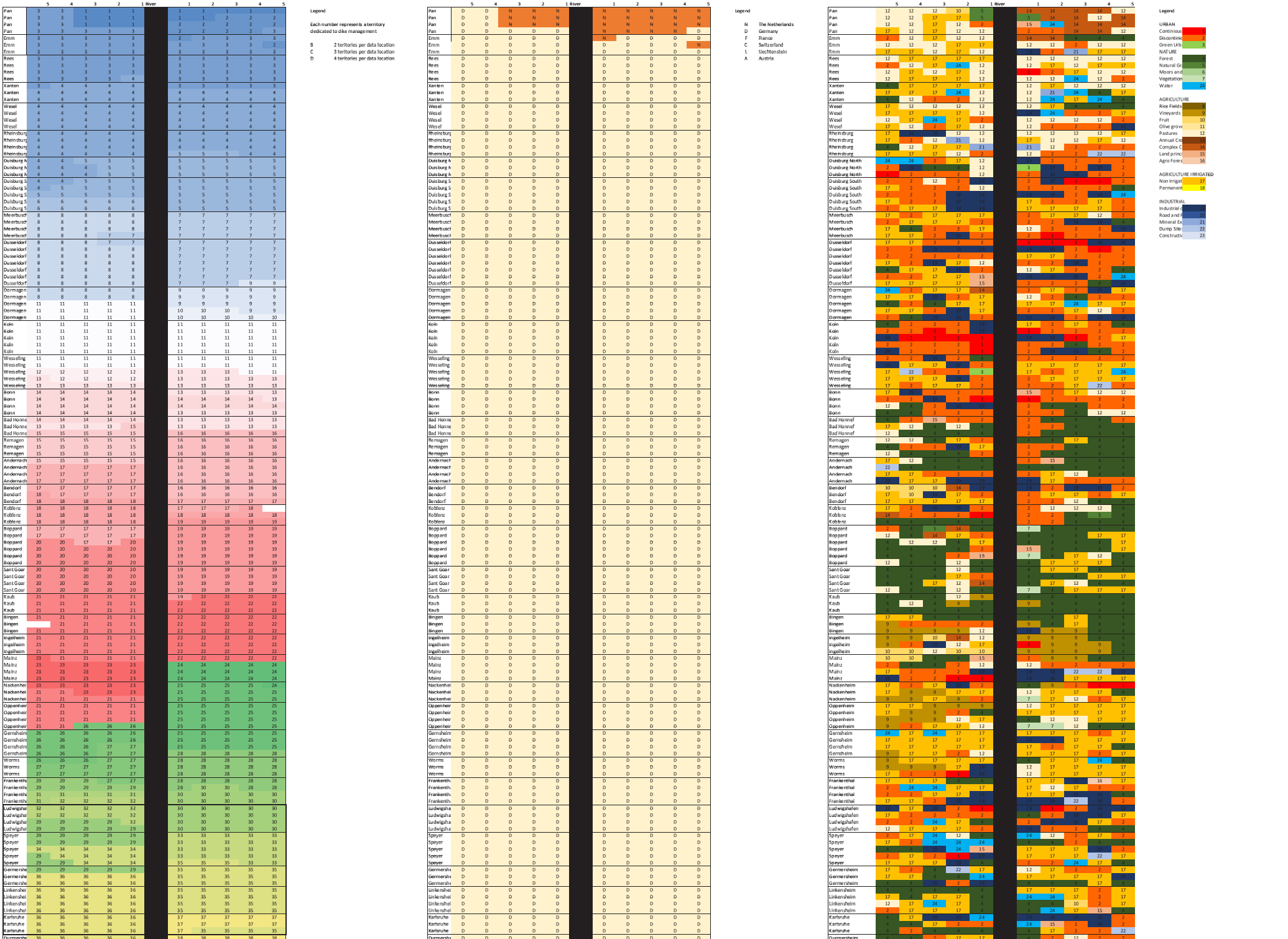
16.4 Authoratative Autonomy

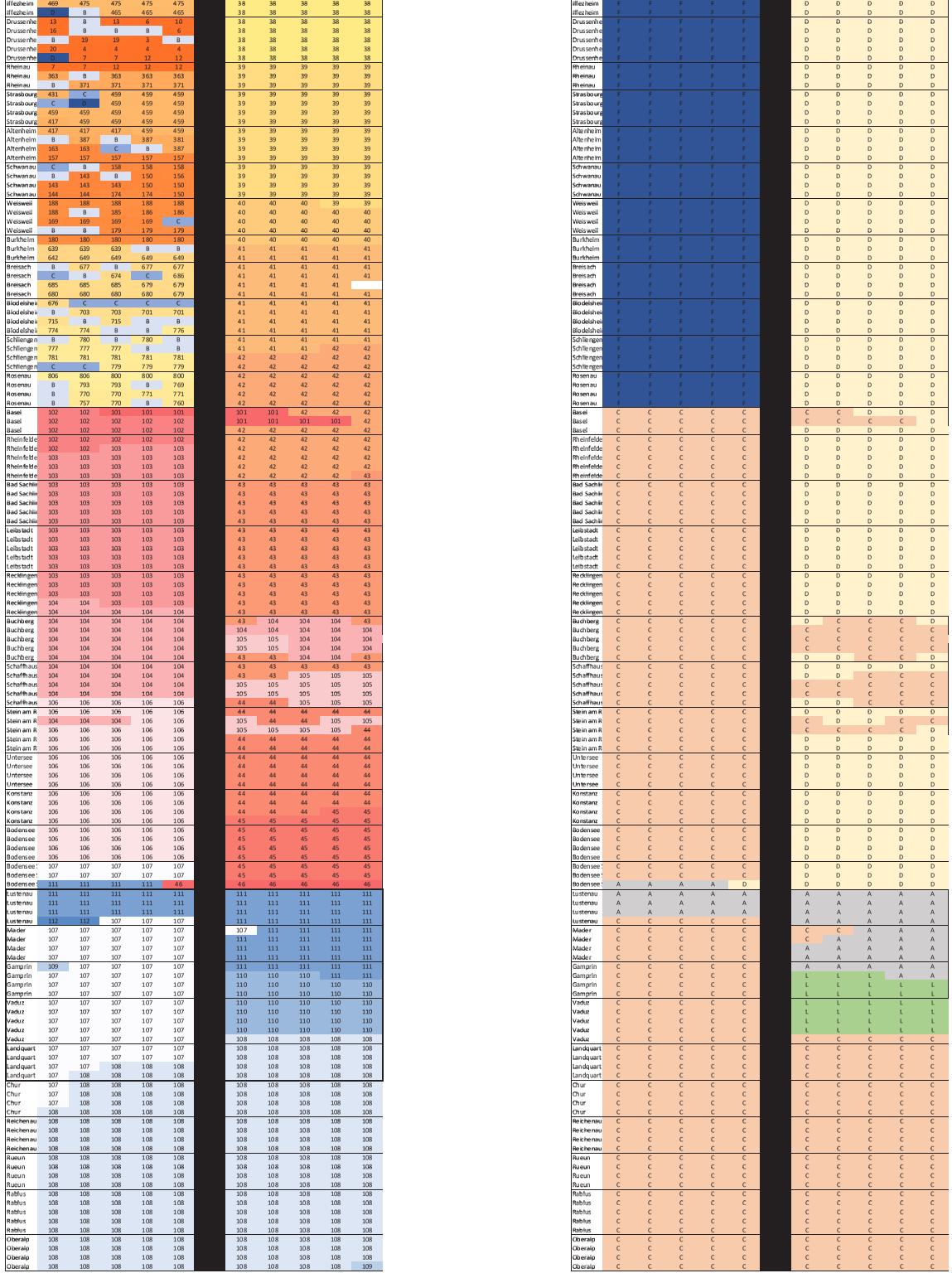
16.5 Calculations of Indicators

16.1

Roadmap Appendix

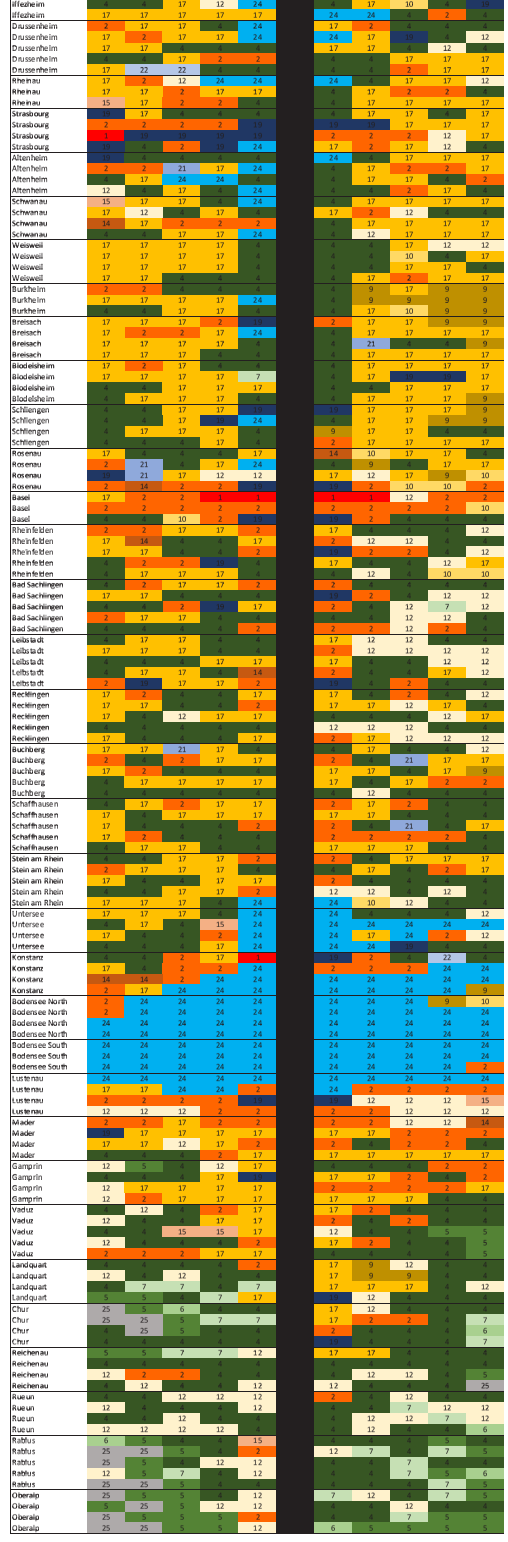
Finding Common Water





DIKE MANAGEMENT

NATIONAL BORDERS



LAND USE

Rhine Line

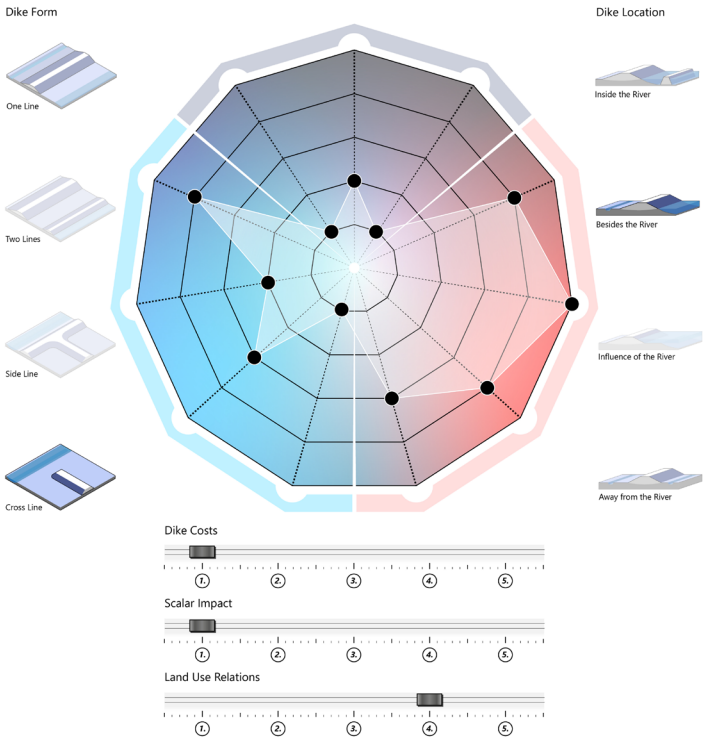
New territorial units of the Rhine Line calculation model

Finding Common Water

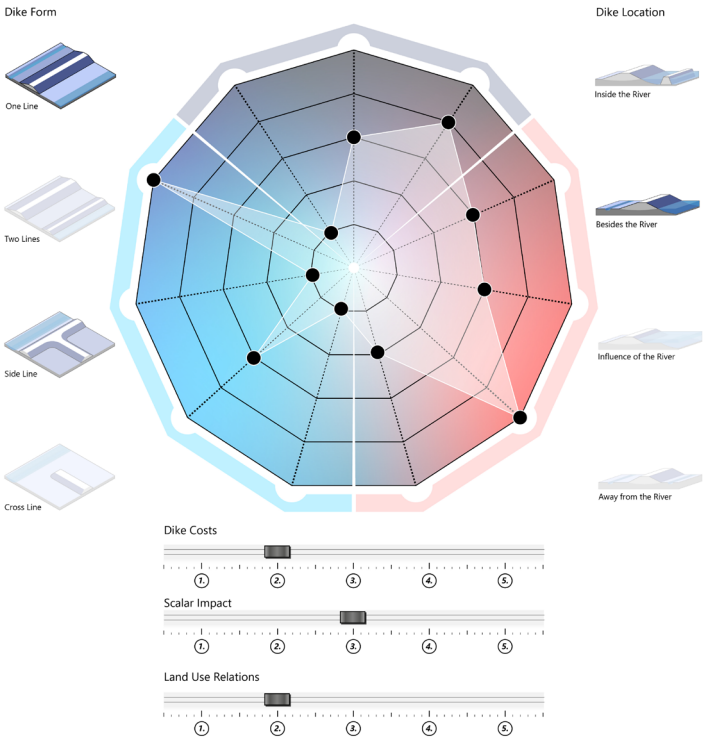
Defining Urgency

Stakeholder relations towards dikes

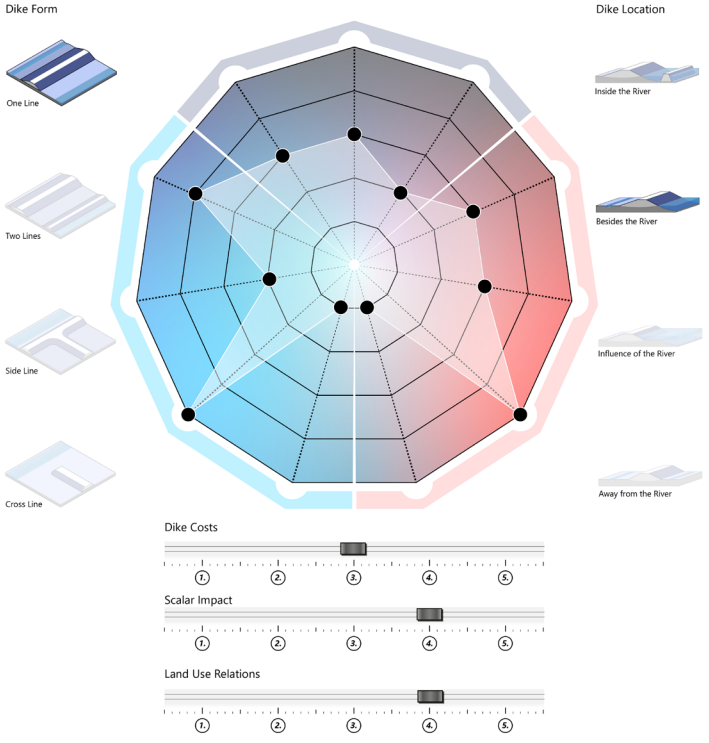
Farmers *As based on their current and potential relationship to dikes*



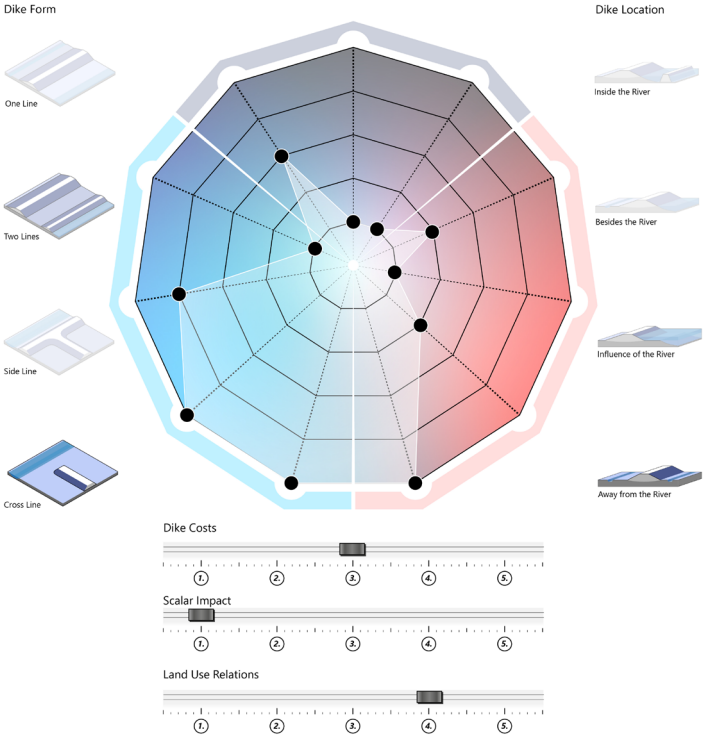
Energy *As based on their current and potential relationship to dikes*



Transport *As based on their current and potential relationship to dikes*

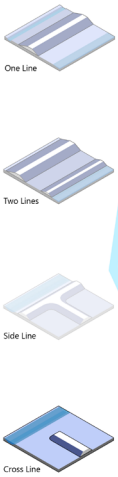


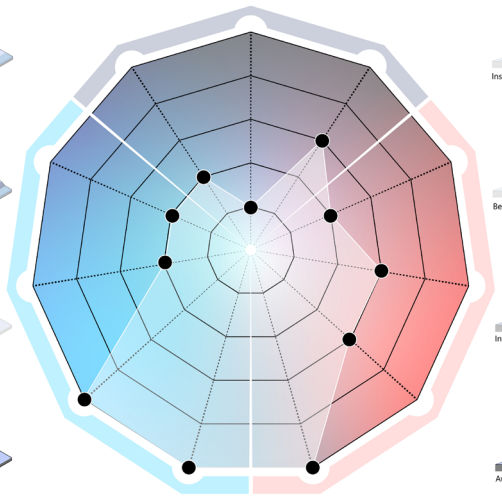
Natural Retention *As based on their current and potential relationship to dikes*



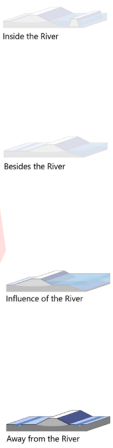
Soil *As based on their current and potential relationship to dikes*

Dike Form





Dike Location



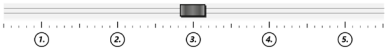
Dike Costs



Scalar Impact

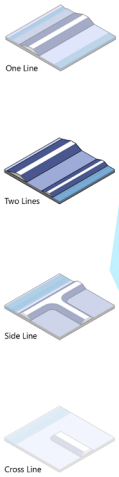


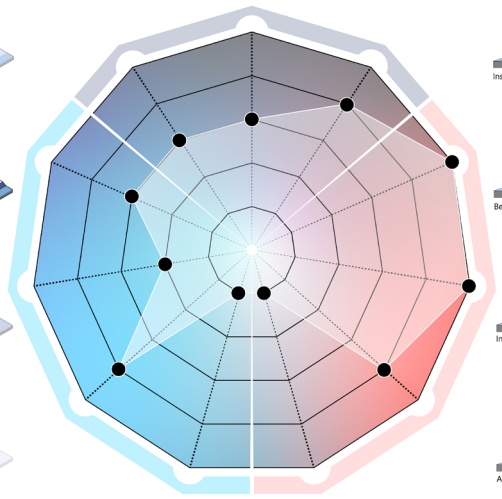
Land Use Relations



Waterworks *As based on their current and potential relationship to dikes*

Dike Form

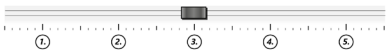




Dike Location



Dike Costs



Scalar Impact

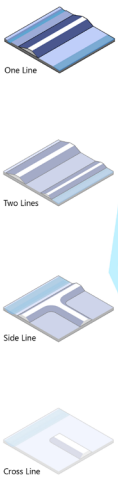


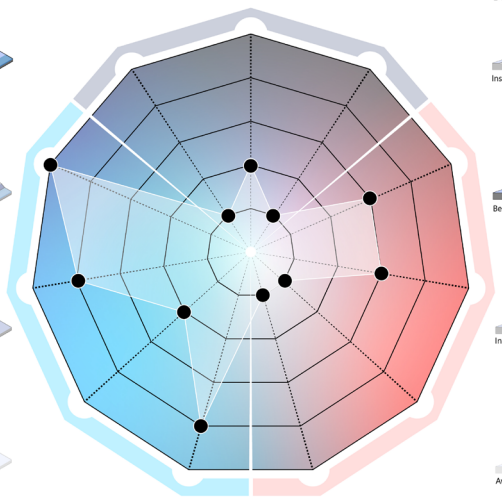
Land Use Relations



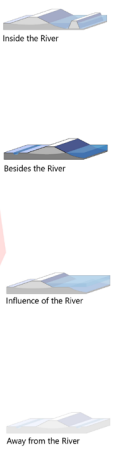
Urban Development *As based on their current and potential relationship to dikes*

Dike Form





Dike Location



Dike Costs



Scalar Impact

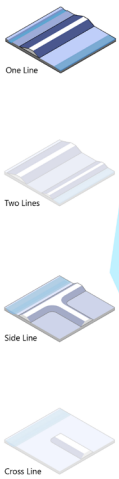


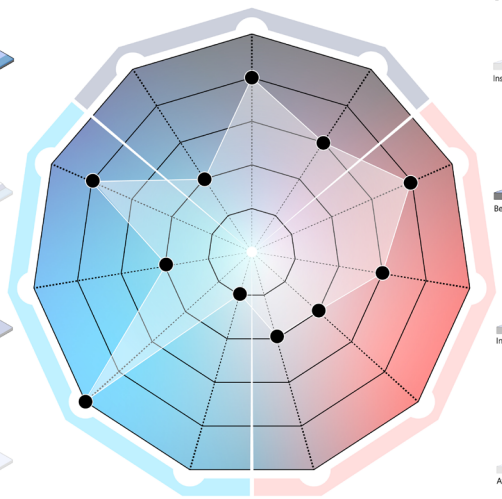
Land Use Relations



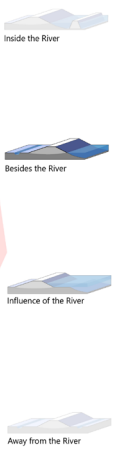
Harbour & Industry *As based on their current and potential relationship to dikes*

Dike Form





Dike Location



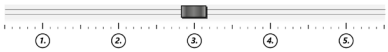
Dike Costs



Scalar Impact



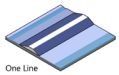
Land Use Relations

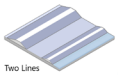


Residents

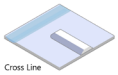
As based on their current and potential relationship to dikes

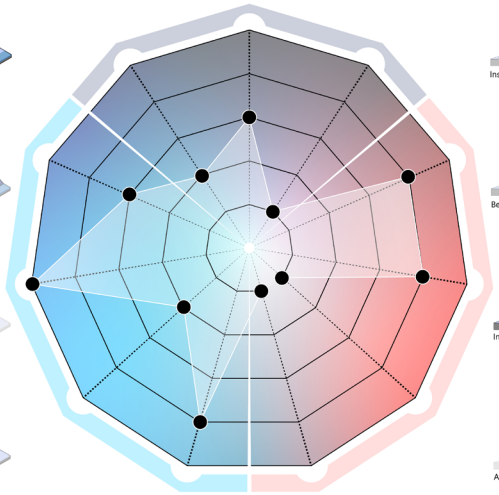
Dike Form


One Line


Two Lines

Side Line


Cross Line



Dike Location

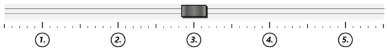

Inside the River


Besides the River

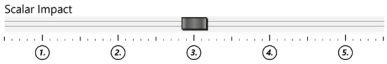

Influence of the River

Away from the River

Dike Costs



Scalar Impact



Land Use Relations



Can the knowledge for the variables be provided by which local actor groups

Yes 3 Maybe 2 No 1

Who is

Variable	Code	Actor Groups: Agriculture	Energy	Transport	Nature Organization	Soil/Water	Waterworks	Urban Development	Harbour & Industry	Local Owners	Public	Europ
Safety Measurements Current	A1	1	1	1	1	1	1	1	1	1		
Safety Measurements Future	A2	1	1	1	1	2	2	1	1	1		
Knowledge in Decision Making	B1	2	2	3	2	3	3	2	2	1		
Funding	B2	1	3	2	2	1	2	3	3	1		
Availability of Space	B3	3	2	1	3	3	1	1	2	2		
Self Organizing Capacity	B4	1	3	2	1	1	3	3	2	1		
Stakeholder Involvement	B5	1	2	3	3	2	2	3	2	2		
Uncertainty levels	B6	1	1	2	2	2	1	2	1	2		
Existing Projects	B7	3	3	3	3	3	3	3	3	3		
Consideres knowledge that is provided by local actor groups (These form the conidtions of whether an actor can operate fully autonomous												
GDP, Purchasing Standard	C1	2	3	2	1	1	2	4	4	1	1	Not at all
Urbanized Regions	C2	2	3	2	4	4	2	4	3	1	2	Can Help
		1	3	2	1	1	3	4	2	2	3	Important
		3	4	4	3	2	1	2	3	2	4	Very Important
How importance are these conditions for the actoral groups												
Water Management Powers	C3	1	2	2	4	4	4	2	2	1		
Dike Management Powers	C4	2	3	3	4	4	4	3	3	2		
Their role in these management relations (of course is different per country)												
Governance Trust	C5	2	3	4	2	2	3	2	3	2		
Adaptiveness	C6	3	1	2	4	4	2	2	1	2	1	Not at all
Citizen Engagement	C7	2	1	1	3	2	1	3	1	4	2	Can Help
Water Management Integration	C8	3	2	4	4	4	2	2	3	1	3	Important
Spatial Planning Discourse	C9	2	3	1	2	2	2	3	2	3	4	Very Important
How importance are these conditions for the actoral groups												
Economic Water Use Efficiency	D1	2	3	3	3	3	3	1	3	2		
Economic Water Efficiency	D2	2	3	3	2	2	3	1	3	1		
Power Plant Water Use	D3	1	3	3	1	1	1	1	3	1		
Waste Water Points	D4	2	3	1	1	2	1	3	3	2		
Water dependent Regions	D5	2	2	1	3	3	2	1	2	1		
Form of the Dikes	E1	2	3	3	2	3	3	2	3	2		
Location Placement	E2	2	3	3	2	3	3	2	3	2		
Dike bodies up and down stream	E3	1	3	3	2	3	3	2	2	1		
Scalar Impact of the Dike	E4	1	1	2	1	2	3	2	1	1		
Safety Failure Mechanisms	F1	2	2	2	1	3	3	2	2	1		
Water Distribution Failure Mechanism	F2	1	1	2	2	2	2	1	1	1		
Water Retention Function	F3	2	3	3	1	2	3	2	2	2		
Water Distribution Function	F4	2	1	2	2	2	3	1	2	2		
Dike relation on Biodiversity	G1	2	1	1	3	3	2	1	1	2		
Dike relation on River Flow	G2	1	2	3	2	3	3	1	2	1		
Dike relation on Society	G3	2	1	1	2	1	1	2	1	3		
Dike relation on Economy	G4	1	2	1	1	1	2	3	2	1		
Land Use Relations	G5	1	1	2	1	2	3	1	1	1		
Area of Protection Zone	H1	3	3	3	3	3	3	3	3	3		
Frequency of Maintenance	H2	2	1	1	2	3	3	1	2	2		
Knowledge for Maintenance/Built	H3	2	1	1	2	2	3	2	1	1		
Materials for Dike Construction	I1	1	1	1	2	2	3	2	1	1		
Dike Cladding Costs	I2	1	2	2	1	1	2	3	2	1		
Water Retention Function	I3 / F3	2	3	3	1	2	3	2	2	2		
Land Use Relations	I4 / G5	1	1	2	1	2	3	1	1	1		
Knowledge for Maintenance/Built	I5 / H3	2	1	1	2	2	3	2	1	1		
Considers the current and future relation of the actor groups with the technical, spatial and management aspects of a dike line												
River Embankments	J1	3	3	3	3	3	3	3	3	3		
Local Dike Systems	J2	2	3	2	2	3	3	2	3	2		
Soil Sealing	K1	3	3	2	3	3	2	3	3	2		
Soil Moisture	K2	2	1	1	3	3	2	1	1	1		
Lithological Depostions	K3	1	2	2	2	3	2	1	1	1		
Groundwater Recharge	L1	2	1	1	2	3	1	2	1	1		
Aquifer Conductivity	L2	1	1	1	2	3	2	1	1	1		
Aquifer Vulnerability	L3	1	1	1	3	3	2	1	1	1		
Flooding Extreme Scenario	M1	1	1	2	2	3	3	1	2	2		
Drought Hydrological Seasons	M2	2	2	2	2	3	2	1	1	2		
Surrounding Water Bodies	N1	3	3	3	3	3	3	3	3	3		
Slope Indications	N2	2	2	2	3	3	2	3	2	1		
Effective Precipitation	N3	2	1	1	2	2	1	1	1	1		
Change between High-Low Flow	O1	1	2	3	2	3	3	1	2	1		
Uncertainty High-Low Flow	O2	1	2	2	1	2	2	1	1	1		
Low Flow Drought conditions	O3	2	2	2	2	3	2	1	1	1		
Quantitative Discharge	O4	2	3	2	3	3	3	1	3	1		
River Widths	P1	1	2	3	2	2	3	1	2	1		
Water Distribution Mechanisms	P2	2	3	1	2	3	3	1	2	1		
Groins	P3	2	2	3	2	3	3	1	2	2		
River Nodes	P4	1	2	3	1	3	3	1	2	1		
Sedimentation Material	Q1	2	1	2	3	3	2	1	1	1		
Sedimentation & Erosion	Q2	2	2	2	2	3	2	1	1	1		
Knowledge System		There potential role in the Knowledge System										
4 Knowledge Producers	KP	X		X	X	X	X			X		
3 Knowledge Enablers	KE		X		X			X				
2 Knowledge Users	KU	X	X	X				X	X	X		
1 Knowledge Intermediaries	KI	X	X		X	X		X	X	X		

s responsible for providing this information

Knowledge of Stakeholders

Knowledge of Data Allocated time of

Sector					Research				
ean	Rhine Authorites	National	Regional	Local	NGOS	Universities	Research Instriutions		Short Term
		X					X	Safety Measurements Current	X
	X	X				X	X	Safety Measurements Future	
				X				Knowledge in Decision Making	
				X				Funding	
				X				Availability of Space	X
				X				Self Organizing Capacity	
				X				Stakeholder Involvement	X
				X				Uncertainty levels	
	X		X	X				Existing Projects	X
		X					X	GDP, Purchasing Standard	
X		X	X			X	X	Urbanized Regions	X
		X	X					0	X
		X	X	X				0	X
X	X	X	X	X				Water Management Powers	X
		X	X	X	X			Dike Management Powers	X
X		X	X	X	X	X	X	Governance Trust	
		X				X		Adaptiveness	
		X	X	X	X	X	X	Citizen Engagement	
		X				X		Water Management Integration	
		X	X	X	X	X		Spatial Planning Discourse	
		X	X				X	Economic Water Use Efficiency	
	X	X	X					Power Plant Water Use	X
	X	X	X	X				Waste Water Points	X
X	X				X	X	X	Water dependent Regions	X
			X	X		X		Form of the Dikes	X
			X	X		X		Location Placement	X
		X	X					Dike bodies up and down stream	X
		X	X	X		X		Scalar Impact of the Dike	
				X		X	X	Safety Failure Mechanisms	
	X			X		X	X	Water Distribution Failure Mechansism	
		X	X	X				Water Retention Function	X
			X	X				Water Distribution Function	X
			X	X	X	X		Dike relation on Biodiversity	
X	X	X	X	X		X	X	Dike relation on River Flow	
X		X	X	X	X	X		Dike relation on Society	
		X	X	X	X			Dike relation on Economy	
				X				Land Use Relations	X
		X	X	X				Area of Protection Zone	X
			X	X				Frequency of Maintenance	
X	X	X	X	X		X	X	Knowledge for Maintenance/Built	
			X	X		X	X	Materials for Dike Construction	
				X				Dike Cladding Costs	X
0	0	X	X	X				Water Retention Function	X
0	0	0	0	X				Land Use Relations	X
X	X	X	X	X		X	X	Knowledge for Maintenance/Built	
	X		X	X				River Embankments	X
				X				Local Dike Systems	X
			X	X				Soil Sealing	X
X	X	X	X			X	X	Soil Moisture	
	X		X	X		X	X	Lithological Depostions	
X	X	X	X			X		Groundwater Recharge	
X	X	X	X			X		Aquifer Conductivity	
	X	X	X			X		Aquifer Vulnerability	
	X	X	X	X		X	X	Flooding Extreme Scenario	X
X	X	X	X			X	X	Drought Hydrological Seasons	X
			X	X				Surrounding Water Bodies	X
			X	X				Slope Indications	X
X	X	X	X			X	X	Effective Precipitation	
	X	X	X			X	X	Change between High-Low Flow	
	X	X	X			X	X	Uncertainty High-Low Flow	
	X	X	X			X	X	Low Flow Drought conditions	
	X	X	X				X	Quantitative Discharge	X
	X		X	X				River Widths	
			X	X				Water Distribution Mechanisms	X
			X	X				Groins	X
	X	X		X				River Nodes	X
			X	X				Sedimentation Material	X
	X		X	X		X	X	Sedimentation & Erosion	
	X	X			X	X	X		
X		X	X		X		X		
	X	X	X	X					
				X	X				

f collection of information		Scale of Data				Allocated time of direct influence in change		
Middle Term	Long Term	Rhine Basin	National	Regional	Local	Short Term	Middle Term	Long Term
			X	X				
	X		X	X				
X					X			
X					X			
					X			
X					X			
					X			
	X				X			
X		X		X	X			
X			X					
	X	X	X	X				
				X				
		X	X	X	X			
			X					
			X					
X			X					
X			X					
X			X					
X			X					
X			X					
X					X			
					X			
					X			
		X						
					X			
					X			
X					X			
X					X			
				X				
X					X			
					X			
X					X			
X					X			
					X			
					X			
					X			
X

Dike Autonomy

Relations between stakeholders & Dike identities

PROTECTION

	Agriculture	Energy	Transport	Nature	Soil/Water	Waterworks	Urban Development	Harbour & Industry	Local Owners	
Form of the Dikes	0.375	0.5	0.75	0.375	0.5	0.625	0.625	0.5	0.625	
Location Placement	0.625	0.875	0.875	0	0	0.375	0.625	0.5	0.5	
	0.5	0.6875	0.8125	0.1875	0.25	0.5	0.625	0.5	0.5625	
Safety Failure Mechanisms	1	0	0	0	0	1	0	0	0	
Water Distribution Failure Mechansism	0	0	1	0	0	1	1	0	1	
Water Retention Function	0	0	0	0	0	1	0	0	0	
Water Distribution Function	0	0	0	1	0	0	0	1	0	
	0.25	0	0.25	0.25	0	0.75	0.25	0.25	0.25	
Dike relation on Biodiversity	1	1	1	0	0	1	0	1	0	
Dike relation on River Flow	1	1	0	0	0	0	0	0	0	
Dike relation on Society	1	0	1	0	1	1	0	1	0	
Dike relation on Economy	0	0	0	1	0	0	0	0	0	
Land Use Relations	0	0	0	1	1	0	0	0	1	
	0.6	0.4	0.4	0.4	0.4	0.4	0	0.4	0.2	
Area of Protection Zone	0	0	0	0	0	0	0	0	0	
Frequency of Maintenance	0	1	1	0	0	1	0	0	1	
Knowledge for Maintenance/Built	1	0	0	1	0	0	1	0	1	
	0.333333	0.333333	0.333333	0.333333	0	0.333333	0.333333	0	0.666667	
Dike Costs	0	0	0	0	0	0	0	0	0	
Scalar Impact of the Dike	0	0	0	0	0	1	0	0	0	
Total	6	4.375	5.625	4.375	2.5	8	3.25	4	5.125	

16

DISTRIBUTION

	Agriculture	Energy	Transport	Nature	Soil/Water	Waterworks	Urban Development	Harbour & Industry	Local Owners
Form of the Dikes	0.125	0.5	0.375	0.125	0.25	0.625	0.625	0.5	0.25
Location Placement	0.625	0.875	0.875	0	0	0.375	0.625	0.5	0.5
	0.375	0.6875	0.625	0.0625	0.125	0.5	0.625	0.5	0.375
Safety Failure Mechanisms	0	0	0	0	0	0	0	0	0
Water Distribution Failure Mechansism	0	0	0	1	1	0	0	0	0
Water Retention Function	0	0	0	1	1	0	0	0	0
Water Distribution Function	0	1	1	0	0	0	0	0	0
	0	0.25	0.25	0.5	0.5	0	0	0	0
Dike relation on Biodiversity	1	1	1	0	0	1	0	1	0
Dike relation on River Flow	0	0	1	1	1	0	0	1	0
Dike relation on Society	1	0	1	0	1	1	0	1	0
Dike relation on Economy	0	0	0	0	0	1	0	0	1
Land Use Relations	0	0	0	0	0	0	0	0	0
	0.4	0.2	0.6	0.2	0.4	0.6	0	0.6	0.2
Area of Protection Zone	1	1	0	0	0	0	1	1	0
Frequency of Maintenance	0	0	0	0	0	0	0	1	0
Knowledge for Maintenance/Built	0	0	0	0	0	0	0	0	0
	0.333333	0.333333	0	0	0	0	0.333333	0.666667	0
Dike Costs	0	0	0	0	0	1	0	0	1
Scalar Impact of the Dike	1	1	0	1	1	0	1	1	0
Total	4.75	5.375	5.25	4.125	5.25	5	3.25	7	2.75

16

NATURAL

	Agriculture	Energy	Transport	Nature	Soil/Water	Waterworks	Urban Development	Harbour & Industry	Local Owners	
Form of the Dikes	0.5	0	0.25	0.875	0.625	0.125	0.125	0	0.5	
Location Placement	0.125	0	0	0.875	0.875	0.375	0.125	0.375	0.125	
	0.3125	0	0.125	0.875	0.75	0.25	0.125	0.1875	0.3125	1
Safety Failure Mechanisms	0	0	0	1	0	0	0	0	0	
Water Distribution Failure Mechansism	0	0	0	1	1	0	0	0	0	
Water Retention Function	0	0	0	1	1	0	0	0	0	
Water Distribution Function	0	0	0	1	0	0	0	1	0	
	0	0	0	1	0.5	0	0	0.25	0	
Dike relation on Biodiversity	0	0	0	1	1	0	0	0	0	
Dike relation on River Flow	0	0	1	1	1	0	0	1	0	
Dike relation on Society	0	0	0	1	0	0	1	0	0	
Dike relation on Economy	0	0	0	1	0	0	0	0	0	
Land Use Relations	1	1	1	0	0	1	0	1	0	
	0.2	0.2	0.4	0.8	0.4	0.2	0.2	0.4	0	1
Area of Protection Zone	0	0	1	1	0	1	0	0	0	
Frequency of Maintenance	0	0	0	1	1	0	0	0	0	
Knowledge for Maintenance/Built	1	0	0	1	0	0	1	0	1	
	0.333333	0	0.333333	1	0.333333	0.333333	0.333333	0	0.333333	
Dike Costs	1	0	0	1	0	0	0	0	0	
Scalar Impact of the Dike	1	1	0	1	1	0	1	1	0	
Total	4.625	2	3.25	14.75	7.5	2.5	3.25	4.375	1.625	

16

LANDSCAPE

	Agriculture	Energy	Transport	Nature	Soil/Water	Waterworks	Urban Development	Harbour & Industry	Local Owners	
Form of the Dikes	0.25	0.375	0.25	0.25	0.375	0.375	0.5	0.375	0.5	
Location Placement	0.125	0.375	0.375	0.375	0.375	0.375	0.5	0.75	0.625	
	0.1875	0.375	0.3125	0.3125	0.375	0.375	0.5	0.5625	0.5625	
Safety Failure Mechanisms	0	1	1	0	1	0	1	1	0	
Water Distribution Failure Mechansism	0	0	1	0	0	1	1	0	1	
Water Retention Function	1	0	0	0	0	0	0	1	1	
Water Distribution Function	0	0	0	1	0	0	0	1	0	
	0.25	0.25	0.5	0.25	0.25	0.25	0.5	0.75	0.5	
Dike relation on Biodiversity	0	0	0	1	1	0	0	0	0	
Dike relation on River Flow	1	1	0	0	0	0	0	0	0	
Dike relation on Society	0	0	0	0	0	0	0	0	1	
Dike relation on Economy	0	0	0	1	0	0	0	0	0	
Land Use Relations	1	1	1	0	0	1	0	1	0	
	0.4	0.4	0.2	0.2	0.4	0.2	0	0.2	0.2	
Area of Protection Zone	0	0	0	0	1	0	0	0	1	
Frequency of Maintenance	0	1	1	0	0	1	0	0	1	
Knowledge for Maintenance/Built	1	0	0	1	0	0	1	0	1	
	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333	0	1	
Dike Costs	0	0	0	0	0	1	0	0	1	
Scalar Impact of the Dike	0	0	0	0	0	0	0	0	1	
Total	4.375	4.75	4.625	3.625	4.75	4.75	4	5.125	9.125	

16

MULTIFUNCTIONAL

	Agriculture	Energy	Transport	Nature	Soil/Water	Waterworks	Urban Development	Harbour & Industry	Local Owners
Form of the Dikes	0.125	0.5	0.375	0.125	0.25	0.75	0.625	0.5	0.25
Location Placement	0.25	0.5	0.5	0.125	0.125	0.625	0.625	0.5	0.75
	0.1875	0.5	0.4375	0.125	0.1875	0.6875	0.625	0.5	0.5
Safety Failure Mechanisms	0	1	1	0	1	0	1	1	0
Water Distribution Failure Mechansism	1	0	0	0	0	0	0	0	0
Water Retention Function	0	1	1	0	0	0	1	0	0
Water Distribution Function	0	0	0	0	1	1	0	0	0
	0.25	0.5	0.5	0	0.5	0.25	0.5	0.25	0
Dike relation on Biodiversity	0	0	0	0	0	0	1	0	1
Dike relation on River Flow	0	0	0	0	0	1	0	0	0
Dike relation on Society	0	0	0	1	0	0	1	0	0
Dike relation on Economy	1	0	1	0	0	0	0	1	0
Land Use Relations	0	0	0	0	0	0	0	0	0
	0.2	0	0.2	0.2	0	0.2	0.4	0.2	0.2
Area of Protection Zone	0	0	0	0	0	0	0	0	0
Frequency of Maintenance	0	0	0	1	1	0	0	0	0
Knowledge for Maintenance/Built	0	0	0	0	0	0	0	0	0
	0	0	0	0.333333	0.333333	0	0	0	0
Dike Costs	0	0	1	0	0	0	0	0	0
Scalar Impact of the Dike	0	0	0	0	0	1	0	0	0
Total	2.375	3	4.875	2.25	3.375	4.375	5.25	3	2

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LOCAL MAINTENANCE

	Agriculture	Energy	Transport	Nature	Soil/Water	Waterworks	Urban Development	Harbour & Industry	Local Owners	
Form of the Dikes	0.625	0.25	0.5	0.625	0.75	0.25	0.375	0.25	0.75	
Location Placement	0.625	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.125	
	0.625	0.375	0.5	0.5625	0.625	0.375	0.3125	0.375	0.4375	1
Safety Failure Mechanisms	0	0	0	0	0	0	0	0	0	
Water Distribution Failure Mechansism	0	0	0	0	0	0	0	0	0	
Water Retention Function	0	0	0	1	1	0	0	0	0	
Water Distribution Function	0	0	0	1	0	0	0	1	0	
	0	0	0	0.5	0.25	0	0	0.25	0	1
Dike relation on Biodiversity	0	0	0	0	0	0	0	0	0	
Dike relation on River Flow	1	1	0	0	0	0	0	0	0	
Dike relation on Society	0	0	0	0	0	0	0	0	1	
Dike relation on Economy	0	0	0	1	0	0	0	0	0	
Land Use Relations	0	0	0	0	0	0	1	0	0	
	0.2	0.2	0	0.2	0	0	0.2	0	0.2	1
Area of Protection Zone	1	1	0	0	0	0	1	1	0	
Frequency of Maintenance	0	0	0	0	0	0	0	0	0	
Knowledge for Maintenance/Built	1	0	0	1	0	0	1	0	1	
	0.666667	0.333333	0	0.333333	0	0	0.666667	0.333333	0.333333	
Dike Costs	1	0	0	1	0	0	0	0	0	
Scalar Impact of the Dike	1	1	0	1	1	0	1	1	0	
Total	6.25	3.75	1	7.125	3.25	0.75	4.625	3.75	2.875	

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Dike Autonomy

Relations between dike catalog & Natural retention dike (top)

Dike Autonomy

Relations between dike catalog & Protective dike (bottom)

NATURAL RETENTION

	Form of the Dikes	Location Placement	TOTAL	Safety Failure Mechanisms	Water Distribution Failure Mechanism	Water Retention Function	Water Distribution Function	TOTAL	Dike relation on Biodiversity	Dike relation on River Flow	Dike relation on Society	Dike relation on Economy	Land Use Relations	TOTAL	Area of Protection Zone	Frequency of Maintenance	Knowledge for Maintenance/ Built	TOTAL	Dike Costs	Scalar Impact of the Dike	TOTAL	
Opdijk	0.5	0.75	0.625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2.25	0
Stuifdijk	0.25	0.625	0.4375	0	0	0	0	0	1	0	0	0	0	0.2	0	1	0	0.333333	0	0	2.875	0
Dijk-in-Duin	0.25	0.625	0.4375	0	0	0	0	0	0	0	1	0	1	0.4	0	0	0	0	0	0	2.875	0
Dijk-in-Boulevard	0.25	0.375	0.3125	0	0	0	0	0	0	0	1	0	0	0.2	0	0	0	0	0	0	1.625	0
Havenkanaaldijk	0	0.25	0.125	0	0	1	0	0.25	0	1	0	0	0	0.2	1	0	0	0.333333	0	0	3.25	0
Spuikomdijk	0.25	0.25	0.25	0	0	1	0	0.25	0	1	0	0	0	0.2	0	0	0	0	0	0	2.5	0
Zomerdijk	0.125	0.25	0.1875	0	1	0	0	0.25	0	0	0	1	0	0.2	0	1	1	0.666667	1	0	5.375	1
Winterdijk	0.125	0.625	0.375	0	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	1.75	0
Dwarsdijk	0.5	0.75	0.625	0	0	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	3.25	0
Schaardijk	0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0
Vingerling	0	0.875	0.4375	0	0	0	0	0	0	1	0	0	0	0.2	1	0	0	0.333333	0	0	2.875	0
Overlaatdijk	0	0.375	0.1875	0	1	0	0	0.25	0	0	1	0	0	0.2	0	0	0	0	0	1	3.375	0
Leidijk	0.25	0.875	0.5625	0	0	1	0	0.25	0	0	1	0	0	0.2	1	0	0	0.333333	0	0	4.125	0
Limburgse Zijdewende	0.5	0.75	0.625	0	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2.25	0
Kadijk	0.5	0.25	0.375	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.333333	1	0	2.75	0
Tiendweg	0.5	0.25	0.375	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.666667	1	1	4.75	0
Ringdijk	0	0.25	0.125	0	0	1	0	0.25	0	0	0	0	0	0	1	0	0	0.333333	0	0	2.25	0
Boezemdijk	0.25	0.25	0.25	0	0	0	0	0	0	0	0	1	1	0.4	0	0	0	0	0	0	2.5	0
Landscheidingsdijk	0.5	0.75	0.625	0	0	0	1	0.25	0	0	0	0	1	0.2	0	0	1	0.666667	1	0	6.25	1
Compartimenteringsdijk	0.625	0.875	0.75	0	0	1	0	0.25	0	0	0	1	0	0.2	0	0	0	0	0	0	3.5	0
Kanaaldijk	0	0.25	0.125	0	0	1	0	0.25	0	1	0	0	0	0.2	1	0	0	0.333333	0	0	3.25	0
Hoofdweerstandslijn	0.25	0.875	0.5625	0	0	0	1	0.25	0	0	1	0	0	0.2	1	0	0	0.333333	0	0	4.125	0
Access	0.5	0.375	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.875	0
Spoeldijk	0.25	0.25	0.25	0	0	0	0	0	0	0	0	1	0	0.2	0	1	0	0.333333	0	0	2.5	0
Inside dijk	0	0.375	0.1875	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0.666667	0	1	3.375	0
Slimme dijk	0	0.375	0.1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.375	0
Energie dijk	0	0.25	0.125	0	0	1	0	0.25	0	0	0	1	0	0.2	0	0	0	0	0	1	3.25	0
Delta dijk	0	0.375	0.1875	0	0	0	0	0	0	0	0	0	1	0.2	0	0	1	0.333333	0	0	2.375	0
Hybride dijk	0.125	0.375	0.25	0	0	0	0	0	1	0	1	0	0	0.4	0	0	0	0	0	0	2.5	0
Multifunctionele dijk	0.25	0.375	0.3125	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	1.625	0
Hergebruikte dijk	0	0.375	0.1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.375	0
Minimale dijk	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	1	0.2	1	1	1	1	0	0	5	1
Superdijk	0	0.375	0.1875	0	0	0	0	0	0	0	0	0	1	0.2	0	0	1	0.333333	0	0	2.375	0
Plug-and-play dijk	0.375	0.625	0.5	0	0	0	0	0	0	0	1	0	0	0.2	0	0	0	0	0	0	2	0
Kunstriffen	0.375	0.25	0.3125	1	1	0	0	0.5	1	0	0	1	0	0.4	0	1	0	0.333333	0	0	5.625	1
Rijke Dijken	0.5	0.625	0.5625	0	0	0	1	0.25	1	0	0	0	0	0.2	0	0	1	0.333333	0	1	5.125	1
Luwtedam	0.25	0.25	0.25	0	0	1	0	0.25	0	1	0	1	0	0.4	0	0	0	0	0	0	3.5	0
Palenbos	0.375	0.25	0.3125	0	0	0	1	0.25	0	0	0	0	0	0	0	1	1	0.666667	1	0	4.625	0
Schorbuffer	0.375	0.25	0.3125	1	1	1	1	1	1	0	0	0	0	0.2	0	1	0	0.333333	0	0	6.625	1
Westkeetshaven Zwijndrecht	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	1	0.4	0	0	0	0	0	0	2.5	0
Sumida River Tokyo	0.25	0.375	0.3125	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	1.625	0
Hafencity Hamburg	0.5	0.375	0.4375	0	0	0	1	0.25	0	0	0	1	0	0.2	0	0	0	0	0	1	3.875	0
Katwijk Dijk Duin	0.25	0.625	0.4375	0	0	0	0	0	0	0	0	0	1	0.2	1	0	0	0.333333	0	0	2.875	0
Kustboulevard Cleveleys	0.25	0.375	0.3125	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.333333	0	0	1.625	0
Baggerdijk	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sawadijk (Terrassen)	0.25	0.375	0.3125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.625	0
Drift Park Rhyl	0.25	0.375	0.3125	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	1.625	0
Trapdijk Rotterdam	0.5	0.625	0.5625	0	0	1	0	0.25	0	0	0	0	1	0.2	0	0	0	0	0	0	3.125	0
Trippledijk (Kwel)	0.625	0.625	0.625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.25	0
Overloopdijk	0.625	0.375	0.5	0	1	0	1	0.5	0	0	1	0	0	0.2	0	1	0	0.333333	0	0	5	1
Terpdijk	0.5	0.375	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.333333	0	0	1.875	0
Ara River Japan	0.25	0.375	0.3125	0	0	0	0	0	1	0	0	0	1	0.4	0	0	0	0	0	0	2.625	0
Hole Dijk	0.5	0.625	0.5625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.125	0
Distributie Dijk	0	0.375	0.1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.375	0
Bevaarbare Dijk	0.375	0.25	0.3125	0	0	1	0	0.25	0	0	0	0	1	0.2	0	1	0	0.333333	0	0	3.625	0
Bewegende Dijk	0.25	0.25	0.25	0	0	0	0	0	0	0	0	1	1	0.4	0	1	0	0.333333	0	1	4.5	0
Sedimentatie Dijk	0.375	0.375	0.375	0	0	0	1	0.25	1	0	0	0	0	0.2	0	0	0	0	0	1	3.75	0
Floodwalls	0.25	0.25	0.25	0	0	0	0	0	0	0	0	1	0	0.2	0	1	1	0.666667	0	1	4.5	0
Water front parks	0.25	0.375	0.3125	0	0	0	1	0.25	1	0	1	0	1	0.6	0	0	0	0	0	0	4.625	0
Bulkhead	0.25	0.25	0.25	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	0	1.5	0
Revetments	0.25	0.25	0.25	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	0	1.5	0
Living Shorelines	0.375	0.25	0.3125	0	0	0	1	0.25	1	0	1	0	0	0.4	0	0	0	0	0	0	3.625	0
Breakwater Islands	0.625	0.25	0.4375	0	0	1	0	0.25	0	1	0	0	1	0.4	1	0	0	0.333333	0	0	4.875	0
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PROTECTION

	Form of the Dikes	Location Placement	TOTAL	Safety Failure Mechanisms	Water Distribution Failure Mechanism	Water Retention Function	Water Distribution Function	TOTAL	Dike relation on Biodiversity	Dike relation on River Flow	Dike relation on Society	Dike relation on Economy	Land Use Relations	TOTAL	Area of Protection Zone	Frequency of Maintenance	Knowledge for Maintenance/ Built	TOTAL	Dike Costs	Scalar Impact of the Dike	TOTAL	
Opdijk	0.5	0.25	0.375	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	0	0	1.75	0
Stuifdijk	0.75	0.25	0.5	0	1	1	0	0.5	0	1	0	0	0	0.2	0	0	0	0	0	1	5	0
Dijk-in-Duin	0.75	0.25	0.5	0	0	1	0	0.25	0	1	0	0	0	0.2	0	0	0	0	0	0	3	0
Dijk-in-Boulevard	0.75	0.5	0.625	1	1	0	0	0.5	1	1	0	0	0	0.4	1	1	0	0.666667	0	0	7.25	1
Havenkanaaldijk	0.5	0.75	0.625	0	1	0	0	0.25	1	0	0	0	1	0.4	0	0	0	0	0	0	4.25	0
Spuikomdijk	0.25	0.75	0.5	1	0	0	0	0.25	1	0	1	0	1	0.6	0	1	0	0.333333	0	0	6	0
Zomerdijk	0.75	0.75	0.75	0	0	0	0	0	0	0	0	1	0	0.2	0	0	1	0.333333	0	0	3.5	0
Winterdijk	0.75	0.25	0.5	0	0	0	1	0.25	0	1	0	0	0	0.2	0	0	0	0	0	1	4	0
Dwarsdijk	0.5	0.25	0.375	0	0	0	1	0.25	0	0	1	0	0	0.2	0	0	0	0	0	0	2.75	0
Schaardijk	0.5	0.75	0.625	0	0	1	0	0.25	1	0	0	0	1	0.4	1	0	0	0.333333	0	0	5.25	0
Vingerling	0.5	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Overlaatdijk	0.5	0.5	0.5	0	0	0	0	0	1	0	0	0	1	0.4	1	0	0	0.333333	0	0	4	0
Leidijk	0.25	0	0.125	0	0	0	0	0	0	0	1	1	0	0.4	0	1	0	0.333333	0	0	3.25	0
Limburgse Zijdewende	0.5	0.25	0.375	0	0	0	1	0.25	0	1	0	0	1	0.4	0	1	0	0.333333	0	0	4.75	0
Kadijk	0.5	0.75	0.625	0	0	0	0	0	0	1	1	0	0	0.4	0	0	0	0.333333	0	0	4.25	0
Tiendweg	0.5	0.75	0.625	0	0	0	0	0	0	1	1	0	0	0.4	0	0	1	0.333333	0	0	4.25	0
Ringdijk	0.5	0.75	0.625	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	2.25	0
Boezemdijk	0.75	0.75	0.75	0	0	0	0	0	0	0	1	1	0	0.4	0	1	0	0.333333	0	0	4.5	0
Landscheidingsdijk	0.5	0.25	0.375	0	0	0	1	0.25	0	0	0	1	0	0.2	0	0	1	0.333333	0	0	3.75	0
Compartimenteringsdijk	0.75	0	0.375	0	0	0	0	0	0	0	1	1	0	0.4	0	0	0	0	0	0	2.75	0
Kanaaldijk	0.5	0.75	0.625	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	2.25	0
Hoofdweerstandslijn	0.25	0	0.125	0	0	0	1	0.25	1	0	0	0	0	0.2	0	1	0	0.333333	0	0	3.25	0
Access	0.5	0.5	0.5	1	1	1	0	0.75	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Spoeldijk	0.75	0.75	0.75	1	1	1	0	0.75	1	0	0	1	1	0.6	1	0	0	0.333333	1	0	9.5	1
Inside dijk	0.5	0.5	0.5	0	0	1	0	0.25	1	0	0	0	0	0.2	0	0	0	0	0	0	3	0
Slimme dijk	0.5	0.5	0.5	0	0	0	0	0	0	1	0	0	1	0.4	0	0	0	0	0	0	3	0
Energie dijk	0.5	0.75	0.625	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0	0	0	2.25	0
Delta dijk	0.5	0.5	0.5	0	0	1	0	0.25	0	1	1	0	0	0.4	0	1	1	0.666667	0	1	7	1
Hybride dijk	0.75	0.5	0.625	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0.666667	0	0	3.25	0
Multifunctionele dijk	0.25	0.5	0.375	1	0	0	0	0.25	0	1	0	0	0	0.2	1	0	0	0.333333	0	0	3.75	0
Hergebruikte dijk	0.5	0.375	0.4375	0	0	0	0	0	0	1	0	0	1	0.4	0	0	0	0	0	0	2.875	0
Minimale dijk	0.5	0.25	0.375	0	0	0	0	0	0	0	0	1	0	0.2	0	0	1	0.333333	0	0	2.75	0
Superdijk	0.5	0.5	0.5	0	0	1	0	0.25	0	1	1	0	0	0.4	0	1	1	0.666667	0	1	7	1
Plug-and-play dijk	0.5	0.25	0.375	1	0	0	0	0.25	1	1	0	0	1	0.6	0	0	0	0	0	0	4.75	0
Kunstriffen	1	0.625	0.8125	0	0	0	0	0	0	0	1	1	0	0.4	0	0	0	0	0	0	3.625	0
Rijke Dijken	0.5	0.25	0.375	0	0	0	1	0.25	0	1	0	0	0	0.2	0	0	1	0.333333	0	0	3.75	0
Luwtedam	0.75	0	0.375	0	1	0	0	0.25	0	0	1	1	0	0.4	0	0	0	0	0	0	3.75	0
Palenbos	1	0.625	0.8125	0	0	0	1	0.25	0	1	0	0	1	0.4	0	0	1	0.333333	0	0	5.625	0
Schorbuffer	1	0.625	0.8125	0	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2.625	0
			1															1				
Westkeetshaven Zwijndrecht	0.75	0.75	0.75	0	0	0	0	0	1	0	0	0	0	0.2	0	1	0	0.333333	0	0	3.5	0
Sumida River Tokyo	0.75	0.5	0.625	1	1	0	0	0.5	1	0	1	0	0	0.4	0	0	0	0	0	0	5.25	0
Hafencity Hamburg	0.5	0.5	0.5	0	0	0	1	0.25	1	0	0	0	0	0.2	0	0	0	0	1	0	4	0
Katwijk Dijk Duin	0.75	0.25	0.5	1	1	0	0	0.5	0	0	1	0	0	0.2	0	1	0	0.333333	1	0	6	0
Kustboulevard Cleveleys	0.75	0.5	0.625	1	1	1	0	0.75	1	0	0	0	0	0.2	0	0	0	0	1	1	7.25	1
Baggerdijk	1	0.25	0.625	0	0	0	0	0	0	1	0	0	0	0.2	1	0	0	0.333333	0	0	3.25	0
Sawadijk (Terrassen)	0.75	0.5	0.625	0	0	0	0	0	0	1	0	0	1	0.2	0	0	0	0	0	0	2.25	0
Drift Park Rhyl	0.75	0.5	0.625	1	1	1	0	0.75	1	0	0	0	0	0.2	0	0	0	0	1	1	7.25	1
Trapdijk Rotterdam	0.5	0	0.25	1	1	0	0	0.5	0	1	1	0	0	0.4	0	0	0	0	0	0	4.5	0
Trippledijk (Kwel)	0.75	0.25	0.5	0	0	0	0	0	0	1	1	0	0	0.4	1	1	0	0.666667	0	0	5	0
Overloopdijk	0.75	0.5	0.625	0	0	0	1	0.25	0	1	0	0	0	0.2	0	0	0	0	0	0	3.25	0
Terpdijk	0.5	0.5	0.5	0	0	1	0	0.25	0	0	1	0	1	0.4	1	0	1	0.666667	0	0	6	0
Ara River Japan	0.75	0.5	0.625	1	1	1	0	0.75	0	0	0	0	0	0	0	0	0	0	0	1	5.25	0
Hole Dijk	0.5	0.25	0.375	1	1	0	0	0.5	1	0	0	0	1	0.4	1	1	0	0.666667	0	0	6.75	1
Distributie Dijk	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	2	0
Bevaarbare Dijk	1	0.625	0.8125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.625	0
Bewegende Dijk	0.75	0.75	0.75	1	1	0	0	0.5	1	0	0	0	1	0.4	0	0	0	0	0	0	5.5	0
Sedimentatie Dijk	1	0.5	0.75	0	0	0	1	0.25	0	1	0	0	1	0.4	1	0	0	0.333333	0	0	5.5	0
Floodwalls	0.75	0.75	0.75	0	0	0	0	0	1	0	0	1	0	0.4	0	0	1	0.333333	0	0	4.5	0
Water front parks	0.75	0.5	0.625	0	0	0	1	0.25	0	0	0	0	0	0	0	1	0	0.333333	0	0	3.25	0
Bulkhead	0.75	0.75	0.75	1	1	1	0	0.75	1	0	0	1	0	0.4	0	1	0	0.333333	0	0	7.5	1
Revetments	0.75	0.75	0.75	1	0	1	0	0.5	0	1	1	1	1	0.8	0	0	0	0	0	0	7.5	1
Living Shorelines	1	0.625	0.8125	0	0	0	1	0.25	0	0	0	0	0	0	1	1	0	0.666667	0	0	4.625	0
Breakwater Islands	0.75	0.625	0.6875	0	0	0	0	0	0	0	1	0	0	0.2	0	0	0	0	0	0	2.375	0
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Dike Autonomy

Relations between dike catalog & Distribution dike (top)

Dike Autonomy

Relations between dike catalog & Landscape dike (bottom)

DISTRIBUTION

	Form of the Dikes	Location Placement	TOTAL	Safety Failure Mechanisms	Water Distribution Failure Mechanism	Water Retention Function	Water Distribution Function	TOTAL	Dike relation on Biodiversity	Dike relation on River Flow	Dike relation on Society	Dike relation on Economy	Land Use Relations	TOTAL	Area of Protection Zone	Frequency of Maintenance	Knowledge for Maintenance/ Built	TOTAL	Dike Costs	Scalar Impact of the Dike	TOTAL	
	Opdijk	0.125	0.25	0.1875	0	0	0	0	0	0	0	0	1	0.2	1	0	0	0.333333	0	0	2.375	0
	Stuifdijk	0.375	0.25	0.3125	0	0	0	0	0	0	0	1	1	0.4	0	0	0	0	1	0	3.625	0
	Dijk-in-Duin	0.375	0.25	0.3125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1.625	0
	Dijk-in-Boulevard	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	1	0	2.875	0
	Havenkanaaldijk	0.625	0.75	0.6875	0	0	1	1	0.5	1	1	0	0	0.4	0	0	0	0	0	0	5.375	0
	Spuikomdijk	0.375	0.75	0.5625	0	0	1	1	0.5	1	1	1	1	0	0.8	0	0	0	0	0	7.125	1
	Zomerdijk	0.75	0.75	0.75	1	1	0	0	0.5	0	0	0	0	0	0	1	0	0	0.333333	0	4.5	0
	Winterdijk	0.75	0.25	0.5	0	0	0	0	0	0	0	0	1	1	0.4	0	1	0	0.333333	1	0	5	0
	Dwarsdijk	0.125	0.25	0.1875	0	0	1	0	0.25	0	0	1	0	0	0.2	0	0	0	0	0	2.375	0
	Schaardijk	0.625	0.75	0.6875	0	0	0	0	0	1	0	0	1	0	0.4	0	0	1	0.333333	1	0	5.375	0
	Vingerling	0.625	0	0.3125	0	0	0	0	0	0	0	0	1	1	0.2	0	1	0	0.333333	1	0	3.625	0
	Overlaatdijk	0.625	0.5	0.5625	0	0	1	1	0.5	1	0	0	0	0	0.2	0	0	0	0	0	1	5.125	0
	Leidijk	0.375	0	0.1875	0	0	1	1	0.5	0	0	0	1	0	0.4	0	0	0	0	0	0	4.375	0
	Limburgse Zijdewende	0.125	0.25	0.1875	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	0	1.375	0
	Kadijk	0.125	0.75	0.4375	0	0	0	1	0.25	1	0	1	0	1	0.6	0	0	0	0	0	0	4.875	0
	Tiendweg	0.125	0.75	0.4375	0	0	0	0	0	0	0	0	1	0	0.2	1	0	0	0	0.333333	0	1	3.875	0
	Ringdijk	0.625	0.75	0.6875	0	1	1	1	0.75	0	0	0	1	0	0.2	0	1	0	0.333333	0	0	6.375	1
	Boezemdijk	0.375	0.75	0.5625	0	0	0	1	0.25	0	0	1	0	0	0.2	0	0	0	0	1	0	4.125	0
	Landscheidingsdijk	0.125	0.25	0.1875	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	1	1.375	0
	Compartimenteringsdijk	0.25	0	0.125	0	0	0	1	0	0.25	0	0	1	0	0.2	0	0	0	0	0	0	2.25	0
	Kanaaldijk	0.625	0.75	0.6875	0	0	1	1	0.5	0	1	0	0	0	0.2	0	1	0	0.333333	0	0	5.375	0
	Hoofdweerstandslijn	0.375	0	0.1875	0	0	0	0	0	1	0	0	1	1	0.6	0	0	0	0	0	0	3.375	0
	Access	0.125	0.5	0.3125	0	0	0	0	0	0	0	0	1	0	0.2	0	1	0	0.333333	1	0	3.625	0
	Spoeldijk	0.375	0.75	0.5625	0	0	0	0	0	1	0	0	0	0	0.2	0	0	1	0.333333	0	0	3.125	0
	Inside dijk	0.625	0.5	0.5625	0	0	0	0	0	1	0	0	0	0	0.2	0	0	1	0.333333	1	1	5.125	0
	Slimme dijk	0.625	0.5	0.5625	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	1	0	3.125	0
	Energie dijk	0.625	0.75	0.6875	0	0	1	1	0.5	0	0	0	0	1	0.2	0	0	0	0	0	1	5.375	0
	Delta dijk	0.625	0.5	0.5625	0	0	0	0	0	0	0	0	1	1	0.4	0	0	0	0	1	0	4.125	0
	Hybride dijk	0.75	0.5	0.625	1	1	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	3.25	0
	Multifunctionele dijk	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1.875	0
	Hergebruikte dijk	0.625	0.375	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0
	Minimale dijk	0.5	0.25	0.375	1	1	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	2.75	0
	Superdijk	0.625	0.5	0.5625	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	1	0	3.125	0
	Plug-and-play dijk	0.5	0.25	0.375	0	0	0	0	0	1	0	0	1	0	0.4	0	0	0	0	0	0	2.75	0
	Kunstriffen	0.5	0.625	0.5625	1	1	0	0	0.5	0	0	0	1	0	0.4	1	0	0	0.333333	0	0	6.125	1
	Rijke Dijken	0.125	0.25	0.1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1.375	0
	Luwtedam	0.375	0.625	0.5	0	0	1	0	0.25	0	1	1	0	1	0.6	1	0	0	0.333333	0	0	6	1
	Palenbos	0.5	0.625	0.5625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.125	0
	Schorbuffer	0.5	0.625	0.5625	1	1	1	0	0.75	0	0	0	1	1	0.4	0	0	0	0	0	0	6.125	1
	Westkeetshaven Zwijndrecht	0.375	0.75	0.5625	0	0	0	0	0	1	0	0	0	0	0.2	1	0	0	0.333333	1	0	4.125	0
	Sumida River Tokyo	0.375	0.5	0.4375	0	0	0	0	0	1	0	1	1	0	0.6	1	0	0	0.333333	1	0	5.875	1
	Hafencity Hamburg	0.125	0.5	0.3125	0	0	0	0	0	1	0	0	0	0	0.2	0	0	0	0	0	1	2.625	0
	Katwijk Dijk Duin	0.375	0.25	0.3125	0	0	0	0	0	0	0	1	0	0	0.2	0	0	0	0	0	0	1.625	0
	Kustboulevard Cleveleys	0.375	0.5	0.4375	0	0	0	0	0	1	0	0	0	0	0.2	0	0	0	0	0	0	1.875	0
	Baggerdijk	0.5	0.25	0.375	0	1	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	1.75	0
	Sawadijk (Terrassen)	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	1	0	2.875	0
	Drift Park Rhyl	0.375	0.5	0.4375	0	0	0	0	0	1	0	0	1	0	0.4	0	0	0	0	0	0	2.875	0
	Trapdijk Rotterdam	0.125	0.25	0.1875	0	0	1	0	0.25	0	0	1	0	0	0.2	0	1	0	0.333333	0	0	3.375	0
	Trippledijk (Kwel)	0.375	0.25	0.3125	0	1	0	0	0.25	0	0	1	0	0	0.2	0	0	0	0	0	0	2.625	0
	Overloopdijk	0.25	0.5	0.375	1	1	0	0	0.5	0	0	0	0	1	0.2	0	0	0	0	0	0	3.75	0
	Terpdijk	0.125	0.5	0.3125	0	0	0	0	0	0	0	0	1	1	0.4	0	1	0	0.333333	1	0	4.625	0
	Ara River Japan	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1.875	0
	Hole Dijk	0.125	0.25	0.1875	0	0	0	0	0	1	0	0	0	0	0.2	0	0	0	0	1	0	2.375	0
	Distributie Dijk	0.625	0.5	0.5625	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	1	1	4.125	0
	Bevaarbare Dijk	0.5	0.625	0.5625	0	1	1	0	0.5	0	0	0	1	0	0.2	0	0	1	0.333333	1	0	6.125	1
	Bewegende Dijk	0.375	0.75	0.5625	0	0	0	0	0	1	0	0	0	0	0.2	0	0	0	0.333333	1	1	5.125	0
	Sedimentatie Dijk	0.5	0.5	0.5	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	1	3	0
	Floodwalls	0.375	0.75	0.5625	0	0	0	0	0	1	0	0	0	0	0.2	1	0	0	0.333333	0	1	4.125	0
	Water front parks	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1.875	0
	Bulkhead	0.375	0.75	0.5625	0	0	0	0	0	1	0	0	0	1	0.4	0	0	0	0	1	0	4.125	0
	Revetments	0.375	0.75	0.5625	0	0	0	0	0	0	0	1	0	0	0.2	0	1	0	0.333333	1	0	4.125	0
	Living Shorelines	0.5	0.625	0.5625	0	0	0	0	0	0	0	0	1	1	0.4	0	0	0	0	0	0	3.125	0
	Breakwater Islands	0.375	0.625	0.5	0	1	1	1	0.75	0	1	1	0	0	0.4	0	0	0	0	0	0	6	1
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LANDSCAPE

	Form of the Dikes	Location Placement	TOTAL	Safety Failure Mechanisms	Water Distribution Failure Mechanism	Water Retention Function	Water Distribution Function	TOTAL	Dike relation on Biodiversity	Dike relation on River Flow	Dike relation on Society	Dike relation on Economy	Land Use Relations	TOTAL	Area of Protection Zone	Frequency of Maintenance	Knowledge for Maintenance/ Built	TOTAL	Dike Costs	Scalar Impact of the Dike	TOTAL	
	Opdijk	0.375	0.25	0.3125	1	0	0	0	0.25	0	0	0	1	0	0.2	0	1	0	0.333333	0	0	3.625	0
	Stuifdijk	0.25	0.75	0.5	0	0	0	0	0	1	1	0	0	0	0.4	1	0	0	0.333333	1	0	5	0
	Dijk-in-Duin	0.25	0.75	0.5	0	0	0	0	0	0	1	0	0	1	0.4	0	0	0	0	1	1	5	0
	Dijk-in-Boulevard	0.25	0.875	0.5625	0	0	1	0	0.25	0	1	0	0	0	0.2	0	1	0	0.333333	1	0	5.125	0
	Havenkanaaldijk	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Spuikomdijk	0.5	0.625	0.5625	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0.666667	0	0	3.125	0
	Zomerdijk	0.5	0.625	0.5625	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.333333	0	1	3.125	0
	Winterdijk	0.5	0.75	0.625	0	0	1	1	0.5	0	1	0	0	0	0.2	0	0	0	0	1	0	5.25	0
	Dwarsdijk	0.375	0.25	0.3125	1	0	0	1	0.5	0	0	0	1	0	0.2	1	0	0	0.333333	0	1	5.625	0
	Schaardijk	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	0
	Vingerling	0.375	0.5	0.4375	1	0	0	0	0.25	0	0	0	1	0	0.2	0	0	0	0	1	0	3.875	0
	Overlaatdijk	0.375	0.875	0.625	1	0	0	0	0.25	0	0	0	1	0	0.2	0	0	0	0	0	0	3.25	0
	Leidijk	0.5	0.5	0.5	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	0	0	2	0
	Limburgse Zijdewende	0.375	0.25	0.3125	1	0	0	1	0.5	0	1	0	0	0	0.2	1	1	0	0.666667	0	0	5.625	0
	Kadijk	0.375	0.625	0.5	0	0	0	0	0	0	0	0	1	0	0.2	1	0	1	0.666667	0	0	4	0
	Tiendweg	0.375	0.625	0.5	0	0	0	0	0	0	1	0	1	0	0.4	0	0	1	0.333333	0	0	4	0
	Ringdijk	0.375	0.625	0.5	1	0	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Boezemdijk	0.25	0.625	0.4375	1	0	0	1	0.5	0	0	0	0	1	0.2	0	0	1	0	0.333333	1	6.875	1
	Landscheidingsdijk	0.375	0.25	0.3125	0	0	0	1	0.25	0	0	0	0	0	0	1	1	0	0.666667	0	0	3.625	0
	Compartimenteringsdijk	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Kanaaldijk	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Hoofdweerstandslijn	0.5	0.5	0.5	0	0	1	1	0.5	0	0	0	0	0	0	0	1	0	0.333333	0	0	4	0
	Access	0.375	0.875	0.625	0	1	0	0	0.25	0	0	0	1	0	0.2	0	0	0	0	1	0	4.25	0
	Spoeldijk	0.25	0.625	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.875	0
	Inside dijk	0.375	0.875	0.625	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	1	0	3.25	0
	Slimme dijk	0.375	0.875	0.625	0	0	1	0	0.25	0	1	1	0	0	0.4	0	0	0	0	1	0	5.25	0
	Energie dijk	0.375	0.625	0.5	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0	0	0	2	0
	Delta dijk	0.375	0.875	0.625	0	0	0	0	0	0	1	0	0	1	0.4	0	1	1	0.666667	1	0	6.25	1
	Hybride dijk	0.5	0.875	0.6875	1	0	0	1	0.5	1	0	0	1	0	0.4	0	0	1	0.333333	0	0	6.375	1
	Multifunctionele dijk	0.5	0.875	0.6875	0	0	0	1	0.25	0	1	1	0	1	0.6	0	0	0	0	0	1	7.375	1
	Hergebruikte dijk	0.375	0.375	0.375	1	0	0	0	0.25	0	1	1	0	0	0.4	0	0	0	0	0	0	3.75	0
	Minimale dijk	0.625	0.75	0.6875	0	0	1	0	0.25	0	0	0	0	0	0	0	0	1	0.333333	0	1	4.375	0
	Superdijk	0.375	0.875	0.625	0	0	0	0	0	0	1	0	1	1	0.6	0	1	1	0.666667	1	0	7.25	1
	Plug-and-play dijk	0.625	0.625	0.625	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0	0	0	2.25	0
	Kunstriffen	0.375	0.25	0.3125	0	0	0	0	0	1	0	0	0	0	0.2	0	0	0	0	0	0	1.625	0
	Rijke Dijken	0.375	0.75	0.5625	0	0	1	1	0.5	1	1	1	1	0	0.8	0	0	0	0.333333	0	0	8.125	1
	Luwtedam	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
	Palenbos	0.375	0.25	0.3125	0	0	0	1	0.25	0	1	0	1	0	0.4	0	0	1	0.333333	0	0	4.625	0
	Schorbuffer	0.375	0.25	0.3125	0	0	0	1	0.25	1	0	0	0	0	0.2	0	0	0	0	0	0	2.625	0
	Westkeetshaven Zwijndrecht	0.25	0.625	0.4375	0	0	0	0	0	0	0	0	0	1	0.2	0	1	0	0.333333	1	0	3.875	0
	Sumida River Tokyo	0.25	0.875	0.5625	0	0	1	0	0.25	0	0	0	0	1	0.2	0	0	0	0	1	0	4.125	0
	Hafencity Hamburg	0.375	0.875	0.625	0	0	1	0	0.25	0	0	0	0	0	0	1	0	0	0.333333	0	0	3.25	0
	Katwijk Dijk Duin	0.25	0.75	0.5	0	0	1	0	0.25	0	0	0	0	1	0.2	0	1	0	0.333333	0	0	4	0
	Kustboulevard Cleveleys	0.25	0.875	0.5625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.125	0
	Baggerdijk	0.375	0.75	0.5625	1	0	0	0	0.25	0	1	0	0	0	0.2	0	0	0	0	0	0	3.125	0
	Sawadijk (Terrassen)	0.25	0.875	0.5625	1	0	1	0	0.5	0	0	0	1	0	0.2	0	0	0	0	1	1	6.125	1
	Drift Park Rhyl	0.25	0.875	0.5625	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	0	2.125	0
	Trapdijk Rotterdam	0.375	0.625	0.5	0	0	0	0	0	0	1	0	1	1	0.4	1	0	0	0	0.333333	0	4	0
	Trippledijk (Kwel)	0.125	0.75	0.4375	1	0	0	1	0.5	0	1	0	0	1	0.4	0	1	0	0.333333	0	1	6.875	1
	Overloopdijk	0.5	0.875	0.6875	1	0	0	1	0.5	0	1	0	1	0	0.4	1	0	0	0.333333	0	0	6.375	1
	Terpdijk	0.375	0.875	0.625	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.333333	1	0	3.25	0
	Ara River Japan	0.25	0.875	0.5625	0	0	0	0	0	1	0	0	0	1	0.4	0	0	0	0	1	0	4.125	0
	Hole Dijk	0.375	0.625	0.5	0	0	0	0	0	0	0	1	0	0	0.2	0	1	0	0.333333	1	0	4	0
	Distributie Dijk	0.375	0.875	0.625	1	0	0	0	0.25	0	0	0	1	0	0.2	0	0	0	0	1	0	4.25	0
	Bevaarbare Dijk	0.375	0.25	0.3125	1	0	0	0	0.25	0	0	0	0	1	0.2	1	0	0	0.333333	1	0	4.625	0
	Bewegende Dijk	0.25	0.625	0.4375	0	1	1	0	0.5	0	0	0	0	1	0.2	0	0	0	0	1	0	4.875	0
	Sedimentatie Dijk	0.375	0.875	0.625	1	0	1	1	0.75	1	1	0	0	0	0.4	0	0	0	0	0	0	6.25	1
	Floodwalls	0.25	0.625	0.4375	1	0	0	0	0.25	0	0	1	0	0	0.2	0	0	1	0.333333	0	0	3.875	0
	Water front parks	0.25	0.875	0.5625	1	0	1	1	0.75	1	0	0	0	1	0.4	0	1	0	0.333333	1	0	8.125	1
	Bulkhead	0.25	0.625	0.4375	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0.666667	1	0	3.875	0
	Revetments	0.25	0.625	0.4375	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0	1	0	2.875	0
	Living Shorelines	0.375	0.25	0.3125	1	0	0	1	0.5	1	0	0	0	0	0.2	0	1	0	0.333333	0	0	4.625	0
	Breakwater Islands	0.125	0.25	0.1875	1	0	0	0	0.25	0	0	0	1	1	0.4	0	0	0	0	0	0	3.375	0
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Dike Autonomy

Relations between dike catalog & Local Maintenance dike (top)

Dike Autonomy

Relations between dike catalog & Multifunctional dike (bottom)

LOCAL MAINTAINED ELEMENT

	Form of the Dikes	Location Placement	TOTAL	Safety Failure Mechanisms	Water Distribution Failure Mechanism	Water Retention Function	Water Distribution Function	TOTAL	Dike relation on Biodiversity	Dike relation on River Flow	Dike relation on Society	Dike relation on Economy	Land Use Relations	TOTAL	Area of Protection Zone	Frequency of Maintenance	Knowledge for Maintenance/ Built	TOTAL	Dike Costs	Scalar Impact of the Dike	TOTAL	
Opdijk	0.75	0.75	0.75	0	0	1	0	0.25	0	0	0	0	0	0	1	0	0	0.333333	1	0	4.5	0
Stuifdijk	0.5	0.25	0.375	0	0	0	0	0	0	1	0	1	0	0.2	0	0	0	0	0	0	1.75	0
Dijk-in-Duin	0.5	0.25	0.375	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0	0	0	1.75	0
Dijk-in-Boulevard	0.5	0.5	0.5	0	0	0	0	0	0	1	0	0	1	0.4	0	0	0	0	0	0	3	0
Havenkanaaldijk	0.25	0.75	0.5	0	0	1	0	0.25	0	0	0	0	0	0	0	1	0	0.333333	0	0	3	0
Spuikomdijk	0.5	0.75	0.625	0	0	1	0	0.25	0	0	0	0	0	0	0	0	0	0	0	1	3.25	0
Zomerdijk	0.375	0.75	0.5625	0	1	1	0	0.5	0	0	0	0	1	0.2	1	0	1	0.666667	1	0	7.125	1
Winterdijk	0.375	0.25	0.3125	0	0	0	1	0.25	1	1	0	0	0	0.4	0	0	0	0	0	0	3.625	0
Dwarsdijk	0.75	0.75	0.75	0	0	1	1	0.5	1	0	0	0	0	0.2	0	0	0	0	0	0	4.5	0
Schaardijk	0.25	0.75	0.5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	0	0	2	0
Vingerling	0.25	0.5	0.375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0
Overlaatdijk	0.25	0.5	0.375	0	0	1	0	0.25	0	0	0	0	0	0	0	1	0	0.333333	0	1	3.75	0
Leidijk	0.5	0.5	0.5	0	0	1	0	0.25	1	0	0	0	1	0.4	0	0	0	0	0	0	4	0
Limburgse Zijdewende	0.75	0.75	0.75	0	0	0	1	0.25	1	1	0	0	0	0.4	0	0	0	0	0	0	4.5	0
Kadijk	0.75	0.75	0.75	0	0	1	0	0.25	0	0	0	0	0	0	0	0	1	0.333333	1	0	4.5	0
Tiendweg	0.75	0.75	0.75	0	0	1	0	0.25	0	1	0	0	0	0.2	1	0	1	0.666667	1	1	7.5	1
Ringdijk	0.25	0.75	0.5	0	0	1	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Boezemdijk	0.5	0.75	0.625	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	2.25	0
Landscheidingsdijk	0.75	0.75	0.75	0	0	1	1	0.5	0	0	0	0	1	0.2	0	0	1	0.333333	1	0	6.5	1
Compartimenteringsdijk	0.875	0.5	0.6875	0	0	1	0	0.25	0	0	0	0	1	0.2	0	0	0	0	0	0	3.375	0
Kanaaldijk	0.25	0.75	0.5	0	0	1	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Hoofdweerstandslijn	0.5	0.5	0.5	0	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Access	0.75	0.5	0.625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.25	0
Spoeldijk	0.5	0.75	0.625	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	2.25	0
Inside dijk	0.25	0.5	0.375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.75	0
Slimme dijk	0.25	0.5	0.375	0	0	0	0	0	0	1	1	0	0	0.4	0	1	0	0.333333	0	0	3.75	0
Energie dijk	0.25	0.75	0.5	0	0	1	0	0.25	0	1	0	0	0	0.2	0	1	0	0.333333	0	1	5	0
Delta dijk	0.25	0.5	0.375	0	0	0	0	0	0	1	1	0	0	0.4	0	0	1	0.333333	0	0	3.75	0
Hybride dijk	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.875	0
Multifunctionele dijk	0.5	0.5	0.5	0	0	0	0	0	1	1	1	0	0	0.6	0	1	0	0.333333	0	0	5	0
Hergebruikte dijk	0.25	0.5	0.375	0	0	0	0	0	1	1	1	0	0	0.6	0	1	0	0.333333	0	1	5.75	1
Minimale dijk	0.625	0.25	0.4375	0	0	0	0	0	0	0	0	1	0	0.2	0	0	1	0.333333	0	0	2.875	0
Superdijk	0.25	0.5	0.375	0	0	0	0	0	1	1	0	0	0	0.4	0	0	1	0.333333	0	0	3.75	0
Plug-and-play dijk	0.625	0.75	0.6875	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0	0	0	2.375	0
Kunstriffen	0.625	0.25	0.4375	1	1	1	0	0.75	0	0	0	1	0	0.2	1	0	0	0.333333	0	0	5.875	1
Rijke Dijken	0.75	0.25	0.5	0	0	0	1	0.25	0	1	1	0	0	0.4	0	1	1	0.666667	0	1	7	1
Luwtedam	0.5	0.25	0.375	0	0	1	0	0.25	1	0	0	1	0	0.4	1	0	0	0.333333	0	0	4.75	0
Palenbos	0.625	0.25	0.4375	0	0	1	1	0.5	0	1	0	0	0	0.2	0	0	1	0.333333	1	0	5.875	1
Schorbuffer	0.625	0.25	0.4375	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4.875	0
Westkeetshaven Zwijndrecht	0.5	0.75	0.625	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.333333	0	0	2.25	0
Sumida River Tokyo	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.333333	0	0	2	0
Hafencity Hamburg	0.75	0.5	0.625	0	0	0	1	0.25	0	0	0	0	1	0.2	0	0	0	0	0	1	4.25	0
Katwijk Dijk Duin	0.5	0.25	0.375	0	0	0	0	0	1	0	0	0	0	0.2	0	0	0	0	0	0	1.75	0
Kustboulevard Cleveleys	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	2	0
Baggerdijk	0.625	0.25	0.4375	0	0	0	0	0	1	1	0	0	0	0.4	0	1	0	0.333333	0	0	3.875	0
Sawadijk (Terrassen)	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Drift Park Rhyl	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Trapdijk Rotterdam	0.75	0.75	0.75	0	0	1	0	0.25	0	1	0	0	0	0.2	0	0	0	0	0	0	3.5	0
Trippledijk (Kwel)	0.375	0.25	0.3125	0	0	0	0	0	1	1	0	0	0	0.4	0	0	0	0	0	0	2.625	0
Overloopdijk	0.875	0.5	0.6875	0	1	0	1	0.5	1	1	0	0	0	0.4	0	0	0	0	0	0	5.375	0
Terpdijk	0.75	0.5	0.625	0	0	0	0	0	1	0	0	0	0	0.2	0	0	1	0.333333	0	0	3.25	0
Ara River Japan	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	0	0	2	0
Hole Dijk	0.75	0.75	0.75	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0	0	0	2.5	0
Distributie Dijk	0.25	0.5	0.375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.75	0
Bevaarbare Dijk	0.625	0.25	0.4375	0	0	1	0	0.25	1	0	0	0	0	0.2	0	0	0	0	0	0	2.875	0
Bewegende Dijk	0.5	0.75	0.625	0	0	0	0	0	0	0	0	1	0	0.2	1	0	0	0.333333	0	1	4.25	0
Sedimentatie Dijk	0.625	0.5	0.5625	0	0	0	1	0.25	0	1	0	0	0	0.2	0	1	0	0.333333	0	1	5.125	0
Floodwalls	0.5	0.75	0.625	0	0	0	0	0	0	0	1	1	0	0.4	1	0	1	0.666667	0	1	6.25	1
Water front parks	0.5	0.5	0.5	0	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Bulkhead	0.5	0.75	0.625	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	0	2.25	0
Revetments	0.5	0.75	0.625	0	0	0	0	0	0	1	0	1	0	0.4	0	0	0	0	0	0	3.25	0
Living Shorelines	0.625	0.25	0.4375	0	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	1.875	0
Breakwater Islands	0.375	0.25	0.3125	0	0	1	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	1.625	0
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MULTIFUNCTIONAL ELEMENT

	Form of the Dikes	Location Placement	TOTAL	Safety Failure Mechanisms	Water Distribution Failure Mechanism	Water Retention Function	Water Distribution Function	TOTAL	Dike relation on Biodiversity	Dike relation on River Flow	Dike relation on Society	Dike relation on Economy	Land Use Relations	TOTAL	Area of Protection Zone	Frequency of Maintenance	Knowledge for Maintenance/ Built	TOTAL	Dike Costs	Scalar Impact of the Dike	TOTAL	
Opdijk	0.125	0	0.0625	1	0	0	1	0.5	0	0	0	0	1	0.2	0	1	0	0.333333	0	0	4.125	0
Stuifdijk	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	1	2.875	0
Dijk-in-Duin	0.375	0.5	0.4375	0	0	0	0	0	1	0	1	1	0	0.6	0	0	0	0	0	0	3.875	0
Dijk-in-Boulevard	0.375	0.625	0.5	0	0	0	0	0	0	0	1	0	0	0.2	1	1	0	0.666667	0	1	5	0
Havenkanaaldijk	0.625	0.375	0.5	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0	0	0	2	0
Spuikomdijk	0.375	0.375	0.375	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	0	0	1.75	0
Zomerdijk	0.875	0.375	0.625	0	0	0	0	0	1	0	0	0	0	0.2	0	0	1	0.333333	0	0	3.25	0
Winterdijk	0.875	0.5	0.6875	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	1	3.375	0
Dwarsdijk	0.125	0	0.0625	1	1	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	2.125	0
Schaardijk	0.625	0.375	0.5	0	0	0	0	0	0	1	0	0	0	0.2	1	0	0	0.333333	0	0	3	0
Vingerling	0.625	0.25	0.4375	1	1	1	0	0.75	1	0	1	0	1	0.6	0	0	0	0	0	0	6.875	1
Overlaatdijk	0.625	0.625	0.625	1	1	0	0	0.5	0	0	1	0	0	0.2	1	0	0	0.333333	0	0	5.25	0
Leidijk	0.375	0.25	0.3125	0	0	0	0	0	0	1	0	0	1	0.4	0	1	0	0.333333	0	0	3.625	0
Limburgse Zijdewende	0.125	0	0.0625	1	1	1	0	0.75	0	0	0	0	0	0	0	1	0	0.333333	0	0	4.125	0
Kadijk	0.125	0.375	0.25	0	0	0	0	0	0	1	0	0	1	0.4	0	0	1	0.333333	0	0	3.5	0
Tiendweg	0.125	0.375	0.25	0	0	0	1	0.25	0	0	0	0	0	0	0	0	1	0.333333	0	0	2.5	0
Ringdijk	0.625	0.375	0.5	1	1	0	0	0.5	0	1	0	0	0	0.2	0	0	0	0	0	1	5	0
Boezemdijk	0.375	0.375	0.375	1	0	0	0	0.5	1	1	0	0	0	0.4	0	1	0	0.333333	0	0	5.75	1
Landscheidingsdijk	0.125	0	0.0625	0	0	0	0	0	0	0	0	0	1	0.2	0	0	1	0.333333	0	0	2.125	0
Compartimenteringsdijk	0.375	0.25	0.3125	0	0	0	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	1.625	0
Kanaaldijk	0.625	0.375	0.5	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	1	3	0
Hoofdweerstandslijn	0.375	0.25	0.3125	0	0	0	0	0	0	0	1	0	1	0.4	0	1	0	0.333333	0	1	4.625	0
Access	0.125	0.625	0.375	0	0	0	0	0	0	1	0	0	1	0.4	0	0	0	0	0	1	3.75	0
Spoeldijk	0.375	0.375	0.375	0	0	0	0	0	0	1	0	0	0	0.2	1	0	0	0.333333	1	0	3.75	0
Inside dijk	0.625	0.625	0.625	0	0	1	0	0.25	0	1	0	0	0	0.2	0	0	0	0	0	0	3.25	0
Slimme dijk	0.625	0.625	0.625	0	1	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	2.25	0
Energie dijk	0.625	0.375	0.5	0	1	0	0	0.25	0	0	1	1	1	0.6	0	0	0	0	0	0	5	0
Delta dijk	0.625	0.625	0.625	0	1	0	0	0.25	0	0	0	0	0	0	0	1	1	0.666667	0	1	5.25	0
Hybride dijk	0.875	0.625	0.75	1	1	0	0	0.5	0	0	1	0	0	0.2	1	1	0	0.666667	0	0	6.5	1
Multifunctionele dijk	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.333333	0	0	2	0
Hergebruikte dijk	0.625	0.625	0.625	1	1	1	0	0.75	0	0	0	1	0	0.2	0	0	0	0	0	0	5.25	0
Minimale dijk	0.625	0.5	0.5625	0	1	0	0	0.25	0	0	0	0	0	0	0	0	1	0.333333	0	0	3.125	0
Superdijk	0.625	0.625	0.625	0	1	0	0	0.25	0	0	0	0	0	0	0	1	1	0.666667	0	1	5.25	0
Plug-and-play dijk	0.625	0.375	0.5	0	0	1	0	0.25	0	0	1	0	0	0.2	0	0	0	0	0	0	3	0
Kunstriffen	0.625	0.625	0.625	0	0	0	0	0	0	1	0	0	1	0.4	0	0	0	0	0	0	3.25	0
Rijke Dijken	0.125	0.5	0.3125	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.333333	0	0	1.625	0
Luwtedam	0.375	0.625	0.5	0	0	0	1	0.25	0	0	0	0	0	0	1	0	0	0	0	0	3	0
Palenbos	0.625	0.625	0.625	0	1	0	0	0.25	0	0	0	0	0	0	0	0	1	0.333333	0	0	3.25	0
Schorbuffer	0.625	0.625	0.625	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	1	3.25	0
Westkeetshaven Zwijndrecht	0.375	0.375	0.375	0	0	1	1	0.5	0	0	1	1	0	0.4	0	1	0	0.333333	0	0	5.75	1
Sumida River Tokyo	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hafencity Hamburg	0.125	0.625	0.375	0	0	1	0	0.25	0	0	1	0	0	0.2	0	0	1	0	0	1	3.75	0
Katwijk Dijk Duin	0.375	0.5	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.333333	1	0	2.875	0
Kustboulevard Cleveleys	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	1	1	4	0
Baggerdijk	0.625	0.5	0.5625	1	1	1	0	0.75	0	0	0	1	0	0.2	1	0	0	0.333333	0	0	6.125	1
Sawadijk (Terrassen)	0.375	0.625	0.5	1	1	0	0	0.5	1	1	0	0	0	0.4	0	0	0	0	0	0	5	0
Drift Park Rhyl	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	3	0
Trapdijk Rotterdam	0.125	0.375	0.25	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	0	0	0	1.5	0
Trippledijk (Kwel)	0.5	0.5	0.5	1	1	0	1	0.75	0	0	0	0	0	0	1	1	0	0.666667	0	0	6	1
Overloopdijk	0.375	0.625	0.5	1	0	1	0	0.5	0	0	1	0	1	0.4	0	0	0	0	0	0	5	0
Terpdijk	0.125	0.625	0.375	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.666667	0	0	2.75	0
Ara River Japan	0.375	0.625	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
Hole Dijk	0.125	0.375	0.25	0	0	1	0	0.25	0	0	0	1	0	0.2	1	1	0	0.666667	0	0	4.5	0
Distributie Dijk	0.625	0.625	0.625	1	1	1	1	1	1	0	0	0	0	0.2	0	0	0	0	0	0	6.25	1
Bevaarbare Dijk	0.625	0.625	0.625	1	1	0	1	0.75	0	1	0	0	0	0.2	0	0	0	0	0	0	5.25	0
Bewegende Dijk	0.375	0.375	0.375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0
Sedimentatie Dijk	0.625	0.625	0.625	1	1	0	0	0.5	0	0	0	0	0	0	1	0	0	0.333333	0	0	4.25	0
Floodwalls	0.375	0.375	0.375	1	1	1	0	0.75	0	0	0	0	0	0	0	0	1	0.333333	0	0	4.75	0
Water front parks	0.375	0.625	0.5	1	1	0	0	0.5	0	0	1	1	0	0.4	0	1	0	0.333333	0	1	7	1
Bulkhead	0.375	0.375	0.375	0	0	0	0	0	0	1	0	0	1	0.4	0	1	0	0.333333	0	0	3.75	0
Revetments	0.375	0.375	0.375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.75	0
Living Shorelines	0.625	0.625	0.625	1	1	0	0	0.75	0	0	1	0	1	0.4	1	1	0	0.666667	0	1	6.25	1
Breakwater Islands	0.5	0.625	0.5625	1	1	0	0	0.5	1	0	0	0	0	0.2	0	0	0	0	0	0	4.125	0
			1					1						1				1			16	9

16.2

Dikes of the Rhine

Characteristics of the classification of a Dike

The first dikes were established in the Mediterranean region around 7,000 years ago to protect small settlements against the storms and floods coming from the sea. Recent archeological excavations near the current city of Haifa in Israel have discovered the remains of a 100-meter-long sea dike (Flinders University, 2023).
This report however follows the description and knowledge given by Dutch example. As knowledge of dike management in the Rhine River is relatively simple, the vast knowledge base of the Dutch management sector is used to indicate the possibilities that arise in future dike management arrangements of the other Rhine nations. To understand the main characteristics of dikes, the classifications can be distinguished into sea dikes (direct dikes against the sea) and land dikes (dikes being distributed on land primarily found beside rivers) (Climate Technology Centre & Network, n.d.). The sea dike is larger in mass and forms a direct protective line against tidal and/or floods from the sea. The land dike (or river dike) is thinner in width and has the primary function of distributing the water from the river away towards the sea. This report focuses on the land dikes as the main focus lies on the river of the Rhine.

Dikes in the context of this report are: "Respectively higher elevated spatial elements that form a transition between the main river and the direct surrounding areas."

Spatial Layout

The classification of a dike is considered to be a spatial element in the form of a mound that protects land area from a source of water (river, sea, lake, etc.). The structure of a dike has a high volume which helps to resist water pressure coming from the adjacent water source, sloping sides to reduce the wave loadings, and established crest heights to prevent overtopping (Linham & Nicholls, 2010). Over time the spatial abilities of the dike have been used in various sectors of industry to sustain a source of water that can be used for production purposes. Often the dike slopes are laid with grass, which also has the functionality of holding the watertight layer of the dike in place (Lola Landscape Architects, 2014). Besides the basic layout of the dike as a mound with two slopes leading to the main crest, there are also possibilities for side verges to be created. These are primarily used to react to the different water heights of low and high flow and to increase the overall mass of the dike. The final spatial element is the so-called toe protection, which is often a stone or concrete layer right on the edge of the water, that protects the overall stability of the dike against degradation of the erosion process of the river.

Technical Layout

The basic technical specifications of a dike are considered to be an earth structure predominantly consisting of a sand or clay core (although sand is preferred to ensure the water that enters the dike can drain away), a watertight outer protection layer of clay, and a drainage channel

to relieve the water that enters the dike and seepage created by the mass of the dike pushing the adjacent groundwater to the surface (CTCN, n.d). Furthermore, both sides of the dike slope have a different function. The slope toward the body of water has a gradient between 1:2 and 1:3 to retain a constant flow of water towards the mouth of the river. The slope towards the land faces a gradient between 1:3 and 1:6 (CTCN, n.d). This is primarily due to sustaining a high volume of mass to protect against the water pressure and decrease the possibility of seepage below the dike.

Maintenance Layout

Due to the large amount of material used to construct and sustain a dike, the maintenance of the dike is often part of a national governmental agency. Dikes are designed based on the anticipated wave loadings and heights in combination with flood safety measurements that are laid out by national ministries (CTCN, n.d.). Due to the large risks involved, dike management is considered to be expensive. Reportedly the construction costs of dike heightening procedures can go up to 29.2 million US dollars per linear km of dike line (Hillen et al., 2010). The Dutch national authorities of Rijkswaterstaat and the waterboards are spending up to 360 million euros per year on dike projects (HWBP, 2023). Although the main expenses are made in strengthening or heightening the dike, more forms of maintenance take place daily. So-called dike watchers form the first line of inquiry for the conditions of the dike as they inspect the dike regularly to investigate its stability. Often different authorities and stakeholders work together in maintaining a dike, leaving the highly technical and expensive measurements for higher authorities, whilst local farmers or residents help sustain the grass layer of the dike (Lola Landscape Architects, 2014). So although the dike might be limited for local stakeholders, they do have responsibilities in retaining the overall stability of the dike line.

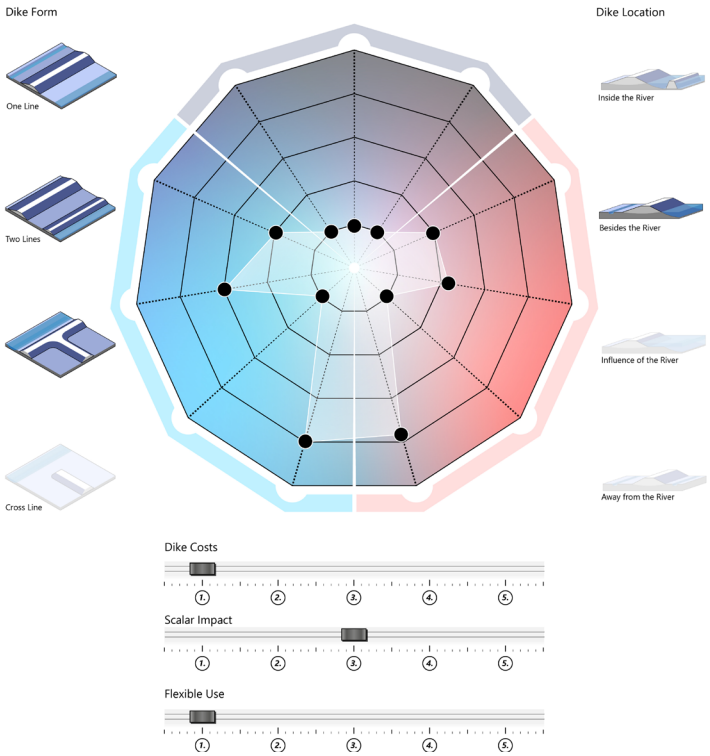
Maintenance of Dikes

Maintenance of dikes can be classified into three main practices: Technical maintenance, everyday maintenance, and monitoring. Technical maintenance does not occur daily and considers itself the main change of the dike line that surrounds the structural integrity and stability of the dike (Lola Landscape Architects, 2014). This is often facilitated by specialized private civil engineering companies under the guidance of national and regional authorities. Besides these large technical maintenance practices, there is also daily maintenance of dike lines. This considers keeping the protective clay layer around the crest of the dike intact by maintaining the grass but most of all it focuses on the monitoring of the dike itself. Here special units scour the dike for anomalies like, toe degradations, dike cracks, and saturation levels, and even monitor muskrat burrows.

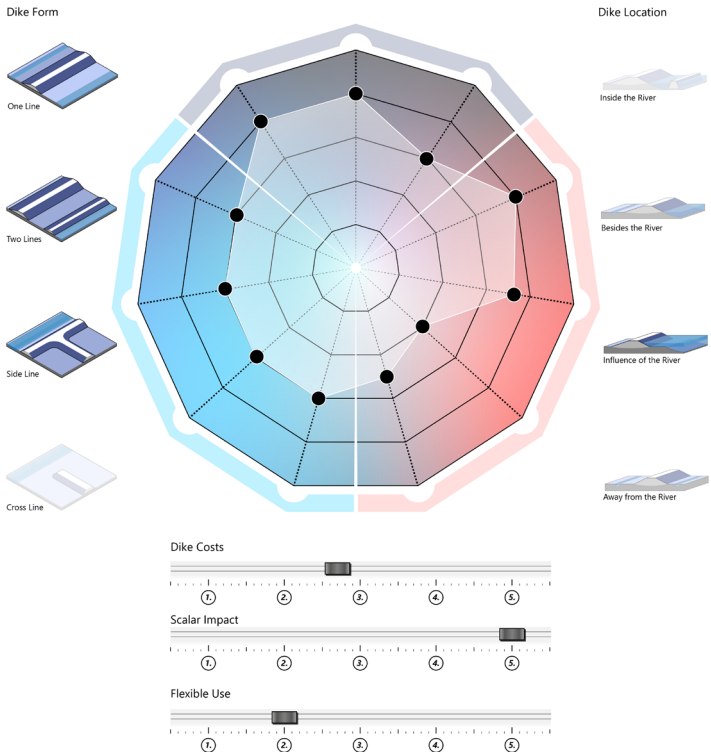
Dike Autonomy

Stakeholder relations towards dikes

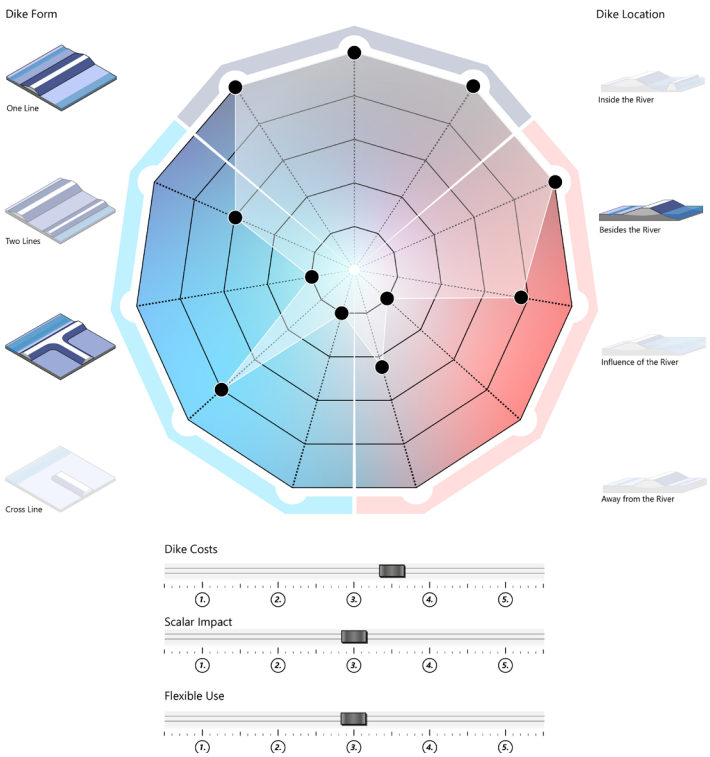
Summer dike



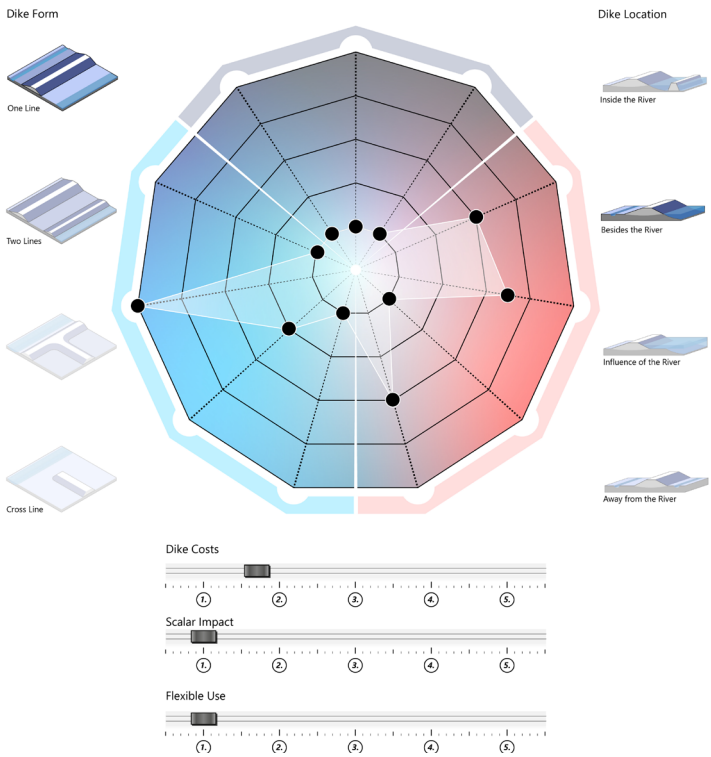
Winter dike



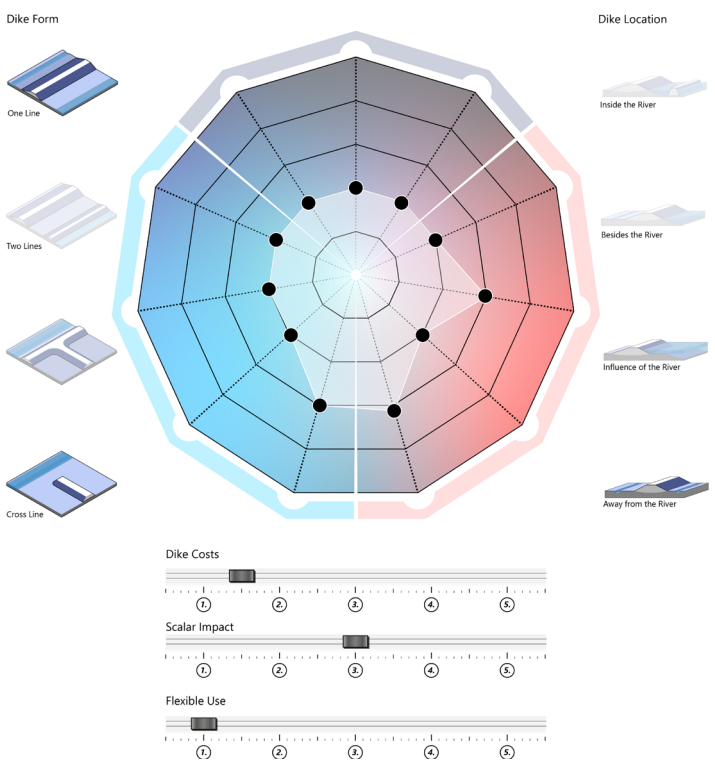
Shear Dike



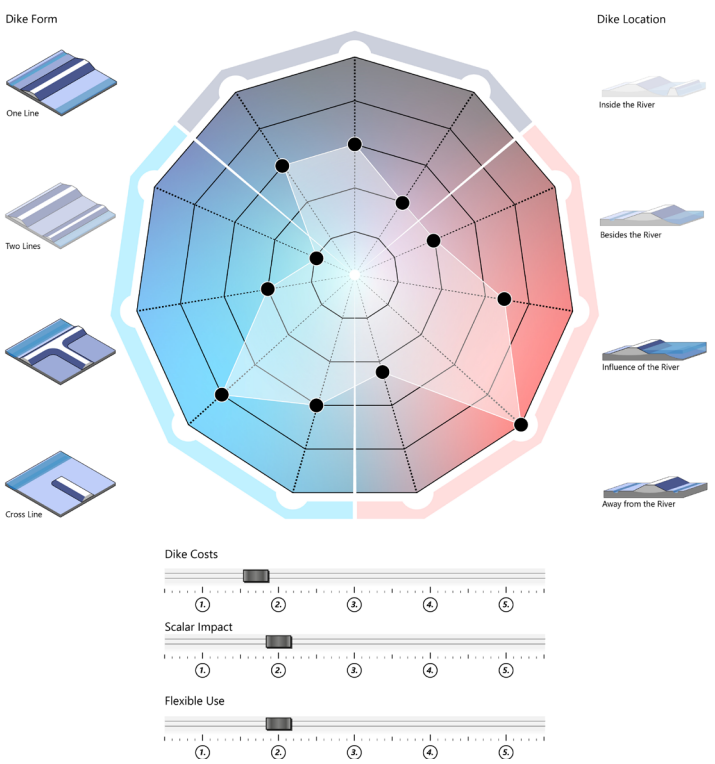
Flood Wall



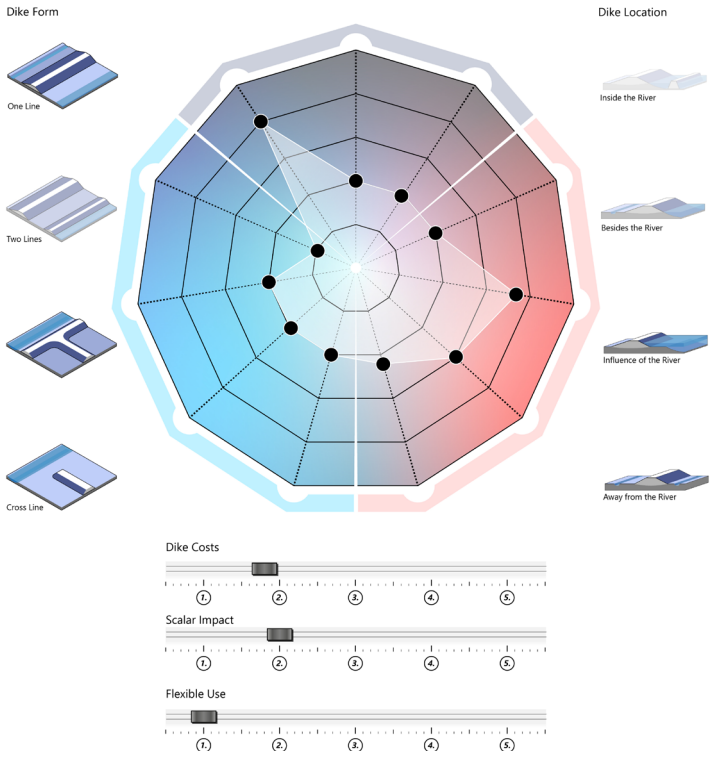
Side Dike



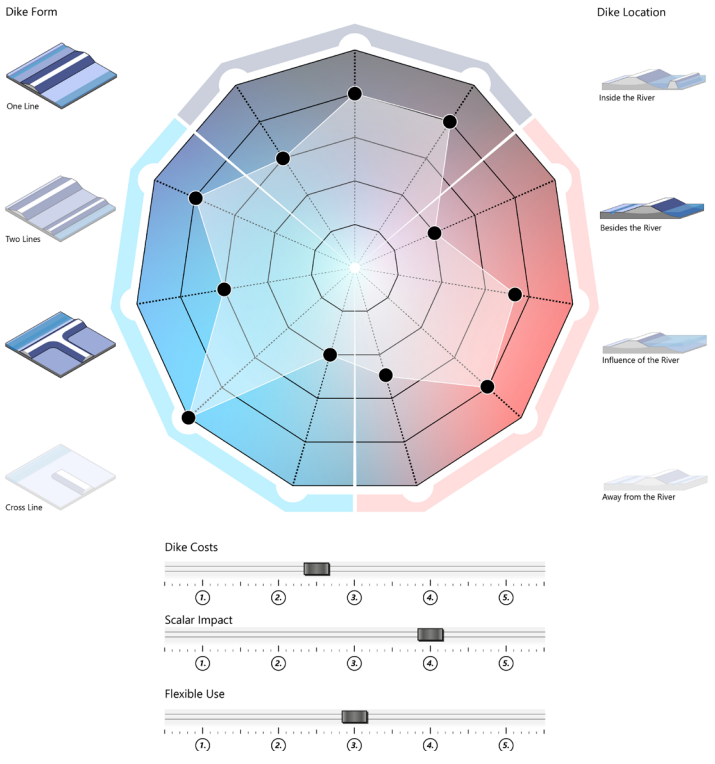
Leading Dike



Compartment Dike

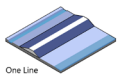


Canal Dike



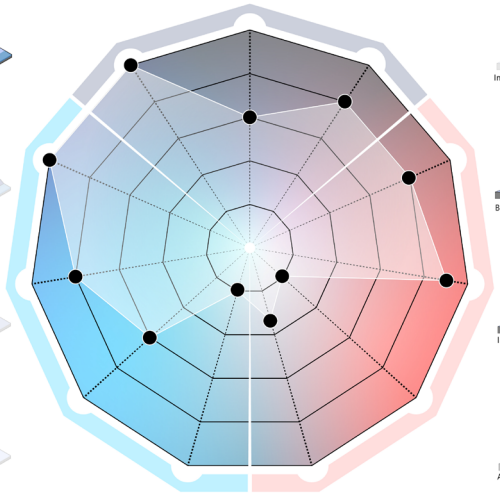
Dike in Boulevard

Dike Form


One Line

Two Lines

Cross Line



Dike Location

Inside the River


Besides the River


Influence of the River


Away from the River

Dike Costs



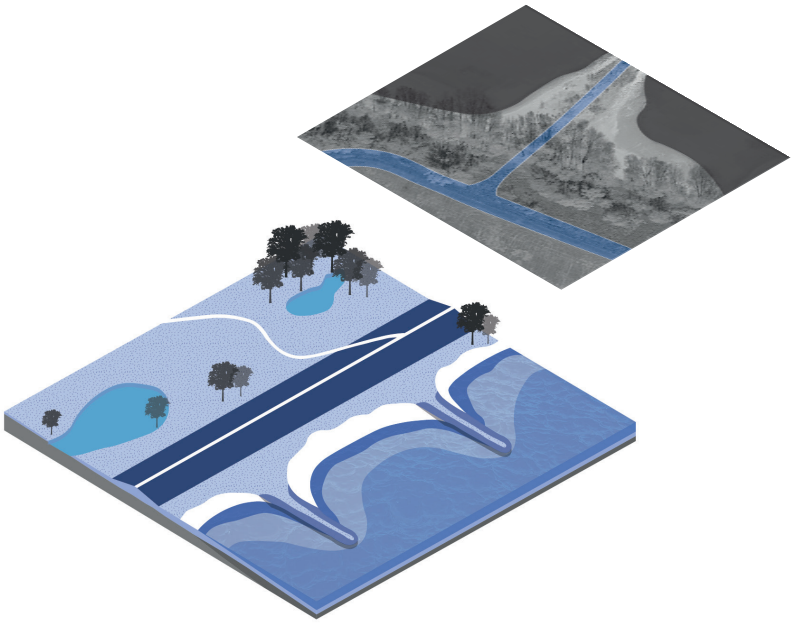
Scalar Impact



Flexible Use

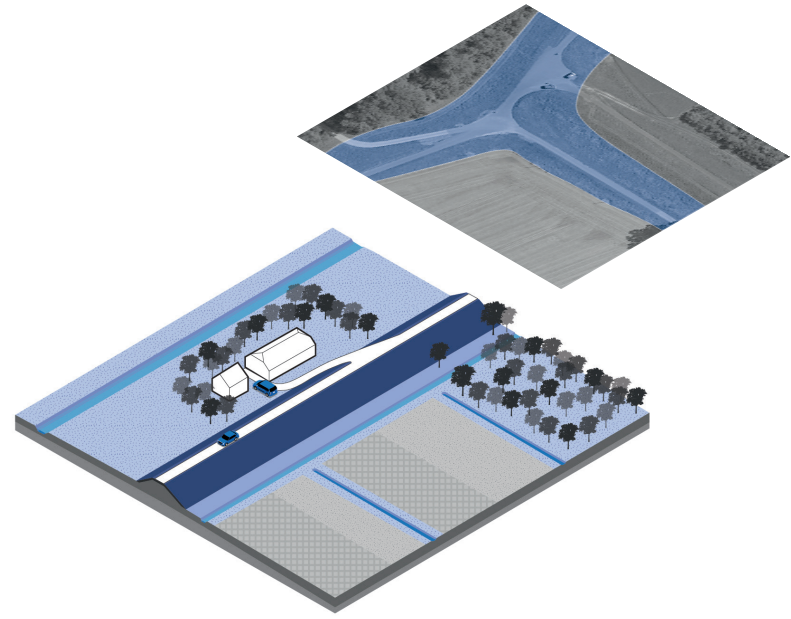


Dike Typologies of the Rhine



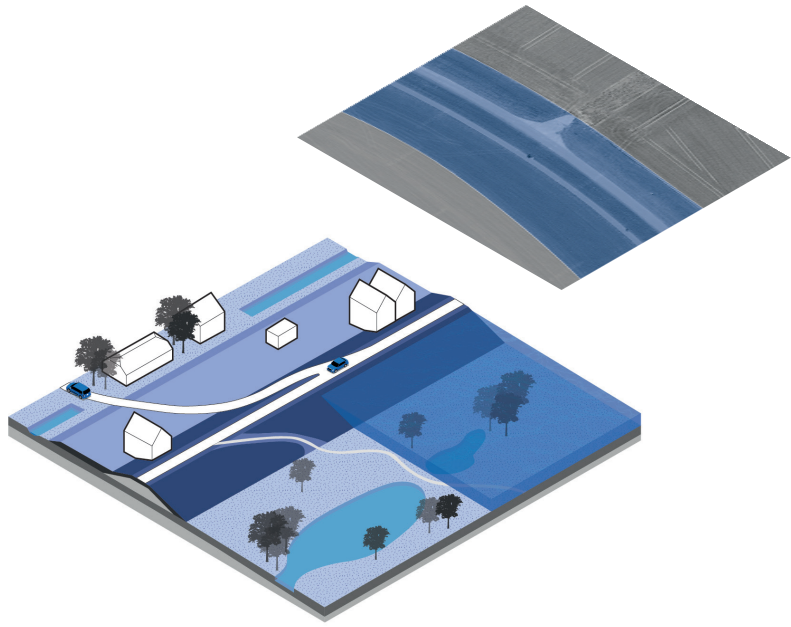
Summer dike

A summer dike is called the 'Summer' dike due to the fact that the dike keeps the river flowing in periods of low flow, which occur during summertime. Often these dikes are found in the middle of the floodplains or right beside the rivers edge. Sometimes groins are integrated, to make sure the streamflow of the river is constant in periods of low flow to keep the river navigable. Over the last decade, the summer dike has undergone a transformation into a more natural transition zone. The fact that the groins and dredging practices kept the river flowing, the need for summer dikes became somewhat irrelevant.



Side dike

A side dike is a dike that is situated perpendicular between the summer and winter dikes. These dikes are used in periods of high flow to keep the residents and factories in the floodplain connected to the region. Also these dikes can be situated behind the winter dike and function, in the case of a dike breach as secondary protection dikes to compartment the flooding at hand.

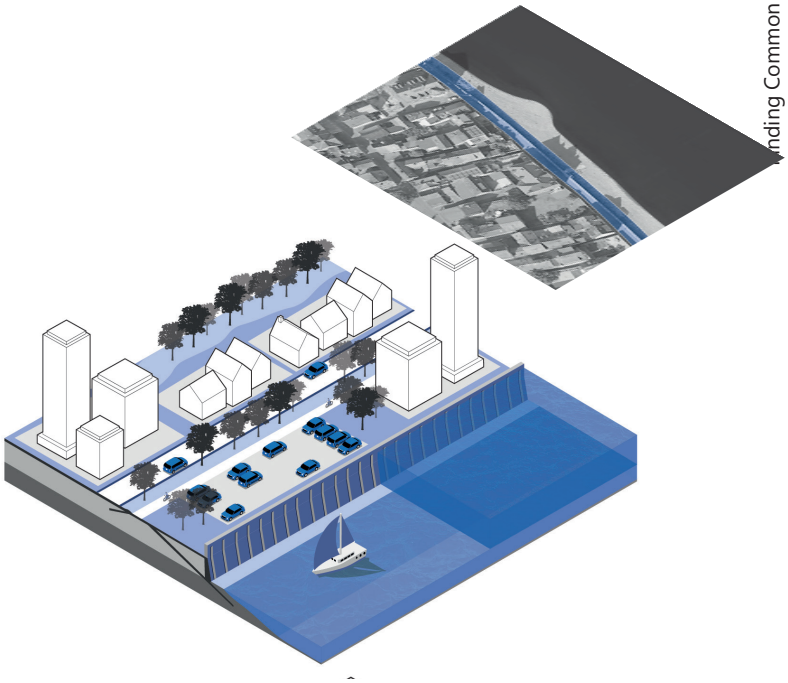


Winter dike

A winter dike is called the 'Winter' dike based on its water retaining function is has during the seasonal high flows of a river, which often take place during the winter. The dike is situated away from the river and its main function is to retain the water in periods of high low. This dike is the main structure used in the any given river basin and can therefore plenty be found along the Rhine. More than 50% of all dikes classified along the Rhine are Winter dikes. These dikes are often combined with infrastructure as they form direct connection of the regional infrastructural network.

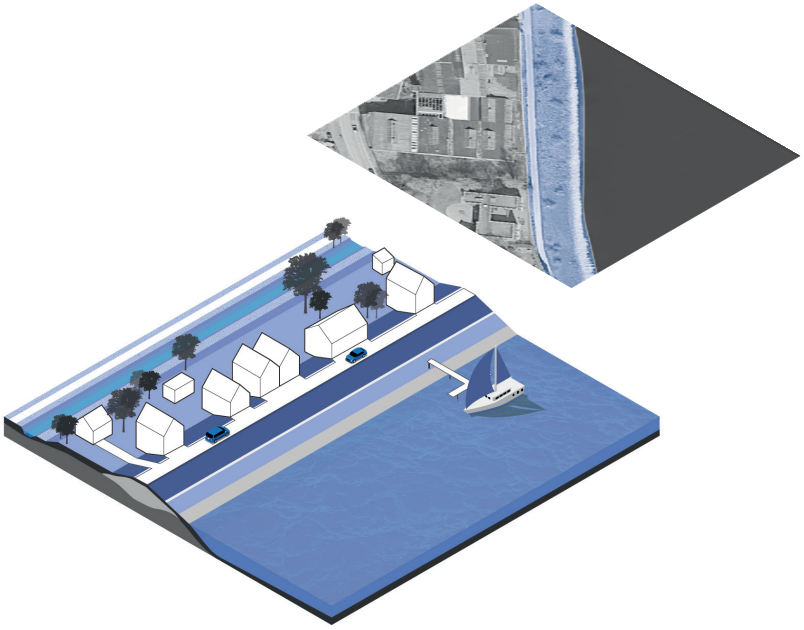
Floodwall

The floodwall is a water retaining wall that directly forms a border between the river and the backland. Floodwall are integrated into urban land uses, where a city is locally walled to keep the water out during periods of high flow.



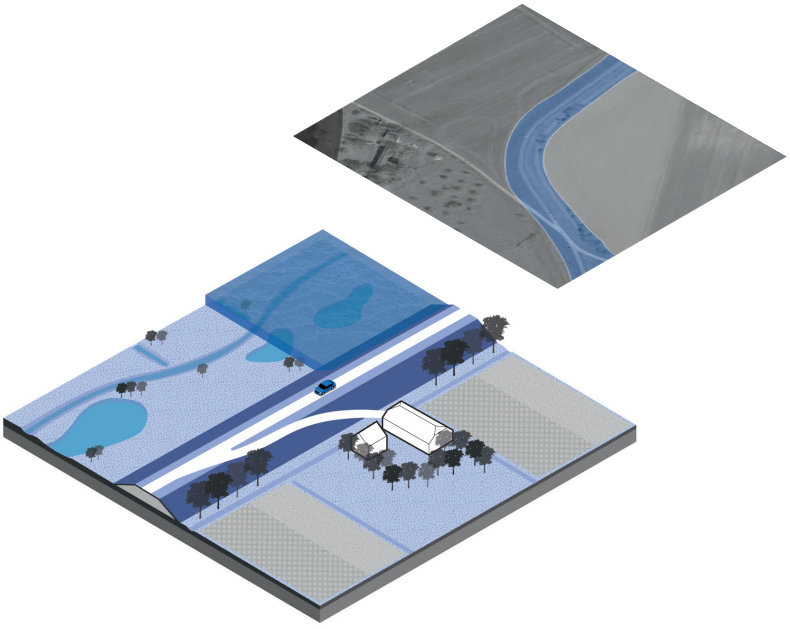
Shear dike

A shear dike is a winterdike that is directly situated alongside of the river. Therefore it is cladded with stones and concrete slabs to protect the main integrity of the dike against the water pressures of the river. These dikes are often situated as the edges of the river where the urban fabric directly borders the river.



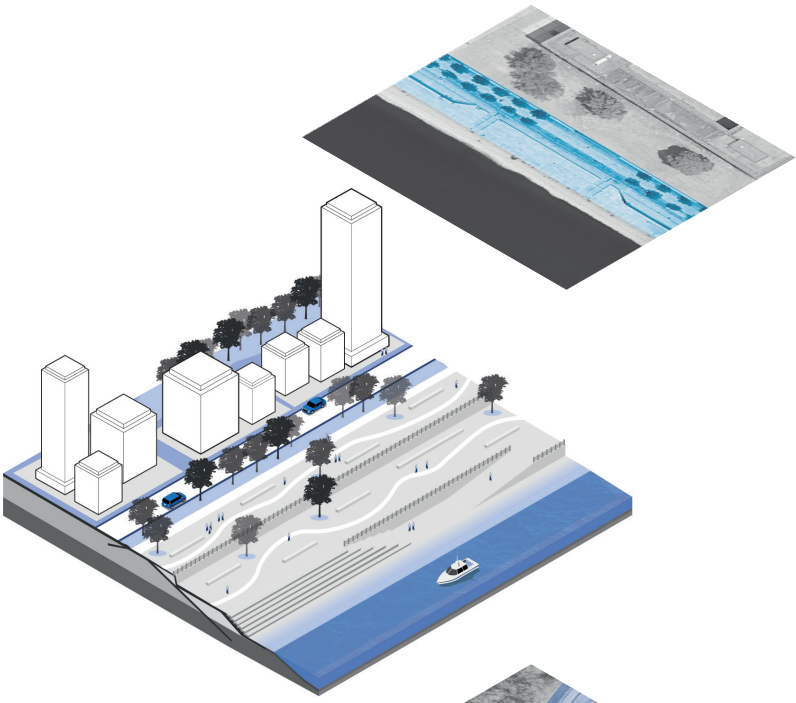
Leading dike

A leading is placed the same as the side dike, but is primarily used to redistribute water in periods of high flow. As secondary protection measures, these dikes can relief pressure from other dikes by redistributing the water away from the other dike lines. As the area between the leading dikes is not often filled with water, it primarily functions as a natural retention zone or as agricultural pastures.



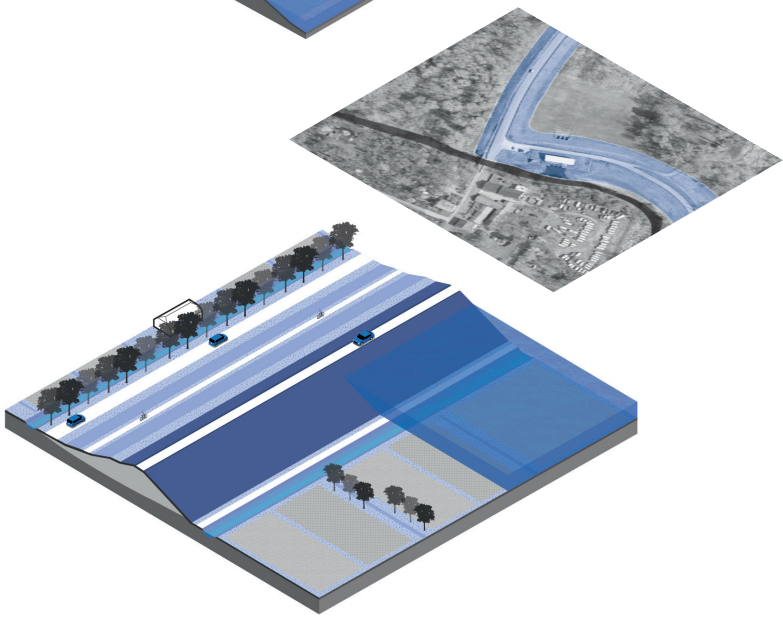
Dike – In – Boulevard

This dike is situated in the middle of a urban region. It facilitated a water retaining function to protect large cities as Koln, Dusseldorf, Basel & Bonn. The structural dike is often integrated into the urban fabric, creating an urban boulevard as a result. These areas are often highlights of the city offering high end touristic attractions.



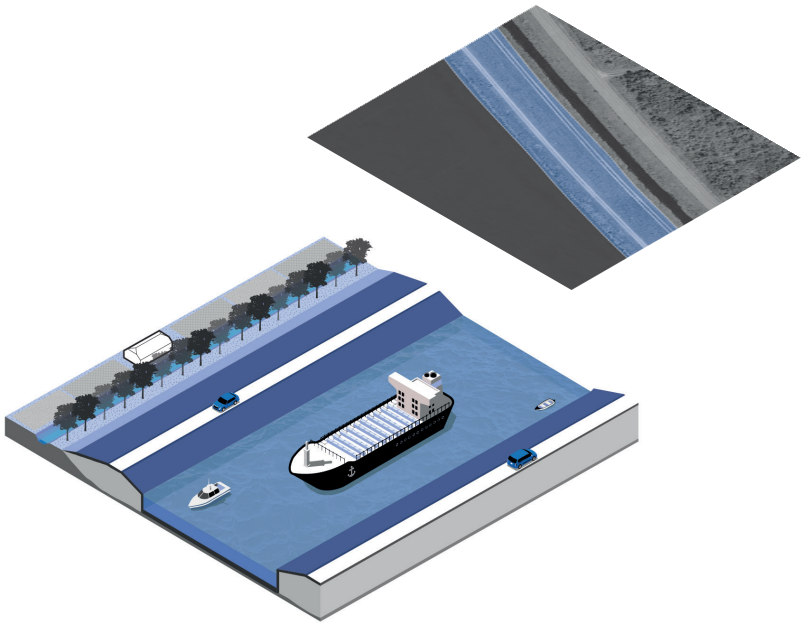
Compartment dike

These dikes originate from the reclamation of the polders in the Netherlands, but along the Rhine they are used to compartment areas of water in periods where the river can not provide enough water. These dikes are often related to industrial practices as they offer the creation of a water buffer. Furthermore are these dikes often integrated with a spillover system in the form of a pump of small gap within the dike itself.



Canal dike

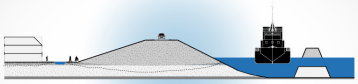
These dikes are primarily constructed to keep the river in a constant flow during the year. The canalized section of the Rhine between Iffezheim and Rosenau was constructed in the 19th century due to the large flooding the lower floodplains of the Upper Rhine valley were dealing with. The canalization made it possible for residents to keep dry feet and for the larger industrial sector to use this constant waterflow for energy production and navigation. Due to the direct connection between the dike and the river, a large amount of maintenance is needed to retain the original structure of the dike. Therefore these dikes seen with a side ditch and maintenance roads.



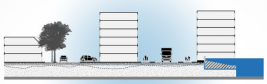
Dike Autonomy

Dikes of the Netherlands

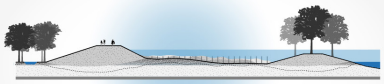
Dijk	Naam	Locatie	Voltooid	Kruinhoogte t.o.v. Waterpeil/NAP (m)	Kruinhoogte t.o.v. Voorland	Kruinhoogte t.o.v. Achterland	Dijklengte (Km)	Dijkgroep	Dijktype	Dijksysteem	Waterkerende functie
1	Afsluitdijk	Den Oever - Cornwerd	1932	8.4	0	0	29.5	Dammen en stormvloedkeringen	Gesloten dam		Primaire Waterkering
2	Amsteldiepdijk	Van Ewijcksluis - Westerland	1926	8.5	0	0	2.4	Dammen en stormvloedkeringen	Gesloten dam		Primaire Waterkering
3	Baardwijkse Overlaat	Elshout - Hedikhuizen	1765	0	3.8	4	23.6	Rivierdijken	Overlaat	Overlaat Leidijk	Regionale kering
4	Balgstuw bij Ramspol	Ramspol	2002	4	0	0	0.4	Dammen en stormvloedkeringen	Open dam		Primaire Waterkering
5	Bergse linker Rottekade	Hellevoeterbrug - Rotterdam	1200	1		3.5	20	Polderdijken van het veenlandschap	Boezemdijk	Polder-Boezemdijk	Regionale kering
6	**Blokzijlerdijk**	Lemmer - Moespot	1418		4.1	4.5	30	Meerdijken	Meerdijk van het oude land		Primaire Waterkering
7	Boulevard Scheveningen	Scheveningen	2014	8.5	0	0	2	Zeedijken van het kustgebied	Dijk-in-Boulevard		Primaire Waterkering
8	Diefdijk	Fort Everdingen - Asperen	1284	0	6.4	6.4	9.7	Rivierdijken	Dwarsdijk	Zomer-Winterdijk	Primaire Waterkering
9	Diefdijk	Fort Everdingen - Asperen	1284	0	6.4	6.4	9.7	Waterliniedijken	Hoofdweerstandslijn	Hoofdverdediging-Access-Innundatie	Primaire Waterkering
10	**Diemerzeedijk**	Amsterdam-Muiden	1310		3.7	4	9.1	Meerdijken	Meerdijk van het oude land		Primaire Waterkering
11	Geniedijk	Vijfhuizen - Aalsmeerderbrug	1881	0	4.7	4.7	10.9	Waterliniedijken	Hoofdweerstandslijn	Hoofdverdediging-Access-Innundatie	Regionale kering
12	**Grebbedijk** & Slaperdijk	Rhenen - Wageningen	1369	0	4.8	5.1	5.3	Rivierdijken	Winterdijk	Zomer-Winterdijk	Primaire Waterkering
13	Grebbedijk & **Slaperdijk**	Rhenen - Wageningen	1369	0	4.8	5.1	2.6	Waterliniedijken	Access	Hoofdverdediging-Access-Innundatie	Dijkrelict
14	Groenendijk	Cappelle aan den Ijssel - Nieuwekerk aan den Ijssel	1250	0	2.1	6.1	7.8	Rivierdijken	Winterdijk	Zomer-Winterdijk	Primaire Waterkering
15	Groenendijk	Cappelle aan den Ijssel - Nieuwekerk aan den Ijssel	1250	0	2.1	6.1	7.8	Rivierdijken	Schaardijk	Zomer-Winterdijk	Primaire Waterkering
16	Haarlemmerringdijk	Zwanenburg - Vijfhuizen	1845	0	0.5	4.6	59.5	Polderdijken van het veenlandschap	Ringdijk	Polder-Boezemdijk	Regionale kering
17	Haringvlietdam	Hellevoetssluis - Stellendam	1971		18.5	17.3	1	Dammen en stormvloedkeringen	Doorlatende dam		Primaire Waterkering
18	Hondsbossche Zeewering	Petten - Schoorl	1783		12.6	13.7	5.8	Zeedijken	Waker	Waker-Slaper-Dromer	Primaire Waterkering
19	**Kade Tuindorp-Oostzaan**	Oostzanerdijk - Coentunnelcircuit	1876		1.1	0.9	2	Kanaaldijken	Kanaaldijk		Primaire Waterkering
20	**Kanaaldijk West aan het Amsterdam-Rijnkanaal**	Amsterdam Zuidoost - Utrecht	1952		5.3	7	68.3	Kanaaldijken	Kanaaldijk		Primaire Waterkering
21	**Knardijk**	Lelystad - Zeewolde	1954		7.4	7.4	23	Meerdijken	Compartimenteringsdijk	Meerdijk-Compartimentering	Regionale kering
22	Meidijk	Zuilichem	1327		5.4	5.1	1.4	Rivierdijken	Dwarsdijk	Zomer-Winterdijk	Regionale kering
23	**Oostvaardersdijk**	Almere - Lelystad	1969		4	3.9	33.8	Meerdijken	Meerdijk van het nieuwe land	Meerdijk-Compartimentering	Primaire Waterkering
24	Pannerdensch Kanaal Overlaat en Kop	Arnhem - Pannerden	1707		5.3	5.3	13	Rivierdijken	Winterdijk	Zomer-Winterdijk	Primaire Waterkering
25	Pannerdensch Kanaal Overlaat en Kop	Arnhem - Pannerden	1707		5.3	5.3	13	Rivierdijken	Overlaat	Overlaat Leidijk	Primaire Waterkering
26	Poldijk	Zwarte Haan - Oude Bildtzijl	1754		7.1	7.8	6.5	Zeedijken van het noordelijk zeeklei	Waker	Waker-Slaper-Dromer	Primaire Waterkering
27	Nieuwe Bildtdijk	Zwarte Haan - Nieuwebiltdtzijl	1600		3	3	6.3	Zeedijken van het noordelijk zeeklei	Slaper	Waker-Slaper-Dromer	
28	Oude Bildtdijk	Westhoek - Oude Syl	1505		2.8	2.8	11.4	Zeedijken van het noordelijk zeeklei	Dromer	Waker-Slaper-Dromer	
29	Ringdijk bij Keent	Keent	1282		2.7	3.4	4.4	Rivierdijken	Winterdijk	Zomer-Winterdijk	Primaire Waterkering
30	Ringdijk bij Wilnis	Wilnis	1800		0.5	0.5	24	Polderdijken van het veenlandschap	Ringdijk	Polder-Boezemdijk	Regionale kering
31	Schelphoek	Burgh - Zierikzee	1953		6.5	3.2	4.5	Zeedijken van het Zuidwestelijk zeeklei	Waker	Waker-Inlaagdijk	Primaire Waterkering
32	Schielands Hoge Zeedijk	Schiedam - Gouda	1250		4.4	5.1	31	Rivierdijken	Winterdijk	Zomer-Winterdijk	Primaire Waterkering
33	Slachtedijk	Oostbierum - Raerd	1500		1	1	42.2	Polderdijken van het kustlandschap	Ringdijk		Dijkrelict
34	Spaarndammerdijk	Spaarndam - Amsterdam	1200		4.1	4.7	22	Polderdijken van het kustlandschap	Ringdijk		Primaire Waterkering
35	Stenendijk bij Hasselt	Hasselt - Gennerdijk	1558		2.7	2.8	0.8	Rivierdijken	Schaardijk	Zomer-Winterdijk	Primaire Waterkering
36	Verdronken dijk van Texel	Texel	1715	-18			0.4	Verdwenen dijk			
37	Voorstraat en Wantijdijk	Bomhaven - Kop van 't Land	1100		1.5	1.6	14.1	Rivierdijken	Winterdijk	Zomer-Winterdijk	Primaire Waterkering
38	Waterlandse Zeedijk bij Durgerdam	Durgerdam - Monnickendam	1100		2.5	3.5	23	Meerdijken	Meerdijk van het oude land		Primaire Waterkering
39	Westfriese Omringdijk	Schagen - Eenigenburg	1320		5.1	5.3	126	Meerdijken	Meerdijk van het oude land		Primaire Waterkering
40	Westfriese Omringdijk	Schagen - Eenigenburg	1320		5.1	5.3	126	Polderdijken van het kustlandschap	Aanwasdijk		Regionale kering
41	Westkapelse Zeewering	Westkapelle	1540		16.6	15.7	5	Zeedijken van het duingebied	Dijk-in-Duin		Primaire Waterkering
42	Zaagtanddijk	Kamperland - Colijnsplaat	1598		8.2	7.6	16	Zeedijken van het Zuidwestelijk zeeklei	Waker	Waker-Inlaagdijk	Primaire Waterkering
43	Zanddijk bij de Koog	De Cocksdorp - De Koog	1629		14.5	16.1	7.5	Zeedijken van het duingebied	Stuifdijk		Primaire Waterkering
44	Zanddijk bij Limmen	Limmen	1105				0.9	Verdwenen dijk			
45	Zeedijk Hedwigepolder	Hedwigepolder	1907		6	8.2	3.8	Zeedijken van het Zuidwestelijk zeeklei	Waker	Waker-Inlaagdijk	Primaire Waterkering
46	Zomerdijk bij Eemnes	Eemnes - Eembrugge	1306		0.9	1.3	7.5	Meerdijken	Meerdijk van het oude land		Regionale kering
47	Zuidelijke vechtdijk bij Dalfsen	Dalfsen	1400		2.4	2.4	14	Rivierdijken	Winterdijk	Zomer-Winterdijk	Primaire Waterkering



Name: **Navigable dike**
Dike category: **Dike system**
Characteristics: **Functional dike**



Name: **Moving dike**
Dike category: **Dike system**
Characteristics: **Protection dike**



Name: **Sedimentation dike**
Dike category: **Dike system**
Characteristics: **Functional dike**



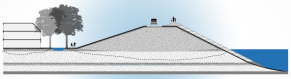
Name: **Multifunctional dike**
Dike category: **Dike system**
Characteristics: **Functional dike**



Name: **Energy dike**
Dike category: **Dike system**
Characteristics: **Functional dike**



Name: **Bulkhead**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



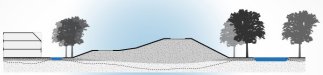
Name: **Revetment dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



Name: **Waterfront Parks**
Dike category: **Spatial dike**
Characteristics: **Functional dike**



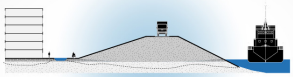
Name: **Living shorelines**
Dike category: **Spatial dike**
Characteristics: **Functional dike**



Name: **Winter dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



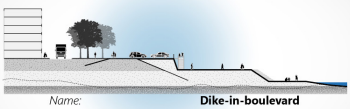
Name: **Vingerling dike**
Dike category: **Spatial dike**
Characteristics: **Functional dike**



Name: **Shear dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



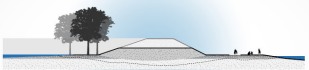
Name: **Summer dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**



Name: **Dike-in-boulevard**
Dike category: **Spatial dike**
Characteristics: **Functional dike**



Name: **Side dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



Name: **Overflow dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**

Leidijk



Name: **Leading dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**



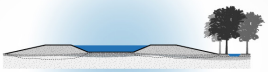
Name: **Compartment dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**



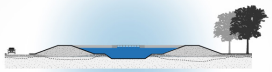
Name: **Land division dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



Name: **Canal dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**



Name: **Polder dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**



Name: **Cistern dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**

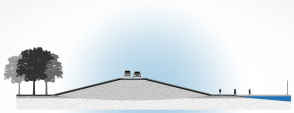


Name: **Tench dike**
Dike category: **Spatial dike**
Characteristics: **Distribution dike**

Dike Autonomy

Dike Catalgo

Dikes typologies used in this report based on the type of dike and its primairy characteristics



Name: **Coil dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



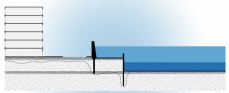
Name: **Delta dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



Name: **Mound dike**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



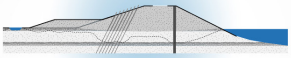
Name: **Floodwall**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



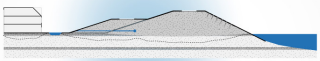
Name: **Concrete walls**
Dike category: **Spatial dike**
Characteristics: **Protection dike**



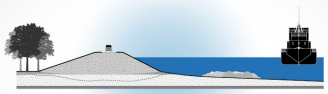
Name: **Sawa dike**
Dike category: **Spatial dike**
Characteristics: **Functional dike**



Name: **Inside dike**
Dike category: **Additional dike**
Characteristics: **Protection dike**



Name: **Smart dike**
Dike category: **Additional dike**
Characteristics: **Functional dike**



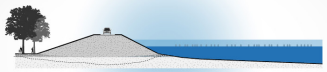
Name: **Artificial reefs**
Dike category: **Additional dike**
Characteristics: **Distribution dike**



Name: **Rich dike**
Dike category: **Additional dike**
Characteristics: **Protection dike**



Name: **Levee dam**
Dike category: **Additional dike**
Characteristics: **Distribution dike**



Name: **Pole forest**
Dike category: **Additional dike**
Characteristics: **Protection dike**



Name: **Dredge dike**
Dike category: **Additional dike**
Characteristics: **Functional dike**



Name: **Seepage dike**
Dike category: **Additional dike**
Characteristics: **Functional dike**



Name: **Pole forest**
Dike category: **Additional dike**
Characteristics: **Protection dike**

ing Common Water

	Name	Spatial Element	Functionality of Element	Instrument	Categories	Dijksysteem	PROTECTION										DISTRIBUTION			
		Structural, Land, River, Additional	Protective, Distributive, Functional				1 LINE	2 LINE	ZIJDIJK	DWARSDIJK		INSIDE	BESIDES	INFLUENCE	AWAY		1 LINE	2 LINE	ZIJDIJK	DWARSDIJ
1	Opdijk	Structural	Distributive	Dijk	Zeedijk	Waker-Slaper-Dromer	1	0	1	0	0.5	0	0	1	0	0.25	0.5	0	0	
2	Stuifdijk	Structural	Protective	Dijk	Zeedijk	Duin dijken	1	0	1	1	0.75	0	0	0	1	0.25	0.5	0	0	
3	Dijk-in-Duin	Structural	Protective	Dijk	Zeedijk	Duin dijken	1	0	1	1	0.75	0	0	0	1	0.25	0.5	0	0	
4	Dijk-in-Boulevard	Structural	Protective, Functional	Dijk	Zeedijk	Duin dijken	1	0	1	1	0.75	0	1	0	1	0.5	0.5	0	0	
5	Havenkanaaldijk	River	Distributive	Dijk	Zeedijk	Havenkanaal-Spuikomdijk	1	0	0	1	0.5	0	1	1	1	0.75	0.5	0	1	
6	Spuikomdijk	River	Distributive	Dijk	Zeedijk	Havenkanaal-Spuikomdijk	1	0	0	0	0.25	0	1	1	1	0.75	0.5	0	1	
7	Zomerdijk	Structural	Distributive	Dijk	Rivierdijk	Winter-Zomerdijk	1	1	0	1	0.75	0	1	1	1	0.75	0.5	0.5	1	
8	Winterdijk	Structural	Protective	Dijk	Rivierdijk	Winter-Zomerdijk	1	1	0	1	0.75	0	0	0	1	0.25	0.5	0.5	1	
9	Dwarsdijk	Structural	Protective	Dijk	Rivierdijk	Winter-Zomerdijk	1	0	1	0	0.5	0	0	1	0	0.25	0.5	0	0	
10	Schaardijk	Structural	Protective	Dijk	Rivierdijk	Winter-Zomerdijk	1	0	0	1	0.5	0	1	1	1	0.75	0.5	0	1	
11	Vingerling	River	Functional	Dijk	Rivierdijk	Winter-Zomerdijk	1	0	0	1	0.5	0	0	0	0	0	0.5	0	1	
12	Overlaatdijk	Structural	Distributive	Dijk	Rivierdijk	Overlaat-Leidijk	1	0	0	1	0.5	0	1	0	1	0.5	0.5	0	1	
13	Leidijk	Structural	Distributive	Dijk	Rivierdijk	Overlaat-Leidijk	1	0	0	0	0.25	0	0	0	0	0	0.5	0	1	
14	Limburgse Zijdewende	Structural	Protective	Dijk	Rivierdijk	Historische dijk	1	0	1	0	0.5	0	0	1	0	0.25	0.5	0	0	
15	Kadijk	Structural	Distributive	Dijk	Polderdijk	Polderdijk	1	0	1	0	0.5	0	1	1	1	0.75	0.5	0	0	
16	Tiendweg	Structural	Distributive	Dijk	Polderdijk	Polderdijk	1	0	1	0	0.5	0	1	1	1	0.75	0.5	0	0	
17	Ringdijk	Structural	Distributive	Dijk	Polderdijk	Polder-Boezem	1	0	0	1	0.5	0	1	1	1	0.75	0.5	0	1	
18	Boezemdijk	Structural	Distributive	Dijk	Polderdijk	Polder-Boezem	1	0	1	1	0.75	0	1	1	1	0.75	0.5	0	0	
19	Landscheidingsdijk	Structural	Distributive	Dijk	Polderdijk	Polder-Boezem	1	0	1	0	0.5	0	0	1	0	0.25	0.5	0	0	
20	Compartimenteringsdijk	Structural	Distributive	Dijk	Meerdijk	Meerdijk-Compartimenterings	1	1	1	0	0.75	0	0	0	0	0	0.5	0.5	0	
21	Kanaaldijk	Structural	Distributive	Dijk	Kanaaldijk	Kanaaldijk	1	0	0	1	0.5	0	1	1	1	0.75	0.5	0	1	
22	Hoofdweerstandslijn	Land	Functional	Dijk	Waterliniedijk	Hoofdweerstand - Access - Spoeldijk	1	0	0	0	0.25	0	0	0	0	0	0.5	0	1	
23	Access	Addition	Functional	Dijk	Waterliniedijk	Hoofdweerstand - Access - Spoeldijk	1	0	1	0	0.5	0	1	0	1	0.5	0.5	0	0	
24	Spoeldijk	Structural	Protective	Dijk	Waterliniedijk	Hoofdweerstand - Access - Spoeldijk	1	0	1	1	0.75	0	1	1	1	0.75	0.5	0	0	
25	Inside dijk	Addition	Protective	Dijk	Toekomstdijk	Toekomstdijk	1	0	0	1	0.5	0	1	0	1	0.5	0.5	0	1	
26	Slimme dijk	Addition	Protective	Dijk	Toekomstdijk	Toekomstdijk	1	0	0	1	0.5	0	1	0	1	0.5	0.5	0	1	
27	Energie dijk	Addition	Functional	Dijk	Toekomstdijk	Toekomstdijk	1	0	0	1	0.5	0	1	1	1	0.75	0.5	0	1	
28	Delta dijk	Structural	Protective	Dijk	Toekomstdijk	Toekomstdijk	1	0	0	1	0.5	0	1	0	1	0.5	0.5	0	1	
29	Hybride dijk	River	Protective	Dijk	Toekomstdijk	Toekomstdijk	1	1	0	1	0.75	0	1	0	1	0.5	0.5	0.5	1	
30	Multifunctionele dijk	Land	Protective, Functional	Dijk	Toekomstdijk	Toekomstdijk	1	0	0	0	0.25	0	1	0	1	0.5	0.5	0	1	
31	Hergebruikte dijk	Addition	Protective	Dijk	Circulaire dijk	Toekomstdijk	1	0	0	1	0.5	0.5	1	0	0	0.375	0.5	0	1	
32	Minimale dijk	Structural	Protective	Dijk	Circulaire dijk	Toekomstdijk	1	1	0	0	0.5	0	0	0	1	0.25	0.5	0.5	1	
33	Superdijk	Structural	Protective	Dijk	dijk	Toekomstdijk	1	0	0	1	0.5	0	1	0	1	0.5	0.5	0	1	
34	Plug-and-play dijk	Addition	Protective	Dijk	dijk	Toekomstdijk	1	1	0	0	0.5	0	1	0	0	0.25	0.5	0.5	1	
35	Kunstriffen	River	Protective	Secondair	Natuurlijk	Reductie dijk	1	1	1	1	1	0.5	0	1	1	0.625	0.5	0.5	0	
36	Rijke Dijken	River, Addition	Protective	Dijk	Natuurlijk	Zomer-Winterdijk	1	0	1	0	0.5	0	0	0	1	0.25	0.5	0	0	
37	Luwtedam	River	Distributive	Dam	Dam	Reductie dijk	1	0	1	1	0.75					0	0.5	0	0	
38	Palenbos	River	Protective, Distributive	Secondair	Natuurlijk	Reductie dijk	1	1	1	1	1	0.5	0	1	1	0.625	0.5	0.5	0	
39	Schorbuffer Westkeetshaven	River	Protective	Secondair	Natuurlijk	Reductie dijk	1	1	1	1	1	0.5	0	1	1	0.625	0.5	0.5	0	
40	Zwijndrecht	Land	Functional	Kade	Urban	Muur	1	0	1	1	0.75	0	1	1	1	0.75	0.5	0	0	
41	Sumida River Tokyo (Urban Stairs	Land	Protective, Functional	Kade	Urban	Muur	1	0	1	1	0.75	0	1	0	1	0.5	0.5	0	0	
42	Hafencity Hamburg	Structural	Functional	Kade	Urban	Muur	1	0	1	0	0.5	0	1	0	1	0.5	0.5	0	0	
43	Katwijk Dijk Duin	Land, Addition	Protective, Functional	Dijk	Urban	Zeedijk, Duin-Dijk	1	0	1	1	0.75	0	0	0	1	0.25	0.5	0	0	
44	Kustboulevard Cleveleys	Structural	Functional	Dijk	Urban	Zeedijk, Muur	1	0	1	1	0.75	0	1	0	1	0.5	0.5	0	0	
45	Baggerdijk	Land	Protective, Functional	Dijk	Circulaire dijk	Sedimentatie	1	1	1	1	1	0	0	0	1	0.25	0.5	0.5	0	
46	Sawadijk (Terrassen)	River	Protective	Dijk	Toekomstdijk	Reductie dijk	1	0	1	1	0.75	0	1	0	1	0.5	0.5	0	0	
47	Drift Park Rhyl	Structural	Functional	Dijk	Urban	Multifunctionele	1	0	1	1	0.75	0	1	0	1	0.5	0.5	0	0	
48	Trapdijk Rotterdam	Addition	Functional	Dijk	Urban	Multifunctionele	1	0	1	0	0.5					0	0.5	0	0	
49	Trippledijk (Kwel)	Land	Protective	Dijk	Natuurlijk	Sedimentatie	0	1	1	1	0.75	0	0	0	1	0.25	0	0.5	0	
50	Overloopdijk	Land, Structural	Distributive	Dijk	Overstroomb aar	Reductie dijk	1	1	1	0	0.75	0	1	0	1	0.5	0.5	0.5	0	
51	Terpdijk	Addition	Protective	Dijk	Toekomstdijk	Multifunctionele	1	0	1	0	0.5	0	1	0	1	0.5	0.5	0	0	
52	Ara River Japan	Structural	Protective, Functional	Dijk	Toekomstdijk	Multifunctionele	1	0	1	1	0.75	0	1	0	1	0.5	0.5	0	0	
53	Hole Dijk	Structural	Functional	Dijk	Toekomstdijk	Toekomstdijk	1	0	1	0	0.5	0	1	0	0	0.25	0.5	0	0	
54	Distributie Dijk	Land, River	Distributive	Dijk	Natuurlijk	Toekomstdijk	1	0	0	1	0.5	0	1	0	1	0.5	0.5	0	1	
55	Bevaarbare Dijk	River	Functional	Dijk	Toekomstdijk	Reductie dijk	1	1	1	1	1	0.5	0	1	1	0.625	0.5	0.5	0	
56	Bewegende Dijk	Addition	Protective	Dijk	Urban	Toekomstdijk	1	0	1	1	0.75	0	1	1	1	0.75	0.5	0	0	
57	Sedimentatie Dijk	River	Protective	Dijk	Natuurlijk	Toekomstdijk	1	1	1	1	1	0	1	0	1	0.5	0.5	0.5	0	
58	Floodwalls	Structural	Protective	Dam	Urban	Muur	1	0	1	1	0.75	0	1	1	1	0.75	0.5	0	0	
59	Water front parks	River	Protective	Dijk	Natuurlijk	Multifunctionele	1	0	1	1	0.75	0	1	0	1	0.5	0.5	0	0	
60	Bulkhead	Structural	Protective	Dam	Urban	Muur	1	0	1	1	0.75	0	1	1	1	0.75	0.5	0	0	
61	Revetments	Addition	Protective	Dam	Urban	Reductie dijk	1	0	1	1	0.75	0	1	1	1	0.75	0.5	0	0	
62	Living Shorelines	River	Protective	Dijk	Natuurlijk	Sedimentatie	1	1	1	1	1	0.5	0	1	1	0.625	0.5	0.5	0	
63	Breakwater Islands	River	Protective, Distributive	Secondair	Natuurlijk	Reductie dijk	0	1	1	1	0.75	0.5	0	1	1	0.625	0	0.5	0	

ORIGINAL
PROTECTION
DISTRIBUTION

							NATURAL RETENTION											LANDSCAPE										MULTIFUNTIONAL							
AR		BESIDE	INFLUE						ZIJDIJ	DWAR		BESIDE	INFLUE				2		DWAR			BESIDE	INFLUE							DWARS		
K		INSIDE	S	NCE	AWAY		1 LINE	2 LINE	K	SDIJK		INSIDE	S	NCE	AWAY		1 LINE	LINE	ZIJDIJK	SDIJK		INSIDE	S	NCE	AWAY		1 LINE	2 LINE	ZIJDIJK	DIJK			
0	0.125	0	0	1	0	0.25	0	0	1	1	0.5	1	1	0	1	0.75	1	0	0	0.5	0.375	1	0	0	0	0.25	0.5	0	0	0	0		
1	0.375	0	0	0	1	0.25	0	0	1	0	0.25	1	1	0.5	0	0.625	1	0	0	0	0.25	1	0	1	1	0.75	0.5	0	0	1			
1	0.375	0	0	0	1	0.25	0	0	1	0	0.25	1	1	0.5	0	0.625	1	0	0	0	0.25	1	0	1	1	0.75	0.5	0	0	1			
1	0.375	0	1	0	1	0.5	0	0	1	0	0.25	1	0	0.5	0	0.375	1	0	0	0	0.25	1	0.5	1	1	0.875	0.5	0	0	1			
1	0.625	0	1	1	1	0.75	0	0	0	0	0	1	0	0	0	0.25	1	0	0.5	0	0.375	1	0.5	0	1	0.625	0.5	0	1	1			
0	0.375	0	1	1	1	0.75	0	0	0	1	0.25	1	0	0	0	0.25	1	0	0.5	0.5	0.5	1	0.5	0	1	0.625	0.5	0	1	0			
1	0.75	0	1	1	1	0.75	0	0.5	0	0	0.125	1	0	0	0	0.25	1	0.5	0.5	0	0.5	1	0.5	0	1	0.625	0.5	1	1	1			
1	0.75	0	0	0	1	0.25	0	0.5	0	0	0.125	1	1	0.5	0	0.625	1	0.5	0.5	0	0.5	1	0	1	1	0.75	0.5	1	1	1			
0	0.125	0	0	1	0	0.25	0	0	1	1	0.5	1	1	0	1	0.75	1	0	0	0.5	0.375	1	0	0	0	0.25	0.5	0	0	0			
1	0.625	0	1	1	1	0.75	0	0	0	0	0	1	0	0	0	0.25	1	0	0.5	0	0.375	1	0.5	0	1	0.625	0.5	0	1	1			
1	0.625	0	0	0	0	0	0	0	0	0	0	1	1	0.5	1	0.875	1	0	0.5	0	0.375	1	0	1	0	0.5	0.5	0	1	1			
1	0.625	0	1	0	1	0.5	0	0	0	0	0	1	0	0.5	0	0.375	1	0	0.5	0	0.375	1	0.5	1	1	0.875	0.5	0	0	1			
0	0.375	0	0	0	0	0	0	0	0	1	0.25	1	1	0.5	1	0.875	1	0	0.5	0.5	0.5	1	0	1	0	0.5	0.5	0	1	0			
0	0.125	0	0	1	0	0.25	0	0	1	1	0.5	1	1	0	1	0.75	1	0	0	0.5	0.375	1	0	0	0	0.25	0.5	0	0	0			
0	0.125	0	1	1	1	0.75	0	0	1	1	0.5	1	0	0	0	0.25	1	0	0	0.5	0.375	1	0.5	0	1	0.625	0.5	0	0	0			
0	0.125	0	1	1	1	0.75	0	0	1	1	0.5	1	0	0	0	0.25	1	0	0	0.5	0.375	1	0.5	0	1	0.625	0.5	0	0	0			
1	0.625	0	1	1	1	0.75	0	0	0	0	0	1	0	0	0	0.25	1	0	0.5	0	0.375	1	0.5	0	1	0.625	0.5	0	1	1			
1	0.375	0	1	1	1	0.75	0	0	0	1	0.25	1	0	0	0	0.25	1	0	0	0	0.25	1	0.5	0	1	0.625	0.5	0	0	1			
0	0.125	0	0	1	0	0.25	0	0	1	1	0.5	1	1	0	1	0.75	1	0	0	0.5	0.375	1	0	0	0	0.25	0.5	0	0	0			
0	0.25	0	0	0	0	0	0	0.5	1	1	0.625	1	1	0.5	1	0.875	1	0.5	0	0.5	0.5	1	0	1	0	0.5	0.5	1	0	0			
1	0.625	0	1	1	1	0.75	0	0	0	0	0	1	0	0	0	0.25	1	0	0.5	0	0.375	1	0.5	0	1	0.625	0.5	0	1	1			
0	0.375	0	0	0	0	0	0	0	0	1	0.25	1	1	0.5	1	0.875	1	0	0.5	0.5	0.5	1	0	1	0	0.5	0.5	0	1	0			
0	0.125	0	1	0	1	0.5	0	0	1	1	0.5	1	0	0.5	0	0.375	1	0	0	0.5	0.375	1	0.5	1	1	0.875	0.5	0	0	0			
1	0.375	0	1	1	1	0.75	0	0	1	0	0.25	1	0	0	0	0.25	1	0	0	0	0.25	1	0.5	0	1	0.625	0.5	0	0	1			
1	0.625	0	1	0	1	0.5	0	0	0	0	0	1	0	0.5	0	0.375	1	0	0.5	0	0.375	1	0.5	1	1	0.875	0.5	0	1	1			
1	0.625	0	1	0	1	0.5	0	0	0	0	0	1	0	0.5	0	0.375	1	0	0.5	0	0.375	1	0.5	1	1	0.875	0.5	0	1	1			
1	0.625	0	1	1	1	0.75	0	0	0	0	0	1	0	0	0	0.25	1	0	0.5	0	0.375	1	0.5	0	1	0.625	0.5	0	1	1			
1	0.625	0	1	0	1	0.5	0	0	0	0	0	1	0	0.5	0	0.375	1	0	0.5	0	0.375	1	0.5	1	1	0.875	0.5	0	1	1			
1	0.75	0	1	0	1	0.5	0	0.5	0	0	0.125	1	0	0.5	0	0.375	1	0.5	0.5	0	0.5	1	0.5	1	1	0.875	0.5	1	1	1			
0	0.375	0	1	0	1	0.5	0	0	0	1	0.25	0	0	0.5	1	0.375	1	0	0.5	0.5	0.5	1	0.5	1	1	0.875	0.5	0	1	0			
1	0.625	0.5	1	0	0	0.375	0	0	0	0	0	0	0	0.5	1	0.375	1	0	0.5	0	0.375	0	0.5	1	0	0.375	0.5	0	1	1			
0	0.5	0	0	0	1	0.25	0	0.5	0	1	0.375	1	1	0.5	0	0.625	1	0.5	0.5	0.5	0.625	1	0	1	1	0.75	0.5	1	1	0			
1	0.625	0	1	0	1	0.5	0	0	0	0	0	1	0	0.5	0	0.375	1	0	0.5	0	0.375	1	0.5	1	1	0.875	0.5	0	1	1			
0	0.5	0	1	0	0	0.25	0	0.5	0	1	0.375	1	0	0.5	1	0.625	1	0.5	0.5	0.5	0.625	1	0.5	1	0	0.625	0.5	1	1	0			
1	0.5	0.5	0	1	1	0.625	0	0.5	1	0	0.375	0	1	0	0	0.25	1	0.5	0	0	0.375	0	0	0	1	0.25	0.5	1	0	1			
0	0.125	0	0	0	1	0.25	0	0	1	1	0.5	1	1	0.5	0	0.625	1	0	0	0.5	0.375	1	0	1	1	0.75	0.5	0	0	0			
1	0.375	0.5	0	1	1	0.625	0	0	1	0	0.25	0	1	0	0	0.25	1	0	0	0	0.25	0	0	0	1	0.25	0.5	0	0	1			
1	0.5	0.5	0	1	1	0.625	0	0.5	1	0	0.375	0	1	0	0	0.25	1	0.5	0	0	0.375	0	0	0	1	0.25	0.5	1	0	1			
1	0.5	0.5	0	1	1	0.625	0	0.5	1	0	0.375	0	1	0	0	0.25	1	0.5	0	0	0.375	0	0	0	1	0.25	0.5	1	0	1			
1	0.375	0	1	1	1	0.75	0	0	1	0	0.25	1	0	0	0	0.25	1	0	0	0	0.25	1	0.5	0	1	0.625	0.5	0	0	1			
1	0.375	0	1	0	1	0.5	0	0	1	0	0.25	1	0	0.5	0	0.375	1	0	0	0	0.25	1	0.5	1	1	0.875	0.5	0	0	1			
0	0.125	0	1	0	1	0.5	0	0	1	1	0.5	1	0	0.5	0	0.375	1	0	0	0.5	0.375	1	0.5	1	1	0.875	0.5	0	0	0			
1	0.375	0	0	0	1	0.25	0	0	1	0	0.25	1	1	0.5	0	0.625	1	0	0	0	0.25	1	0	1	1	0.75	0.5	0	0	1			
1	0.375	0	1	0	1	0.5	0	0	1	0	0.25	1	0	0.5	0	0.375	1	0	0	0	0.25	1	0.5	1	1	0.875	0.5	0	0	1			
1	0.5	0	0	0	1	0.25	0	0.5	1	0	0.375	1	1	0.5	0	0.625	1	0.5	0	0	0.375	1	0	1	1	0.75	0.5	1	0	1			
1	0.375	0	1	0	1	0.5	0	0	1	0	0.25	1	0	0.5	0	0.375	1	0	0	0	0.25	1	0.5	1	1	0.875	0.5	0	0	1			
1	0.375	0	1	0	1	0.5	0	0	1	0	0.25	1	0	0.5	0	0.375	1	0	0	0	0.25	1	0.5	1	1	0.875	0.5	0	0	1			
0	0.125	0	1	0	0	0.25	0	0	1	1	0.5	1	0	0.5	1	0.625	1	0	0	0.5	0.375	1	0.5	1	0	0.625	0.5	0	0	0			
1	0.625	0	1	0	1	0.5	0	0	0	0	0	1	0	0.5	0	0.375	1	0	0.5	0	0.375	1	0.5	1	1	0.875	0.5	0	1	1			
1	0.5	0.5	0	1	1	0.625	0	0.5	1	0	0.375	0	1	0	0	0.25	1	0.5	0	0	0.375	0	0	0	1	0.25	0.5	1	0	1			
1	0.375	0	1	1	1	0.75	0	0	1	0	0.25	1	0	0	0	0.25	1	0	0	0	0.25	1	0.5	0	1	0.625	0.5	0	0	1			
1	0.5	0	1	0	1	0.5	0	0.5	1	0	0.375	1	0	0.5	0	0.375	1	0.5	0	0	0.375	1	0.5	1	1	0.875	0.5	1	0	1			
1	0.375	0	1	1	1	0.75	0	0	1	0	0.25	1	0	0	0	0.25	1	0	0	0	0.25	1	0.5	0	1	0.625	0.5	0	0	1			
1	0.375	0	1	0	1	0.5	0	0	1	0	0.25	1	0	0.5	0	0.375	1	0	0	0	0.25	1	0.5	1	1	0.875	0.5	0	0	1			
1	0.375	0	1	1	1	0.75	0	0	1	0	0.25	1	0	0	0	0.25	1	0	0	0	0.25	1	0.5	0	1	0.625	0.5	0	0	1			
1	0.5	0.5	0	1	1	0.625	0	0.5	1	0	0.375	0	1	0	0	0.25	1	0.5	0	0	0.375	0	0	0	1	0.25	0.5	1	0	1			
1	0.375	0.5	0	1	1	0.625	1	0.5	1	0	0.625	0	1	0	0	0.25	0	0.5	0	0	0.125	0	0	0	1	0.25	0	1	0	1			

| | | |

Het voorkomen van Faalmechansismen	1-5 (5 vaak, 1 nooit)												Effect on Socio-Economic and Natural Statusses
Overloop en golfoverslag	Macro en mirco instabiliteit	Piping en Heave	Zetting	Beschadiging	Veenoxidatie	TOTAL Veiligheidsvoorkomen	TOTAL Water Distributie Effect	TOTAL Veiligheidsvoorkomen	Safety Failure Mechamism	TOTAL Water Distributie Effect	Waterkerende functie Primair, Regionaal, Verdwenen	Water Distributie functie Dijk als leidende lijn voor water distributie	Biodiversity (Increase the natural conditions of the dike + surrounding regions
4	3	1	2	2	3	2.681818182	2.388888889	2.681818182	3.318181818	2.388888889	1	3	2
2	4	2	2	2	1	2.409090909	2	2.409090909	3.590909091	2	5	1	5
1	3	4	1	1	1	2.090909091	2.111111111	2.090909091	3.909090909	2.111111111	5	1	4
1	1	1	4	4	1	1.545454545	1.666666667	1.545454545	4.454545455	1.666666667	4	1	1
3	2	1	2	2	2	2.045454545	1.944444444	2.045454545	3.954545455	1.944444444	2	4	1
2	2	1	2	2	2	1.818181818	1.666666667	1.818181818	4.181818182	1.666666667	2	5	1
5	4	5	1	1	3	3.727272727	3.833333333	3.727272727	2.272727273	3.833333333	1	1	4
2	2	2	4	4	2	2.363636364	2.444444444	2.363636364	3.636363636	2.444444444	4	2	3
3	3	3	4	2	3	3	3.111111111	3	3	3.111111111	2	2	3
1	2	2	5	4	1	2.090909091	2.222222222	2.090909091	3.909090909	2.222222222	5	1	1
2	3	4	3	2	1	2.590909091	2.777777778	2.590909091	3.409090909	2.777777778	3	1	4
5	2	2	3	1	1	2.545454545	2.833333333	2.545454545	3.454545455	2.833333333	2	5	1
2	3	2	3	3	2	2.454545455	2.277777778	2.454545455	3.545454545	2.277777778	2	5	3
3	3	3	2	3	1	2.636363636	2.611111111	2.636363636	3.363636364	2.611111111	3	2	3
3	2	1	2	2	3	2.181818182	2.055555556	2.181818182	3.818181818	2.055555556	1	4	1
3	2	1	2	2	3	2.181818182	2.055555556	2.181818182	3.818181818	2.055555556	1	3	2
2	2	4	4	3	4	2.909090909	3.277777778	2.909090909	3.090909091	3.277777778	2	4	2
3	3	3	2	1	3	2.727272727	2.722222222	2.727272727	3.272727273	2.722222222	4	5	4
4	2	1	2	2	2	2.272727273	2.222222222	2.272727273	3.727272727	2.222222222	1	2	2
3	2	2	2	2	2	2.227272727	2.277777778	2.227272727	3.772727273	2.277777778	2	3	2
3	2	3	2	2	1	2.272727273	2.5	2.090909091	3.909090909	2.166666667	2	4	2
1	3	3	2	2	3	2.363636364	2.222222222	2.363636364	3.636363636	2.222222222	4	2	1
1	2	1	3	1	2	1.590909091	1.5	1.590909091	4.409090909	1.5	5	1	2
1	1	2	5	1	1	1.545454545	2	1.545454545	4.454545455	2	5	1	1
2	1	2	4	4	2	2.090909091	2.388888889	2.090909091	3.909090909	2.388888889	5	1	1
2	2	3	3	4	2	2.454545455	2.611111111	2.454545455	3.545454545	2.611111111	4	1	2
2	2	4	2	3	1	2.318181818	2.611111111	2.318181818	3.681818182	2.611111111	2	4	2
1	2	2	5	5	3	2.454545455	2.5	2.454545455	3.545454545	2.5	5	1	3
3	3	4	3	2	3	3.090909091	3.277777778	3.090909091	2.909090909	3.277777778	4	1	5
2	1	1	4	4	2	1.909090909	2.055555556	1.909090909	4.090909091	2.055555556	4	1	3
3	4	3	4	2	3	3.272727273	3.166666667	3.272727273	2.727272727	3.166666667	3	1	3
4	5	4	3	2	1	3.590909091	3.444444444	3.590909091	2.409090909	3.444444444	4	1	2
1	2	2	5	5	3	2.454545455	2.5	2.454545455	3.545454545	2.5	5	1	3
2	1	2	3	3	2	1.909090909	2.166666667	1.909090909	4.090909091	2.166666667	3	1	1
5	5	5	1	1	3	4	3.888888889	4	2	3.888888889	1	1	5
2	2	2	3	2	3	2.227272727	2.277777778	2.227272727	3.772727273	2.277777778	4	2	5
4	3	1	1	1	1	2.227272727	1.944444444	2.227272727	3.772727273	1.944444444	2	3	3
5	1	3	1	1	1	2.272727273	2.777777778	2.272727273	3.727272727	2.777777778	1	2	2
4	5	5	2	1	5	4.136363636	4	4.136363636	1.863636364	4	2	2	5
3	2	1	3	4	3	2.454545455	2.333333333	2.454545455	3.545454545	2.333333333	3	3	1
2	1	1	3	4	2	1.818181818	1.888888889	1.818181818	4.181818182	1.888888889	4	1	1
3	2	1	4	5	1	2.363636364	2.333333333	2.363636364	3.636363636	2.333333333	3	2	1
1	1	1	4	4	1	1.545454545	1.666666667	1.545454545	4.454545455	1.666666667	4	1	3
1	2	1	4	2	1	1.636363636	1.611111111	1.636363636	4.363636364	1.611111111	5	1	1
3	4	4	2	1	5	3.454545455	3.333333333	3.454545455	2.545454545	3.333333333	3	1	3
3	2	3	3	2	3	2.636363636	2.888888889	2.636363636	3.363636364	2.888888889	4	1	4
1	1	1	4	2	1	1.363636364	1.555555556	1.363636364	4.636363636	1.555555556	5	1	1
2	2	2	2	2	2	2	2	2	4	2	2	1	2
3	4	5	1	1	4	3.409090909	3.388888889	3.409090909	2.590909091	3.388888889	4	3	3
5	3	4	2	1	4	3.5	3.722222222	3.5	2.5	3.722222222	3	2	3
1	2	2	4	4	3	2.272727273	2.277777778	2.272727273	3.727272727	2.277777778	5	1	3
1	1	1	5	5	2	1.863636364	2	1.863636364	4.136363636	2	5	1	5
2	1	1	4	4	1	1.772727273	1.944444444	1.772727273	4.227272727	1.944444444	3	1	1
3	2	2	3	4	2	2.5	2.555555556	2.5	3.5	2.555555556	3	3	4
5	3	4	2	2	1	3.181818182	3.444444444	3.181818182	2.818181818	3.444444444	2	3	3
2	1	1	1	1	1	1.227272727	1.277777778	1.227272727	4.772727273	1.277777778	4	1	1
3	4	4	2	1	4	3.318181818	3.222222222	3.318181818	2.681818182	3.222222222	4	2	5
4	1	3	3	1	3	2.5	3.055555556	2.5	3.5	3.055555556	3	1	1
3	2	3	3	2	3	2.636363636	2.888888889	2.636363636	3.363636364	2.888888889	4	2	5
1	1	1	5	4	1	1.636363636	1.833333333	1.636363636	4.363636364	1.833333333	5	1	1
1	1	2	4	3	2	1.772727273	2.055555556	1.772727273	4.227272727	2.055555556	5	1	2
3	3	4	2	2	3	3	3.111111111	3	3	3.111111111	3	2	5
4	4	4	2	1	3	3.409090909	3.388888889	3.409090909	2.590909091	3.388888889	2	4	4
									4	2	5	2	1
									2.5	3.25	2	4	1

Riverflow (Effect on stabilizing River Flow of High + Low Flow)	Social (Connection to dike maintanance + Increasing social awareness, Spatial Landscape	Economic Returns (Possibility to gain economic advantages from dike construction)	In andere Excel Sheet staat nog de andere interpretatie van deze rij Urban vs Suburban vs Rural vs Nature	Difference	TOTAL KOSTEN VAN DIJK BOUW	TOTAL KOSTEN VAN DIJK BOUW	Beheerprofiel Dijkbasis Kernzone + Beschermingszone Area	Maintainance Frequency	Knowledge
2	1	2	2	-0.604938272	1.395061728	1.395061728	1	3	2
3	3	3	2	-0.052469136	2.947530864	2.947530864	2	1	3
3	4	4	4	-0.596296296	3.403703704	3.403703704	4	2	4
3	4	5	5	-1.67654321	3.32345679	3.32345679	5	3	4
5	3	4	3	-1.560493827	2.439506173	2.439506173	3	5	4
5	2	3	3	-0.560493827	2.439506173	2.439506173	2	3	4
1	3	1	1	0.046296296	1.046296296	1.324074074	1	1	1
3	3	3	2	-0.313580247	2.686419753	2.85308642	4	4	3
2	2	2	1	-0.481481481	1.518518519	1.685185185	2	2	2
4	1	3	3	0.516666667	3.516666667	2.961111111	5	5	5
2	4	2	2	0.12962963	2.12962963	2.685185185	3	4	3
1	4	2	3	0.191358025	2.191358025	2.191358025	5	5	4
4	2	1	2	0.685185185	1.685185185	1.685185185	3	3	2
3	3	3	3	-0.616049383	2.383950617	2.383950617	2	3	2
4	2	2	2	-0.774691358	1.225308642	1.225308642	2	2	1
3	2	2	1	-0.969135802	1.030864198	1.030864198	1	1	1
4	3	3	3	-0.817901235	2.182098765	2.182098765	3	4	4
4	2	1	4	1.936419753	2.936419753	2.936419753	4	3	3
1	1	1	2	0.169753086	1.169753086	1.169753086	2	1	1
2	2	1	1	0.775925926	1.775925926	1.775925926	4	2	2
5	3	4	3	-1.535802469	2.464197531	2.464197531	3	4	4
1	4	3	2	-0.592592593	2.407407407	2.407407407	3	3	3
4	3	2	2	0.851851852	2.851851852	2.851851852	4	4	4
4	1	1	3	2.713580247	3.713580247	3.713580247	5	1	5
4	3	2	1	1.155555556	3.155555556	3.155555556	3	1	5
3	5	3	3	-0.388888889	2.611111111	2.611111111	4	5	3
3	4	4	2	-1.929012346	2.070987654	2.070987654	4	5	4
3	2	3	4	-0.088271605	2.911728395	2.911728395	6	3	1
2	4	2	1	0.069753086	2.069753086	2.069753086	5	3	2
3	5	5	4	-1.734567901	3.265432099	3.265432099	5	5	4
3	5	4	3	-1.734567901	2.265432099	2.265432099	4	5	3
2	3	1	1	0.910493827	1.910493827	1.910493827	3	1	1
3	2	2	4	1.007407407	3.007407407	3.007407407	6	3	1
3	4	3	3	-0.731481481	2.268518519	2.268518519	4	2	3
4	2	1	2	0.682098765	1.682098765	1.682098765	1	1	2
3	5	2	1	-0.151234568	1.848765432	1.848765432	4	5	1
5	2	1	2	1.045679012	2.045679012	2.045679012	1	2	3
3	1	2	3	-0.657407407	1.342592593	1.342592593	4	1	1
2	3	3	2	-1.385802469	1.614197531	1.614197531	4	1	2
2	4	4	4	-0.617901235	3.382098765	3.382098765	1	3	3
2	2	3	4	0.45	3.45	3.45	1	2	2
1	4	5	5	-1.281481481	3.718518519	3.718518519	2	2	4
1	2	5	4	-1.201234568	3.798765432	3.798765432	3	3	4
1	1	4	5	0.116666667	4.116666667	4.116666667	3	2	3
3	3	4	1	-2.095679012	1.904320988	1.904320988	5	5	3
4	3	2	3	0.643209877	2.643209877	2.643209877	4	4	2
1	1	3	4	1.104320988	4.104320988	4.104320988	4	2	4
3	2	4	4	-1.52345679	2.47654321	2.47654321	2	4	3
3	2	2	1	0.182098765	2.182098765	2.182098765	5	3	3
3	4	2	2	0.055555556	2.055555556	2.055555556	2	1	3
2	2	3	3	-0.196296296	2.803703704	2.803703704	5	4	1
2	1	5	4	-1.862962963	3.137037037	3.137037037	6	5	2
2	5	4	3	-0.879012346	3.120987654	3.120987654	5	3	3
2	3	2	3	0.553703704	2.553703704	2.553703704	4	4	3
4	1	3	4	0.487654321	3.487654321	3.487654321	2	1	5
1	1	1	4	1.62345679	2.62345679	2.62345679	1	1	2
3	3	3	3	-0.651234568	2.348765432	2.348765432	5	5	2
2	5	1	1	0.682098765	1.682098765	1.682098765	1	1	1
2	4	4	4	-1.453703704	2.546296296	2.546296296	4	3	2
4	1	1	2	2.210493827	3.210493827	3.210493827	2	3	3
3	2	1	3	2.113580247	3.113580247	3.113580247	4	4	3
2	4	3	2	-1.064814815	1.935185185	1.935185185	5	3	2
5	2	2	4	0.12345679	2.12345679	2.12345679	3	2	3
3	2	1	3			3.5	5	3	1
5	2	3	2			3	1	4	5

		Characteristics								Ruimtelijk profiel	
Impact schaal		Technisch Profiel				Kosten				Dijkbekleding	
Lengte van het dijklichaam als onderdeel van het systeem		Dijkkern	5-1 (Kosten per Grondsoorten)	Dijkafwerking	5-1 (Kosten per Grondsoorten)	TOTAL DIJK Materiaal	Ondergrond	Aanwezigheid Bermsloot	Aanwezigheid Steunbermen	DIJK CONSTRUCTION	Gras	5-1 Codering
2		Klei	1	Klei	1	1	Zanderig	0	--	1.801587302	+	4
5		Zand	2	Zand, Asfalt	2	2	Zanderig	--	0	3.150793651	++	5
3		Klei	1	Asfalt	4	1.6	Zanderig	--	0	2.780952381	+	4
4		Klei	1	Asfalt	4	1.6	Zanderig	--	--	2.86031746	-	2
2		Zand	2	Klei	1	1.8	Klei	-	-	3.001587302	+	4
2		Zand	2	Klei	1	1.8	Klei	-	+	3.001587302	+	4
3		Klei	1	Klei	1	1	Zand, Klei	-	--	1.761904762	++	5
5		Zand	2	Klei	1	1.8	Zand, Klei	++	++	3.065079365	+	4
3		Klei	1	Klei	1	1	Zware Klei	+	-	1.833333333	+	4
3		Zand	2	Klei	1	1.8	Zware Klei	+	++	3.2	0	3
2		Klei	1	Klei	1	1	Zand, Klei	-	-	1.833333333	+	4
1		Klei	1	Klei	1	1	Zand, Klei	-	++	1.849206349	+	4
2		Klei	1	Klei	1	1	Zware Klei	-	-	1.833333333	+	4
2		Zand	2	Klei	1	1.8	Zand, Klei	-	0	3.001587302	+	4
2		Klei, Veen	1	Klei	1	1	Klei, Veen	++	--	1.793650794	0	3
1		Klei	1	Klei	1	1	Klei, Veen	++	--	1.722222222	+	4
4		Klei, Veen	1	Klei	1	1	Veen	++	0	1.825396825	0	3
3		Zand	2	Klei	1	1.8	Klei, Veen	++	+	2.850793651	++	5
2		Klei, Veen	1	Klei	1	1	Klei, Veen	+	-	1.650793651	++	5
2		Zand	2	Klei	1	1.8	Zand, Klei	+	++	3.00952381	++	5
4		Zand, Klei	2	Klei	1	1.8	Zand, Klei	++	0	3.065079365	+	4
4		Klei	1	Klei	1	1	Zware Klei	+	+	1.833333333	+	4
4		Klei	1	Klei	1	1	Zand, Klei	+	+	1.833333333	+	4
2		Zand	2	Asfalt	4	2.4	Zand, Klei	-	++	4.092063492	-	2
1		Zand	2	Klei	1	1.8	Zand, Klei	+	++	3.128571429	+	4
2		Zand, Klei	1	Klei	1	1	Zand, Klei	++	+	1.928571429	+	4
1		Zand, Klei	1	Klei	1	1	Zand, Klei	++	+	1.968253968	0	3
5		Zand, Klei	2	Klei	1	1.8	Zand, Klei	0	+++	2.93015873	++	5
2		nvt	1	nvt	2	1.2	nvt	+	++	1.950793651	++	5
3		Zand	2	Klei	2	2	Zand, Klei	-	+++	3.396825397	+	4
1		Zand, Klei	1	Klei	1	1	Zand, Klei	+	++	1.753968254	+	4
3		Zand, Klei	1	Klei	1	1	Zand, Klei	+	0	1.841269841	0	3
5		Zand, Klei	2	Klei	1	1.8	Zand, Klei	0	+++	3.176190476	+	4
2		Zand, Klei	1	Klei	1	1	Zand, Klei	0	0	1.761904762	++	5
2		Zand	2	Zand	2	2	Zand, Klei	--	--	3.182539683	++	5
1		Zand, Klei	1	Klei	1	1	Zand, Klei	++	++	1.682539683	+++	5
2		Zand, Klei	1	Klei, Staal	4	1.6	Zand, Klei	--	-	2.717460317	+	4
2		nvt	1	nvt	1	1	Zand, Klei	--	--	1.666666667	0	3
4		nvt	1	nvt	1	1	Zand, Klei	-	--	1.650793651	++	5
2		Beton	4	Zand	2	3.6	Zand, Klei	0	--	5.868253968	0	3
2		Beton	4	Zand	2	3.6	Zand, Klei	--	--	5.757142857	0	3
1		Beton	4	Zand	2	3.6	Zand, Klei	0	-	5.876190476	+	4
2		Beton	4	Zand	2	3.6	Zand	--	0	5.796825397	+	4
5		Beton	4	Zand	2	3.6	Zand	--	-	5.9	0	3
2		Zand, Klei	1	Klei	1	1	Zand, Klei	-	+	1.682539683	++	5
3		Zand, Klei	2	Klei	1	1.8	Zand, Klei	0	++	2.953968254	+	4
5		Beton	4	Zand	2	3.6	Zand	--	0	5.868253968	0	3
2		Zand, Klei, Beton	2	Klei	1	1.8	Zand, Klei	-	-	3.096825397	+	4
3		Zand, Klei	1	Klei	1	1	Zand, Klei	++	0	1.682539683	++	5
2		Zand, Klei	1	Klei	1	1	Zand, Klei	++	0	1.642857143	+	4
2		Zand, Klei	2	Klei	1	1.8	Zand, Klei	0	+	3.080952381	+	4
5		Zand, Klei, Beton	2	Klei	1	1.8	Zand, Klei	0	+++	3.080952381	+	4
2		Beton, Staal	4	Klei	1	3.4	Zand	-	+	5.496825397	+	4
1		Zand, Klei	2	Klei	1	1.8	Zand, Klei	++	-	3.00952381	0	3
2		Beton, Staal	4	Beton	4	4	Zand, Klei	--	--	6.253968254	-	2
1		nvt	1	nvt	1	1	Zand, Klei	--	--	1.96031746	-	2
1		Zand, Klei	1	Klei	1	1	Zand, Klei	+	++	1.682539683	++	5
1		nvt	1	nvt	1	1	Zand, Klei	-	--	1.968253968	0	3
4		Zand, Klei	1	Klei	1	1	Zand, Klei	++	0	1.761904762	++	5
2		Zand, Klei, Beton	2	Beton, Steen	4	2.4	Zand, Klei	--	--	4.084126984	--	1
4		Zand, Klei	1	Beton, Steen	4	1.6	Zand, Klei	0	+	2.892063492	-	2
4		Zand, Klei	1	Klei	1	1	Zand, Klei	++	0	1.761904762	++	5
2		Zand, Klei	1	Klei	1	1	Zand, Klei	0	0	1.6746031750	+	4

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				Kosten	Waterkerende kunstwerken						6.5		5.5		
Steen, Beton	5-1 Codering	Asfalt (geld ook voor wegen)	5-1 Codering	TOTAL DIJK Bekleding	Zijlen, Schutten en spuisluizen	Stormvloed Impact	Coupures	TOTAL Veiligheid svoorkom en	Safety Failure Mechamis m	TOTAL Water Distributi e Effect	PROT		DIS		NAT
--	1	0	3	2.111111111	--	0	+	3	3	2	10.9375	0	14.84375	0	14.0
--	1	--	1	1.055555556	--	-	--	2	4	2	31.25	0	22.65625	0	17.96
--	1	+	4	2.666666667	-	0	--	2	4	2	18.75	0	10.15625	0	17.96
+	4	+	4	3.222222222	-	-	+	2	4	2	45.3125		17.96875	0	10.15
--	1	0	3	2.111111111	++	-	+	2	4	2	26.5625	0	33.59375		20.3
--	1	0	3	2.111111111	+	--	+	2	4	2	#VERW!	#VERW!	#VERW!	#VERW!	15
-	2	-	2	1.833333333	--	--	-	4	2	4	21.875	0	28.125	0	33.59
0	3	0	3	2.555555556	-	--	-	2	4	2	25	0	31.25	0	10.9
-	2	0	3	2.333333333	--	--	0	3	3	3	17.1875	0	14.84375	0	20.3
++	5	+	4	3.5	-	0	-	2	4	2	32.8125	0	33.59375		1.5
-	2	0	3	2.333333333	--	--	--	3	3	3	3.125	0	22.65625	0	17.96
++	5	-	2	2.444444444	-	--	++	3	3	3	25	0	32.03125	0	21.09
-	2	0	3	2.333333333	--	--	-	2	4	2	20.3125	0	27.34375	0	25.78
--	1	0	3	2.111111111	--	--	-	3	3	3	29.6875	0	8.59375	0	14.0
--	1	0	3	2.055555556	0	--	-	2	4	2	26.5625	0	30.46875	0	17.1
--	1	-	2	1.555555556	0	--	--	2	4	2	26.5625	0	24.21875	0	29.6
-	2	0	3	2.277777778	+	--	--	3	3	3	14.0625	0	39.84375		14.0
--	1	--	1	1.055555556	++	-	--	3	3	3	28.125	0	25.78125	0	15
--	1	--	1	1.055555556	--	--	+	2	4	2	23.4375	0	8.59375	0	39.0
--	1	0	3	2.166666667	-	--	+	2	4	2	17.1875	0	14.0625	0	21
0	3	0	3	2.555555556	++	--	0	2	4	2	14.0625	0	33.59375		20.3
-	2	0	3	2.333333333	--	-	++	2	4	2	20.3125	0	21.09375	0	25.78
-	2	0	3	2.333333333	--	0	-	2	4	2	25	0	22.65625	0	5.46
++	5	+	4	3.444444444	--	-	0	2	4	2	59.375		19.53125	0	15
++	5	0	3	3	-	-	-	2	4	2	18.75	0	32.03125	0	21.09
++	5	0	3	3	-	0	-	2	4	3	18.75	0	19.53125	0	2.34
+	4	+	4	3.277777778	+	-	--	2	4	3	14.0625	0	33.59375		20.3
--	1	-	2	1.611111111	--	-	--	2	4	3	43.75		25.78125	0	14.84
--	1	--	1	1.055555556	--	--	--	3	3	3	20.3125	0	20.3125	0	15
+	4	0	3	2.777777778	-	--	-	2	4	2	23.4375	0	11.71875	0	10.15
-	2	-	2	1.777777778	+	0	+	3	3	3	17.96875	0	12.5	0	8.59
++	5	-	2	2.388888889	+	-	+	4	2	3	17.1875	0	17.1875	0	3
+	4	+	4	3.333333333	--	++	--	2	4	3	43.75		19.53125	0	14.84
-	2	-	2	1.833333333	-	-	-	2	4	2	29.6875	0	17.1875	0	
-	2	--	1	1.277777778				4	2	4	22.65625	0	38.28125		35.15
-	2	--	1	1.277777778				2	4	2	23.4375	0	8.59375	0	32.03
+	4	-	2	2.222222222				2	4	2	23.4375	0	37.5		21
-	2	--	1	1.166666667				2	4	3	35.15625		7.03125	0	28.90
--	1	--	1	1.055555556				4	2	4	16.40625	0	38.28125		41.40
+	4	+	4	3.277777778				2	4	2	21.875	0	25.78125	0	15
0	3	0	3	2.5				2	4	2	32.8125	0	36.71875		10.15
+	4	+	4	3.333333333				2	4	2	25	0	16.40625	0	24.21
+	4	0	3	2.777777778				2	4	2	37.5		10.15625	0	17.96
++	5	+	4	3.5				2	4	2	45.3125		11.71875	0	10.15
-	2	--	1	1.277777778				3	3	3	20.3125	0	10.9375	0	
-	2	-	2	1.777777778				3	3	3	14.0625	0	17.96875	0	3.90
+	4	+	4	3.277777778				1	5	2	45.3125		17.96875	0	10.15
+	4	0	3	2.777777778				2	4	2	28.125	0	21.09375	0	19.53
-	2	--	1	1.277777778				3	3	3	31.25	0	16.40625	0	7.8
--	1	--	1	1				4	2	4	20.3125	0	23.4375	0	3
--	1	+	4	2.666666667				2	4	2	37.5		28.90625	0	11.71
--	1	+	4	2.666666667				2	4	2	32.8125	0	11.71875	0	16.40
+	4	0	3	2.777777778				2	4	2	42.1875		14.84375	0	7.03
+	4	-	2	2.166666667				3	3	3	12.5	0	25.78125	0	8.59
++	5	--	1	1.777777778				3	3	3	10.15625	0	38.28125		22.65
+	4	+	4	3.222222222				1	5	1	34.375		32.03125	0	28
-	2	--	1	1.277777778				3	3	3	34.375		18.75	0	23.4
+	4	+	4	3.277777778				1	5	1	28.125	0	25.78125	0	28
-	2	-	2	1.833333333				3	3	3	20.3125	0	11.71875	0	28.90
++	5	+	4	3.388888889				2	4	2	46.875		25.78125	0	9
++	5	+	4	3.444444444				2	4	2	46.875		25.78125	0	9
-	2	-	2	1.833333333				3	3	3	28.90625	0	19.53125	0	22.65
-	2	--	1	1.222222222				3	3	3	14.84375	0	37.5		30.46
												#VERW!		#VERW!	

5		6		5.5		5.5										
		LAN		MUL		LOC							Dikes 3 New		Dikes 5 New	
0625	0	22.65625	0	25.78125	0	28.125	0	0					18.25687057		18.4282076	
6875	0	31.25	0	17.96875	0	10.9375	0	0					22.01795213		22.91179102	
6875	0	31.25	0	24.21875	0	10.9375	0	0					18.4275266		19.09846503	
5625	0	32.03125	0	31.25	0	18.75	0	1	Dijk-in-Boulevard		X		24.09463652		26.12713381	
3125	0	6.25	0	12.5	0	18.75	0	1	Havenkanaaldijk				20.53080674		19.85046118	
.625	0	19.53125	0	10.9375	0	20.3125	0	#VERW!	Spuiomkijkdijk				#VERW!		#VERW!	
9375		19.53125	0	20.3125	0	44.53125		2	Zomerdijk				28.52947695	X	28.00712417	
9375	0	32.8125	0	21.09375	0	22.65625	0	0					23.01196809		23.77994218	
3125	0	35.15625		13.28125	0	28.125	0	1	Dwarsdijk				21.29765071		22.21400055	
5625	0	18.75	0	18.75	0	12.5	0	1	Schaardijk				18.53612589		19.34109994	O
6875	0	24.21875	0	42.96875		4.6875	0	1	Vingerling				18.51285461		17.22019548	
9375	0	20.3125	0	32.8125	0	23.4375	0	0					25.29033688		24.84082461	I
3125	0	12.5	0	22.65625	0	25	0	0					22.72273936		21.898231	
0625	0	35.15625		25.78125	0	28.125	0	1	Limburgse Zijdewende				21.97140957		23.80403359	
1875	0	25	0	21.875	0	28.125	0	0					24.34286348		24.67218475	
6875	0	25	0	15.625	0	46.875		1	Tiendweg				28.16378546	X	28.54746008	X
0625	0	12.5	0	31.25	0	12.5	0	1	Ringdijk				20.38009752		18.96940391	
.625	0	42.96875		35.9375		14.0625	0	2	Boezemdijk				25.7712766		26.70532764	
0625		22.65625	0	13.28125	0	40.625		2	Landscheidingsdijk				25.67708333		25.93784416	
1875	0	6.25	0	10.15625	0	21.09375	0	0					15.85549645	O	15.49593888	
3125	0	6.25	0	18.75	0	12.5	0	1	Kanaaldijk				18.42087766		16.93195898	
3125	0	25	0	28.90625	0	12.5	0	0					22.49224291		22.12537858	
6875	0	26.5625	0	23.4375	0	7.8125	0	0					17.34707447		18.18815391	
.625	0	5.46875	0	23.4375	0	14.0625	0	1	Spoeldijk		X		22.44680851		23.82124174	
9375	0	20.3125	0	20.3125	0	10.9375	0	0					21.1768617		20.46307131	
4375	0	32.8125	0	14.0625	0	23.4375	0	0					16.95700355	O	18.42562638	
3125	0	12.5	0	31.25	0	31.25	0	1	Energie dijk				23.33222518		22.15635325	
4375	0	39.0625		32.8125	0	23.4375	0	2	Delta Dijk		X		28.36657801	X	30.12716823	X
.625	0	39.84375		40.625		5.46875	0	2	Hybride Dijk				22.42021277		22.8515625	
5625	0	46.09375		12.5	0	31.25	0	1	Multifunctionele dijk				21.12256206	I	23.44782489	
9375	0	23.4375	0	32.8125	0	35.9375		1	Hergebruikte dijk				19.52903369		20.41058645	
1.25	0	27.34375	0	19.53125	0	17.96875	0	0					22.6739805		22.40070898	I
4375	0	45.3125		32.8125	0	23.4375	0	2	Superdijk		X		28.15381206		30.41626514	X
12.5	0	14.0625	0	18.75	0	14.84375	0	0					17.37256206		18.0031663	
5625		10.15625	0	20.3125	0	36.71875		3	Kunstriffen				28.46187943		27.00302863	
3125	0	50.78125		10.15625	0	43.75	0	2	Rijke Dijken				28.22251773	X	30.06780011	O
1875	0	3.125	0	18.75	0	29.6875	0	1	Luwtedam				22.87455674		21.74077643	
0625	0	28.90625	0	20.3125	0	36.71875		2	Palenbos				25.8998227		27.33342511	O
0625		16.40625	0	20.3125	0	30.46875	0	2	Schorbuffer				29.16223404	X	27.27147577	
.625	0	24.21875	0	35.9375		14.0625	0	1	Westkeetshaven Zwijndrecht				21.93262411		21.79756333	
5625	0	25.78125	0	6.25	0	12.5	0	1	Sumida River Tokyo				20.92974291		21.72184747	
1875	0	20.3125	0	23.4375	0	26.5625	0	0					22.52437943		22.75863849	
6875	0	25	0	17.96875	0	10.9375	0	1	Katwijk Dijk Duin				19.73958333		21.17032627	
5625	0	7.03125	0	25	0	12.5	0	1	Kustboulevard Cleveleys				17.57867908		18.85152808	
6.25	0	19.53125	0	38.28125		24.21875	0	1	Baggerdijk				17.4722961	O	18.20364124	
0625	0	38.28125		31.25	0	6.25	0	1	Sawadijk (Terrassen)				16.80740248	O	17.69514042	
5625	0	13.28125	0	18.75	0	6.25	0	1	Drift Park Rhyl				18.12832447		19.42972192	
3125	0	25	0	9.375	0	21.875	0	0					21.16578014		21.96018034	
3125	0	42.96875		37.5		16.40625	0	2	Tripple Dijk				23.03745567		24.86405562	
1.25	0	39.84375		31.25	0	33.59375		2	Overloopdijk				29.68085106	X	29.8483962	X
1875	0	20.3125	0	17.1875	0	20.3125	0	1					22.09884752		23.04773541	
0625	0	25.78125	0	12.5	0	12.5	0	0					18.58931738		19.95973293	
3125	0	25	0	28.125	0	15.625	0	1					20.37677305		22.24927726	
9375	0	26.5625	0	39.0625		10.9375	0	1					18.9516844		18.68719025	
5625	0	28.90625	0	32.8125	0	17.96875	0	1					25.05762411		23.84361233	
.125	0	30.46875	0	4.6875	0	26.5625	0	1					27.29609929	I	27.93743117	
4375	0	39.0625		26.5625	0	32.03125	0	2	Sedimentatiedijk				28.19259752		29.61694659	
.125	0	24.21875	0	29.6875	0	39.0625		1					28.75	I	28.81848844	
0625	0	50.78125		43.75		12.5	0	2	Water Front Parks				27.16201241		27.80664923	I
.375	0	24.21875	0	23.4375	0	14.0625	0	1					22.88120567		24.46826817	
.375	0	17.96875	0	10.9375	0	20.3125	0	1					21.33865248		22.98836729	
5625	0	28.90625	0	57.8125		11.71875	0	1			X		26.58244681		26.46613436	I
6875	0	21.09375	0	25.78125	0	10.15625	0	1					24.59441489	I	22.95997384	
	4		13		9		9									

16.3

River dynamics

Dynamics Conditions

Sedimentation statistics along the Rhine

Gravel/ Cobble

		River Section	Alpine Section				Impounded Section				Free Flowing Section				Delta Section			
			Alpine Rhine		Lake Constance		High Rhine - Oberrhein		Upper Rhine Graben		Upper Rhine Graben		Lower Rhine Graben		Upper Delta		Lower Delta	
			167		63		310		50		312		212		93		82	
			206 until 39		39 until +24		24 until 334		174 until 224		334 until 646		646 to 858		858 until 951		951 until 1033	
			Estimate	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*
Input	Iup	Upstream Area	0.121	0.036	0.000	0.003	0.000	0.000	0.000	0.005	0.000	0.002	0.059	0.024	0.016	0.042	0.000	0.050
	Itr	Tributaries	0.208	0.062	0.000	0.002	0.048	0.048			0.000	0.002	0.000	0.002			0.000	0.020
	Ido	Downstream Area															0.000	0.050
	Iar	Artificial Sediment					0.000	0.003	0.000	0.003	0.718	0.144	0.700	0.140				
	Ise	Secondary Channels					0.002	0.003										
	Idi	Diffuse Sediment Sources					0.000	0.001			0.000	0.002	0.000	0.002				
	Iab	Abbrasion Erosion																
	Tot		0.329	0.098	0.000	0.005	0.050	0.055	0.000	0.008	0.718	0.150	0.759	0.168	0.016	0.042	0.000	0.120
Output	Oab	Abbrasion Sedimentation	0.121	0.030			0.000	0.004	0.001	0.003	0.095	0.048	0.049	0.025				
	Ose	Secondary Channels					0.000	0.005										
	Odo	Downstream Area	0.000	0.003	0.000	0.000	0.000	0.002	0.002	0.003	0.059	0.024	0.106	0.042	0.000	0.060	0.000	0.003
	Odr	Dredging	0.182	0.055			0.037	0.037			0.286	0.057	0.289	0.058	0.055	0.280	0.000	0.050
	Ogr	Net output Groyne Fields							0.016	0.008	0.082	0.062	0.036	0.027	0.000	0.000		
	Ofl	Floodplain sedimentation					0.000	0.000			0.000	0.002	0.000	0.002				
	Opo	Deposition in Ports															0.000	0.010
	Tot		0.303	0.088	0.000	0.000	0.037	0.048	0.019	0.014	0.522	0.193	0.480	0.154	0.055	0.340	0.000	0.063
	Change		**0.026**	***0.013***	**0.000**	***0.003***	**0.013**	***0.020***	**-0.019**	***0.004***	**0.196**	***0.039***	**0.279**	***0.056***	**0.051**	***0.051***	**0.000**	***0.001***

0.016 Includes deposition on Floodplains
0.718 Includes 0.280-0.050 Mt/a sediment that were dredged and subsequently dumped back in the river
0.700 Includes 0.280-0.020 Mt/a sediment that were dredged and subsequently dumped back in the river

Sand

		River Section	Alpine Section				Impounded Section				Free Flowing Section				Delta Section			
			Alpine Rhine		Lake Constance		High Rhine - Oberrhein		Upper Rhine Graben		Upper Rhine Graben		Lower Rhine Graben		Upper Delta		Lower Delta	
			Estimate	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*
Input	Iup	Upstream Area	0.366	0.110	0.559	0.140	0.000	0.000	0.086	0.034	0.077	0.031	0.420	0.168	0.594	0.238	0.534	0.294
	Itr	Tributaries	0.322	0.970	0.189	0.095	0.208	0.104			0.112	0.112	0.006	0.001			0.199	0.152
	Ido	Downstream Area															2.300	1.150
	Iar	Artificial Sediment					0.000	0.001	0.000	0.001	0.147	0.029	0.116	0.023				
	Ise	Secondary Channels					0.000	0.050										
	Idi	Diffuse Sediment Sources					0.000	0.001			0.000	0.100	0.000	0.100				
	Iab	Abbrasion Erosion																
	Tot		0.688	1.080	0.748	0.235	0.208	0.156	0.086	0.035	0.336	0.272	0.542	0.292	0.594	0.238	3.033	1.596
Output	Oab	Abbrasion Sedimentation																
	Ose	Secondary Channels					0.086	0.034										
	Odo	Downstream Area	0.559	0.140	0.000	0.001	0.077	0.015	0.000	0.050	0.420	0.168	0.594	0.238	0.584	0.292	0.350	0.152
	Odr	Dredging	0.130	0.039			0.045	0.009			0.180	0.036	0.127	0.025	0.189	0.095	2.497	0.624
	Ogr	Net output Groyne Fields									0.106	0.080	0.224	0.168				
	Ofl	Floodplain sedimentation					0.000	0.050	0.075	0.038	0.149	0.149	0.220	0.220	0.126	0.038		
	Opo	Deposition in Ports															0.634	0.317
	Tot		0.689	0.179	0.000	0.001	0.208	0.108	0.075	0.088	0.855	0.433	1.165	0.651	0.899	0.425	3.481	1.093
	Change		**0.000**	***0.001***	**0.748**	***0.187***	**0.000**	***0.002***	**0.011**	***0.002***	**-0.519**	***0.208***	**-0.623**	***0.125***	**-0.305**	***0.305***	**-0.448**	***1.390***

0.016 Includes small portion of deposition in groyne fields
0.718 Includes 0.100-0.010 Mt/a sediment that were dredged and subsequently dumped back in the river
0.700 Includes 0.120-0.010 Mt/a sediment that were dredged and subsequently dumped back in the river

Silt & Clay

		River Section	Alpine Section				Impounded Section				Free Flowing Section				Delta Section			
			Alpine Rhine		Lake Constance		High Rhine - Oberrhein		Upper Rhine Graben		Upper Rhine Graben		Lower Rhine Graben		Upper Delta		Lower Delta	
			Estimate	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*	*Estimate*	*Uncertainty*
Input	Iup	Upstream Area	1.615	0.485	3.014	0.603	0.000	0.002	0.460	0.184	0.845	0.338	2.359	0.944	2.107	0.843	1.488	0.945
	Itr	Tributaries	1.282	0.385	0.991	0.496	1.125	0.225			1.109	1.109	0.061	0.061			0.387	0.194
	Ido	Downstream Area															3.500	1.750
	Iar	Artificial Sediment					0.000	0.000	0.000	0.001	0.000	0.050	0.000	0.050				
	Ise	Secondary Channels					0.414	0.083										
	Idi	Diffuse Sediment Sources					0.195	0.098			0.879	0.879	0.317	0.032				
	Iab	Abbrasion Erosion	0.121	0.030			0.000	0.004	0.001	0.001	0.095	0.048	0.049	0.025				
	Tot		3.018	0.900	4.005	1.099	1.734	0.412	0.461	0.186	2.928	2.424	2.786	1.112	2.107	0.843	5.375	2.889
Output	Oab	Abbrasion Sedimentation																
	Ose	Secondary Channels					0.460	0.184										
	Odo	Downstream Area	3.014	0.603	0.000	0.002	0.845	0.169	0.414	0.166	2.359	0.944	2.107	0.843	1.717	0.859	0.900	0.364
	Odr	Dredging	0.004	0.001			0.153	0.031			0.000	0.050	0.000	0.050	0.000	0.000	2.739	0.685
	Ogr	Net output Groyne Fields									0.000	0.100	0.000	0.100				
	Ofl	Floodplain sedimentation					0.276	0.138	0.038	0.019	0.569	0.285	0.679	0.340	0.390	0.195		
	Opo	Deposition in Ports															1.433	0.717
	Tot		3.018	0.604	0.000	0.002	1.734	0.522	0.452	0.185	2.928	1.379	2.786	1.333	2.107	1.054	5.072	1.766
	Change		**0.000**	***0.001***	**4.005**	***0.801***	**0.000**	***0.110***	**0.009**	***0.002***	**0.000**	***0.050***	**0.000**	***0.050***	**0.000**	***0.000***	**0.303**	***2.260***

0.016 Includes small portion of deposition in groyne fields
0.718 Includes 0.100-0.010 Mt/a sediment that were dredged and subsequently dumped back in the river
0.700 Includes 0.120-0.010 Mt/a sediment that were dredged and subsequently dumped back in the river

Dynamics Conditions

The width segments of the Rhine

RHINE				Length (m)	Width (m)						
Begin Point	Country	End Point	Country		Max	Med	Mean	Width	NR	Min	SD
Pannerdensch Ka	NL	Wesel	DE	54024	569	390	372	390	3	254	54,18
Wesel	DE	Duisburg	DE	32955	510	362	372	362	3	270	38,74
Duisburg	DE	Koblenz	DE	187665	654	351	372	351	3	210	55,09
Koblenz	DE	Bingen	DE	55846	611	317	319	317	3	159	82,62
Bingen	DE	Mainz	DE	32612	947	611	655	611	5	420	122,89
Mainz	DE	Mannheim	DE	68201	664	327	319	327	3	189	74,41
Mannheim	DE	Breisach	DE	202097	978	256	271	256	2	123	96,67
FRENCH Corridor											
Breisach	DE	Geiswasser	FR	4367	345	212	228	212	2	108	56,43
Geiswasser	FR	Basel	CH	47172	507	136	155	136	1	92	51,52
GERMAN Corridor											
Breisach	DE	Geiswasser	FR	4720	254	171	190	171	1	127	18,86
Geiswasser	FR	Hartheim	DE	11170	219	150	155	150	1	60	37,17
Hartheim	DE	Basel	CH	36394	212	108	97	108	1	36	26,70
Basel	CH	Felsenau	CH	70310	429	203	190	203	2	42	52,00
Felsenau	CH	Ellikon am Rhein	CH	37997	311	128	124	128	1	67	37,14
Ellikon am Rhein	CH	Konstanz	DE	72542	10658	169	*572*	169	1	30	866,33
Konstanz	DE	Reichenau	CH	130550	18943	84	*2829*	84	1	30	4072,03
							Are not related to each other as these include lakes				
Voorrijn Reichenau	CH	Tavanasa	CH	32570	169	48	50			30	20,31
Achterrijn Reichenau	CH	Thusis	CH	15821	138	54	50			30	19,50
Konstanz	End of Data corresponds with the border between Germany and Switzerland in Lake Constance										
Konstanz	Large part of the Data corresponds with the width provided by Lake Constance										
MOSSELLE											
Koblenz	DE	Konz	DE	200170	337	150	155			30	42,26
Konz	DE	Custines	FR	153715	279	108	124			30	36,77
Custines	FR	Arches	FR	117282	317	54	72			30	43,92
Custines	Potential error in Data (loss of river way)										
Aingeray	FR	Villey-le-Sec	FR	22349	365	130	155			42	55,25
MAIN											
Mainz	DE	Hausen	DE	417336	378	94	97			30	39,64
Main-Donau Kanal Hausen	DE	Schaftnach	DE	48724	170	48	50			30	18,91
Regenz Hausen	DE	Vach	DE	21052	92	42	50			30	12,26
WAAL											
Pannerdensch	NL	Nijmegen	NL	16034	537	346	372			254	44,6
Nijmegen	NL	Biesbosch	NL	75157	960	381	372			30	83,89
Biesbosch	NL	Biesbosch	NL	7456	3240	647	747			492	464,98
IJSSEL											
Pannerdensch	NL	Pannerdensch	NL	na	711	150	155			84	
Pannerdensch	NL	Arnhem	NL	na	275	169	155			42	
Rheden	NL	Doesburg	NL	na	136	84	97			42	
Doesburg	NL	Zwolle	NL	na	629	105	97			42	
Zwolle	NL	Ketelmeer	NL	na	402	172	190			108	

16.5

Authoratative Autonomy

Authoritative Regions

Decision Making Autonomy Land Use Classifications

Land Use	NR	Land Use Group (Agriculture, Urban, Industrial, Natural)	Actor Groups	A.K: Level of Knowledge	A.K: Methods & Data	A.K: Adaptive Response	Available Knowledge (HIGH)	Available Knowledge (HIGH)	Available Funds (HIGH)	Availability of Space (MED)	Authority within Water Management (MED)	A.W: Additional Integration within Spatial Planning	Authority within Water Management (MED) TOTAL	S.I: Width of Participation	S.I: Depth of Participation	Stakeholder Involvement (MED) NEGATIVE	D.U: Consideration of Alternatives	D.U: Handling of Uncertainty	Dealing with Uncertainties (LOW)	Total		
				1	0.75	0.5	2	2	1.75	1.5	1	(+Additonal) *See BLAD 2	1			0.75			0.5	7.5		
Continuous urban fabric	1	Urban	Residents, Public Governments	4	5	5	4.555555556	4.6	5	1	5			1	1	1	1	2	**1.5**	3.46	**3.5**	10
Discontinuous urban fabric	2	Urban	Residents, Public Governments	3	4	4	3.555555556	3.6	4	2	4			2	1	1.5	2	3	**2.5**	3.143333333	**3.1**	8
Green urban areas	3	Urban	Residents, Public Governments	3	4	4	3.555555556	3.6	3	3	2			2	2	2	4	3	**3.5**	2.96	**3**	7
Forrest (Broad-leaved, forest, Coniferous forest, Mixed forest)	4	Natural	Governmental organizations, NGO's, local groups.	4	3	2	3.222222222	3.2	2	3	3			3	4	3.5	3	3	**3**	2.87	**2.9**	7
Natural Grasslands	5	Nature	Governmental organizations, NGO's, local groups.	3	2	1	2.222222222	2.2	1	5	1			5	5	5	5	5	**5**	2.786666667	**2.8**	6
Moors and Heathland	6	Nature	Governmental organizations, NGO's, local groups.	4	2	1	2.666666667	2.7	1	4	2			5	5	5	3	4	**3.5**	2.753333333	**2.8**	6
Vegetation (Transitional woodland/shrub)	7	Nature	Governmental organizations, NGO's, local groups.	3	1	1	1.888888889	1.9	1	5	1			5	4	4.5	4	5	**4.5**	2.623333333	**2.6**	5
Vineyards	9	Agriculture	Farmers, Farmer Organizations	4	3	2	3.222222222	3.2	1	3	2			4	4	4	2	2	**2**	2.486666667	**2.5**	5
Fruit	10	Agriculture	Farmers, Farmer Organizations	4	3	2	3.222222222	3.2	1	3	2			4	3	3.5	3	2	**2.5**	2.47	**2.5**	4
Pastures	12	Agriculture	Farmers, Farmer Organizations	2	1	1	1.444444444	1.4	1	4	1			5	4	4.5	4	4	**4**	2.256666667	**2.2**	3
Complex Cultivation	14	Agriculture	Farmers, Farmer Organizations	3	2	2	2.444444444	2.4	2	3	3			2	3	2.5	2	3	**2.5**	2.523333333	**2.5**	5
Land Principality Agriculture	15	Agriculture	Governmental organizations, NGO's, local groups, Farmers, Farmer Organizations	2	1	1	1.444444444	1.4	1	5	1			5	3	4	5	5	**5**	2.473333333	**2.5**	4
Agro Forrestry	16	Agriculture	Farmers, Farmer Organizations	2	1	1	1.444444444	1.4	1	3	2			4	4	4	3	3	**3**	2.073333333	**2.1**	2
Non Irrigated Agricultural Land	17	Agriculture	Farmers, Farmer Organizations	3	1	1	1.888888889	1.9	1	4	2			5	3	4	4	4	**4**	2.473333333	**2.5**	4
Industrial or Commercial Units	19	Industrial	Private Industries, Retailers	2	2	4	2.444444444	2.4	4	2	4			3	2	2.5	2	2	**2**	2.89	**2.9**	7
Mineral Extraction	21	Industrial	Private Industries, Retailers	4	3	3	3.444444444	3.4	3	3	3			4	2	3	1	2	**1.5**	3.006666667	**3**	8
Dump Sites	22	Industrial	Private Industries, Retailers	1	1	3	1.444444444	1.4	2	2	2			4	1	2.5	1	1	**1**	1.823333333	**1.8**	1
Water	24	Nature	Governmental organizations, NGO's, local groups.	5	5	3	4.555555556	4.6	2	2	4			4	2	3	4	5	**4.5**	3.226666667	**3.2**	9

Average

Authoritative Regions

Decision Making Autonomy
Policy integration

Land Use	NR	Land Use Group (Agriculture, Urban, Industrial, Natural)	Actor Groups	Authority within Water Management (MED)	A.W: Additional Integration within Spatial Planning (+Additonal)	Countries	Austria	TOT	NR	Switzerland	TOT	NR	Germany	TOT	NR	France	TOT	NR	Liechtenstein	TOT	NR	Netherlands	TOT	NR
				1																				
Continuous urban fabric	1	Urban	Residents, Public Governments	5			0.115740741	5	**5**	0.916666667	5	**5**	0.5	5	**5**	0.449074074	5.224537037	**5**	0.305555556	5.152777778	**5**	0.87037037	5.435185185	**5**
Discontinuous urban fabric	2	Urban	Residents, Public Governments	4			0.115740741	4.115740741	**4.1**	0.916666667	4.458333333	**4.5**	0.5	4.25	**4.3**	0.449074074	4.224537037	**4.2**	0.305555556	4.152777778	**4.2**	0.87037037	4.435185185	**4.4**
Green urban areas	3	Urban	Residents, Public Governments	2			0.115740741	2.115740741	**2.1**	0.916666667	2.458333333	**2.5**	0.5	2.25	**2.3**	0.449074074	2.224537037	**2.2**	0.305555556	2.152777778	**2.2**	0.87037037	2.435185185	**2.4**
Forrest (Broad-leaved, forest, Coniferous forest, Mixed forest)	4	Natural	Governmental organizations, NGO's, local groups.	3			0.25	3.25	**3.3**	0.916666667	3.458333333	**3.5**	0.916666667	3.458333333	**3.5**	0.416666667	3.208333333	**3.2**	0.125	3.0625	**3.1**	0.916666667	3.458333333	**3.5**
Natural Grasslands	5	Nature	Governmental organizations, NGO's, local groups.	1			0.25	1.25	**1.3**	0.916666667	1.458333333	**1.5**	0.916666667	1.458333333	**1.5**	0.416666667	1.208333333	**1.2**	0.125	1.0625	**1.1**	0.916666667	1.458333333	**1.5**
Moors and Heathland	6	Nature	Governmental organizations, NGO's, local groups.	2			0.25	2.25	**2.3**	0.916666667	2.458333333	**2.5**	0.916666667	2.458333333	**2.5**	0.416666667	2.208333333	**2.2**	0.125	2.0625	**2.1**	0.916666667	2.458333333	**2.5**
Vegetation (Transitional woodland/shrub)	7	Nature	Governmental organizations, NGO's, local groups.	1			0.25	1.25	**1.3**	0.916666667	1.458333333	**1.5**	0.916666667	1.458333333	**1.5**	0.416666667	1.208333333	**1.2**	0.125	1.0625	**1.1**	0.916666667	1.458333333	**1.5**
Vineyards	9	Agriculture	Farmers, Farmer Organizations	2			0.208333333	2.208333333	**2.2**	0.75	2.375	**2.4**	0.25	2.125	**2.1**	0.25	2.125	**2.1**	0.4375	2.21875	**2.2**	0.25	2.125	**2.1**
Fruit	10	Agriculture	Farmers, Farmer Organizations	2			0.208333333	2.208333333	**2.2**	0.75	2.375	**2.4**	0.25	2.125	**2.1**	0.25	2.125	**2.1**	0.4375	2.21875	**2.2**	0.25	2.125	**2.1**
Pastures	12	Agriculture	Farmers, Farmer Organizations	1			0.208333333	1.208333333	**1.2**	0.75	1.375	**1.4**	0.25	1.125	**1.1**	0.25	1.125	**1.1**	0.4375	1.21875	**1.2**	0.25	1.125	**1.1**
Complex Cultivation	14	Agriculture	Farmers, Farmer Organizations	3			0.208333333	3.208333333	**3.2**	0.75	3.375	**3.4**	0.25	3.125	**3.1**	0.25	3.125	**3.1**	0.4375	3.21875	**3.2**	0.25	3.125	**3.1**
Land Principality Agriculture	15	Agriculture	Governmental organizations, NGO's, local groups, Farmers, Farmer Organizations	1			0.208333333	1.208333333	**1.2**	0.75	1.375	**1.4**	0.25	1.125	**1.1**	0.25	1.125	**1.1**	0.4375	1.21875	**1.2**	0.25	1.125	**1.1**
Agro Forrestry	16	Agriculture	Farmers, Farmer Organizations	2			0.208333333	2.208333333	**2.2**	0.75	2.375	**2.4**	0.25	2.125	**2.1**	0.25	2.125	**2.1**	0.4375	2.21875	**2.2**	0.25	2.125	**2.1**
Non Irrigated Agricultural Land	17	Agriculture	Farmers, Farmer Organizations	2			0.208333333	2.208333333	**2.2**	0.75	2.375	**2.4**	0.25	2.125	**2.1**	0.25	2.125	**2.1**	0.4375	2.21875	**2.2**	0.25	2.125	**2.1**
Industrial or Commercial Units	19	Industrial	Private Industries, Retailers	4			0.25	4.25	**4.3**	0.875	4.4375	**4.4**	0.541666667	4.270833333	**4.3**	0.416666667	4.208333333	**4.2**	0.15625	4.078125	**4.1**	0.75	4.375	**4.4**
Mineral Extraction	21	Industrial	Private Industries, Retailers	3			0.041666667	3.041666667	**3**	0	3	**3**	0.5	3.25	**3.3**	0.333333333	3.166666667	**3.2**	0	3	**3**	0.083333333	3.041666667	**3**
Dump Sites	22	Industrial	Private Industries, Retailers	2			0.25	2.25	**2.3**	0.875	2.4375	**2.4**	0.541666667	2.270833333	**2.3**	0.416666667	2.208333333	**2.2**	0.15625	2.078125	**2.1**	0.75	2.375	**2.4**
Water	24	Nature	Governmental organizations, NGO's, local groups.	4			0	4	**4**	0.916666667	4.458333333	**4.5**	0.333333333	4.166666667	**4.2**	0.458333333	4.229166667	**4.2**	0.5	4.25	**4.3**	0.5	4.25	**4.3**

Austria

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	100.00	100.00	100.00	82.00	86.75	52.18	57.40	54.54	53.41	53.37	18.00	16.31	16.28	16.28	15.44	15.47	15.00	15.00	14.96	14.91
PP	12.48	12.43	12.37	10.10	10.62	6.34	6.94	6.58	6.42	6.40	2.15	1.94	1.93	1.92	1.81	1.79	1.72	1.71	1.69	1.68
Electricity cooling	1629.40	1844.10	1830.80	1570.92	1674.77	1744.68	1688.71	1701.34	4.00	1803.65	1856.91	1718.08	1895.34	1783.37	1708.44	1704.71	1702.32	1783.54	1171.57	1221.40
PP	203.38	229.30	226.52	193.50	205.00	212.11	204.25	205.10	0.48	216.23	222.09	204.81	224.93	210.37	199.96	197.54	194.78	202.79	132.57	137.58
Mining and quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP																				
Public water supply	587.70	583.01	578.00	572.66	566.99	561.00	554.67	548.02	608.00	533.74	587.00	566.96	562.57	572.18	567.24	567.33	660.00	605.04	608.45	610.97
PP	73.36	72.49	71.52	70.54	69.40	68.20	67.09	66.07	73.06	63.99	70.21	67.59	66.76	67.50	66.39	65.74	75.52	68.79	68.85	68.82
Manufacturing	1259.20	1239.50	1220.20	1242.16	1317.94	1368.02	1465.15	1557.45	1657.05	1433.39	1526.56	1627.32	1628.94	1643.60	1664.97	1708.26	1708.00	1708.00	1781.44	0.00
PP	157.17	154.12	150.98	153.01	161.33	166.32	177.21	187.75	199.13	171.84	182.58	193.99	193.32	193.88	194.87	197.96	195.43	194.20	201.57	0.00
Manufacturing cooling																				
Construction																				
Total	3576.30	3766.61	3729.00	3467.74	3646.44	3725.88	3765.93	3861.36	2322.46	3824.16	3988.47	3928.66	4103.13	4015.42	3956.09	3995.77	4085.32	4111.58	3576.43	1847.27
Inhabitants	8.011566	8.042293	8.082121	8.118245	8.169441	8.225278	8.267948	8.295189	8.321541	8.341483	8.361069	8.388534	8.426311	8.47723	8.543932	8.629519	8.739806	8.795073	8.837707	8.877637
Total Per Inhabitant	446.39234	468.3508	461.3888	427.1539	446.3516	452.9787	455.4853	465.4943	279.0897	458.4503	477.0291	468.3373	486.9429	473.6718	463.0297	463.0346	467.4385	467.4863	404.6782	208.0818

France

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	4871.93	4767.22	4290.59	5516.90	5147.92	4695.49	4757.04	3932.85	2587.89	3144.93	3045.02	3052.36	2913.10	2776.27	2114.01	3213.16	3113.09	2942.55	3006.40	2434.06
PP	80.23	77.94	69.65	88.93	82.38	74.58	75.04	61.66	40.35	48.79	47.01	46.90	44.54	42.23	31.90	48.31	46.68	44.00	44.79	36.14
Electricity cooling	18338.89	19161.26	18507.98	20095.41	19077.87	19787.52	18937.31	18509.77	18000.61	17819.60	17149.73	17002.64	18839.35	17021.90	17218.30	17030.01	15708.49	16099.18	16091.07	18213.20
PP	302.00	313.28	300.43	323.92	305.29	314.30	298.73	290.21	280.68	276.45	264.77	261.23	288.05	258.94	259.79	256.04	235.55	240.71	239.72	270.40
Mining and quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.98	0.00	83.61	90.13	97.97	93.74	51.83	45.24	46.66	103.56	34.39	0.00
PP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.65	0.00	1.29	1.38	1.50	1.43	0.78	0.68	0.70	1.55	0.51	0.00
Public water supply	5871.73	5966.01	5965.99	6197.89	6013.59	5915.34	5861.67	5682.97	5518.82	5645.20	5490.22	5379.54	5480.90	5283.25	5066.35	5216.16	5174.02	5391.24	5288.84	5300.47
PP	96.69	97.54	96.84	99.91	96.23	93.96	92.46	89.10	86.05	87.58	84.76	82.65	83.80	80.37	76.44	78.42	77.58	80.61	78.79	78.69
Manufacturing	2397.82	2408.21	2359.50	2390.26	2315.37	2287.26	2142.85	2165.32	2034.68	1952.92	1757.31	1804.85	2245.15	2194.00	2238.38	2303.22	2131.35	2213.22	1697.46	1709.34
PP	39.49	39.37	38.30	38.53	37.05	36.33	33.80	33.95	31.73	30.30	27.13	27.73	34.33	33.38	33.77	34.63	31.96	33.09	25.29	25.38
Manufacturing cooling																				
Construction																				
Total	31480.37	32302.70	31124.05	34200.46	32554.76	32685.60	31698.86	30290.91	28247.98	28562.65	27525.90	27329.52	29576.46	27369.15	26688.87	27807.79	26173.61	26749.74	26118.16	27657.08
Inhabitants	60.72478	61.163237	61.60455	62.03754	62.4908	62.95833	63.39341	63.78128	64.13317	64.45872	64.77317	65.08732	65.403	65.73596	66.27667	66.51256	66.68856	66.88331	67.12507	67.35605
Total Per Inhabitant	518.41064	528.13913	505.2233	551.2865	520.9528	519.1625	500.034	474.9185	440.4582	443.1154	424.9583	419.8901	452.2188	416.3497	402.6888	418.0833	392.4752	399.9464	389.097	410.6101

Germany

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	147.55	144.98	142.40	135.92	116.41	115.09	113.82	131.70	172.78	178.57	210.90	251.33	274.99	288.05	297.76	297.87	299.65	210.13	268.45	259.47
PP	1.79	1.76	1.73	1.65	1.41	1.40	1.38	1.60	2.10	2.18	2.58	3.13	3.42	3.57	3.68	3.65	3.64	2.54	3.24	3.12
Electricity cooling	27327.07	24072.00	24083.82	24990.41	22250.90	22435.04	23044.51	19058.20	19053.08	17720.54	19940.60	19313.23	14853.00	12636.40	13354.00	12605.00	11782.12	11106.00	16041.30	13515.46
PP	332.40	292.31	291.97	302.79	269.65	272.04	279.75	231.66	232.04	216.36	243.84	240.59	184.68	156.69	164.90	154.31	143.08	134.36	193.49	162.65
Mining and quarrying	0.00	2385.90	0.00	0.00	2303.40	0.00	0.00	2294.20	0.00	0.00	2122.30	0.00	0.00	1872.09	0.00	0.00	1447.95	0.00	0.00	0.00
PP	0.00	28.97	0.00	0.00	27.91	0.00	0.00	27.89	0.00	0.00	25.95	0.00	0.00	23.21	0.00	0.00	17.58	0.00	0.00	0.00
Public water supply	4791.87	5409.00	4755.41	4742.72	5371.70	4713.04	4689.88	5127.60	4611.54	4550.20	5080.70	4367.78	5062.49	5053.41	5103.69	5153.96	5204.24	5227.11	5244.25	5258.62
PP	58.29	65.68	57.65	57.46	65.10	57.15	56.93	62.33	56.16	55.56	62.13	54.41	62.95	62.66	63.02	63.09	63.20	63.24	63.26	63.29
Manufacturing	9044.73	5374.40	7933.21	7927.95	5411.80	8091.84	8304.54	4896.80	7649.26	6309.80	4660.50	7187.74	4441.00	4226.66	3494.00	3395.00	4387.59	3196.00	3231.16	0.00
PP	110.02	65.26	96.17	96.06	65.58	98.12	100.81	59.52	93.16	77.04	56.99	89.54	55.22	52.41	43.15	41.56	53.28	38.67	38.97	0.00
Manufacturing cooling																				
Construction																				
Total	41311.22	37386.28	36914.84	37797.01	35454.21	35355.01	36152.75	31508.50	31486.66	28759.11	32015.00	31120.08	24631.48	24076.61	22249.45	21451.83	23121.54	19739.24	24785.15	19033.56
Population (OECD)	82.211501	82.349926	82.48849	82.53418	82.51627	82.46942	82.37645	82.26637	82.1101	81.90231	81.77694	80.27498	80.42583	80.64561	80.9825	81.68661	82.34867	82.657	82.90579	83.09296
Total Per Inhabitant	502.4993	453.99282	447.515	457.9558	429.6633	428.7045	438.8724	383.0058	383.4688	351.1392	391.4918	387.6685	306.2633	298.5483	274.744	262.6113	280.7762	238.809	298.9556	229.0634

Netherlands

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	59.80	53.40	52.60	199.03	87.51	74.82	121.84	71.86	71.69	92.88	121.97	119.44	60.20	106.86	82.78	105.90	76.50	119.71	302.17	265.54
PP	3.75	3.33	3.26	12.27	5.37	4.58	7.45	4.39	4.36	5.62	7.34	7.16	3.59	6.36	4.91	6.25	4.49	6.99	17.54	15.31
Electricity cooling	5280.24	6206.43	5654.33	5547.18	6312.05	6667.81	6060.01	6068.38	5696.80	6062.19	6147.63	5360.30	5967.36	5943.78	5096.61	4346.24	3588.72	3586.41	3380.47	5314.59
PP	331.56	386.79	350.14	341.88	387.68	408.57	370.73	370.44	346.40	366.73	370.00	321.11	356.15	353.70	302.20	256.57	210.73	209.35	196.18	306.41
Mining and quarrying	0.00	0.00	0.00	1.23	1.06	0.98	0.93	0.86	0.85	0.84	0.75	0.82	0.75	0.72	0.74	0.76	0.79	0.78	0.85	0.00
PP	0.00	0.00	0.00	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.00
Public water supply	1313.00	1303.00	1256.00	1318.00	1277.00	1256.00	1279.00	1248.40	1251.96	1234.97	1217.16	1229.05	1217.36	1221.81	1224.10	1237.21	1260.34	1199.37	1312.20	1272.07
PP	82.45	81.20	77.78	81.23	78.43	76.96	78.24	76.21	76.13	74.71	73.25	73.63	72.66	72.71	72.58	73.04	74.01	70.01	76.15	73.34
Manufacturing	836.62	1351.90	1354.28	3014.02	3439.20	2594.00	2640.00	2952.10	2929.69	3572.94	2871.04	2925.55	2962.18	2836.72	2522.17	2225.63	2540.65	2520.91	2447.87	2433.18
PP	52.53	84.25	83.86	185.76	211.23	158.95	161.51	180.21	178.14	216.14	172.79	175.26	176.79	168.81	149.55	131.38	149.18	147.15	142.06	140.28
Manufacturing cooling																				
Construction																				
Total	7489.67	8914.73	8317.21	10079.46	11116.82	10593.61	10101.78	10341.60	9950.99	10963.82	10358.55	9635.16	10207.85	10109.89	8926.40	7915.74	7467.00	7427.17	7443.56	9285.38
Inhabitants	15.925505	16.046182	16.14892	16.2253	16.28178	16.31987	16.3461	16.3817	16.44559	16.53039	16.61539	16.69307	16.75496	16.80443	16.86501	16.93993	17.03031	17.1313	17.23162	17.34488
Total Per Inhabitant	470.29377	555.56705	515.0319	621.2186	682.7768	649.1234	617.9934	631.2899	605.0856	663.2525	623.431	577.1951	609.2434	601.6203	529.285	467.2832	438.4532	433.5442	431.9708	535.3384

Switzerland

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	140.64	140.64	140.64	140.64	140.64	140.64	132.00	140.08	140.08	140.80	141.52	141.24	160.20	135.34	135.07	134.81	134.77	134.77	134.38	134.15
	19.58	19.46	19.31	19.16	19.03	18.91	17.64	18.55	18.32	18.18	18.09	17.85	20.03	16.73	16.50	16.28	16.10	15.95	15.78	15.64
Electricity cooling	36.52	38.79	37.81	37.97	38.10	37.88	1682.00	37.62	39.09	39.37	38.26	37.03	37.40	39.04	36.60	35.82	36.49	0.00	0.00	0.00
	5.08	5.37	5.19	5.17	5.16	5.09	224.75	4.98	5.11	5.08	4.89	4.68	4.68	4.83	4.47	4.33	4.36	0.00	0.00	0.00
Mining and quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public water supply	1066.00	1036.00	1069.00	1085.00	1029.00	1004.00	980.00	960.00	980.00	967.00	940.00	954.00	935.00	917.00	901.00	933.00	923.00	931.00	953.00	950.57
	148.38	143.36	146.74	147.84	139.25	135.00	130.95	127.13	128.14	124.87	120.13	120.57	116.92	113.36	110.03	112.65	110.23	110.15	111.93	110.85
Manufacturing	172.00	174.00	190.00	158.00	179.00	172.00	490.00	155.45	171.00	191.00	180.00	198.00	588.66	198.00	199.00	212.00	212.00	212.00	223.66	0.00
	23.94	24.08	26.08	21.53	24.22	23.13	65.47	20.59	22.36	24.66	23.00	25.02	73.61	24.48	24.30	25.60	25.32	25.08	26.27	0.00
Manufacturing cooling																				
Construction																				
Total	1415.17	1389.43	1437.45	1421.61	1386.75	1354.53	3284.00	1293.15	1330.18	1338.17	1299.78	1330.28	1732.36	1289.37	1271.67	1315.63	1306.27	1277.77	1311.04	1084.72
Inhabitants	7.18425	7.226647	7.284754	7.339002	7.389626	7.437116	7.483935	7.551117	7.647676	7.743832	7.82491	7.912396	7.996861	8.089346	8.188646	8.282398	8.373334	8.451834	8.514327	8.57528
Total Per Inhabitant	196.98202	192.26505	197.3235	193.7067	187.6611	182.1306	438.8066	171.2529	173.932	172.8048	166.108	168.1258	216.63	159.3913	155.2966	158.8468	156.0034	151.1831	153.9801	126.4937

Water Abstraction Use = million m3

Water use Autonomy

Water abstraction data (EEA, 2019) based on sectoral numbers

GEM	TREND	T.O.V.	
44.86			
5.45	0.308076	1.195245	**AGRICULTURE**
1686.00			
201.20	0.683801	44.11372	**ELECTRICIY (POWER PLANTS)**
0		0	**INDUSTRY (MINING)**
580.08			
69.09	0.996045	15.14897	**PUBLIC**
1513.53			
180.35	1.117677	39.54206	**INDUSTRY (MANUFACTURING)**
456.10	**TOT**	100	Percentage of water use per inhabitant

GEM	TREND	T.O.V.	
3616.14			
56.60	0.638444	12.38624	**AGRICULTURE**
17930.50			
279.02	0.969099	61.05897	**ELECTRICIY (POWER PLANTS)**
75.31			
1.15	0.446517	0.251092	**INDUSTRY (MINING)**
5585.51			
86.92	0.905303	19.02	**PUBLIC**
2137.42			
33.28	0.762634	7.281889	**INDUSTRY (MANUFACTURING)**
456.97	**TOT**	100.00	Percentage of water use per inhabitant

GEM	TREND	T.O.V.	
202.89			
2.48	1.259976	0.646306	**AGRICULTURE**
18459.13			
224.98	0.722979	58.66923	**ELECTRICIY (POWER PLANTS)**
2070.97			
25.25	0.696251	6.585659	**INDUSTRY (MINING)**
4975.96			
60.68	1.042988	15.82334	**PUBLIC**
5745.47			
70.08	0.556127	18.27546	**INDUSTRY (MANUFACTURING)**
383.47	**TOT**	100	Percentage of water use per inhabitant

GEM	TREND	T.O.V.	
112.32			
6.72	2.279581	1.192953	**AGRICULTURE**
5414.38			
327.17	0.936551	58.11514	**ELECTRICIY (POWER PLANTS)**
0.86			
0.05	0.957132	0.009155	**INDUSTRY (MINING)**
1256.40			
75.74	0.968369	13.45306	**PUBLIC**
2548.53			
153.29	0.915131	27.22969	**INDUSTRY (MANUFACTURING)**
562.96	**TOT**	100	Percentage of water use per inhabitant

Water use Autonomy

Water use & Water efficiency Autonomy

GEM	TREND	T.O.V.	
139.15			
17.85	0.876218	10.28051	**AGRICULTURE**
37.74			
4.90	0.888695	2.823916	**ELECTRICIY (POWER PLANTS)**
11.10			
1.39	1	0.799248	**INDUSTRY (MINING)**
975.68			
125.42	0.883796	72.22056	**PUBLIC**
188.07			
24.10	1.090083	13.87577	**INDUSTRY (MANUFACTURING)**
173.67	**TOT**	100	Percentage of water use per inhabitant

	Austria			France			Germany			Netherlands			Switzerland			Liechtenstein	
	GEM		TREND	GEM		TREND	GEM		TREND	GEM		TREND	GEM		TREND		
Agriculture	5.451477	2	0.308076	1	56.60197	5	0.638444	2	2.478384	1	1.259976	4	6.71585	2	2.279581	5	17.85403	3	0.876218	3	
Electricy Cooling	201.2013	3	0.683801	1	279.024	4	0.969099	4	224.9785	3	0.722979	2	327.1651	5	0.936551	4	4.904258	1	0.888695	3	
Mining & Quarying	0		0		1.147429	2	0.446517	2	25.25398	5	0.696251	3	0.051537	1	0.957132	5	1.388045	2	1	5	
Public Water Supply	69.09397	2	0.996045	3	86.92483	3	0.905303	2	60.67765	2	1.042988	3	75.73535	2	0.968369	3	125.4245	5	0.883796	2	
Manufacturing	180.3501	5	1.117677	5	33.27638	1	0.762634	2	70.08077	3	0.556127	1	153.2923	5	0.915131	4	24.09787	1	1.090083	5	
Total	456.0968				456.9746				383.4692				562.9602				173.6687				
Water Use Efficiency	Efficiency		AUT	Efficiency		AUT	Efficiency		AUT	Efficiency		AUT	Efficiency		AUT	Efficiency	AUT
Industrial	24.22		2	21.11		2	48.75		3	21.65		2	272.17		5		
Agriculture	0.65		1	1.69		2	4.74		3	19.8		5	6.21		3		
Public Service	477.01		4	354.33		3	225.81		2	304.54		3	577.16		5	480.97	4

Member States	**Netherlands**	**Belgium**	**France**	**Germany**	**Luxemburg**	**Austria**	**Switzerland**
Highest Scale		3 Regions	18 Regions	16 Federal states	3 Districts	9 Federal states	7 Federal Councillors
		3 Communities					
	12 Provinces (21 Water Boards)	10 Provinces	101 Departments	401 Counties	12 Cantons	95 Districts	26 Cantons
	355 Municipalities	581 Municipalities	35.358 Municipalities	11.054 Municipalities	102 Municipalities	2.098 Municipalities	2.172 Municipalities
Lowest Scale							

Multi-Level Responsibilities	**Netherlands**	**Belgium**	**France**	**Germany**	**Luxemburg**	**Austria**	**Switzerland**
Central (National Authorities)	National policy framework and strategic objectives for water management. Producing National Water plan, containing RBMP, FRMP. Responsibility for national water investment and management. Supporting water monitoring and implementation of measures. Responsibility for major water infrastructure (dykes, flood protections). - Rijkswaterstaat Chairs Water Steering Group (Stuurgroep Water), responsible for coordination between Rijkswaterstaat, provinces, municipalities and Water Authorities.	Coordination of federal and regional authorities. Management of coastal water under WFD.	Development and implementation of water legislation. Developing national water policy, addressing common issues across river basins. Coordination and cooperation on water management with neighbouring countries.	Formulate guidelines for the implementation of WFD and FD (through working group. Fora for federal states on transboundary issues. Update and optimize scientific bases for drinking water. For some river basins, a common RBMP through collaboration between federal states.	*Ministry of Sustainable Development and Infrastructure.* Overall Water policy. Enforcement of water regulations. Coordination and implementation measures. Funding for environmental projects. Establishment of administrative entities. Coordination of government action for protection of water sources. National drinking water supply policy Flood risk management. *Water Management Agency* Monitoring and assessment of groundwater and surface waters. Conducting impact assessments. Preparation RBMP, FRMP Public Participation Supporting implementation of RBMP & FRMP.	Austrian Constitution - Competence to govern water rights and control waters for floods and navigation, Pollution emissions to the environment Implementation of water policy. Monitoring and assessment of ground and surface water. Enforcement of regulations, economic analysis. Preparation of RBMP, FRMP. Coordination of public participation. Implementation of measures and coordination. International cooperation via the international commissions of the River basins.	
Regional	*Provinces* **Translating** the national water policy into regional measures. **Monitoring and assessing** status of groundwater. Enforce regulations. Impact assessment and pressure analysis.	Legislation and implementation of policies. Management of River Basin Districts (in their borders). Coordination with neighbouring countries in shared river basins. Preparation of FRMPs and RBMPs (Flood & River	Represented on the river basin committees, which set **river basin objectives**, adopt RBMP & FRMP and **provide coordination among bodies and stakeholders**. Final approval of RBMP. Coordinate water	Coordination and strategic direction of **water management at lower levels**. Preparing RBMP, FRMP. Licencing **polluting industry** installations. **Public Participation**. Reporting and		Implementation and enforcement of national laws. Emergency flood management and legislation. Flood warning and defence. Contribution to the	
	Coordinate **public participation**. Implement and coordinate the implementation of measurements. Responsibility for **spatial planning**, including permitting for **flood protection infrastructure**. Ownership of water service companies (some cases). *Water Boards* Undertake operational water management. **Oversee and monitor water quantity and quality** (treatment and drinking water). Water management plans for water quality. Collaboration between municipalities and provinces. Gather and balance the views and interests of stakeholders represented in their governance structures. **Responsibility for water infrastructure not managed at national level** (dykes/flood protection).	Basin). Regulation of polluting industries and protection and supply of water. Oversight of water quality, treatment and environmental plans. Setting standards of water quality, regulating catchment areas. Monitoring drink water quality. Water services (drinking water, sewage and waste water via regionally owned companies)	management in their river basins, including **enforcement of water regulations**. Regional directorates for the environment, planning and housing, support water authorities (DREAL). **Water agencies** provide technical and scientific support at river-basin level.	**measurements** of stations (quality & quantity).		preparation of FRMP, RBMP. Setting standards and rules for water treatment. Implementation of measures and coordination. Management of water supply and water treatment.	
Intermediate Level (Kreise Germany)				Water resource planning. Household water collection and disposal. Permitting, legislation **Monitoring of the rivers**.			
Local	Providing water supply, sewage and water treatment infrastructures through water companies. Take responsibility for groundwater in urban areas. Supporting the coordination for the implementation of WFD measures. Take responsibility for the coordination of **crisis management** during emergencies.	Implementing legislation Management of small and non-navigable water bodies. Management of drinking water and sewage services	Local implementation of water policies and plans including **local water management projects**. Managing **drinking water supply**, water treatment (through municipal or privately owned operators). **Local water protection and flood prevention measures**. Joining together in inter-municipal unions to	Procedures under water management law (implementation). **Monitoring of smaller water bodies** Providing expert advice. **Maintenance and management** of sewage and water treatment. Drinking water supply.	Implementation of government policies. Local water management and protection. Implementation of water services (drinking water, sewage, water treatment). Issuing of abstraction and discharge permits.	Local compliance with regional and federal laws. **Monitoring of drinking water**. **Water supply**, sewage and water treatment (municipal owned companies). Implementation of measures and coordination.	

			manage common water services. They are represented on the river basin committees. Local Water Commissions together with water users and stakeholders (development of water plans). Participate in river contracts that implement RBMP & FRMP and lower-level plans.				

Responsible Ministries/bodies	**Netherlands**	**Belgium**	**France**	**Germany**	**Luxemburg**	**Austria**	**Switzerland**
Central	Ministry of Infrastructure and Water Management, Rijkswaterstaat, National Water Authority.	Federal Public Service for Public Health, Food Chain Safety and Environment	Ministry for the Ecological and Inclusive Transition, Comite National de l'eau	German Working Group on water issues of the Federal States and the Federal Government, German Environment Agency (UBA)	Ministry of Environment, Climate and Sustainable Development, Water Management Agency	Ministry of Agriculture, Regions and Tourism, WISA (Water information system Austria)	Federal Office for the Environment FOEN
Regional	Water Boards (Waterschappen, Hoogheemraadschappen), Provinces.	Brussels Environment, Environment Wallonie, Flanders Environment Agency	Regional councils, Authorities (DREAL), Prefect Coordinators, Water Agencies, River Basin Committees.	Federal state Ministries. Federal state Environmental Agencies		Provinces, Provincial governors.	
Intermediate Level				Regierungsbezirkte, Kreise and Kreisfreie Cities.			Cantonal Water Management on Cantonal waters
Local	Municipalities.	Local Authorities Wallonia River Contracts	Municipalities, Local Water Commissions	Municipalities	Municipalities	District administrative authorities, Municipalities.	Local (Owners) sustain local water bodies (small ponds, lakes, hydropower basins)

DIKE SECTOR (Dike construction, maintenance)

Responsible Ministries/bodies	**Netherlands**	**Belgium**	**France**	**Germany**	**Luxemburg**	**Austria**	**Switzerland**
Central	Ministry of Infrastructure and Water Management, Rijkswaterstaat. Unie van Waterschappen		Regional Directorates for the Environment, Planning and Housing (DREAL) as part of (Ministry of Ecological Transition and Solidarity & Ministry of Territorial Cohesion	Federal Dike System (2017, operational 2019). Authority was handed over to the Ministry of Marine Affairs		The maintenance and regulation of all water bodies (with the exception of torrents and waterways) is the responsibility of the Federal Water Engineering Administration (Bundeswasserbauverwaltung, BWV) + Federal Ministry of Sustainability and Tourism	Bundesamt für Bevölkerungsschutz BABS
Regional	Water Boards (Waterschappen, Hoogheemraadschappen), Regional Units Rijkswaterstaat			There are collaborations of Kreise together within the Provinces that also operate in Dutch-German collaborations and IKSR organisations			
Intermediate Level				Before 2019 was organized at district (Kreise) level. Still direct interventions are made for Kreise levels. Kreise are managed by Dike associations,			
Local	Dike maintenance employees employed at the Waterschappen. Dijkgrafen		Land of the dike is owned by the owner of the land. If no owners are found, the responsibility transfers to the respective municipality.	Land of the dike is owned by the owner of the land (Funded by Dike Associations and Subsidies)			Hochwasserschutz (Flooding) considers cantonal water to be maintained by the Canton. This includes hydraulic engineering (dikes, dams, levees, etc.) The Rhine falls under Cantonal waters.

GERMANY

While there is no 'individual entitlement to flood protection' in Germany and according to the 2009 update of the Federal Water Act, 'every person who may be affected by floods is, as far as possible and reasonable, obliged to take appropriate precautionary measures' (LAWA 1995), extensive flood defence infrastructure is in place, with dikes, levees and other water control structures that are financed, owned and operated by the federal states, municipal water authorities and dike associations (Water & Soil organization that operate at Kreise Level).

Dike associations are corporations under public law (self-governing corporations). At the top of the association is the board of directors with a head (also dike captain). The committee elected by the members monitors the association's business. Within the framework of legal supervision, the districts check whether the applicable law is being observed.

FRANCE

Article 1242 of the Civil Code: " *One is responsible not only for the damage that one causes by one's own act, but also for that which is caused by the act of the persons for whom one must answer, or of the things one has under his guard* ." Owner of a Dyke can be classified as Public (municipality, department, region, the state, trade union), Private (individuals, company) Orphan dikes: these are structures located on land whose owner is unknown. If, after research, no owner is found, according to article 713 of the Civil Code " *Properties which have no master belong to the municipality in whose territory they are located.*

The management of aquatic environments and the prevention of floods (GEMAPI) is a competence entrusted to the **intermunicipalities** (metropolises, urban communities, urban communities, communities of municipalities) by the decentralization laws n ° 2014-58 of January 27, 2014 and n ° 2015-991 of August 7, 2015, since January 1, 2018.

CONCLUSION

Power Distribution	**Netherlands**	**Belgium**	**France**	**Germany**	**Luxemburg**	**Austria**	**Switzerland**
Central	3	1	2	2	5	4	
Regional	5	5	4	3	-	3	
Intermediate Level				2			
Local	2	2	3	1	1	1	

1-5 Level of Power in Water Management

Public Participation (x) and Cross Border (X)	**Netherlands**	**Belgium**	**France**	**Germany**	**Luxemburg**	**Austria**	**Switzerland**
Central			X		x	X x	
Regional	x	X	x	x			
Intermediate Level							
Local							

Land Use	NR	Land Use Group (Agriculture, Urban, Industrial, Natural)	Definition	Ground Surface Information (Soil Sealing in percentages)	What does the class include	Water Use Classification
Continuous urban fabric	1	Urban	The continuous urban fabric class is assigned when urban structures and transport networks are dominating the surface area.	**> 80%** of the land surface is covered by impermeable features	The dominant land use type is residential, which can be also mixed with public services or local governments and commercial or office areas.	Public Service
Discontinuous urban fabric	2	Urban	The discontinuous urban fabric class is assigned when urban structures and transport networks associated with vegetated areas and bare surfaces are present and occupy significant surfaces in a discontinuous spatial pattern.	The impermeable features like buildings, roads and artificially surfaced areas range from **30 to 80 %** land coverage.	Permanent residential built-up areas of sparse to significant soil sealing degree;	Public Service
Green urban areas	3	Urban	Areas with vegetation within or partly embraced by urban fabric. This class is assigned for urban greenery, which usually has recreational or ornamental character and is usually accessible for the public.	**< 30%** Land Coverage	Parks, Gardens, Squares, Public Spaces	Public Service
Forrest (Broad-leaved, forest, Coniferous forest, Mixed forest)	4	Natural	Vegetation formation composed principally of trees, including shrub and bush understorey, where broad-leaved or coniferous species predominate.	**0%** Covered	Forests	Nature
Natural Grasslands	5	Nature	Grasslands under no or moderate human influence. Low productivity grasslands. Often situated in areas of rough, uneven ground, steep slopes; frequently including rocky areas or patches of other (semi-)natural vegetation.	**0%** Covered	Permanent grasslands of natural origin, under minimum human influence, bare rocks or bare natural surfaces covering < 50 % of the area.	Nature
Moors and Heathland	6	Nature	Vegetation with low and closed cover, dominated by bushes, shrubs, dwarf shrubs (heather, briars, broom, gorse, laburnum etc.) and herbaceous plants, forming a climax stage of development.	**0%** Covered	Shrubs and dwarf shrubs, dominating the vegetation, mosses and lichens, outcrops of natural bare surfaces not reaching 50% cover of the area.	Nature
Vegetation (Transitional woodland/shrub)	7	Nature	Transitional bushy and herbaceous vegetation with occasional scattered trees. Can represent woodland degradation, forest regeneration / recolonization or natural succession.	**0%** Covered	Young broad-leaved and/or coniferous trees, fully grown trees, covering < 30% of area, shrubs, bare soil or natural bare surfaces.	Nature
Vineyards	9	Agriculture	Areas planted with vines, vineyard parcels covering >50% and determining the land use of the area.	**0%** Covered	Vine plants, bare soil or grass cover among vine plants, constructions supporting crops.	Agriculture
Fruit	10	Agriculture	Cultivated parcels planted with fruit trees and shrubs, intended for fruit production, including nuts. The planting pattern can be by single or mixed fruit species, both in association with permanently grassy surfaces.	**< 30%** Covered	Woody permanent crops, bare soil or grass among woody crops, fruit trees under greenhouses, buildings, sealed or non-sealed storage areas associated to fruit production < 25 ha.	Agriculture
Pastures	12	Agriculture	Permanent grassland characterized by agricultural use or strong human disturbance. Floral composition dominated by graminacea and influenced by human activity. Typically used for grazing-pastures, or mechanical harvesting of grass–meadows.	**0%** Covered	Permanent grasslands under grazing by domestic animals, herbaceous vegetation, draining ditches, draining ditches	Agriculture
Complex Cultivation	14	Agriculture	Mosaic of small cultivated land parcels with different cultivation types -annual crops, pasture and/or permanent crops-, eventually with scattered houses or gardens.	**< 30%** Covered	Mosaic of land parcels < 25 ha of at least two of the following three cultivation types: arable crop land, pasture and permanent crop land, none of them occupying > 75% of the area. Parcels of arable crops, parcels of permanent crops, such as vineyards, fruit orchards, olives, sealed or non-sealed (dirt or tar macadam) roads.	Agriculture
Land Principality Agriculture	15	Agriculture	Areas principally occupied by agriculture, interspersed with significant natural or semi-natural areas (including forests, shrubs, wetlands, water bodies, mineral outcrops) in a mosaic pattern.	**< 30%** Covered	Mosaic of <25 ha parcels of agricultural land (arable crops, pasture, permanent crops) and scattered patches of natural/semi-natural areas, the latter occupying > 25% but < 75% of the area, agricultural crops in combination with patches of natural vegetation.	Agriculture
Agro Forrestry	16	Agriculture	Annual crops or grazing land under the wooded cover of forestry species.	**0%** Covered	Areas of forest trees intermixed with fruit trees/olive trees, none of them dominating. Arable crops or permanent grassland (pasture) in obligatory combination with trees	Agriculture
Non Irrigated Agricultural Land	17	Agriculture	Cultivated land parcels under rainfed agricultural use for annually harvested non-permanent crops, normally under a crop rotation system, including fallow lands within such crop rotation. Fields with sporadic sprinkler-irrigation with non-permanent devices to support dominant rainfed cultivation are included.	**0%** Covered	Cultivated herbaceous plants and low growing shrubs, bare soil of cultivated land, dispersed, mostly linear semi-natural or ruderal vegetation between parcels.	Agriculture
Industrial or Commercial Units	19	Industrial	Buildings, other built-up structures and artificial surfaces (with concrete, asphalt, tarmacadam, or stabilised like e.g. beaten earth) occupy most of the area. It can also contain vegetation (most likely grass) or other non-sealed surfaces. This class	**>50%** Covered	All kinds of industrial and production complexes, commercial complexes, energy production and distribution facilities, utilities (waste water treatment plants, drinking water suppliers), industrial and commercial units < 25 ha associated with port activities	Industrial

Land Use Classifications

Land use Classifications based on Corrine Land Cover data (2023)

			is assigned for land units that are under industrial or commercial use or serve for public service facilities.			
Mineral Extraction	21	Industrial	Open-pit extraction sites of construction materials (sandpits, quarries) or other minerals (open-cast mines). Includes flooded mining pits.	**30-50%** Covered	Consolidated or non-consolidated surfaces of mineral materials under active open-pit extraction, water bodies (smaller than 25 ha), usually associated with open pit extraction of gravel, sand, etc.	Industrial
Dump Sites	22	Industrial	Public, industrial or mine dump sites.	**30-80%** Covered	Dump sites of public, communal waste (landfills), industrial waste - waste rock after processing of various raw materials, waste material from wastewater treatment plants (sewage sludge)	Industrial
Water	24	Nature	Natural or artificial water bodies with presence of standing water surface during most of the year.	**0%** Covered	Water surface, natural freshwater and inland salt water lakes, water reservoirs, areas of water retention, disused mineral extraction pits filled with water.	Nature

Land Use Classifications

Water Use & Water Efficiency Autonomy of Land uses, incorporated with water data (EEA, 2019)

Land Use	**NR**	**Land Use Group (Agriculture, Urban, Industrial, Natural)**	**Water Use**	**Water Use NR**	**Water Efficiency NR**	**Ground Surface Information (Soil Sealing in percentages)**	**Soil Sealing NR**	**Soil Sealing Autonomy 1.00**	**Water Use Classification**	**Countries**	**Water Use Autonomy 0.75**	**Water Use Efficiency Classification**	**Countries**	**Water Use Efficiency Autonomy 0.25**	**TOT (1)**
Continuous urban fabric	1	Urban	Public Service	**3**	**5**	**> 80%** of the land surface is covered by impermeable features	**5**	1	4	AT FR DE NL CH +0.5	**2**	5	AT FR DE NL CH LI	**1**	1.75
Discontinuous urban fabric	2	Urban	Public Service	**3**	**5**	The impermeable features like buildings, roads and artificially surfaced areas range from **30 to 80 %** land coverage.	**4**	2	3	AT FR DE NL CH +0.5	**3**	4	AT +0.5 FR DE NL CH +1 LI +0.5	**2**	2.75
Green urban areas	3	Urban	Public Service	**3**	**5**	< **30%** Land Coverage	**3**	3	3	AT FR DE NL CH +0.5	**3**	3	AT +0.5 FR DE NL CH +1 LI +0.5	**3**	3
Forrest (Broad-leaved, forest, Coniferous forest, Mixed forest)	4	Natural	Nature	**1**	**1**	**0%** Covered	**1**	5	1	AT FR DE NL CH	**5**	1	AT FR DE NL CH	**5**	5
Natural Grasslands	5	Nature	Nature	**1**	**1**	**0%** Covered	**1**	5	1	AT FR DE NL CH	**5**	1	AT FR DE NL CH	**5**	5
Moors and Heathland	6	Nature	Nature	**1**	**1**	**0%** Covered	**1**	5	1	AT FR DE NL CH	**5**	1	AT FR DE NL CH	**5**	5
Vegetation (Transitional woodland/shrub)	7	Nature	Nature	**1**	**1**	**0%** Covered	**1**	5	1	AT FR DE NL CH	**5**	1	AT FR DE NL CH	**5**	5
Vineyards	9	Agriculture	Agriculture	**1**	**1**	**<15%** Covered	**2**	5	2	AT FR + 1 DE NL CH +0.5	**4**	2	AT FR DE +0.25 NL +1 CH +0.25	**4**	4
Fruit	10	Agriculture	Agriculture	**1**	**1**	**<15%** Covered	**2**	4	2	AT FR + 1	**4**	2	AT FR	**4**	4
										DE NL CH +0.5			DE +0.25 NL +1 CH +0.25		
Pastures	12	Agriculture	Agriculture	**1**	**1**	**0%** Covered	**1**	5	1	AT FR + 1 DE NL CH +0.5	**5**	1	AT FR DE +0.25 NL +1 CH +0.25	**5**	5
Complex Cultivation	14	Agriculture	Agriculture	**1**	**1**	**<15%** Covered	**2**	4	2	AT FR + 1 DE NL CH +0.5	**4**	2	AT FR DE +0.25 NL +1 CH +0.25	**4**	4
Land Principality Agriculture	15	Agriculture	Agriculture	**1**	**1**	**<15%** Covered	**1**	4	1	AT FR + 1 DE NL CH +0.5	**5**	1	AT FR DE +0.25 NL +1 CH +0.25	**5**	5
Agro Forrestry	16	Agriculture	Agriculture	**1**	**1**	**0%** Covered	**1**	5	1	AT FR + 1 DE NL CH +0.5	**5**	1	AT FR DE +0.25 NL +1 CH +0.25	**5**	5
Non Irrigated Agricultural Land	17	Agriculture	Agriculture	**1**	**1**	**0%** Covered	**1**	5	1	AT FR + 1 DE NL CH +0.5	**5**	1	AT FR DE +0.25 NL +1 CH +0.25	**5**	5
Industrial or Commercial Units	19	Industrial	Industrial (Electricity, Manufact.)	**5(3)**	**2**	**>50%** Covered	**4**	2	5	AT +1 FR +0.5 DE NL +1 CH -0.5	**1**	2	AT FR DE +0.25 NL CH +1	**4**	1.75
Mineral Extraction	21	Industrial	Industrial (Mining)	**2**	**2**	**30-50%** Covered	**3.5**	2.5	2	AT FR DE +1 NL CH	**4**	3	AT FR DE +0.25 NL CH +1	**3**	3.75
Dump Sites	22	Industrial	Industrial (Mining)	**2**	**2**	**30-80%** Covered	**4**	2	2	AT FR DE +1 NL CH	**4**	2	AT FR DE +0.25 NL CH +1	**4**	4
Water	24	Nature	Nature	**1**	**1**	**0%** Covered	**1**	5	1	AT FR DE NL	**5**	1	AT FR DE NL	**5**	5

Existing Projects IKSR

Existing projects related to water management noted by the IKSR (BAFG, 2015)

Type Project (Nederlandse Vertaling)	Beschrijving	Hoeveelheid	Project Definition (Relation to Autonomy)	EFFECT ON ADJACENT DIKE LINES	Autonomy	Initiator	Project Collaboration (Relation to Autonomy)	Locatie	Total Autonomy = 1.5 * Definition + 1 * Collaboration / 2.5	Addition
Compenserende maatregel in het kader van de verbreding van de Duitse A6	Het **uitbaggeren** van een **oude bedding van de Rijn** leidde tot het herstel van een voormalige Rijnstrang met aanliggende **uiterwaard**; versterking en herstel van natuurlijke en dynamische processen in de uiterwaard	1	FORELAND (+ EMBANKMENT)	NO	4	Hessen Mobil (Bundes Ministerie of Infrastructure DE)	1	Grens Bingen Ingelheim (DE)	2.8	0.5
Compenserende maatregelen in verband met de vernieuwing van de vergunning van de waterkrachtcentrale van Kembs	In het kader van het **ecologisch herstel van het eiland** bij Kembs is ongeveer 100 ha maïsveld natuurlijk hersteld, waarbij het mozaïek van functionele natuurlijke milieus in zijn oorspronkelijk staat is teruggebracht, hetgeen bevorderlijk is voor de	1	FORELAND (+ EMBANKMENT)	NO	4	Gesellschaft EDF (Energie collectief FR) https://www.edf.fr/groupe-edf	4	Rosenau (FR-DE)	4	0.75
Dynamische verbinding met de Rijn	Sinds 2009 worden er op de **rechteroever** van de Rijn gebieden afgegraven ten behoeve van het hoogwaterretentiegebied Weil-Breisach. Deze verlaging creëert een dynamische verbinding met de Rijn. Op de dieper gelegen kale grindgebieden ontstaat door succes	1	EMBANKMENT (+ FORELAND)	NO	4	Regierungspräsidium Freiburg (Regional Council), Referat 53.3 (Council Integrated Rhine Program)	2	Rosenau (DE)	3.2	0.5
EG-KRW		5								
Herstel van de oevers	De Zwitserse dienst Weg- en Waterbouw heeft tussen september 2018 en maart 2019 aan beide kanten van de Rijn tussen de Schwarzwald- en de Wettsteinbrug een **aantrekkelijkere oever** gecreëerd.	1	EMBANKMENT	NO	3	Kt. Basel - Stadt	1	Basel (CH)	2.2	0.25
Herstel van de oevers, Vispasseerbaarheid		2								
Kweek en vermeerdering van bestaande plantensoorten	Station voor de vermeerdering van planten	1	FORELAND	NO	3	NABU Landesverband Rheinland-Pfalz	3	Bingen (DE)	3	0.5
LIFE Project		8								
LIFE+ natuurbeschermingsproject	De prioriteiten van dit project waren het herstel van **uiterwaarden**, de verbetering van de **hydromorfologie van rivieren**, het behoud van strangen, de ontwikkeling van soortenrijk grasland en speciale maatregelen ter bescherming van de biodiversiteit.	1	FORELAND + BACKLAND + EMBANKMENT(DIKE DID NOT CHANGE)	YES	4	Regierungspräsidium Karlsruhe	2	Iffezheim, Durmersheim, Karlsruhe (DE)	3.2	0.5
LIFE+ werkzaamheden in natuurreservaat	In het kader van het herstel van de **uiterwaarddynamiek** op het **eiland Rohrschollen** is een **waterinlaat** vanuit de gekanaliseerde Rijn gebouwd, een afvoergeul aangelegd en de monding van de waterloop op het eiland heringericht.	1	FORELAND	YES	4	Stadt Straßburg	1	Strassbourg (DE-FR)	2.8	0.5
Natuurlijk herstel en scheiding van de gebruiksfuncties	Verplaatsing van het strand naar een plek buiten het beschermde gebied. Suppletie van een breed strand in het noordelijke gebied. **Vergroting van het zwem- en strandoppervlak** van 2,5 ha tot 22 ha met groot zandstrand en ligweide.	1	BACKLAND	NO	2	Land RP, Fa. Juwi	3	Gernsheim (DE)	2.4	0.25
Natuurlijk herstel uiterwaarden	Door de **zijtak Chly Rhy** weer aan te takken aan de hoofdstroom en andere maatregelen is de **uiterwaard** Chly Rhy de kern van het uiterwaardpark Aargau geworden.	1	FORELAND (+ EMBANKMENT)	NO	3	Kanton Aargau - Pro Natura	3	Recklingen (CH)	3	0.5
Aanleg paaiwateren	**Nieuwe paaiwateren** zoals de plassen bij Dienheim helpen om restbestanden van amfibieën uit te breiden en populaties met elkaar te verbinden. Daarnaast hebben ook veel andere planten- en diersoorten hier profijt van.	1	BACKLAND	NO	2	NABU Landesverband Rheinland-Pfalz	3	Oppenheim (DE)	2.4	0.25
Ontwikkeling van natuurvriendelijke, dynamische oeverstructuren	Verwijdering van **harde oeverbekleding**, zodat de oever nu blootstaat aan de dynamiek van de Rijn. De overgangen naar de oeververharding die niet werd verwijderd, zijn bevestigd met **technisch-biologische maatregelen**.	1	EMBANKMENT	YES	4	Bundesumweltministerium	1	Nackenheim (DE)	2.8	0.5
Plan Vitale Rijn (Rhin Vivant); groene en blauwe hoofdstructuur	In het kader van de ecologische herinrichting van **vijvers** die vroeger door de **kali-industrie** werden gebruikt, zal een uitgestrekt en open waterrijk gebied ontstaan. Het gebied zal ecologisch worden beheerd en beleefbaar gemaakt door de	1	FORELAND	NO	3	Gemeindeverband Rhin-Brisach	2	Blodelsheim (DE-FR)	2.6	0.5
Resten van uiterwaarden, strangen aantakken, structuurrijkdom vergroten	Pilot: resten van **uiterwaarden**, stilstaande en vrijgemaakte wateren. Doorsteken strangen Giriz; onderhoud gepland, natuurvriendelijke ontwikkeling, **uitbaggeren**	1	RIVER (+ EMBANKMENT FORELAND)	NO	2	Kanton Aargau	1	Leibstadt (CH-DE)	1.6	0.25
Revitalisering uiterwaardgebied	De revitalisering van in totaal 350 ha is in 2007 begonnen en zal 15 jaar duren (tot 2022).	1	FORELAND (NEW LOCATION DIKE LINES)	YES	4	PanEco / Kanton	3	Buchberg (CH)	3.6	0.75
Revitalisering rietgebied	In het kader van de strategische **revitalisering van de rivieren** in het kanton Schaffhausen is het herstel van het **rietgebied** als prioritaire maatregel opgenomen.	1	FORELAND (+ EMBANKMENT)	NO	4	Bund, Kanton Schaffhausen	2	Stein am Rhein (CH)	3.2	0.5
Schema voor de inrichting en het beheer van wateren	De hydromorfologische functie van de rivier de Altwasser op het eiland van Marckolsheim is verbeterd dankzij de aanleg van een **waterinlaat** vanuit de oude loop van de Rijn, het **opnieuw aantakken van oude Rijnstrangen** en de reconstructie van een	1	FORELAND	YES	4	Gemeindeverband des Marckolsheimer Rieds und Wasser- und Abwasserverband Elsass-Mosel	3	Burkheim, Weisweil (FR-DE)	3.6	0.75
Uiterwaarddynamiek, diversiteit van soorten en locaties	**Oeververhardingen weghalen** en een **natuurlijke overgang tussen water en uiterwaard** herstellen. Vervangende leefgebieden die kenmerkend zijn voor **uiterwaarden** aanleggen. Vegetatie die kenmerkend is voor uiterwaarden bevorderen. Mogelijkheden voor	1	EMBANKMENT (+ FORELAND)	NO	4	Land Rheinland-Pfalz, Stadt Braubach, Stadt Lahnstein	2	Koblenz, Boppard (DE)	3.2	0.5

Vispasseerbaarheid	De stroomopwaartse vismigratie- en paairivier lijkt qua grootte en inrichting op een kleine rivier in het Zwarte Woud. Met stroomversnellingen, diepe geulen en grindeilandjes vormt de **bypass een leefgebied** voor veel dieren en biedt	1	RIVER (+ EMBANKMENT)	NO	2	Kraftwerk Rheinfelden	5	Rheinfelden (CH-DE)	3.2	0.5

Type Project (Nederlandse Vertaling) LIFE PROJECTEN + EG KRW	**Beschrijving**	**NR**	**Locatie**	**Project Definition (Relation to Autonomy)**	**EFFECT ON ADJACENT DIKE LINES**	**Autonomy**	**Initiator**	**Project Collaboration (Relation to Autonomy)**	**Total Autonomy**	**Addition**
Verbeteren van de habitatomstandigheden voor bedreigde weidevogels door aangepast beheer en ontwikkeling van extensieve **vochtige graslanden** evenals optimalisatie van de wateren en de waterhuishouding.	LIFE	1	Pannerden, Emmerich (DE-NL grens)	BACKLAND	NO	2	EU, Land NRW, NABU Naturschutzstation Niederrhein, Stiftung für Natur und Heimat in de Gelderse Poort	3	2.4	0.25
Herstel van het natte karakter met diverse **uiterwaardwateren** en overstromingsgebieden met vegetatie- en leefgebiedtypes die kenmerkend zijn voor uiterwaarden door de waterhuishouding te optimaliseren.	LIFE	2	Emmerich (DE)	FORELAND	NO	3	EU, Land NRW, NABU-Naturschutzstation Niederrhein e.V.	3	3	0.5
Aanleg van een **meestromende nevengeul** naar de Rijn om de rivier en de uiterwaard met elkaar te vervlechten. Ontwikkeling van zacht- en hardhoutooibossen	LIFE	3	Emmerich (DE)	FORELAND (+ EMBANKMENT	NO	3	EU, Land NRW, Kurt Lange Stiftung, HIT Umwelt- und Naturschutz Stiftungs-GmbH, Naturschutzbund Deutschland, NABU-Naturschutzstation Niederrhein e.V.	3	3	0.5
Verbeteren van het leefgebied voor de grutto en andere weidevogels door hervernatting, extensivering en aaneenschakeling van graslanden	LIFE	4	Emmerich, Rees (DE)	BACKLAND	NO	2	EU, Land NRW, Nordrhein-Westfalen-Stiftung, NABU-Naturschutzstation Niederrhein e. V., Naturschutzzentrum im Kreis Kleve e.V.	3	2.4	0.25
Optimalisering en ontwikkeling van leefgebieden met riet en **drijvende vegetatie** en de soorten die daarvan **leven door beverratten te bestrijden**, eerste aanplant van riet, dynamisering van de waterstanden en bosontginning om plaats te maken voor riet	LIFE	5	Rees (DE)	FORELAND + BACKLAND	YES	3	EU, Land NRW, Stöckmann-Stiftung, Kreis Kleve, Deichverband Bislich-Landesgrenze, HIT Umweltstiftung, Naturschutzzentrum im Kreis Kleve e.V.	3	3	0.5
Optimalisering van de Rijn en de uiterwaard door een goede **ecologische en hydrologische verbinding**. Natuurlijke overstromings- en grondwateromstandigheden creëren door een inlaatwerk te installeren om de nevengeul verder te ontwikkelen	LIFE	6	Xanten (DE)	FORELAND + EMBANKMENT (CHANGE IN DIKE LINE FOR RETENTION)	YES	4	EU, Land NRW, Kurt Lange Stiftung, Michael Otto Stiftung für Umweltschutz, NABU-Naturschutzstation Niederrhein e.V., Biologische Station im Kreis Wes	3	3.6	0.75
Behoud en bevordering van weidevogels, structuurrijkdom en maaiweiden in het **laagland door aanleg van ondiepe wateren**, extensivering	LIFE	7	Rheinsburg (DE)	FORELAND + EMBANKMENT	YES	4	EU, Land NRW, Kreis Wesel, HIT Umwelt- und Naturschutz Stiftungs-GmbH, Biologische Station im Kreis Wesel e.V.	3	3.6	0.75

van grasland, begrazing om houtgroei tegen te gaan.										
Het doel van het **project was om de leefgebieden in de uiterwaarden met elkaar te verbinden**, te herstellen en de soortenrijkdom te bevorderen. De samenwerking tussen natuurbescherming, landbouw, bosbouw, visserij, jacht, gemeentes en instanties	LIFE	8	Germersheim, Linkensheim (DE)	FORELAND, EMBANKMENT, BACKLAND, DIKES	YES	5	Regierungspräsidium Karlsruhe	2	3.8	0.75
Ontwikkeling van een **nat uiterwaardlandschap** bij de monding van de Lippe in de Rijn met een **vrije loop- en profielontwikkeling** en vorming van levensgemeenschappen die kenmerkend zijn voor de monding.	EG KRW	1	Wesel (DE) Border Lippe River	FORELAND, EMBANKMENT (+ DIKE)	YES	5	Land NRW (Bundesland North Rhein Westfalen), Lippeverband	3	4.2	1
Natuurlijk herstel van de Sieg en de **uiterwaard** bij de monding in de Rijn. Aanleg van een seminatuurlijk rivier- en uiterwaardlandschap	EG KRW	2	Bonn (DE) Border Sieg River	FORELAND, EMBANKMENT (+ DIKE)	YES	5	Land NRW, Bezirksregierung Köln	2	3.8	0.75
Ombouw van de aanwezige **oeververhardingen** en ontwikkeling van ondiepe wateren die beschermd zijn tegen golfslag	EG KRW	3	Duisburg North	EMBANKMENT	NO	3	Land NRW, Stadt Düsseldorf, Bergisch-Rheinischer Wasserverband, NRW-Stiftung	3	3	0.5
Ontwikkeling van een eigen dynamiek in de Urdenbacher Kämpe. Het moet een **seminatuurlijke rivier** worden in het laagland die voldoet aan het streefbeeld, met biotopen die karakteristiek zijn voor **uiterwaarden**, habitattypes conform	EG KRW	4	Dormagen, Dusseldorf (DE)	FORELAND, EMBANKMENT	NO	4	Emschergenossenschaft	3	3.6	0.75
Heraanleg van de Emscher over 1,6 km met een vispasseerbare verbinding met de Rijn	EG KRW	5	Rheinsberg (DE) Border Emscher River	EMBANKMENT (+ FORELAND)	YES	4	Kt. Basel - Stadt	1	2.8	0.5
Er zijn in totaal 16 maatregelen ter verbetering van de ecologie gerealiseerd.	Herstel van de oevers, Vispasseerbaarheid	1	Rheinfelden (CH-DE)	RIVER	NO	1	Kraftwerk Ryburg - Schwörstadt	5	2.6	0.5
Op een Rijntraject van ongeveer 12 km lang worden tal van maatregelen voor de verbetering van de ecologische kwaliteit zichtbaar.	Herstel van de oevers, Vispasseerbaarheid	2	Leibstadt (CH-DE)	RIVER (+ EMBANKMENT)	YES	2	Kraftwerk Albbruck - Dogern	5	3.2	0.5

Regierungspräsidium = As bundling and coordinating authorities, we stand between the state ministries on the one hand and the districts, cities and municipalities on the other. As a so-called intermediate authority, we bundle various specialist tasks under our roof, for example in the areas of refugee reception, civil protection, building and planning, librarianship, agriculture, road construction, schools, forestry and geology. (https://rp.baden-wuerttemberg.de/rpf/ueber-uns/organisation/) Autonomy = 2

NABU = Nature and Biodiversity Conservation Union (Civil Organization)

Fa. Juwi = The JUWI Group is one of the leading experts for renewable energies providing turnkey project development as well as many other services.

PanEco = Pan-European Transport Network (Paneco is the first company to unite freight forwarders from almost all European countries to such an extent in order to create an efficient transport and forwarding network for its customers.)

Emschergenossenschaft + Lippeverband = From a legal point of view, the Emschergenossenschaft (EG) and the Lippeverband (LV) are two public corporations with comparable statutory tasks. We have been bundling our expertise for more than 90 years and are the largest wastewater disposal company and operator of sewage treatment plants in Germany. Autonomy = 3

Calculation Model of the Rhine Line

Finding Common Water

Empowering localized autonomy of dike management for an adaptive Rhine River.

Calculations of Local dike autonomy:
Jens Berkien
MSc Urbanism, Department of Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology

Graduation Course:
AR3U115 Graduation Lab Urbanism Studio - Planning Complex Cities.

First Mentor: (V.E (Verena) Balz)
Verena Balz (Spatial Planning and Strategy) (TU Delft)

Second Mentor: (Ir. K.P.M (Kristel) Aalbers)
Kristel Aalbers (Environmental Technology & Design) (TU Delft)

Board of Examinors: (Dr.ir. E.W.T.M (Erwin) Heurkens)
Erwin Heurkens (Management in the Built Environment, Urban Development Management)

November 2023

Data Calculations

Information is given to underline the indicators that can be used by local actors to calculate the possibilities of local dike management. Based on 4 classified main calculations categories, local actors not only can conduct the entire calculation at once, but can also indicate their preferences within performing one of the 4 main sub-calculations and either setting up their own calculations by combining important indicators.

The calculation has been divided into four main subdivisions, related to layers that classify the potential for local dike autonomy. **1. Authoritative regions** based on spatial configurations where certain rules, regulations, practices and management systems in relation to water and/or dike management take place. **2. Dike typologies** based on the technical, spatial and management related characteristics. **3. The underlying conditions of the surface**, which include flooding, drought, aquifer and soil conditions allow to understand the suitability conditions of dike management. But as certain conditions cannot be translated over the entire spatial regions due to their direct impact coming from the river itself, the final condition calculation is created: **4. Underlying conditions River Dynamics.**

Sub calculations allow for the formation of a range interpretation from 1-5 on autonomy

(L):	Layer of Autonomy
(SC):	Sub-Calculation
(I):	Indicator

Dike Autonomy

(1.5(Spatial Dike Form) + 1.25*(Technical Dike Profiles) + 1.0*(Spatial Dike Profiles) + 1.0*(Maintenance Dike Profiles) + 0.5*(Dike cost Implications)) / 5.25 + 0.5*(Rhine riverbanks) + 0.75*(Dike systems)*

River Dynamics

1.0(Total Discharge of Rhine) + 1.25*(Rate of Discharge Change) + 0.25*(Tributaries of the Rhine)*

Suitability Conditions

(1.5(Soil Conditions) + 1.0*(Groundwater conditions) + 2.0*(Flooding & Drought) + 0.5*(Effective precipitation)) / 5 + 0.25*(Surrounding Water bodies) + 1.0*(Slope Indications)*

Authoritative Autonomy

1.0(Flood Safety Regions) + 2.0*(Decision making autonomy) + 1.5*(Autonomy of administration) + 1.25*(Water use distribution)) / 5.75*

(L) Dike Autonomy

(SC) Spatial Dike Lines

1.0(Form of the dikes) + 1.25*(Location Placement) + 1.25*(Scalar dike impact) + 0.75*(Dike bodies up & down stream) / 4.25*

(I) Forms of the Dike

The form of the Dike indicates its spatiality in which the size of the dike body, its water retaining function and the lines of defenses (amount of lines) tells the story about the overall mass of the dike on that particular location. This can be done in relation to High Water Retaining Dikes and Secondary Dikes that are not directly related to the Rhine flow but to one of its tributaries.

Dike Typologies	**Overall Dike Mass Weight**	**Autonomy Weight**
(Primary) 1 Line	3	2
(Primary) 2 Line	4	1
Side dike*	2	3
Dwarsdijk*	1	4

Lola Landscape Architects (2014). Dijken van Nederland. Second edition. Nai010 publishers, Rotterdam, the Netherlands. ISBN 978-94-6208-150-5.

(I) Dike bodies Up & Down Stream

To allow for autonomous building, maintaining and monitoring of dike bodies, the understanding of the impact created for other 'autonomous' regions has to be established. As certain dike typologies, locations and forms change due to increase local autonomy, the effect flooding, drought and other water distribution systems can be (unwillingly) adjusted. Although it has none to low direct relation to local dike autonomy, it does increase uncertainties in risk management in the future

Dike lines	**Autonomy Weight**
< 2.5534	5
5.0668 – 2.5534	4
7.6002 – 5.0668	3
10.1336 – 7.6002	2
< 10.1336	1

(I) Location Placement of Dike

The location placement of the dike is important in understanding the impact the line has on the river and vice versa. Therefore a distinction has been made to the placement of the dike in relation to the river. Here the closer the dike line is placed to the river the lower the autonomy of the dike line becomes.

Additionally the impact of the flood extent line of the IKSR (BAFG, 2015) is considered when creating a difference of the 'Influence of the river' as the higher flood extent places additional stress on the dike line.

Dike Systems	Autonomy Weight
Inside River	1
Beside River (100% of location)	1
Beside River/Influence	2
Influence of the river	3
Influence of the river (no flooding)	4
Away from the river	5

(SC) Technical Dike Profiles

1.0(Safety failure mechanisms) + 0.5*(Water distribution failure mechanisms) + 1.25*(Water retention function) + 0.75*(Water distribution function) / 3.5*

(I) Failure Failure mechanisms: Safety against failure mechanisms + Water Distribution effect of failure mechanisms.

Due to the fact that dike bodies are in constant contact with the natural elements and adjacent river dynamics, dike bodies need to be designed and calculated based on certain failure mechanisms that have been gathered in the years of Dutch experience. The location, the material and the height, width and related spatial elements all have different impacts on the stability and strength of dike bodies. Therefore certain dike bodies react differently to certain failure mechanisms and can some failure mechanisms be classified to be more dangerous than others. Overall, a high number of the Safety Failure Mechanism, the better the dike line is suited to prevent one of the 6 Failure Mechanisms known to cause problems in dike and river management. Although failure mechanisms are considered to be bad for the stability of dikes, it does create additional features when considering increasing the local autonomy of dike management. Potentials in relation to local maintenance, construction and the distribution of water does create additional possibilities for the creation of localized dike management.

Failure Mechanism	Safety precautions in relation to failure mechanisms	Additional Autonomy positive effects in relation to failure mechanisms.
Overflow and Wave Overtopping	1.25	1.25 (+)
Macro and Micro instability	1.5	0.25 (-)
Piping and Heave	1	1.5 (+)
Setting of dikes (indentation)	0.5	0.75 (0)
Damage of dike based on spatial elements	0.5	0.25 (-)
Peat oxidation (Drying out of peat, clay)	0.75	0.5 (-)
	5.5	4.5

Lola Landscape Architects (2014). Dijken van Nederland. Second edition. Nai010 publishers, Rotterdam, the Netherlands. ISBN 978-94-6208-150-5.

(I) Water Retaining Function

The main function of a dike is to be able to keep the water out and/or to retain the river within its boundaries for protections as to economic values. Therefore this aspects is considered to be the main function a dike body has. The larger the water retaining function a dike is, the smaller the safety margins allow any change, lowering its localized autonomy.

(I) Water Distribution Function

Next to the fact that the main function of the dike is to be the main protective spatial entity against the unpredictability of river discharge, it also is used to retain water within its original boundaries of the river. Therefore the dike enhances the water distribution ability of the river and related water body.

(I) Scalar Dike Impact

Dikes are often many kilometres long. As water authorities started to become a national organized unit of governance (particularly in the Netherlands), dikes started to become overarching spatial entities flowing through many different administrative regions. Currently large landscape architecture firms and water authoritative programs try to bring back the possibilities for different dike bodies as they tend to be more designed and calculated according to local conditions that allow for more climate resilient dike bodies. Therefore the larger the impact of the dike is within the overall system the lower the autonomy of the dike becomes.

(SC) Spatial Dike Profiles

0.75(Biodiversity impact) + 1.25*(River flow impact) + 1.0*(Societal impact) + 0.5*(Economic impact) + 1.5*(Flexible usage) / 5.0*

(I) Biodiversity Impact

The ability a dike body has to increase the natural conditions of the dike and surrounding regions, allowing for the local biodiversity to gain foothold within the region.

(I) River Flow

The effect a dike body has on stabilizing River Flow of High + Low Flow. Large direct height differences close to the river increase the difference in river heights, therefore putting more pressures on dike bodies, lowering autonomy.

(I) Societal Impact

As dikes have been local constructions throughout large periods of history, they have always been an integrated part of societal life. As these dike bodies have been submerged into national oriented policy regulations and rules, they have become an underutilized spatial feature in the landscape. But as recent Dutch examples have shown (and are still showing) the move towards re-establishing the bond between dikes and the social landscape, increases willingness and autonomy of local dike management, whilst simultaneously holding its protective character in periods of climate uncertainty.

(I) Economic Impact

As dike construction and maintenance is considered to be a sector that is heavily tested due to the large investments needed to be made in order to facilitate the safety margins as proposed, localizing such costs are considered to be futile. Definitely if we are considering dike management in the Rhine valley as this is one of the most urbanized regions in Europe (therefore increasing land values even more). Therefore Dutch practices and architectural firms experiment with dike bodies that can be multifunctional in usage, increasing potential economic returns in real estate, energy and tourism sectors. This therefore lowers the initial pressures of high investments on local authorities and increases potential active subsidiarity programmes from higher up national and regional governments.

(I) Flexible Use

Dikes come in any shape and form and can therefore be applied in different context within different land uses. As the implementation of dike lines can be subjected to the land use they are most related to, the flexibility of the related dike management needed to maintain and/or construct the dike line might decrease. Certain dike typologies are directly related to certain context and/or environments and are therefore not fully flexible in implementation practices around the entire Rhine.

(SC) Maintenance Dike Profiles

1.25(Area of Protection zone) + 0.5*(Frequency maintenance) + 0.75*(Knowledge of maintenance) / 2.5*

(I) Area of the Protection Zone

Not only as part of the large spatial footprint dikes contain within the landscape, making implementation of dike somewhat dependent on the availability of the flatter areas of the region, but as well as the maintenance needed to maintain a dike body is crucially related to the extent of the space, dike bodies cover. Based on the maintenance profile as provided by Dutch examples, a dike consist out of two main maintenance regions: The area of the dike that is considered to be part of the same ‘pile’ (so as related to increasing values of height differences) and the directly related area that is

under direct influence of having the dike in its vicinity (outer protection zone) where spatial impacts can occur due to seepage, inclination and other instability possibilities.

(I) Frequency of Maintenance

Certain dike construction ask more frequent maintenance due to their spatial impact and their technical function. Mainly dike maintenance can occur within two separate ways: Daily maintenance (which considers monitoring effects, grass maintenance and cleaning measures) and Heavy Maintenance (which takes place when certain dike bodies are deemed to have failed current safety and/or integral stability regulations and should therefore be strengthened). But as the latter of the maintenance options could potentially call for a complete change in dike typology due to its unsuitability of facilitating dike protection, the maintenance calculated here will create a full picture of the frequency of maintenance needed to keep the existing dike typology existing.

(I) Knowledge of Maintenance

As different dike typologies consist out of different safety regulations, spatial impacts and used material, the construction and maintenance of the dike line, the knowledge needed to implement a certain dike body could decrease local autonomy as new interventions of dike in relation to complex technical and spatial profiles, increase the need for experimental knowledge, which is often lacking in normal practices.

(SC) Dike Construction

1.75(Materials for construction) + 1.25*(Water retention function) + 0.75*(Knowledge of maintenance) + 0.75*(Flexible usage) / 4.5*

(I) Materials for construction

As per United Nations classifications of dike construction as one of the main measurements for flood prevention, the main financial requirements of dike construction and management is related to: Material, Location, Safety Margins and available Knowledge. Besides the materials needed for dike construction and maintenance, represent the 3 other requirements the three main profiles of dike management.

Lola Landscape Architects (2014). Dijken van Nederland. Second edition. Nai010 publishers, Rotterdam, the Netherlands. ISBN 978-94-6208-150-5.

(SC) Additional Elements

0.5(Rhine riverbanks) + 0.75*(Dike systems)*

(I) Dike Systems

Dike Systems	**Autonomy Weight**
Vingerling Location	+0.75
Overflow/Spillover location	+0.50
Local Floodwall	+1.00
Additional Functional side dike	+0.50
Water Abstraction points	-1.00

(I) River Embankments

Dike Systems	**Autonomy Weight**
River Embankment	+1.00
Canal Dike	+0.25
Winterdike	+0.50

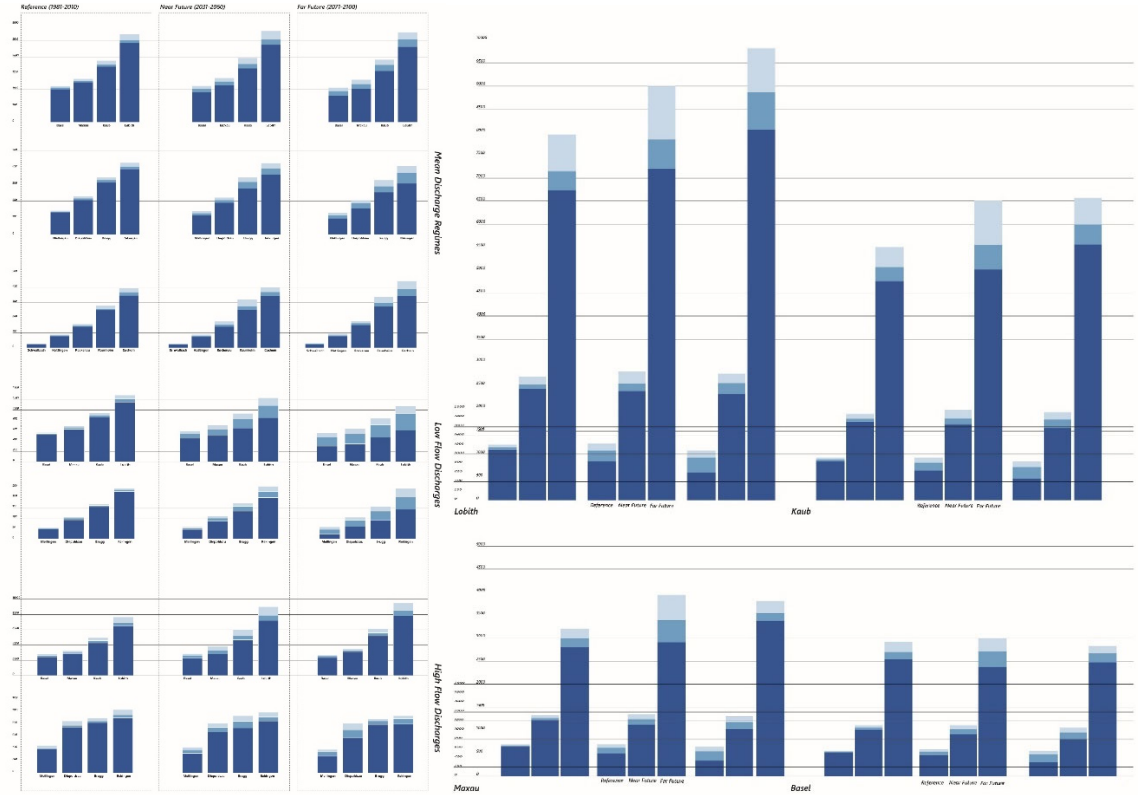
(L) River Dynamics

(SC) River Discharge

1.5(Change High-Low 2050) + 1.0*(Change High-Low 2100) + 1.25*(Low flow drought) + 1.0*(Quantitative discharge) / 4.75*

(I) Change in High-Low Flow (Reference-2050-2100)

As part of dike management, is the flow development of the river an important indicator in the location, the type, the size and risks involved for local dike autonomy. As current dike bodies are built to keep the river in place, current high and low flow data should be able to be controlled by dikes. But as 2050 and 2100 show and increase in both the discharge of High and Low flow in relation to current numbers due to climate change, has a high increase in river discharge to deal with more stable and robust dike bodies (if current typology, location and form is maintained). As the region being researched has to be seen as different autonomous spatial configurations, the difference and change between high and low flow is used to determine the ratio of autonomy. (So how more regions, less change is seen between locations)



Stahl, K., Weiler, M., van Tiel, M., Kohn, I., Hänsler, A., Freudiger, D., Seibert, J., Gerlinger, K., Moretti, G. (2022): Impact of climate change on the rain, snow and glacier melt components of streamflow of the

river Rhine and its tributaries. CHR report no. I 28. International Commission for the Hydrology of the Rhine basin (CHR), Lelystad.

(I) Low Flow Drought

As based on the latest numbers of the European Drought Observatory in relation to the effect of the latest drought of 2022 and its effects on the low flow of the river, the dangers of increasing low flow potentials in the future throughout the year (data is published by month) form dangers for dike stability as they dry out, form cracks and become dangerous in periods of high flow.

European Drought Observatory	Autonomy
Alert	1
Alert & Warning	2
Alert & Watch	3
Warning	3
Warning & Watch	4
Watch	5

Cammalleri, C., Arias-Muñoz, C., Barbosa, P., de Jager, A., Magni, D., Masante, D., Mazzeschi, M., McCormick, N., Naumann, G., Spinoni, J., and Vogt, J. (2021): A revision of the Combined Drought Indicator (CDI) used in the European Drought Observatory (EDO), Nat. Hazards Earth Syst. Sci., 21, 481–495, https://doi.org/10.5194/nhess-21-481-2021, 2021. https://doi.org/10.5194/nhess-21-481-2021

(SC) Water Discharge Current

1.0(Total Discharge of Rhine) + 1.25*(Rate of Discharge Change) + 0.25*(Tributaries of the Rhine)*

(I) Water Discharge Side Rivers (m3/s)

Water Discharge (m3/s)	Autonomy
0-1	5
1-10	4
10-50	3
50-150	2
150+	1

(I) Total water discharge of the Rhine (m3/s) Change of 250 m3/s

Water Discharge (m3/s)	Autonomy
0-250	5
250-500	4.5
500-750	4
750-1000	3.5
1000-1250	3

1250-1500	2.5
1500-1750	2
1750-2000	1.5
2000+	1

(I) Rate of Discharge (Change of discharge between the various GRDC defined stations).

Water Discharge (m3/s)	Autonomy
< -2.5	3
-2.5 – -1.25	4
-1.25 – 2.5	5
2.5 – 7.5	4
7.5 – 12.5	3
12.5 – 25	2
> 25	1

GRDC Data Portal. (2023). GRDC Station Catalogue.
https://portal.grdc.bafg.de/applications/public.html?publicuser=PublicUser#dataDownload/StationCatalogue

GEMStat. (2023). Data Portal. UN Environment Programme GEMStat
https://gemstat.bafg.de/applications/public.html?publicuser=PublicUser#gemstat/Stations

Copernicus (2019). COPERNICUS Land Monitoring Service Reference Data: EU-Hydro.

(SC) Dike System Interruptions

(1.0(Water distribution mechanisms) + 0.75*(Water Nodes) + 0.5*(River Measurements)) / 3.75 + (1.0*(Groins))*

(I) Water Distribution Mechanisms

As part of the ability for human interventions to (next to dikes) manually distribute water sources to locations where they are needed, water distribution mechanisms become an internal part water and therefore also water management. Water Distribution mechanism also occur on a more natural basis in the form of connected side arms and water nodes, but are primarily seen as technical applications for the usage of water and to retain original form of the river itself. Per location multiple of these water distribution mechanism are visible in the landscape. These water distribution mechanisms can form as an anomaly in the larger scale of the dike system or be used as a secondary protection measurement before rivers directly reach a dike.

Water Distribution Mechanism	Weight in River Dynamics	Effect on the Autonomy
Culverts	0.25	+

Sluices	0.75	-
Weirs	1	-
Dams	1.5	-

AMBER Consortium (2020). The AMBER Barrier Atlas. A Pan-European database of artificial instream barriers. Version 1.0 June 29th 2020. https://amber.international/european-barrier-atlas/

(I) Groins

Water Distribution Mechanism	**Weight in River Dynamics**
100 %	+1.00
75 %	+0.75
50 %	+0.50
25 %	+0.25

(I) River Hierarchy

Strahler Classification	**Weighted Autonomy**
6	1
5	1
4	2
3	3
2	4
1	5
C	2

*C: The letter C indicates that the River is considered to be a Canal.

Copernicus (2019). COPERNICUS Land Monitoring Service Reference Data: EU-Hydro.

(I) River Measurements

The width of a river can indicate the fluctuations a regions has when it considers the amount of water being discharged to the relation on the space it takes to distribute it. When considering the difference between maximum, average and minimum river width, we can classify the relation between the extremes of the width of the river.

Begin Point	**End Point**	**Length (m)**	**Width (Med) m**	**Autonomy**
Pannerden (NL)	Wesel (DE)	54024	390	3
Wesel (DE)	Duisburg (DE)	32955	362	3
Duisburg (DE)	Koblenz (DE)	187665	351	3
Koblenz (DE)	Bingen (DE)	55846	317	3
Bingen (DE)	Mainz DE	32612	611	1
Mainz (DE)	Mannheim (DE)	68201	327	3
Mannheim (DE)	Breisach (DE)	202097	256	4
French Corridor				
Breisach (DE)	Geiswasser (FR)	4367	212	4
Geiswasser (FR)	Basel (CH)	47172	136	5
German Corridor				

Breisach (DE)	Geiswasser (FR)	4720	171	5
Geiswasser (FR)	Hartheim (DE)	11170	150	5
Hartheim (DE)	Basel (CH)	36394	108	5
Basel (CH)	Felsenau (CH)	70310	203	5
Felsenau (CH)	Ellikon am Rhein (CH)	37997	128	5
Ellikon am Rhein (CH)	*Konstanz (DE)*	*72542*	*169*	*5*
Konstanz (DE)	*Reichenau (CH)*	*130550*	*84*	*5*

**Calculations on the autonomy of the difference in max-med and med-min could not be made with the existing datasets that were available. As primarily the maximum numbers will create a too big of a difference as these maximum numbers are related to the width of large lakes of the Bodensee and the Untersee (both part of Lake Constance). Median width can be taken as indication in these calculations as they are directed at the river segments.*

Allen and Pavelsky (2018) Global Extent of Rivers and Streams. Science.
https://doi.org/10.1126/science.aat0636

(SC) Sedimentation Patterns

1.25(Sedimentation material) + 1.5*(River angles & Erosion) / 2.75*

(I) Sedimentation Material

The types of sediment says something about the dynamics of the river. High sedimentation rates give indications on the average speed of the river and the erosion risks of a area of the river. As water speed data can only often be found on a daily base (often for navigation purposes). The type of sediment can be traced to the three main groups of Clay, Sand and Gravel. Next to the fact that sedimentation patterns indicate river dynamics on which dike constructions need to be calculated, it also indicates potential material for autonomous building and maintaining of dikes.

Material	**Weighted Autonomy**
Clay	2.0
Sand	1.5
Gravel	1.0

R.M. Frings, G. Hillebrand, N. Gehres, K. Banhold, S. Schriever, T. Hoffmann, From source to mouth: Basin-scale morphodynamics of the Rhine River, Earth-Science Reviews, Volume 196, 2019, 102830, ISSN 0012-8252, https://doi.org/10.1016/j.earscirev.2019.04.002.

(I) Sedimentation & Erosion

One of the silent killers of dike infrastructure is related to erosion of the area due to increasing water speed in river bends (also allows for increasing patterns of sedimentation on the other side). These river bends are calculated to the angle these bends take. The higher the bend becomes, the alternative sides

or the river are either subjected to higher dynamics of sedimentation or erosion, due to higher or lower speeds of rivers.

Angles of Corners	Sedimentation Rate	Erosion Rate	Autonomy
180-165	High	Low	5
165-150			4.5
150-135			4
135-120			3.5
120-105			3
105-90			2.5
90-75			2
75-60			1.5
60-45	Low	High	1
45-30			*1*
30-15			*1*

*45-30 & 30-15 angles degrees where not found during the research

Kasvi, E., Laamanen, L., Lotsari, E. & Alho, P. (2017). Flow Patterns and Morphological Changes in a Sandy Meander Bend during a Flood—Spatially and Temporally Intensive ADCP Measurement Approach. Water 2017, 9, 106; doi:10.3390/w9020106

(L) Suitability Conditions

(SC) Soil Conditions

0.75(Lithological depositions) + 1.25*(Soil moisture) + 1.0*(Soil Sealing) / 3*

(I) Lithological Depositions

	Lithological Composition	**Suitability for Dike stability (Ondergrond)**	**Suitability for Dike Construction (Material)**	**Total Suitability**
1	Calcareous Rocks	1	1	1
2	Calcareous Rocks + Course Sediments	2	2	2
3	Calcareous Rocks + Fine Sediments	1	2	2
4	Course Sediments	5	5	5
5	Fine Sediments	4	4	4
6	Inland Water	1	1	1
7	Magmatic Rocks	1	1	1
8	Metamorphic Rocks	1	2	1
9	Siliciclastic Rocks	2	1	1
10	Siliciclastic Rocks + Course Sediments	3	3	3
11	Siliciclastic Rocks + Fine Sediments	2	3	2
12	Snow Field	1	1	1

Calcareous: Calcareous rocks are formed from a variety of chemical and detrital sediments such as limestone, dolostone, or marl and are largely composed of calcium oxide (CaO), magnesium oxide (MgO), and carbon dioxide (CO2), with varying amounts of aluminum, silicon, iron, and water. (Britannica, 2023).

Siliciclastic: Siliciclastic rocks, also known as terrigenous, detrital, or clastic rocks, are a group of sedimentary rocks consisting of fragments of minerals and rocks derived from pre-existing rocks. (Geology is the Way, 2023)

BGR & UNESCO (eds.) (2019): International Hydrogeological Map of Europe 1:1,500,000 (IHME1500). Digital map data v1.2. Hannover/Paris.

BGR (2005). The 1:5 Million International Geological Map of Europe and Adjacent Areas (IGME5000), publication date of printed IGME5000, 2005-11-21.
https://www.bgr.bund.de/EN/Themen/Sammlungen-Grundlagen/GG_geol_Info/Karten/Europa/IGME5000/igme5000_node_en.html

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(I) Soil Moisture

Soil Moisture Index	Weight of Autonomy
0-0.2	1
0.2-0.4	2
0.4-0.6	3
0.6-0.8	4
0.8-1.0	5

Cammalleri C, Micale F, Vogt J. A novel soil moisture-based drought severity index (DSI) combining water deficit magnitude and frequency. HYDROLOGICAL PROCESSES 30 (2); 2016. p. 289-301. JRC96439 *https://hess.copernicus.org/articles/21/6329/2017/*

(I) Soil Sealing See Appendix X

Copernicus (2018). CORINE Land Cover 2018 (raster 100 m), Europe, 6-yearly - version 2020_20u1, May 2020. DOI: https://doi.org/10.2909/960998c1-1870-4e82-8051-6485205ebbac

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(SC) Groundwater Conditions

1.5(Groundwater recharge) + 0.75*(Aquifer conductivity) + 1.0*(Aquifer vulnerability) / 3.25*

(I) Groundwater Recharge

As based on research conducted by the European Geological Surveys Research Area (GEUS, 2021) as sub missioned by the European Union, the groundwater recharge statistics of Europe are calculated. As dike bodies are subjected to large fluxes of surface and groundwater movements, the recharge of groundwater within an area can indicate whether a dike is suitable for construction. High groundwater recharge means that on an overall bases the ground conditions are well saturated within water, therefore creating a large groundwater backup for periods of drought. As dike bodies are primarily built out of normal soils that can be found everywhere on a regular basis, they also rely on a stable source of groundwater with little fluctuations. Thereby we have to mention that a positive groundwater recharge also has impact on a dike body, primarily destabilizing the dike due to large seepage potentials of the subsoil. But as a negative groundwater recharge has the potential to dry out the whole dike body, the negative numbers (below 100) are weighted higher on the scale of 5-1.

25	50	75	100	150	200	300	400	600	800	1000	>1000
1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1.5	2	2.5	3	3.5	4	4.5	5	5

Geological Survey of Denmark and Greenland (GEUS). (2021). Potential Groundwater Recharge bias corrected [mm/year]. European Geological Data Infrastructure (EDGI). *https://data.geus.dk/egdi/?mapname=egdi_new_structure#baslay=baseMapGEUS&extent=1214110,1571970,4873090,4844540&layers=potentialgroundwaterrechargebiascorrected*

(I) Aquifer Conductivity

The aquifer conductivity, just like the groundwater recharge data, indicates how easily water can be transported/moved within the underlying aquifer. This occurs from top – down movement as well as from side – side movement. Increasing porosity of aquifers indicate the productivity of an aquifer, meaning the movement of water within the aquifer itself. The higher the aquifer conductivity of the area the better conditions it created for dike bodies.

Aquifer	**Autonomy indication**
Highly productive porous Aquifers	5
Highly productive Fissured Aquifers	3
Non-aquiferous rocks, porous or fissured	1
Low and moderaltely productive porous Aquifers	3
Low and moderaltely productive Fissured Aquifers	2
Locally Aquifers (Porous/Fissured)	4
Inland Water/Snow Field	1

- Difference Porous / Fissured Aquifer:
    - **Porous**: *Individual particles the size of **sand or gravel and up to large boulders**. Groundwater moves through the openings, between the individual grains or rocks, called pore spaces. Porous rock layers where grains are cemented to each other are called "consolidated." Sandstones are examples of consolidated porous material. (Spokane Aquifer Joint Board, 2023)*
    - **Fissured:** *Fractured Aquifers. **Solid rock layer** where groundwater is found in fractures, joints or cracks in the rock. Fractured aquifers can be found in many different types of rocks including granite and basalt. (Spokane Aquifer Joint Board, 2023)*

BGR & UNESCO (eds.) (2019): International Hydrogeological Map of Europe 1:1,500,000 (IHME1500). Digital map data v1.2. Hannover/Paris.

(I) Aquifer Vulnerability

As aquifers become vulnerable as based on flooding and or drought potentials of the underlying soil conditions, increasing vulnerability will hamper/danger existing dike constructions as the underlying soil does not create a stable composition for dike lines. The higher the vulnerability of the aquifer is becomes the lower the autonomy of the area can be guaranteed. As the increasing vulnerability increases the knowledge and expertise needed to retain existing and or future dike lines.

Title	Vulnerability for Flood (W=1)	Vulnerability for Drought (W=1.5)	Total Vulnerability	Total Autonomy
High vulnerability to floods and droughts	5	5	5	1
High vulnerability to floods and moderate vulnerability to droughts	5	3	4	2
Low vulnerability to floods and droughts	1	1	1	5
Low vulnerability to floods and moderate vulnerability to droughts	1	3	2	4
Moderate vulnerability to floods and droughts	3	3	3	3
Moderate vulnerability to floods and high vulnerability to droughts	3	5	4	2
Moderate vulnerability to floods and low vulnerability to droughts	3	1	2	4

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) & UNESCO (2015): Global Groundwater Vulnerability to Floods and Droughts 1 : 25 000 000 – Hannover, Paris.

(SC) Flooding & Droughts

2.0(Extreme flooding scenario) + 1.25*(Hydrological drought summer) + 1.0*(Hydrological drought winter) / 4.25*

(I) Flooding Extremes

Flooding based on IKSR Database of the most extreme scenario of Flooding Heights due to Riverine Flooding.

IKSR Data base indications	Flooding Weight	Autonomy Weight
>4m	4	1
2-4m	3	2

0,5-2m	2	3
0-0,5m	1	4
No flood	0	5

Bundesanstalt für Gewässerkunde (2015). Interaktive Karten vom 2. Bewirtschaftungsplan (2015) ArcGIS Web Application. https://geoportal.bafg.de/IKSR-WFD2015-de/

(I) Metrological Droughts

Drought classified as part of the Drought Indicator Classifications of the European Drought Observatory (Drought season of 2022) into Hydrological Winter and Summer Editions.

Increasing possibilities in metrological drought within future climate change scenario's that the European Drought Observatory has indicated with the vulnerabilities of even northern European lands as with the drought year of 2022 where the Rhine was considered to be as low in certain areas, that international shipping trade and economic water use was halted. As based on the indication used by the European Drought Observatory, the translation of drought into hydrological summer and winter situations as is common practice in hydrological fields (CHR), is classified according to multiple watch, warning and alert situation based on the direct translations of the overlay of monthly spatial data. Both the hydrological summer and winter are translated into the calculation manual, but as the hydrological summer often has a larger effect on drought risks, the weight of the hydrological summer is as twice as high as the weight of the hydrological winter.

European Drought Observatory	**Drought Indication**	**Autonomy Weight**
Watch 1	1	1
Watch 2	2	2
Warning 1	3	3
Warning 2	4	4
Alert 1	5	5
Alert 2 (Usually only for Summer Drought)	6	5*

Same conditions as with the Flooding risks are concerned for the Drought indications within the calculations. As the drought calculations of the European Drought Observatory are based around monthly data, these spatial conditions have been overlayed according to the Hydrological Summer and Winter. Therefore the indications of Drought goes from 1-6 rather than from 1-5 as certain drought risk areas in the summer are to intense to not register.

Cammalleri, C., Arias-Muñoz, C., Barbosa, P., de Jager, A., Magni, D., Masante, D., Mazzeschi, M., McCormick, N., Naumann, G., Spinoni, J., and Vogt, J. (2021): A revision of the Combined Drought Indicator (CDI) used in the European Drought Observatory (EDO), Nat. Hazards Earth Syst. Sci., 21, 481–495, https://doi.org/10.5194/nhess-21-481-2021, 2021. https://doi.org/10.5194/nhess-21-481-2021

(SC) Additional Elements

0.5(Effective precipitation) + 0.25*(Surrounding water bodies) + 1.0*(Slope indications)*

(I) Surrounding Water Bodies

Surrounding water bodies have an impact on dike management. As dikes are in the optimal form in the vicinity of water bodies (as this is within water retention zones, high groundwater regions and or in range of river dynamics). Because if a dike comes into contact with water (especially its outer layer that withholds the core) a certain humidity is needed to retain this protective layer of the dike. So the vicinity of dike in relation to other surrounding water bodies could increase autonomy of dike management as a constant source of water is nearby to retain the stability of the dike. Also adjacent side rivers could function as potential side ditches to distribute seepage of the dike (due to its mass, it pushes down the groundwater on that location leading to potential problems related to piping but more importantly it pushes up groundwater at both sides of the dike).

Central Water Bodies	**Autonomy**
Natural	5
Reservoir	2
Unknown	3
Canal	1

Copernicus (2019). COPERNICUS Land Monitoring Service Reference Data: EU-Hydro.

(I) Slope Indications

Dike are often found on flat surfaces for optimal weight distribution, stability and robustness against river flows. Slopes can indicated undiscovered/old dike lines that have not been related to existing datasets and can therefore give indication into dike building. But only when the slope is considered to be between 0 and 20 degrees (higher can also indicate a dike but potential towards dike development seems unlikely).

White (0-2.5): Areas that are considered flat facilitate the equal elevation needed to provide for the establishment of the dike line. As this could be facilitated anywhere, the construction of the dike line needs to be FULLY facilitated by local parties.

Blue (2.5-7.5): Areas that are considered hilly facilitate particular locations that are still considered of equal elevation for the construction of dike lines, whilst also facilitating for a natural platform of elevation, therefore lowering the threshold for local dike construction as these natural lines can be followed.

Red (7.5+): Areas that are considered with a elevation of more than 7.5 degrees already follow a natural line of defense against flooding. Although the natural elevation allows for local parties to minimize the efforts of the construction of dike lines, the need to localize dike management will be less vital than on other locations.

Slope Angles (degrees)	**Autonomy (As an Addition)**
0-2.5	0.5
2.5-7.5	1
7.5 +	0

European Environmental Agency (2016). European Digital Elevation Model (EU-DEM).
https://sdi.eea.europa.eu/catalogue/srv/api/records/d08852bc-7b5f-4835-a776-08362e2fbf4b

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(I) Effective Precipitation

As the Rhine river is considered to be the largest river within its basin, it is not the river that is considered to be the most unpredictable when it comes to flooding. Monitoring of the Rhine is considered to be one of the best applications any river basin has to offer in Europe. But it is primarily its smaller tributaries that show the most unstable characterization. Often this is based on increasing and decreasing amounts and unpredictability of precipitation due to larger periods of intensive rainfall and drought. As this thesis is focused on the dikes of the Rhine it does not consider direct dike bodies that are indicated at other rivers (although they eventually end up in the Rhine river). But as dike calculations should be regulated to the extent of their relation with water in any shape or form (surface, ground and precipitation), higher intensities and fluctuations of precipitation in the area due have an impact on the stability and function of a dike body. Therefore it has also an impact on the autonomy of dikes in the sense of monitoring and maintenance.

25	**50**	**75**	**100**	**150**	**200**	**300**	**400**	**600**	**800**	**1000**	**>1000**
1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1.5	2	2.5	3	3.5	4	4.5	5	5

Geological Survey of Denmark and Greenland (GEUS). (2021). Effective Precipitation [mm/year]. European Geological Data Infrastructure (EDGI).
https://data.geus.dk/egdi/?mapname=egdi_new_structure#baslay=baseMapGEUS&extent=1214110,1571970,4873090,4844540&layers=effectiveprecipitation

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(L) Authoritative Autonomy

(SC) Flood Safety Margins

1.0(Future flood safety: Moderate) + 2.0*(Future flood safety: Extreme) / 4.25*

Safety Standards are always needed to be taken into account considering flooding potentials now, in the near and far future. Height and size of the dike are often in relation to the safety standards (the indication in how many years a dike breach can occur).

Region	Reference (Current Safety)	RACMO (2030)	Relation Current + RACMO	Ranking	WP Extreme (2050)	Relation Current + WP	Ranking	Total	Autonomy (6-Total)
Delta	1:1250	1:673	1.86	**5**	1:437	2.86	**2**	3.5	2.5
Lower Rhine 1	1:500	1:327	1.53	**3**	1:162	3.09	**3**	3.0	3.0
Lower Rhine 2	1:200	1:134	1.49	**3**	1:80	2.50	**1**	2.0	4.0
Middle Rhine	1:200	1:159	1.26	**1**	1:80	2.50	**1**	1.0	5.0
Upper Rhine 1	1:200	1:160	1.25	**1**	1:77	2.60	**1**	1.0	5.0
Upper Rhine 2	1:1000	1:691	1.45	**2**	1:261	3.83	**5**	3.5	2.5
Alpine Rhine	1:200	1:139	1.44	**2**	1:64	3.13	**3**	2.5	3.5

Linde, A. H., Bubeck, P., Dekkers, J. E. C., de Moel, H., and Aerts, J. C. J. H. (2011): Future flood risk estimates along the river Rhine. Nat. Hazards Earth Syst. Sci., 11, 459–473, https://doi.org/10.5194/nhess-11-459-2011, 2011

(SC) Decision Making Autonomy

(2.0(Available knowledge) + 1.75*(Available funds) + 1.5*(Available space) + 1.0*(Self-organizing capacity) + 0.75*(Stakeholder involvement) + 0.5*(Dealing with uncertainties) / 7.5) + 0.75*(Existing projects) + 0.5*(Project influence)*

(I) Available Knowledge: **Appendix 16.4**

Per allocated landuse (Corine Land Cover), the level of knowledge that is available of the hydrological water system as based on. The available knowledge is related to the allocated actor groups that are related to the land uses:

- Level of Knowledge: Knowledge about the natural, technical and social aspects of the water cycle & dike construction (all related to Dike Management)
- Methods & Data: The ability to gain information from monitoring and other data related research regarding the water system
- Adaptive Response: The ability to change course/to act when certain problems danger the existence of current land use practices.

(I) Available Funds: **Appendix 16.4**

Per allocated landuse (Corine Land Cover), the level of available funds to change or adapt to the increasing consequences of floods and drought, without any help from public and/or private sectors. Available funds per related land use is based on the ability of the actor groups to facilitate the change of the existing relation between water and land on a financial basis. As the GDP and Income relations are already discussed in the Autonomy of the Kreise (Dike Management Authorities), the difference between countries in their financial potential will not be included. This calculation is purely based on the relation the various land uses have with each other on a financial basis, indicating which users could facilitate a more radical version of change.

(I) Available Space: **Appendix 16.4**

Per allocated landuse (Corine Land Cover), the amount of space available to change or adapt to the increasing consequences of floods and droughts (water retention zones, protection zones, water storage).

(I) Authority in Water management **Appendix 16.4**

Per allocated landuse (Corine Land Cover), the level of self-organizing capacity to withstand themselves within the management system. As based on the existing power relations between stakeholders of the respective land uses and their incorporation within the managerial system of spatial planning.

Additional points (+1) are defined by the addition on the integration of various policies within the sector of spatial planning. The sectors are related to the main land use it is classified with. The integration of policy is derived from: Agriculture, Environmental, Urban (Culture + Housing), Industry (Industrial + Energy), Mining & Water.

Nature of Integration	**Addition of Autonomy**
Integrated	1
Coordinated	0.5
Informed	0.25
Neglected/Not Relevant	0

Spatial level of Integration	Weight in Addition
National	1
Subnational	2
Local	3

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(I) Stakeholder Involvement **Appendix 16.4**

Per allocated landuse (Corine Land Cover), the level of participation and 'theoretical' interaction within decision-making processes of water management. How more stakeholders in relation to this case, the lower the Autonomy is considered. As based on:

- Width of Participation: The amount of relevant stakeholders per landuse (the actors that have a direct role in the decision making process)
- Depth of Participation: The amount of stakeholders that have the possibility to contribute to alter existing plans and programs

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(I) Dealing with Uncertainties **Appendix 16.4**

Per allocated landuse (Corine Land Cover), the level of dealing with the increasing uncertainties in relation to flooding and drought. The characteristics of how prepared the indicated land use distinction are in related to climate related effects. As based on:

- The consideration of Alternatives: Alternatives in water management to achieve their own set objectives in an open and new way.
- Handling of Uncertainty: Appropriate responses in relation to the severity of the uncertainty. The willingness to change the existing layout for spatial compensation in the case of the spatial change within dike management.

(I) Existing Projects **Appendix 16.4**

The availability of running projects in the vicinity of the potential autonomous dike management regions has a positive impact on the possibilities for local actors to initiate change to their dike lines. The availability of local resources, knowledge and communications from the running projects could invoke new possibilities for local actors for using the available resources, whilst retaining their autonomy within the decision-making process. Therefore the adjacency of certain regions to the project locations could enhance local dike autonomy. The projects known to the IKSR and where the authority have an impact role on the outcome have been chosen as the lead thread within this sub-calculation (BAFG, 2015). The initiators for the distinction of autonomy due to the existence of nearby projects related to the topic of dike management are as followed. The consequences for the overall calculations will be related to an addition of 0, 0.25, 0.5, 0.75, 1, to the overall number of Autonomy (in the calculation the weight of existing projects will have to be laid at 0.75-1.0)

Project Details in relation to dike management (Content characteristics) Relations are made considering the central position of the Rhine river. So if a change is made considering the connection

between the Rhine river and one of its tributaries it is considered to be an intervention related to the foreland of the Rhine (considering the position of a dike line)

- 1 Project in relation to the RIVER
- 3 Project in relation to the EMBANKMENT
- 4 Project in relation to the DIKE (Changing, relocation)
- 3 Project in relation to the FORELAND (Uiterwaarde)
- 2 Project in relation to the BACKLAND (Land behind an available dike line)

Relation to Dike Management	**Area of Intervention**	**Additional Autonomy**	**Influence of Project**
None		0	0
A bit	River	0.25	0.125
Some	Backland	0.5	0.25
Decent amount	Foreland + Embankment	0.75	0.375
A lot		1.00	0.5

**Location of data is based on the set project location.*

Bundesanstalt für Gewässerkunde (2015). Interaktive Karten vom 2. Bewirtschaftungsplan (2015) ArcGIS Web Application. https://geoportal.bafg.de/IKSR-WFD2015-de/

(SC) Autonomy of the Administration

1.75(Socio-economic conditions) + 4.5*(Political landscape) / 6.25*

(SC) Socio Economic Conditions

1.0(GDP as purchasing standard) + 0.75*(Urbanized regions) / 1.75*

GDP at current market prices

See [Berkien_Jens_Calculation_Model_The Rhine Line_Sheet: Authoritative Autonomy]

To understand the possibilities that arise for dike construction (as an expensive business) to take place on a localized base, one of the criteria for local parties is to research if there a financial option available that allows for localized dike management. The data of the purchasing standard per capita is related to the average of Europe (concluding their relation to the EU average and to each other) and related to the average of the respective national statistics (France, Austria, Switzerland, Germany & Netherlands).

This allows to relate the data within the NUTS 2 regions and to the position these regions have within their national countries.

Indicator of Autonomy	Weight Given
GDP of Region per EU Standard (NUTS 2/EU)	0.25
GDP of Region per Rhine Standard (NUTS 2/all NUTS 2)	1.00
GDP of Region per National Standard (NUTS 2/National)	1.25
Total	2.50

Eurostat (2023). Purchasing power adjusted GDP per capita 2018.
https://ec.europa.eu/eurostat/databrowser/product/view/prc_ppp_conv

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(I) Urbanized Regions

Degree of Urbanization	Created Autonomy
Urban	1
Semi-Urban	3
Open/Rural	5
Water	4

European Commission, Eurostat (ESTAT), GISCO (2016). Degree of urbanisation, 2018 - Population distribution – Dataset

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(SC) Political Landscape

1.0(Water management powers) + 1.5*(Dike management powers) + 0.25*(Trust in governance) + 0.5*(Trends in adaptiveness) + 0.5*(Trends in citizen engagement) + 0.5*(Water management integration) + 0.25*(Spatial planning discourse) / 4.5*

(I) Water & Dike Management **Appendix 16.4**

To be able to make decisions regarding water and dike management arrangements, it is necessary to understand the current power relations within the levels of governments and the level of authority these governments layers have in the overall decision-making process. These relations are divided into the four main scalar interpretation of authority (National, Regional, Local & Ownership) where the weight is distributed among the four main scales from 1-4 (as to be used in the determination of the Management Power Relations).

Countries WATER MAN.	National (Am.)	National (1)	Regional (1) (Am.)	Regional (1) (2)	Regional (2) (Am.)	Regional (2) (2)	Local (Am.)	Local (3)		TOTAL Autonomy	W

Netherlands	3	2	12	5	21	3	345	3		**3.375**	**3**
Germany	2	2	16	3	40	2	11.014	2		**2.25**	**2**
France	2	2	18	4	107	-	35.416	2		**2.667**	**3**
Switzerland	1	1	26	4		-	2.122	4		**3.5**	**4**
Austria	2	3	9	3		-	2.093	1		**2.0**	**2**
DIKE MAN.		**National (1)**		**Regional (1) (2)**		**Regional (2) (2)**	**Local (Am.)**	**Local (3)**	**Owners (4)**	**TOTAL**	
Netherlands	3	4	12	3	21	5	345	2	1	**2.5**	**3**
Germany	2	2	16	-	40	3	11.014	5	4	**3.9**	**4**
France	2	4	18	-	107	-	35.416	3	4	**3.625**	**4**
Switzerland	1	2	26	5		-	2.122	-	4	**4.0**	**4**
Austria	2	4	9	-		-	2.093	2	-	**2.5**	**3**

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IKSR. (2021). International flood risk management plan for the International River Basin District "Rhine" (Part A) (catchment areas > 2.500 km2). Second cycle of the FD (period 2022-2027). Final version: December 2021. International Commission for the Protection of the Rhine, Koblenz, Germany.

(I) Trust in Governance

Part of the discourse provided in this thesis is the concept of active subsidiarity as a way to allow for localized autonomy in decision-making with support from European and other international authorities, therefore skipping existing administrative layers of national and regional legislations. Based on research by POLITICO (in 2020), we can indicate trust levels for local residents into National and European Politics. Two distinction can be derived from these statistics: The difference between National + European Trust vs the Trend in trust. Higher trust in European governance makes it potentially easier for active subsidiarity to take effect.

Countries	**Trust in National Governance**	**Trust in European Governance**	**Trend in National Trust**	**Trend in European Trust**	**TOTAL NAT (1)**	**TOTAL EU (2)**	**TOT**	**TOTAL % (EU/NAT)**	**Trust in GOV.**	**Autonomy**
Netherlands	5.0	4.4	-1.1	-0.6	2.9667	2.7333	2.81	0.921	2.589	2
Germany	5.7	5.4	-0.2	+0.2	3.7333	3.6667	3.69	0.985	3.634	4
France	4.3	4.5	+0.4	+0.7	3.0	3.2333	3.16	1.078	3.401	3
Switzerland	-	-	-	-	-	-		-	-	
Austria	5.4	4.8	-1.1	-0.2	3.2333	3.1333	3.17	0.969	3.069	3
Scale = 1-10										

Sugue, M. (2020). Trust has increased in EU but dropped in national governments: survey. POLITICO. https://www.politico.eu/article/survey-trust-in-eu-has-increased-while-trust-in-national-government-has-dropped-coronavirus-pandemic/

(I) Water Management Integration into Politics

As dike and water management are vital components in establishing the possibilities for local autonomy in dike construction and maintenance, integration of the right information and statics that find their translation into policy making is needed to allow for the sharing of information to local conditions.

Countries	**Water management integration (NATIONAL) (1)**	**Water management integration (SUBNAT.) (2)**	**Water management integration (LOCAL) (3)**	**Total**
Netherlands	4	4	4	4
Germany	3	4	3	3.333
France	2	3	4.5	3.583
Switzerland	4	5	5	4.833
Austria	2	2	2	2
Liechtenstein				

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(I) Trends in Adaptiveness

Due to increasing uncertainties in societal discourse, it is vital that existing policies allow for any sense of flexibility in adaptiveness. This relates to setting up the overall framework of rules and regulations without placing specific regulations on specific topics that interfere with local conditions. Therefore it should leave policies, regulations and laws open to local interpretations. Higher adaptation in policy making creates opportunities for local authorities and organizations to interfere in higher up politics as they are directly monitored by national and regional governments.

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(I) Citizen Engagement

Citizen Engagement into policy making is vital to understand the platform that is needed for local conditions to give them the freedom in implementing potential policies within the areas where they are most needed. This not only creates a feedback loop between levels of government but also allows for local autonomy in decision-making.

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(I) Spatial Planning Discourse

The spatial planning discourse explains the relations of where the main decisions are taken place according to the levels of government. How more local the administration of the spatial planning practice becomes, the better local conditions are taken into account within decision making. But it also

means that how more (sub)national layers of government are included in the same discourse how more easy it becomes for institutional thickness to arise.

Countries	Adaptiveness in Policy Making	Nr	Citizen Engagement	Nr	Water management integration	Nr	Spatial planning discourse (lowest level)	Nr	Layers of Spatial Planning	Nr
Netherlands	5 → 4	**4**	4 → 5	**5**	4	**4**	Local		4	
Germany	2	**2**	3 → 4	**4**	3.333	**3**	Local		2	
France	3 → 4	**4**	2 → 4	**4**	3.583	**4**	Local		2	
Switzerland	4 (→)	**4**	4 → 5	**5**	4.833	**5**	Local		3	
Austria	4 → 5	**5**	2 → 3	**3**	2	**2**	Local		4	
Liechtenstein		**4**	5	**5**		**5**				

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(SC) Water Use Distribution

(1.5(Economic water use efficiency) + 1.75*(Water dependent regions) / 3.25) + 0.25*(Quantitative water use)*

(SC) Economic Water Use Data

0.75(Water Use) + 0.25*(Water Efficiency) / 1.0*

(I) Water Use Autonomy **Appendix 16.4**

Water use is qualified based on the efficiency of the main uses of Agriculture, Public and 3 continuous industrial water uses. As the data on the amount of water use per nation cannot directly be projected on the local scale, it is more likely to project when you consider the efficiency of water use per economic sector. As these economic sectors have to follow existing norms and regulation on water use as per national accords, it should (in theory) be better representative of the regional to local conditions.

European Environment Agency (2023). Water Abstraction by Economic Sector, 2000-2019. *https://www.eea.europa.eu/data-and-maps/daviz/water-abstraction-by-economic-sector-1#tab-chart_6_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_country%22%3A%5B%22Austria%22%5D%7D%7D*

European Environment Agency (2023). Water Abstraction by Source, 2000-2019. *https://www.eea.europa.eu/data-and-maps/daviz/water-abstraction-by-source-2000#tab-*

chart_3_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_country%22%3A%5B%22Austria%22%5D%7D%7D

(I) Water Use Efficiency **Appendix 16.4**

The relation of the efficiency of water use towards localized dike management can be classified as a positive relation. When certain large groups of water users are considered to have an efficient water use, the adjacent dike line can be managed on a more efficient percentage.

Aquastat Dissemination System (2023). FAO AQUASTAT Dissemination System. *https://api.data.apps.fao.org/api/v2/bigquery?sql_url=https://data.apps.fao.org/catalog/dataset/945666e6-7803-4621-b8ef-cfd885a84596/resource/4a000a1b-24f0-4328-aab6-b9b525892090/download/query.sql*

(SC) Quantitative water use

1.5(Power plant water use) + 1.0*(Waste water points) / 2.5*

(I) Waste Water Treatment

Based on Waste Water Treatment data (amount of water being treated in waste water treatment plants) from HydroSheds, local water use can be indicated on location. Based on the classifications of these points can clusters and water use intensities be found. These waste water points indicate the locations of water treatment facilities. These facilities are often located in close proximity to the river and/or water body and are protected by localized dike bodies in the event that high water levels could hamper water distribution mechanisms and the potential for waste water to enter the hydrological river system of the Rhine, creating a possibly biohazard. To indicate the impact these waste water treatment facilities have on the surrounding dike lines, multiple indicators are used to indicate the autonomy of the adjacent dike lines.

Waste Water Treated pp (m3 per day)

Function of the Facility in the Area: Waste Water Treated per Person (Waste Distribution / Population Served): Indicates the Waste water that is treated at the facility in m3 per day per inhabitant that is related to the facility (According to the WWTP). This amplifies the functionality of the facility in the overall water management system, where the higher the treated water per person becomes, the higher potential for toxicity at the location (Higher percentage of treated waste water per population, the higher the protection levels will have to become to protect the facility for the power of the river).

Waste Water Treated PP (m3 per day)	**Weighted Autonomy**
0 – 0.15	5
0.15 – 0.3	4
0.3 – 0.45	3
0.45 – 0.6	2
0.6 – 0.9	1

Size of facility

Size of the Facility in Landscape: Total Capacity of the Facility (Designed Capacity – Population Served): Indicates the current size of the facility and its importance in the surrounding water management system. The calculations performed can indicate multiple results in the form of a Positive, Neutral and Negative Number. The more positive the number becomes the higher potential for the local dike body to indicate a higher localized dike autonomy, as there is potentially more room for flexible changes if needed.

Size of facility (Designed Cap – Population Served)	**Weighted Autonomy**
Negative – 0	5
0 – 10.000	4
10.000 – 50.000	3
50.000 – 200.000	2
200.000 – 800.000	1

Ehalt Macedo, H., Lehner, B., Nicell, J. A., Grill, G., Li, J., Limtong, A., Shakya, R (2021): Distribution and characteristics of wastewater treatment plants within the global river network. Earth System Science Data. 2022.

(I) Power Plant Production

As one of the largest water users within the Rhine river system, energy use is one of the largest economies dependent on the water supply of the Rhine river. Increasing searches towards alternative forms of energy have increased the dependency on the hydrological system. Swiss authorities are increasingly investigating the possibilities for new hyrdodams as the solution to its national energy use. Furthermore are the hydro powerplants of France and the energy basins of German coal and gas industries reliant on that same source. As Germany tends to move away from nuclear installations, leaving France as one of the only countries heavily invested in the nuclear economy, the impact on water use for energy consumption will only increase. The location of these power plants can be seen as important notions in the relation towards local dike autonomy. Based on the data of global power Plants, we define two main indicators that have impact on the autonomy of Dike Management

Type of Production

Type of Production: Primary Source: Indicates what type of fuel source is used to produce the energy needed. As these range from Waste Incineration to Nuclear Power Plants, the source and therefore also the amount of water needed in the process changes. The water use of the related power plants has a relation to the surrounding dike lines, as openings need to be facilitated to use the water of the Rhine as the source of water needed + the fact that certain fuel sources need to have local protection measurements included in case of floodings of the river.

Power Plant	**Consumption (Jin, et al. 2019)**	**Water Use (1)**	**Safety Regulations (3)**	**Dike Relations (0.5)**		**Total (W)**
Biomass	85.100	5	3	2		**3**
Coal	2.200	2	4	3		**3**
Gas	598	1	4	3		**3**
Hydro	4.961	3	2	5		**3**
Nuclear	2.290	2	6	5		**5**
Oil	3.220	2	4	3		**3**
Solar	330	1	1	1		**1**

Waste	0	1	3	2		**2**

Jin, Yi & Behrens, Paul & Tukker, Arnold & Scherer, Laura. (2019). Water use of electricity technologies: A global meta-analysis. Renewable and Sustainable Energy Reviews. 115. 10.1016/j.rser.2019.109391.

Production Capacity

Amount of Production: Capacity (mw): Indicates the production size of the power plant facility, further identifying its water usage in relation to its Function and Capacity for production. The higher the capacity of a power plant becomes, the more production it can facilitate, increasing its potential water usage.

Production Capacity (MW)	**Weighted Autonomy**
1 – 10	5
10 – 50	4
50 – 200	3
200 – 1000	2
1000 – 2000	1

Global Energy Observatory, Google, KTH Royal Institute of Technology in Stockholm, Enipedia, World Resources Institute (2019). Global Power Plant Database. Published on Resource Watch and Google Earth Engine. http://resourcewatch.org/ https://earthengine.google.com/

(I) Water Dependent Regions

For the formulation of water dependent regions, the idea is created that these regions (also including drinking water zones and natura 2000 areas) are dependent on a stable supply of water leading to the fact that rules and regulations overpower the autonomy of local water and dike management. This decreases the potential of local autonomy.

Percentage of Area	**Autonomy**
100 %	5
75 %	4
50 %	3
25 %	2
0%	1

Bundesanstalt für Gewässerkunde (2015). Interaktive Karten vom 2. Bewirtschaftungsplan (2015) ArcGIS Web Application. https://geoportal.bafg.de/IKSR-WFD2015-de/
