SYMBIOTIC WATERSCAPES

Interdependent water management in the urbanized
and cultivated landscape of the Rhine basin

Image 1 | Land erosion by powerfull floods in the Rhine basin in 2021
Source: BezirksregierungKöln on (2021) | adapted by author

COLOPHON

Master Thesis P5 report
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Msc Architecture, Urbanism and Buildings Sciences
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Department of Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology

Author: ***Samuel van Engelshoven*** *(4589580)*

Research Studio: ***Transitional Territories***

First Mentor: ***Ir. Leo van den Burg***
Department of Urbanism
Section of Urban Design

Second mentor: ***Denise Piccinini***
Department of Urbanism
Section of Landscape Architecture

Data sources of images and illustrations can be found in the bibliography (if applicable)

I would like to thank Leo and Denise for their support throughout the year, on campus and on distance. The mentoring has kept me motivated and challenged throughout the year.

And I would like to thank the Transitional Territories studio, students and mentors, for an inspirational journey.

MOTIVATION

I have always been fascinated by floodings of the flood plains as I grew up with the Rhine in my backyard. In my experience, it was something positive as nobody felt endangered by the water, and it was a special occurrence, especially when the flood plains completely froze last year and we could ice-skate on the Rhine. On the other hand, I have heard stories about the extremely high water of 1995 in this part of The Netherlands. Therefore I know how fragile we are when the water shows its force. In The Netherlands, the extensive Room for the River project has given back space to the river, but we still depend on how water is handled upstream to prevent floods here.

During my Architecture Bachelor and Urbanism Master in Delft, I have come into contact with the urgency of the climate crisis and mitigation and adaptation to this problem. I believe not enough is done to prevent environmental disasters caused by climate change; therefore, I would like to help tackle this problem within my profession of urbanism.

The droughts in the summers of 2018, 2019, and 2020, and the devastating floods in the summer of 2021 were not only a reminder of the urgency of this problem. It showed that simply dealing with floods is not enough. The urgency of water security is much broader and includes droughts and how people live with water.

Image 2 | Frozen flood plains of the Delta Rhine
Source: by author

ABSTRACT

The river Rhine is Europe's economic powerhouse. Without the Rhine, the Ruhr area and the port of Rotterdam wouldn't have developed into the economically leading industrial regions they are today. The economic power of the Rhine comes forward from the ability of humans to control the river. By rectifying and canalizing the river and constructing dams and locks, the ships' ability to navigate the river increased. This focus on economic development has caused critical environmental problems. Floods, droughts, and pollution are the most notable environmental threats to humans. This is intensified by climate change as extreme rainfall events and periods of drought will become more severe. Our current paradigm in flood risk management tells us to endlessly keep heightening our dykes, which is not a sustainable path to deal with flood risk. Heightening dykes also leads to shifting the problems elsewhere. If a river is not given space to flood its natural floodplains, it is forced to flow downstream more quickly, leading to a higher peak water level and potential floods downstream.

This master thesis introduces the concepts of socio-ecological symbiosis and clearance as means to improve water safety, the connection between humans and water, and the natural habitat. The central question of this research is: *How could water safety downstream be supported by upstream design interventions in the Northern Upper Rhine Valley, based on methods in which socio-ecological symbiosis and clearance are central?* As upstream water management strongly influences the downstream water safety, design exercises are executed in the Northern Rhine Valley with the goal to improve the water safety both downstream and locally. Three typological design exercises are set up which together form the proposed future water management strategy of the whole Rhine Valley.

KEY WORDS: Socio-ecological symbiosis, Clearance, Upstream-downstream interdependencies, Rhine basin, Water safety

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I.I THE RHINE

Symbiotic Waterscapes is formed around the relationship between humans and the river, which has deteriorated over the past century. This master thesis is built on a combination of crises many riverine territories on the globe are dealing with. The most prominent crisis is the risk of floods in communities along the river. Further, the synergistic design of the territory is highly valued. Aspects like drought, pollution, and ecosystem deterioration are all part of the crisis many rivers are experiencing.

The Rhine basin is the territory that is researched. This territory was chosen by the Transitional Territories graduation studio, which this research is developed within. The devastating floods of July 2021 in Germany show the urgency of the crisis. Contrastingly, the years before, the basin was struggling with droughts in the summers.

Downstream communities are highly dependent on how the river is used upstream. Therefore, pollution levels and water security are partly determined by upstream use of the river. This research will focus on how interventions upstream can prevent floods, drought, and pollution downstream. The northern Upper Rhine Valley is selected as a case study for this thesis.

RHINE STATISTICS

The territory that is researched is the Rhine basin in Western Europe. The Rhine flows from Switzerland, through France and Germany, towards the Netherlands, where it discharges into the North Sea. The basin also covers Luxembourg, Austria, Belgium, Liechtenstein, and Italy. The river is divided into the Alpine Rhine, Upper Rhine, Middle Rhine, Lower Rhine, and Delta Rhine. Especially the Upper Rhine, Lower Rhine, and Delta Rhine have extensive natural flood plains (potentially flooded in an extreme scenario, visualized in illustration 1).

The Rhine has a catchment area of 185.260 km2 and has an average discharge of 2.300 m3/s. The river is a primary infrastructure in one of the most vital European economic regions. Almost 60 million people live in its basin in cities like Rotterdam, Mainz, Strasbourg, and Basel. The river is not only used for transportation; energy production, drinking water extraction, tourism, industry, agriculture, and urban sanitation are all supported by its waters. (Arndt et al., 2009)

HISTORIC DEVELOPMENT

"THE RHINE RISES IN THE LAND OF THE LEPONTII, WHO INHABIT THE ALPS, IN A LONG SWIFT COURSE, IT FLOWS THROUGH THE TERRITORIES OF NANTUATES, HELVETII, SEQUANI, MEDIOMATRICES, TRIBOCI, AND TREVERI, AND ON ITS APPROACH TO THE OCEAN DIVIDES INTO SEVERAL STREAMS, FORMING MANY LARGE ISLANDS (A GREAT NUMBER OF WHICH ARE INHABITED BY FIERCE BARBARIC TRIBES, BELIEVED IN SOME INSTANCES TO LIVE ON FISH AND BIRDS' EGGS); THEN BY MANY MOUTHS IT FLOWS INTO THE OCEAN."

This is the first written text about the Rhine, cited in Cioc (2002, p.6-7). Multiple centuries ago, the Rhine functioned mainly as a border; it was best known as a border of the Roman Empire two millennia ago. The best-known border conflict is the annexation of Alsace by the Kingdom of France, making the Upper Rhine its eastern border. Later France annexed the complete western bank of the river from Switzerland to The Netherlands. The Alsace territory has switched administration multiple times; it has belonged to France since the second world war. (Arndt et al., 2009)

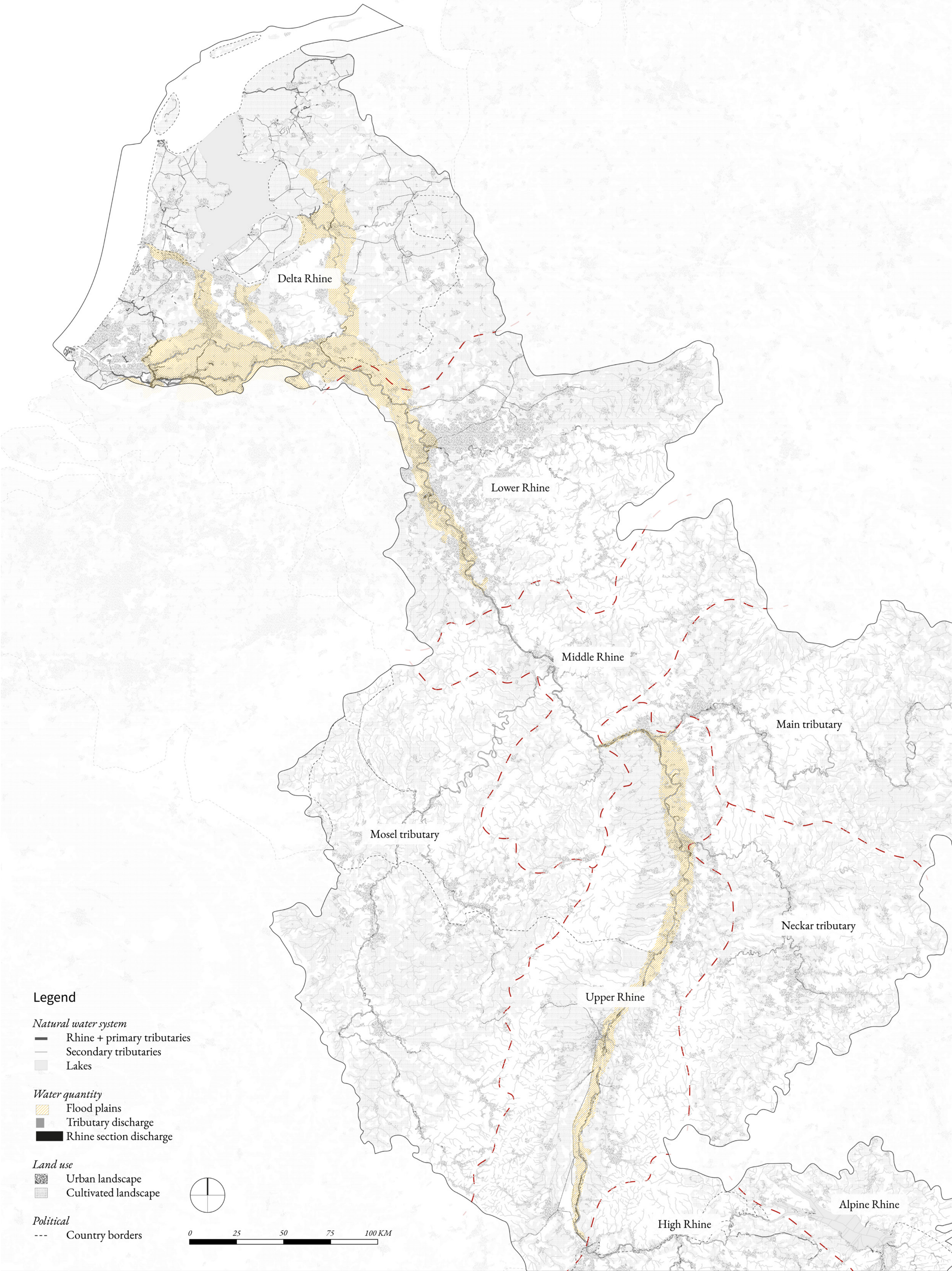


Illustration 1 | Rhine basin and its flood plains
Source: by author

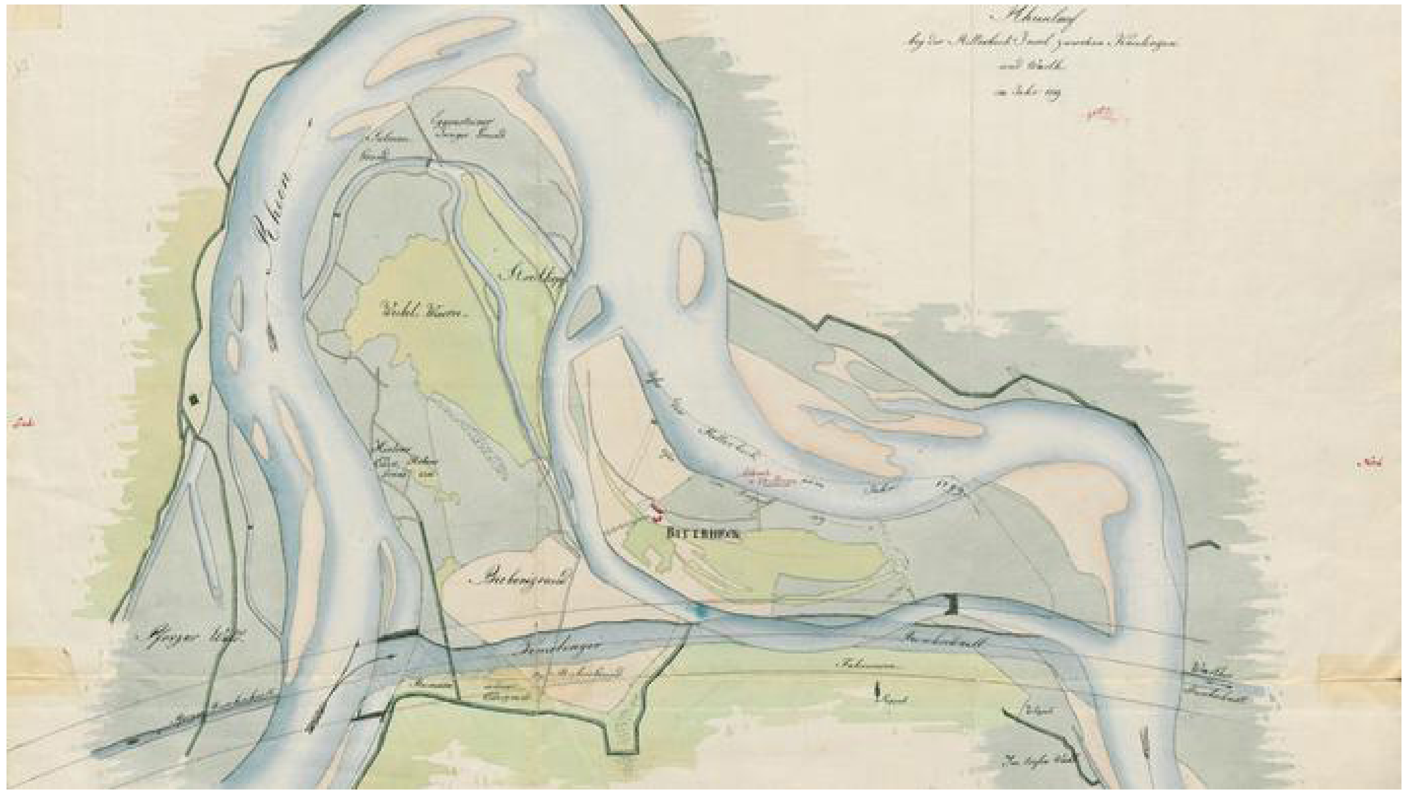
I.I THE RHINE

The impact on the river itself was limited during the border disputes. This would change with the arrival of large-scale mining and chemical industries and a population boom. This led to heavy pollution by wastewater in the lower parts of the Rhine. In 1950 the International Commission for the Protection of the Rhine (ICPR) was established to combat the increasing problems caused by pollution. In 1970 the International Commission for the Hydrology of the Rhine basin (CHR/IKHR) was founded to increase transboundary knowledge on the river's hydrology. (Arndt et al., 2009)

The quality and ecology of the river were, until the establishment of the ICPR, not equally important as the economic power of the Rhine. In 1816 the Central Commission for the Navigation of the Rhine (CCNR) was founded as freedom of navigation on international rivers was established the year before, and international rules for transportation were necessary. The river was already an important trade route during the Roman Empire. Nevertheless, until the 19th century, it was often difficult to navigate. This led, together with the need for flood protection and agricultural land reclamation, to a heavily altered channelized river. These engineering works have caused the river to be navigatable from the North Sea up to the Swiss town of Rheinfelden in the High Rhine. (Arndt et al., 2009)

Engineering works have been standard practice in the Delta Rhine since the Middle Ages. In the Upper Rhine, major changes were made in the 19th century. Johann Gottfried Tulla commissioned the rectification of the Rhine between Basel and Worms; construction was started in 1817 (illustration 2). Cutting of the river's meanders has decreased the length of the Rhine between Basel and Worms by 82km (21% of its length). The project aimed to eliminate water-borne diseases, increase flood safety for multiple towns, reclaim agricultural land, and make the river easier to navigate. Narrow channels were dug, and the river's power was used to erode the channel to a 200-meter (or more) wide river. However, this erosion also had negative consequences. Shortening the river made it steeper, and therefore the water flowed faster. This led to the unexpected erosion of the riverbed. It helped to dewater the swamps to turn them into arable land, but it also created rapids near Basel that were difficult to navigate. (Cioc, 2002)

The second large-scale alteration of the Upper Rhine is the construction of the Grand Canal d'Alsace. This channel was constructed parallel to the river, and its main goals were the production of hydropower and increasing navigability.
(Arndt et al., 2009)



▲ *Illustration 2 | Plan for rectification of the Rhine*
Source: Generalandesarchiv (2021)

I.II THE GLOBAL ISSUE

SUSTAINABILITY CRISIS

Planet Earth is enduring a tumultuous period from the perspective of its ecological system. Earth was going through a relatively balanced period of more than ten thousand years, called the Holocene. The circumstances were perfect for life to flourish, particularly human life, which was able to evolve into the species we are today through this balance. Recently a new geological epoch has manifested itself, the Anthropocene. There is still doubt about when this period began, but the truth is that it identifies the period in which humanity significantly impacted Earth's climate and ecosystems (National Geographic, 2019). Humanity has impacted its home to such an extent that the balanced climate that made us thrive is gone. Unfortunately, our impact goes beyond that. The climate and ecosystems are affected to such a degree that it jeopardizes their ability to support human life and many other forms of life. This makes it a necessity to act, to keep Earth livable for humans and other organisms. Transforming a planet's environment to be habitable for humans is described as the act of terraforming.

This global crisis is such an urgent and unavoidable problem, that the development of the Rhine basin stands in the shadow of the larger act to terraform Earth.

Illustration 3 | An artists illustration of the sustainability crisis
Source: Johansson (n.d.)

I.III THE REGIONAL ISSUE

Zooming back into the rhine basin, the status of this territory is looked at and how problem accelerators like climate change have and will affect them.

PROBLEM ACCELARATORS

In the past century, many engineering works have been done in the Rhine basin, most of which had the purpose of supporting economic growth, forgetting about any environmental concerns. This has caused the relationship between humans and the water to degrade. Due to human activity, the force of water has hurt us to an increasing extent. This has led our relationship with water to be based on fear, as we can see, for example, in the construction of dykes which are made from the fear of flooding.

Due to climate change, extreme rainfall events will be more severe and happen more often. Our current paradigm tells us to heighten the dykes endlessly; this is not a sustainable solution, and we cannot keep going in this direction. It will cause much pain for humans and their environment. Water is the essential element for life to be possible; we need water to sustain us and all other forms of life, now and in the future. To live with water in a sustainable manner, a new balance must be sought in the socio-ecological relations in the Rhine basin. It is time for a new narrative in which we respect the water and natural processes (socio-ecological symbiosis) and make the basin a place for humans to thrive instead of a place that is making us fear.

These problem accelerators primarily affect three problem fields: floods, drought, and pollution.

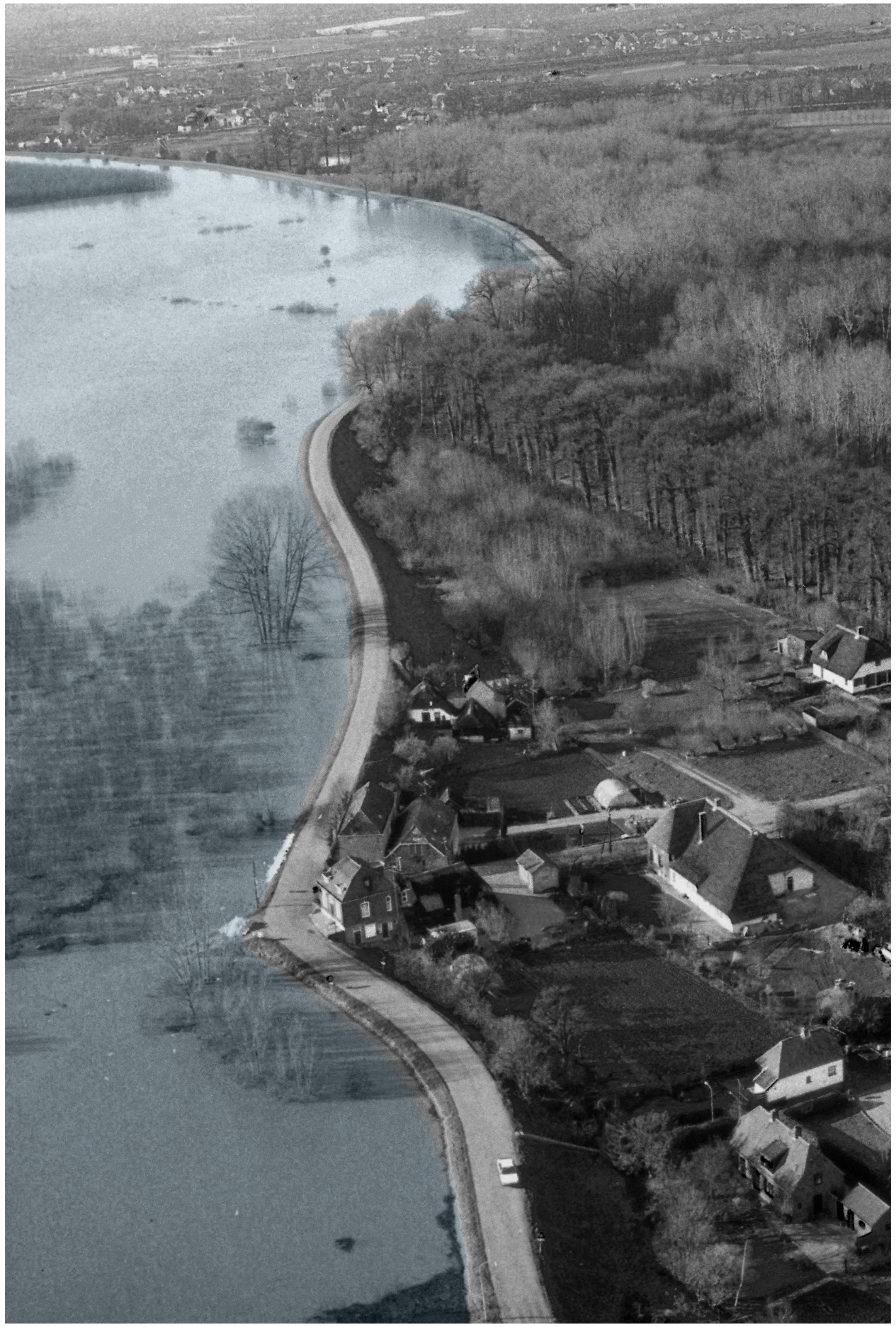
FLOODS

Floods are generated by two processes: melting snow and glaciers and rainfall. The process of melting is a relatively stable yearly re-occurring event. Nevertheless, this process is significantly altered by climate change. The amount and moments of snowfall are changing, the moment of large-scale melting begins at an earlier stage of spring, and glaciers lose more mass throughout the year due to higher average temperatures.

These changes lead to two main focal points, timing and amount of melting-water discharge. The impact of melting water on flooding primarily affects the main branch of the river Rhine. The main problem for this process is how to prevent this from causing floods without being able to tackle the source of the problem.

The second process, rainfall, is less predictable than melting water. Due to climate change, the total rainfall will increase in the Rhine basin, but the main problem is the increased occurrence of extreme rainfall events, leading to floods in the whole Rhine basin. Climate change is making this problem worse, but the source of this problem is not only of climatic nature. Land use, urban areas in flood plains, and anthropic elements in the river are all part of the source of the problem. In July 2021, parts of the Rhine and Meuse basin were flooded due to extreme rainfall. Most damages were recorded in the middle stream of the river, where most rain fell, which caused dramatic flash floods. Downstream areas of the rivers were spared from flooding. However, rainfall in upstream and middle stream parts of the river could lead to floods downstream in the future. Downstream floods could happen if a larger part of the basin receives significant rainfall or the rainfall coincides with a melting-water peak.

A stressing example are the floods of 1995 when extreme rainfall and some melting water caused extreme high water levels downstream the Rhine and Meuse rivers. The Netherlands was on the verge of a disaster. Fortunately, dykes could keep the urban areas dry in most locations (image 3). Nevertheless, a worse flooding event could breach the dykes, a disaster that is becoming more likely due to climate change. Therefore an intervention in the hydrological situation of the Rhine basin is necessary. Interventions in the elements which cause the problem could lead to other problems, the most important of which are food- and energy security. Therefore any intervention needs a broad scope to reach an integral solution to the flooding problem. (Vinet, 2008)



▲ *Image 3 | Extreme high water in Rivierenland in 1995*
Source: van Eyck & Rijkswaterstaat (1995) | adapted by author

I.III THE REGIONAL ISSUE

DROUGHT
Rainfall events are becoming more severe and common, while the annual rainfall will remain relatively stable. This means rain will fall more fragmented, and periods of drought will become more likely. The basin is very vulnerable to this climatic change caused by human alterations to the landscape. These alterations have caused less water to be buffered in the soil and wetlands. Past deforestation and river rectification projects are primarily responsible for this vulnerability. As this problem is opposing floods, it creates a challenging task to tackle both problems together.

POLLUTION
The third environmental problem of the Rhine is pollution. The river is heavily polluted by many sources like pesticides, medicine residue, and microplastics. This is increasingly causing problems for the riverine ecosystem and humans; for example, drinking water extraction is impossible when the river is very contaminated.

ANALYSIS
Understanding these problems within the context of the Rhine basin is essential to determine what is causing them. The problem analysis in the next chapter aims to uncover the sources of the problem fields to mitigate them through concept building and research by design effectively.

▲ *Image 4 | Extreme low water in the Rhine*
Source: Welters & The New York Times (2018)

▲ *Image 5 | Dead eel in the aftermath of Sandoz fire in 1986*
Source: dapd (2011)

II PROBLEM ANALYSIS

ACCUMULATION

.I MATTER

.II TOPOS

.III HABITAT

.IV GEOPOLITICS

.V PROBLEM STATEMENT

MONOGRAPH TAXONOMY

The monograph series *accumulation* is a problem analysis firmly based on the concept of accumulation. The analysis is divided into four lines of inquiry: matter, topos, habitat, and geopolitics. Each line is constructed of three illustrations: composition, alteration, and limit. A catalog of the illustrations is provided in illustration 11.

The notion of accumulation is jointly defined by the Transitional Territories graduation studio:
"The Urban is no longer defined by borders on the spatial domain. Urbanization and its socio-spatial-environmental- cultural and geo-political implications are an accumulation of active and highly dynamic processes, which co-exist, overlap, dissect and interact. In the attempt to unravel the complexity of the contemporary Urban, the Transitional Territories approach to critical mapping seeks for alternative lines of inquiry to deconstruct the ongoing processes towards a synthetic and critical cartography. By deconstructing Accumulation from the perspective of Matter, Topos, Habitat and Geo-politics, we understand how subjects and objects are composed, what are the alterations that influence their nature, and what are the limits of their performance and qualities.

This gradual fading of boundaries between domains is initiated and accelerated by the accumulation of spatial elements and processes that lead to an uncertain living environment. The current era is intrinsically defined by accumulation and because of it, its landscapes can be called "Landscapes of Accumulation". It is not only accumulation of capital (economic, human or other), but also of materials(in the most extensive interpretation of the notion): plastic in the oceans, carbon in the Atmosphere and even anxiety over the impotence of change. (Nick Axel et al, 2019). Through the critical mapping of "the landscapes of accumulation" the studio projects seek for an understanding of the present layers of materialization and processes blocking the agency (nor the narratives) of sustainability to reinforce a more inclusive ethics regarding ecologies and their values.

The identification, deconstruction, and analyses of the landscapes of accumulation defines the problematization of each research project in the studio. What are current conflicting conditions that need to be considered when looking into the future? What are the layers of accumulation of materials and practices? Where is the accumulation stretched to exhaustion of land or resources? What are the socio-cultural, economic, environmental and spatial consequences of the present state of the urban and territorial project?" (Transitional Territories Studio 2021-2022, 2022)

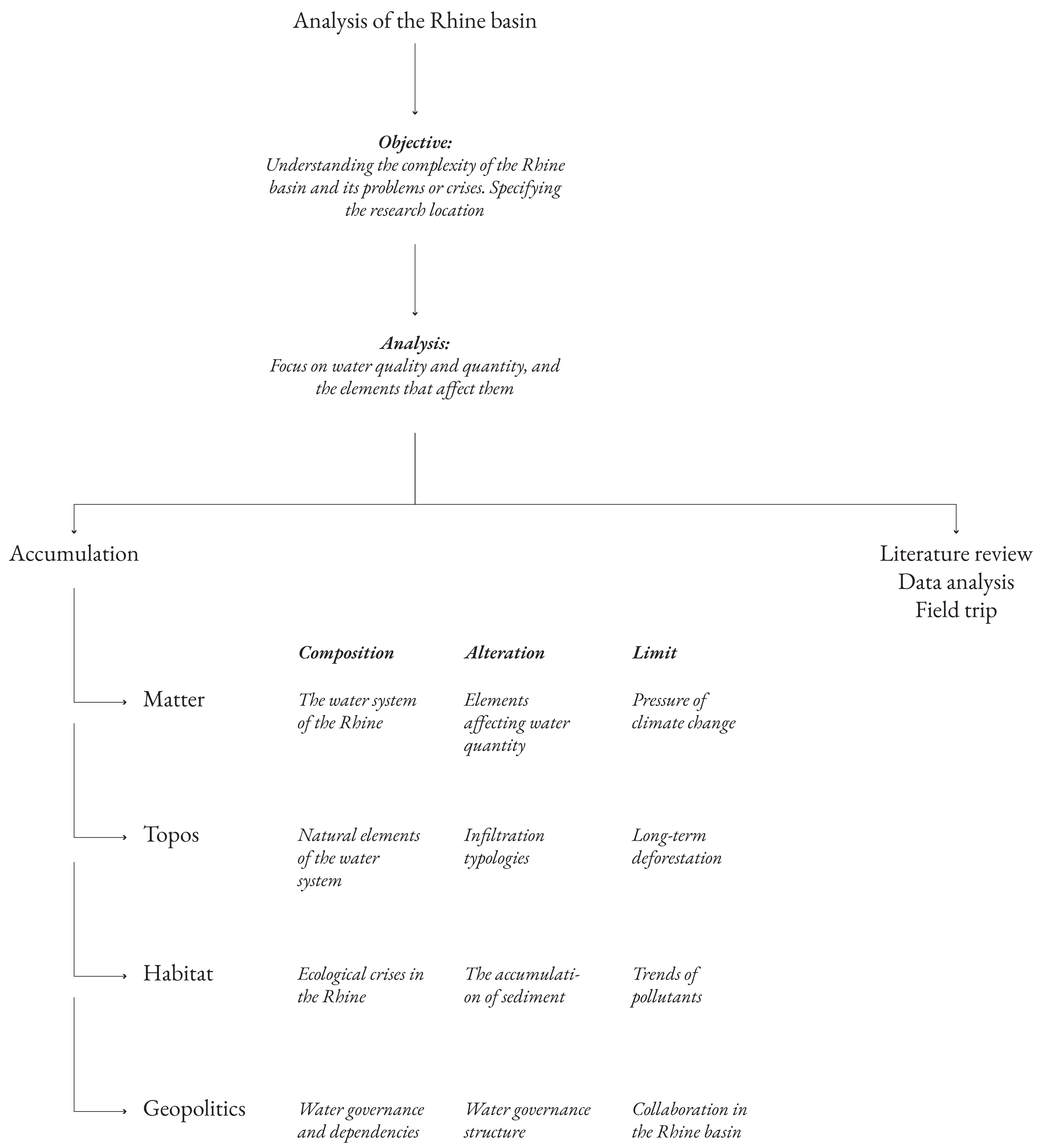


Illustration 4 | Taxonomy of the problem analysis and the monographs of Accumulation
Source: by author

CATALOGUE OF MATTER

- Extreme rainfall quantity (10 year return period)
- Rivers and canals
- Flood plains
- Discharge information
- Cultivation landscape
- Urban landscape

COMPOSITION

The first composition is regarding matter. The type of matter chosen is water, as it is the central element in the flooding problem researched. This composition aims to understand the Rhine's water system and uncover locations of interest. The central question behind this drawing is: where does the water come from, and whereto does it flow? Extreme rainfall data shows that most extreme rainfall occurs in the Upper- and Alpine Rhine, which is caused by the mountainous terrain. Extreme rainfall often leads to high peak discharges in the river's tributaries. The Mosel, Neckar, Aare, and Main are the most important tributaries of the Rhine.

The riverbed is not large enough to contain all its water during peak discharges. Therefore it floods its surrounding lands if the topography allows. The most extensive natural floodplains are found in the Upper Rhine Valley and the Lower- and Delta Rhine. These flood plains are marked with yellow in illustration 5. Due to the construction of dykes the river is prevented from flooding these plains. However, in an extreme scenario, these flood plains could be inundated despite the presence of dykes (ICPR, 2001). Land use data is overlayed to understand the consequences of this extreme scenario. This shows that the potentially inundated area is highly urbanized and used intensively for agriculture. Therefore a large-scale flood would have devastating economic and emotional consequences.

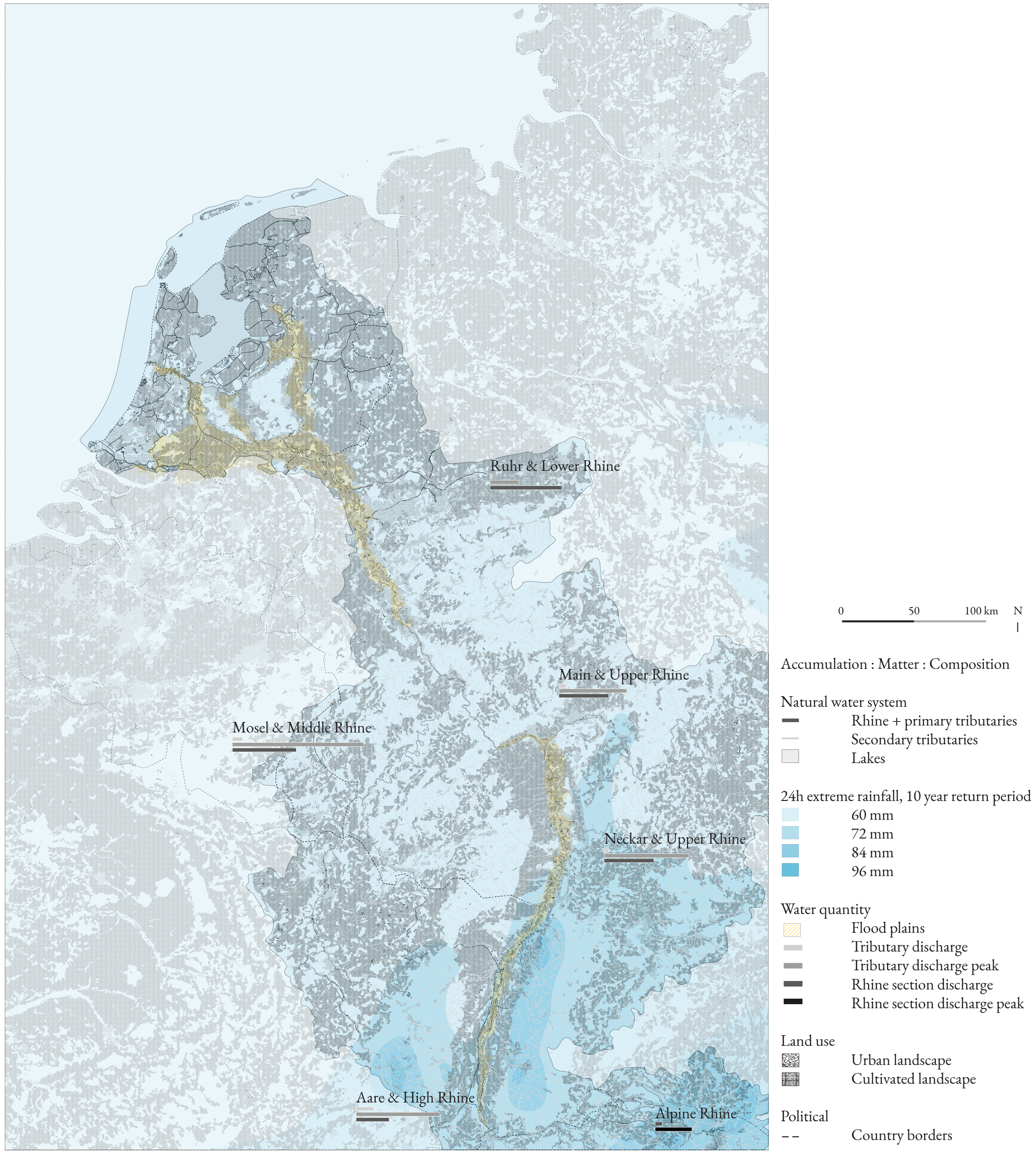


Illustration 5 | Monograph 'Accumulation: matter: composition'
Source: by author

After discussing the general water system, more detail is still necessary to understand the factors which lead to floods. Illustration 6 is a schematic illustration of a few factors. Dykes protect the functional land use within the natural floodplains of the river. By the construction of these barriers, space is taken away from the river. The river is therefore forced to flow downstream more quickly during peak discharge, and the water level is heightened. The additional problem is that it becomes more likely that the discharge peak coincides with the discharge peak of the main tributaries, increasing the problems downstream (Lammersen et al., 2002).

Other essential factors are the amount of rainfall and land use. Cultivated and urban landscapes often have a lower infiltration capacity than a forest. Therefore more water runs off to the river quickly, increasing the discharge peak. In the Rhine basin, most rain falls in mountainous terrain predominantly covered by forest. Areas with low infiltration capacity often endure less rainfall, which is positive as it does not increase the peak discharge.

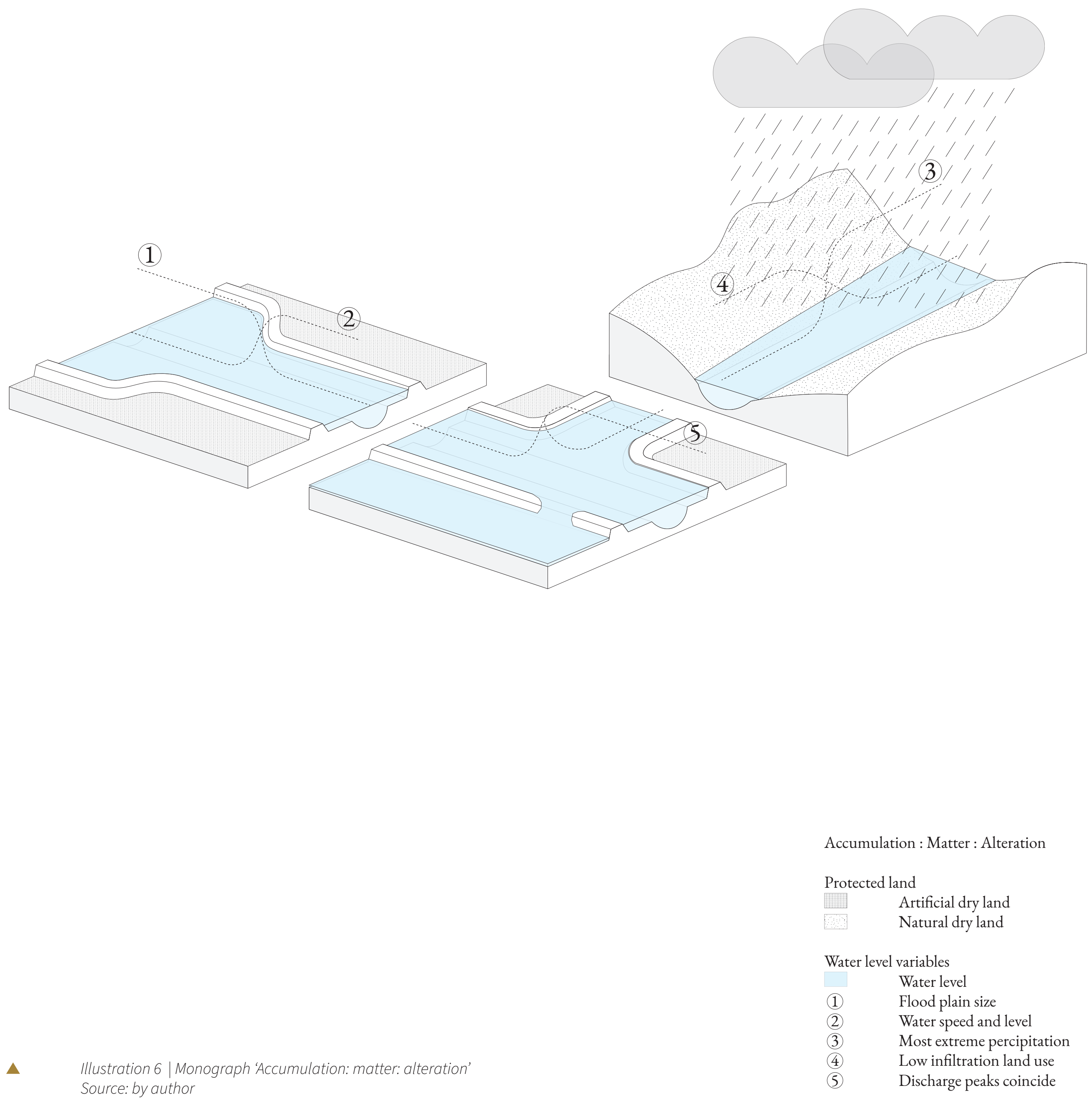
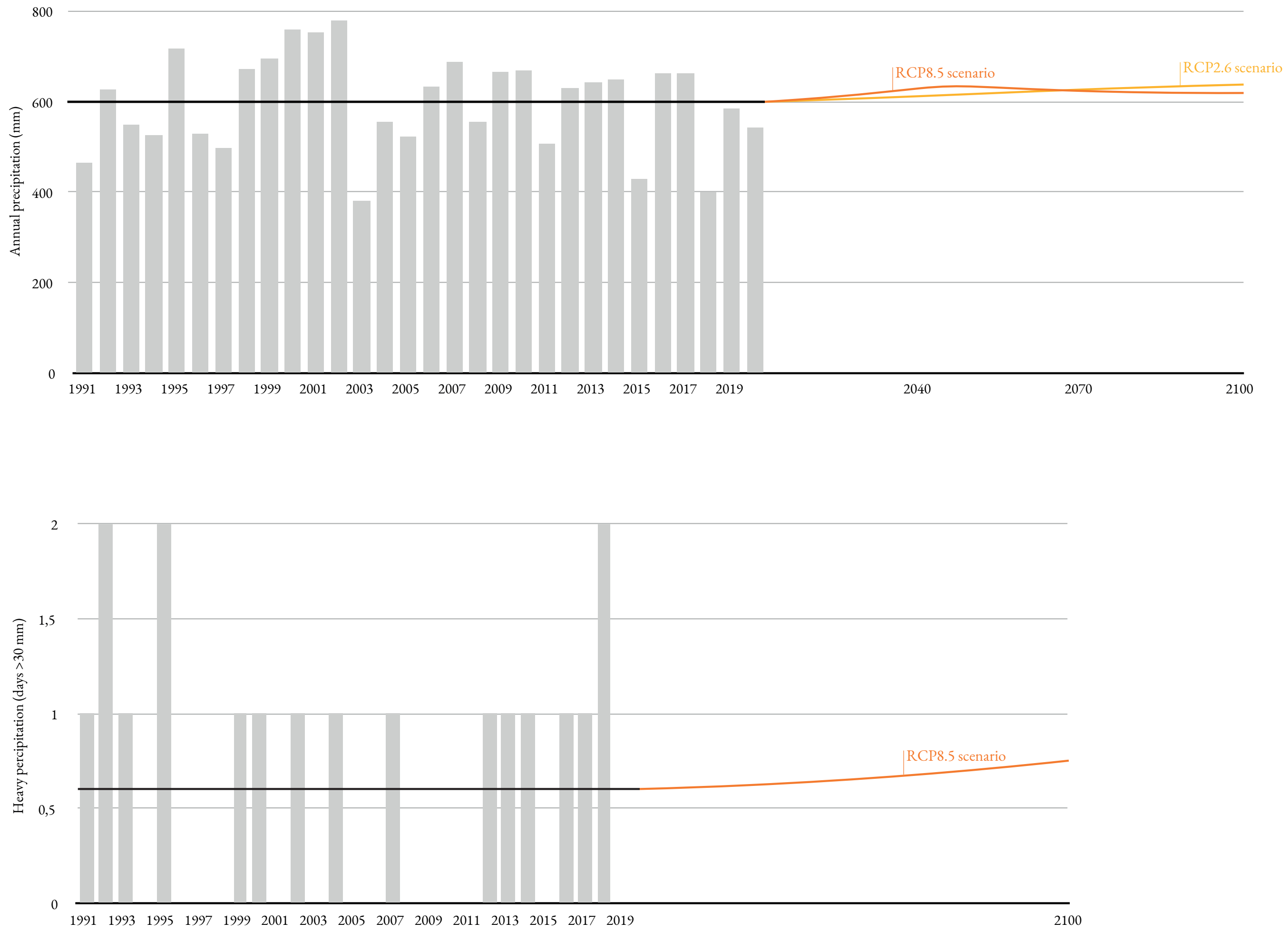


Illustration 6 | Monograph 'Accumulation: matter: alteration'
Source: by author

Climate change is testing the limits of the current water system. The limits of the water system are defined as the balance between the natural and human systems. Climatic projections suggest the annual rainfall will increase slightly, but the increase in extreme rainfall events is more significant. The severity and occurrences will increase so that floods will become more likely.



Accumulation : Matter : Limit

Frankfurt rainfall data
- Projected rainfall RCP2.6
- Projected rainfall RCP8.5
- Historic rainfall average

Illustration 7 | Monograph 'Accumulation: matter: limit'
Source: by author

Image 6 | Droughts in the floodplains
Source: by author

CATALOGUE OF TOPOS

- Forest cover (coniferous, broadleaf, mixed)
- Water absorption capacity
- Topography
- Annual rainfall higher than 1000 mm

COMPOSITION

Topos is the second line of inquiry. This composition shows the natural world beyond humans and animals. Its primary goal is to understand the elements influencing water infiltration. Topography is the base layer, as its adaptation cycle is the slowest. Topography significantly influences water infiltration as quick water run-off is more likely on steep slopes. This means all areas with steep slopes are of interest as it could create an extreme discharge peak in combination with extreme rainfall.

Three other layers which influence the infiltration capacity are projected onto the topography. Forest cover (divided into coniferous, broadleaf, and mixed forest) positively influences rainwater absorption. The soil structure is more capable of water infiltration due to its organic make-up. Furthermore, living and decaying tree roots can transport water underground much faster than the soil can (Marritz, 2021). Each soil type has a different infiltration capacity; therefore, an additional layer showing high water absorption capacity is added. A high infiltration capacity's importance depends on the amount of water a particular location receives. Areas with relatively high annual rainfall are added to the composition.

Most steep slopes are covered by forest and have a relatively good infiltration capacity. However, steep slopes around the Rhine and its main tributaries often lack forest cover as they are mainly used for viniculture, making them fragile for extreme water run-off. The northern Upper Rhine Valley and the area north of the Ruhr tributary are remarkable as they have a low infiltration capacity while having a landscape marked by gentle slopes.

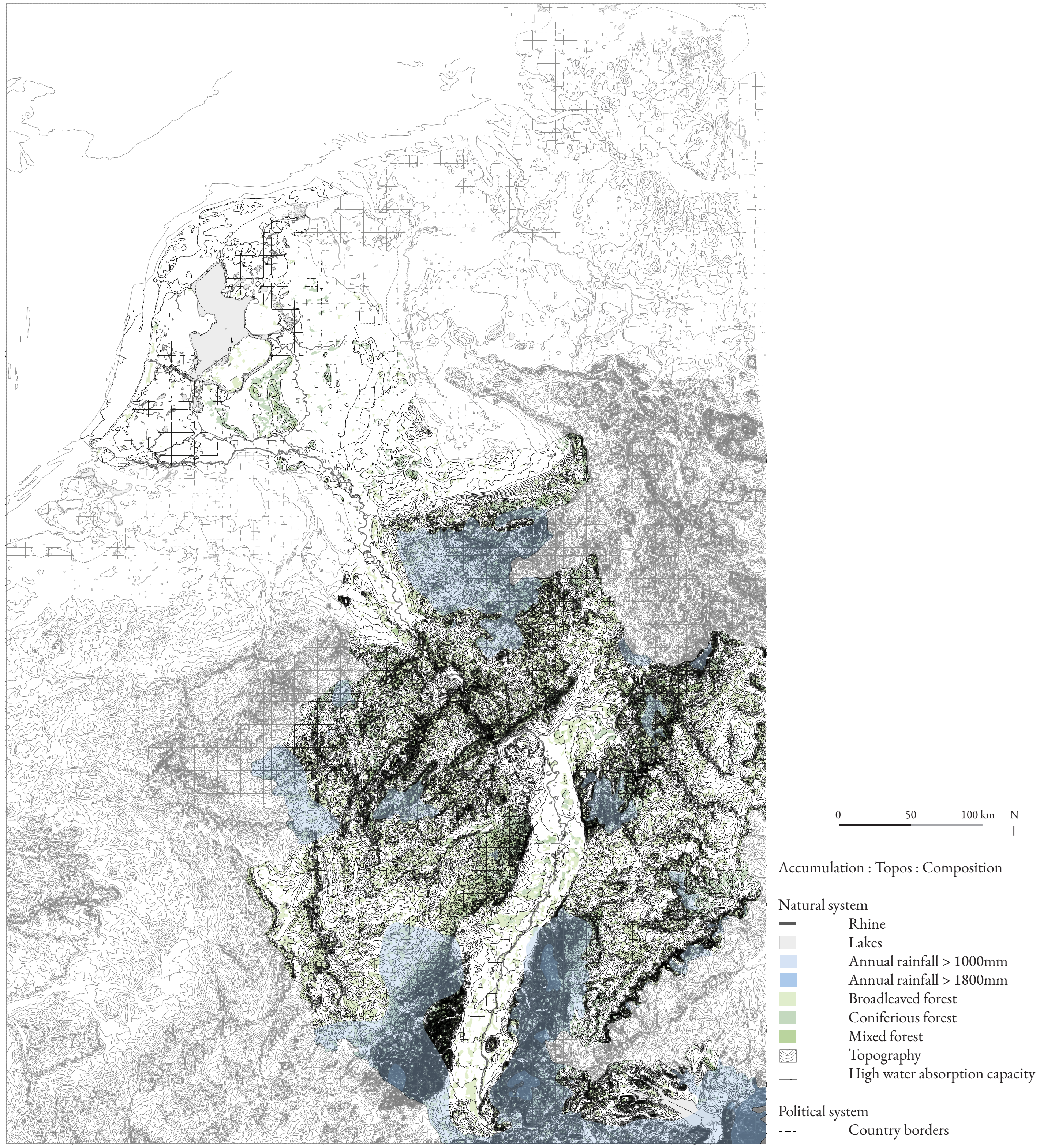
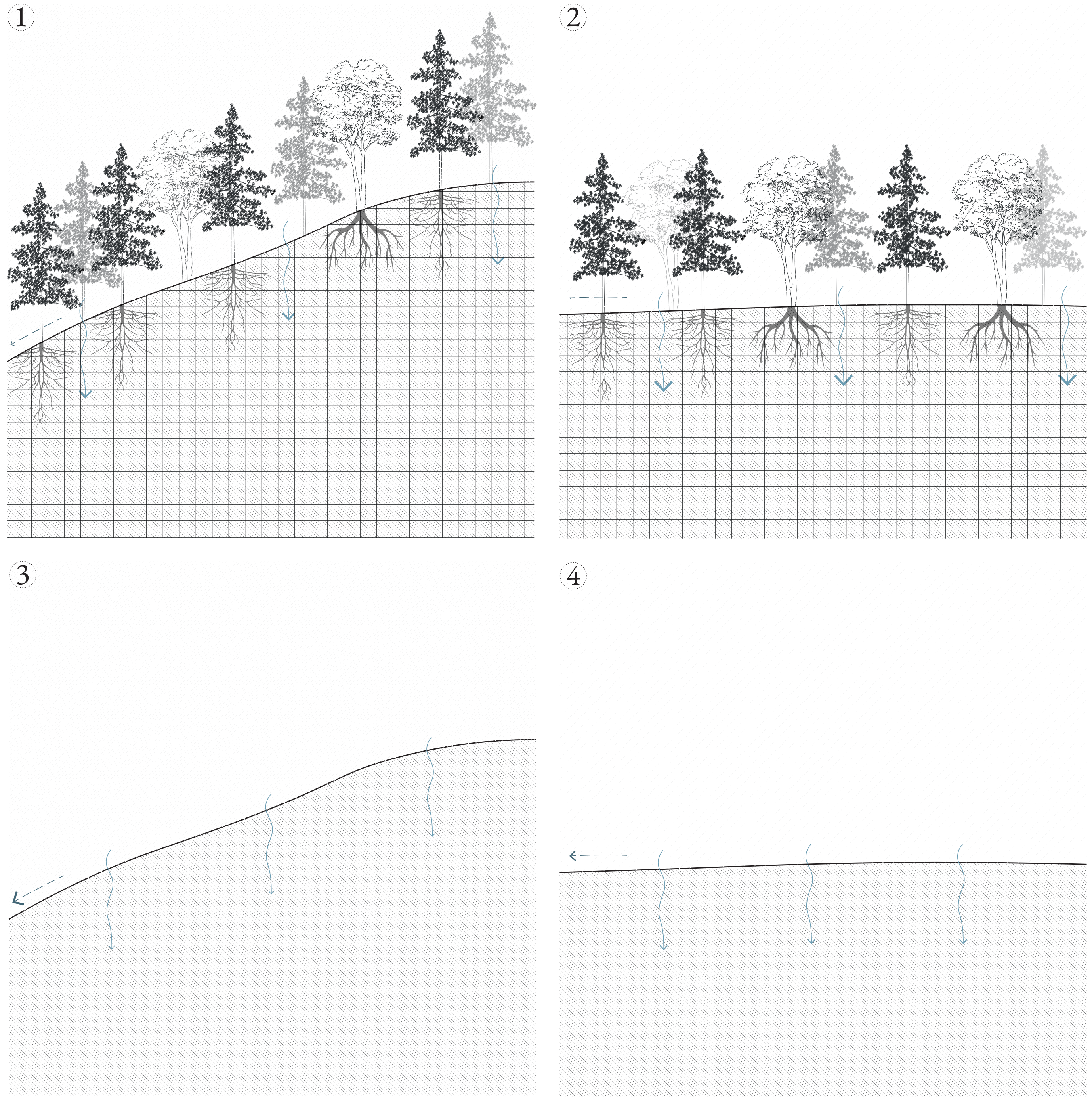


Illustration 8 | Monograph 'Accumulation: topos: composition'
Source: by author

II.II **TOPOS:** ALTERATION

Based on the composite map, four representative infiltration landscapes are illustrated. Areas covered by forests almost always have a high water absorption capacity. There are two distinct infiltration landscapes with forest cover; forests on land with minor height differences and forests on steep slopes with a relatively high quantity of annual rainfall. The higher amount of rainfall and the steep slopes cause more run-off in the second type.

There are also two distinct infiltration landscapes without forest. Run-off is higher than on forested land on both steep and gentle slopes. If the type of soil allows a high absorption capacity on steep hills, more run-off is still expected than on gentle slopes, partly because of the higher amount of annual rainfall.



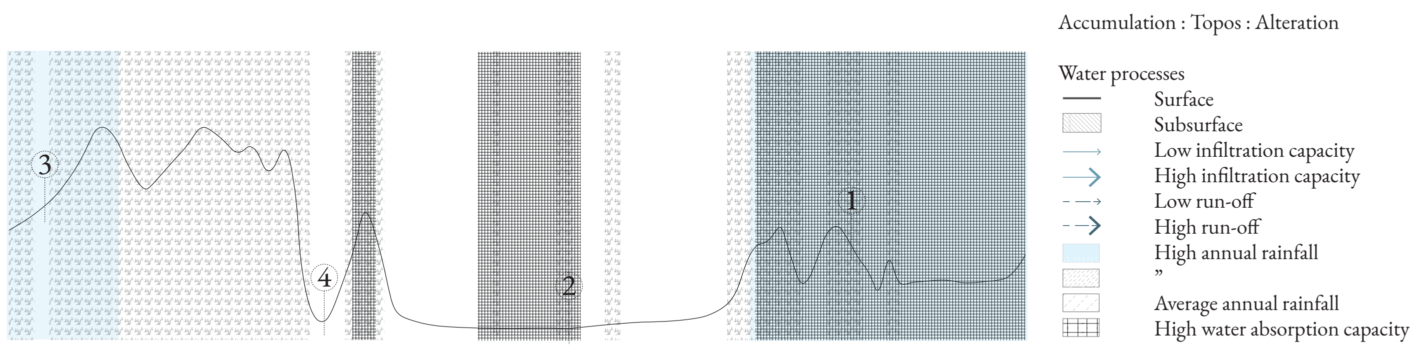


Illustration 9 | Monograph 'Accumulation: topos: alteration'
Source: by author

Forest cover and topography are the leading factors for the infiltration capacity. Both factors are examined through time to understand the possibilities of developing these infiltration landscapes. Topographic alterations are happening at a languid pace; any significant changes to the topography would fall outside the scope of this research. Forest cover changes relatively fast. However, in western Europe, the change in forest cover has developed at a slower rate than, for example, the Amazon rainforest. For the past 100 years, the forest cover has remained relatively stable. Looking back more than 3000 years gives a better representation of deforestation. 1000 BC, about three-quarters of Western Europe was covered by forest. This means that nowadays, the infiltration capacity of this land, including the Rhine basin, is significantly lower than its pristine natural state. Gradually, more pressure has been put on the rivers, making floods more common and severe.

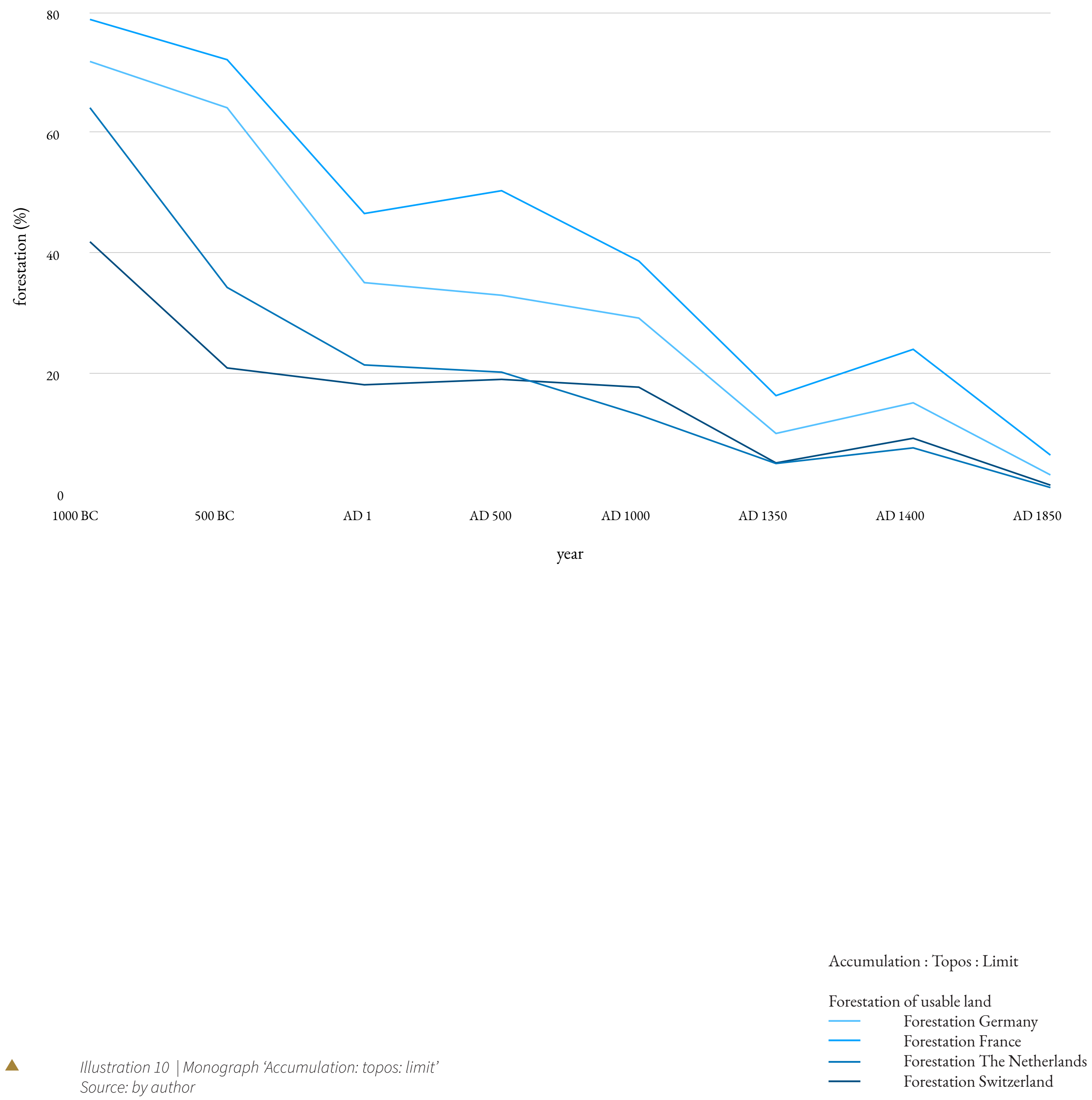


Illustration 10 | Monograph 'Accumulation: topos: limit'
Source: by author

Image 7 | Where forests are gone
Source: by author

CATALOGUE OF HABITAT

- River pollution by pesticides
- River pollution by microplastics
- Cultivated landscape
- Urban landscape
- Dams and dams with fish passage
- Rivers and canals
- Sediment nourishments

COMPOSITION

The notion of habitat explores the impact of human presence on the habitat of animals and nature. Water pollution and ecological barriers are the two topics explored.

The most significant increase in pesticide levels is observed between Lauterbourg in the Upper Rhine and Koblenz in the Middle Rhine. This corresponds to the high percentage of space used for agriculture in the Upper Rhine Valley and the Main and Neckar tributaries. Microplastic concentrations are relatively low in this part of the Rhine. Plastic particles clearly peak in the Lower Rhine. This corresponds with the Ruhr agglomeration. Remarkably, the microplastic levels are significantly lower in Rotterdam; this could mean plastic particles are accumulating on river banks. More research is needed on this topic.

The second disturbance is the multitude of dams. Up to Iffezheim, the Rhine is a free-flowing river. Upstream dams are constructed to increase the river's navigability as the height difference increases. These dams are also used for the extraction of hydropower. In the tributaries, dams are more common than in the main branch of the Rhine. Dams make it impossible for fish to migrate up and downstream. This limits their capability to find suitable breeding grounds. Together with the pollution of the river and overfishing, this has led to the extinction of multiple species like salmon (van Leeningen, 2020). Nowadays, fish passages are installed in the main branch of the Rhine. However, these passages are designed for salmon as bringing back this fish is the goal of new protective policies. This means dams are still difficult to pass for other species. Dams also disturb natural sediment flows, which is discussed in more detail in the next chapter.

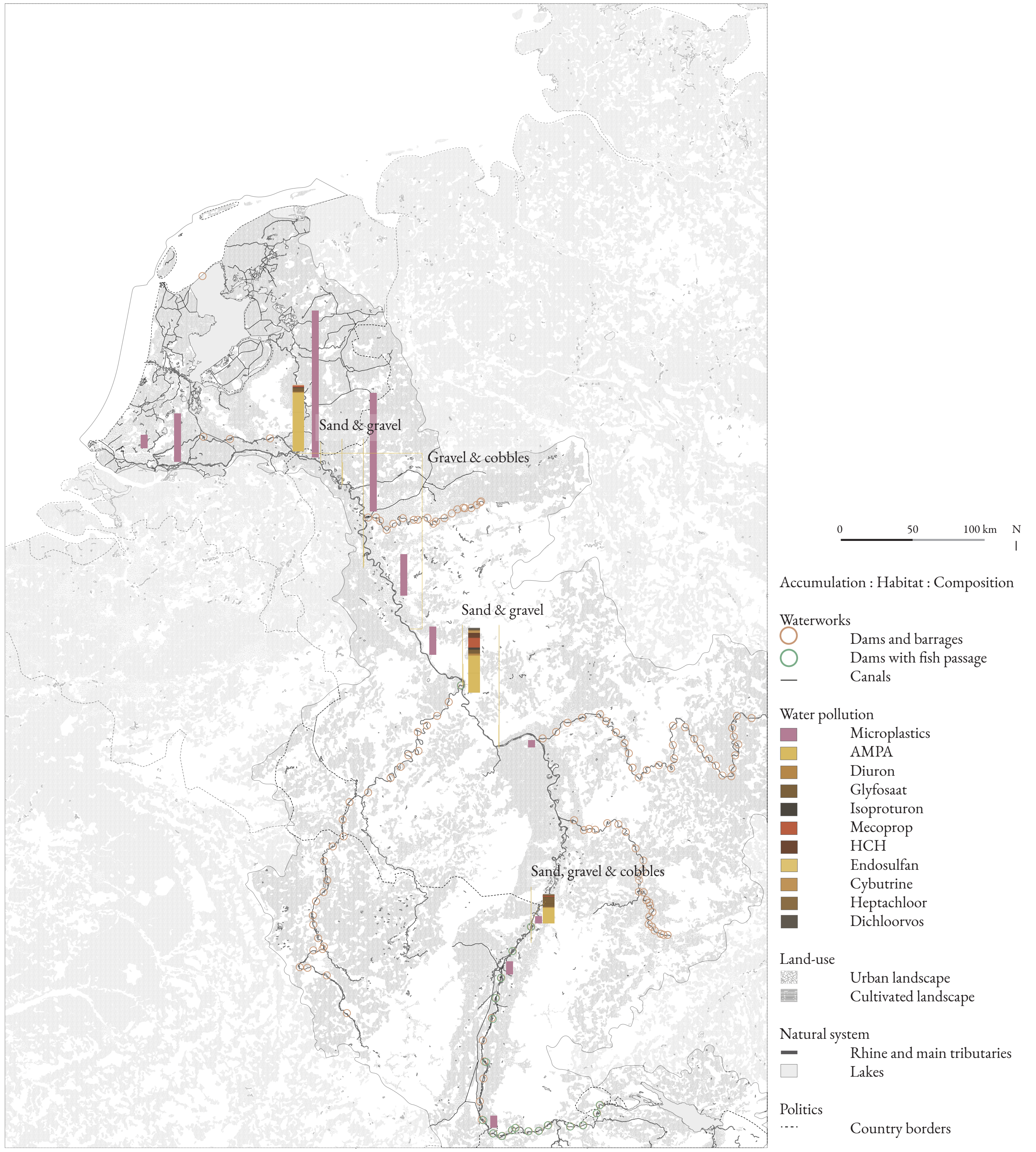


Illustration 11 | Monograph 'Accumulation: habitat: composition'
Source: by author

Downstream of the dams, fewer sediments are present in the river, especially coarse sediment like sand and gravel cannot pass the dams. This leads to the erosion of the riverbed. To combat this, sediment nourishments are carried out in multiple locations (International Commission for the Hydrology of the Rhine basin, 2009). Sediments are crucial for bringing nutrients downstream for marine life and riverbank vegetation.

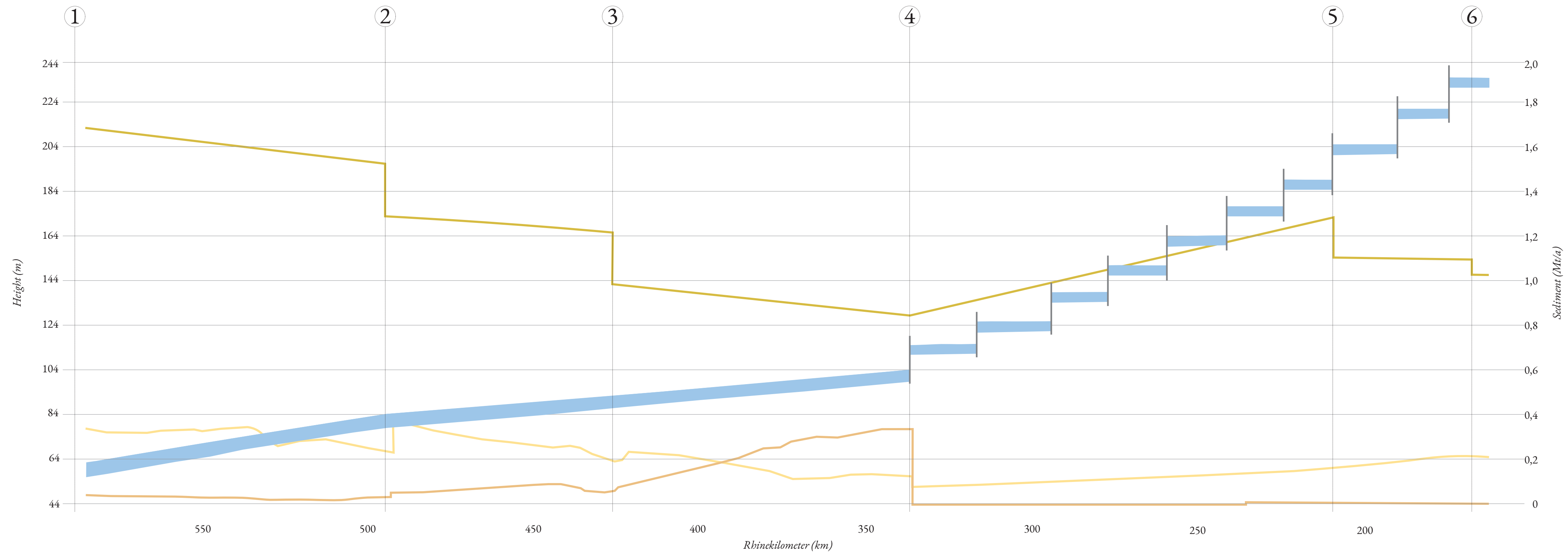


Illustration 12 | Monograph 'Accumulation: habitat:alteration'
Source: by author

Accumulation : Habitat : Alteration

Longidutual sediment flow
Water level
Dam
Clay and sand sediment flow
Sand sediment flow
Gravel and cobble sediment flow

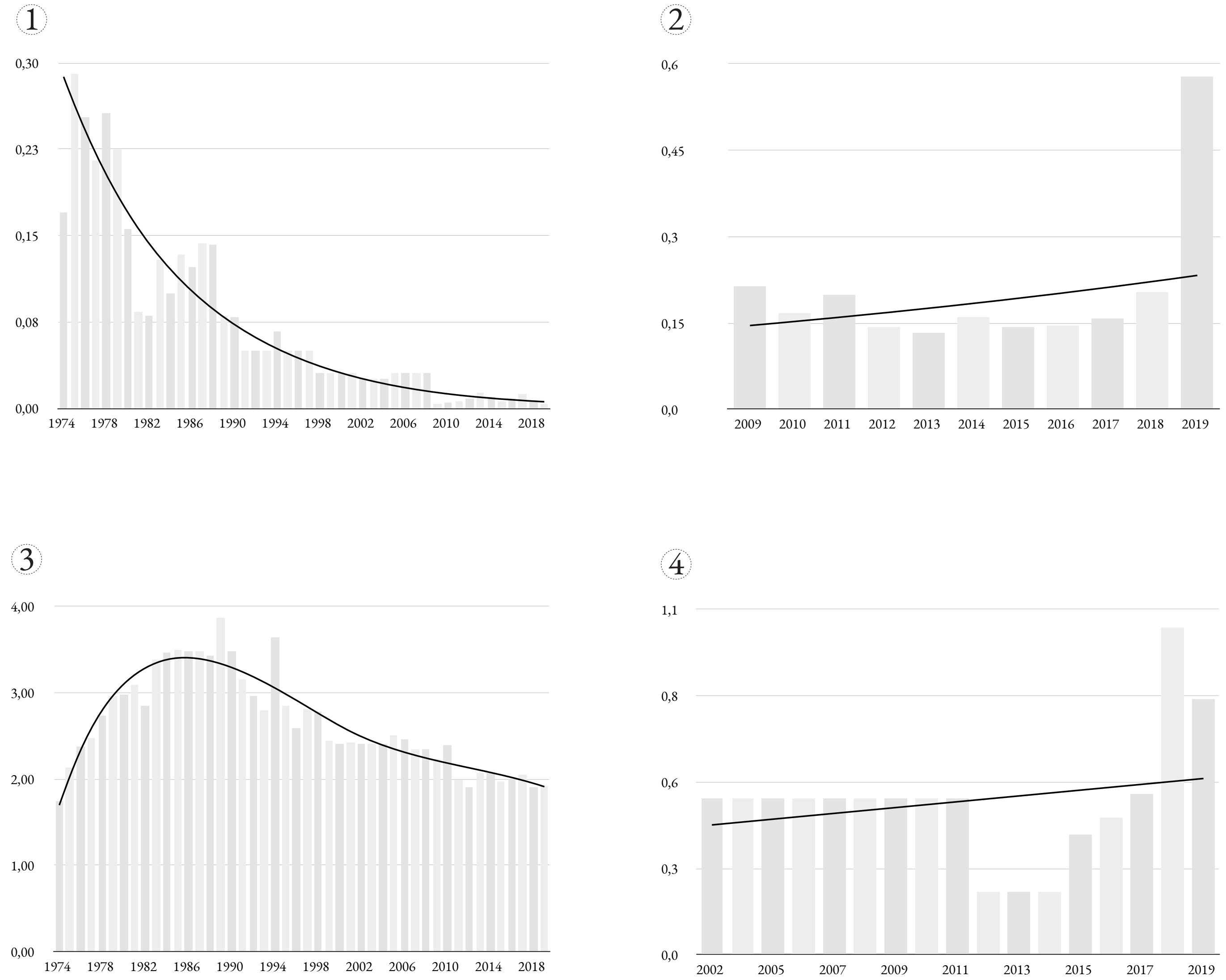
Sediment influx
1 Mosel
2 Main
3 Neckar
4 Nourishment Iffezheim
5 Mine effluent
6 Basel

II.III HABITAT: LIMIT

In 1986 the most severe environmental disaster happened in the Rhine basin. A fire in a warehouse of a chemical plant in the Swiss town of Sandoz caused widespread pollution of the river, killing almost all fish downstream (Plum & Schulte-Wülwer-Leidig, 2013). Following this event, strict international regulations were made to decrease the pollution of the Rhine and prevent any future environmental disasters. These regulations have had a significant effect as pollution by heavy metals was minimalized. However, these regulations did not consider new types of pollution. In the past 30 years, pollution by pesticides, microplastics, and medicine residue has steadily risen. These types of pollution are diffuse and, therefore, difficult to tackle at the source. These pollutants are damaging to the river's ecology, drinking water extraction, and recreation. Unfortunately, it is not easy to filter these tiny particles.

In illustration 13, the development of four chemical substances is shown. These are the primary sources of these substances and their development:

- Mercury is a metal that is primarily used in healthcare nowadays. Due to its toxicity, industrial and household use of the metal has been forbidden in Europe. This can be seen in the declining trend of mercury in river water. The most important source of mercury pollution comes from burning solid fuels like coal (Marnane, 2018).
- Nitrate is a polyatomic ion. It is primarily used as an agricultural fertilizer. The nitrate density in the Rhine is slowly decreasing as laws limit excessive fertilizer use (Europese Unie, 2010).
- Amidotrizoic acid is used in healthcare as an X-ray contrast medium. The substance is increasingly found in the Rhine as its use becomes, like other medicines, more common. Additionally, the acid is tough to remove from wastewater (International Commission for the Protection of the Rhine (ICPR), 2010).
- Bis(2-Ethylhexyl) phthalate is an organic compound used in plastics. It is considered very dangerous for humans; therefore, limits to its use were set in 2020 (Boucher, 2021).



Accumulation : Habitat : Limit

River contamination data
Trend

Metal contamination
① Mercury in µg/l

Medical contamination
② Amidotrizoic acid in µg/l

Organic substances
③ Nitrate in mg/l

Industrial contamination
④ Bis(2-ethylhexyl) phthalate in µg/l

Illustration 13 | Monograph 'Accumulation: habitat: limit'
Source: by author

Image 8 | Polluted sediments
Source: by author

CATALOGUE OF HABITAT

- Primary water governing regions
- Presence of powerful waterboards
- Fragmentation of water governance
- River border crossings
- Water quantity and quality
- Downstream flood risk
- Drinking water extraction from river

COMPOSITION

This composition aims to unravel the governing systems behind the water management of the Rhine. The governance of water management is arranged differently in each nation of the basin. In The Netherlands and France, waterboards have much power in managing the river. However, in The Netherlands, the governance of large rivers is centralized, comparable with Luxembourg. In Germany and Switzerland, respectively states and cantons have the most responsibility for water management. This fragmentation of governance could jeopardize basin-wide initiatives.

The risks for downstream communities are overlayed to clarify which governing regions are responsible and which endure the risk. Points where the river crosses borders exemplify differing management strategies when examined in more detail.

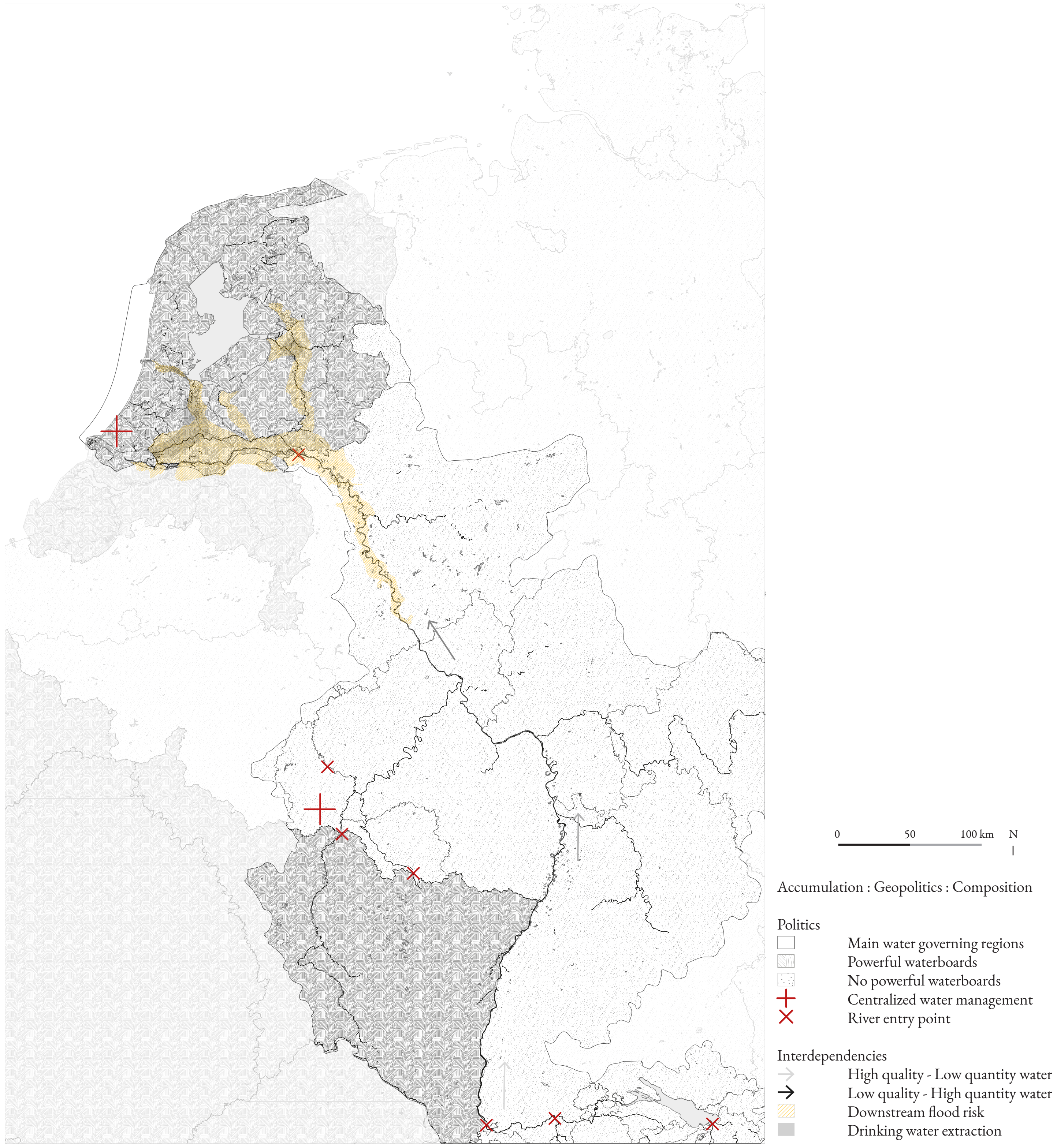


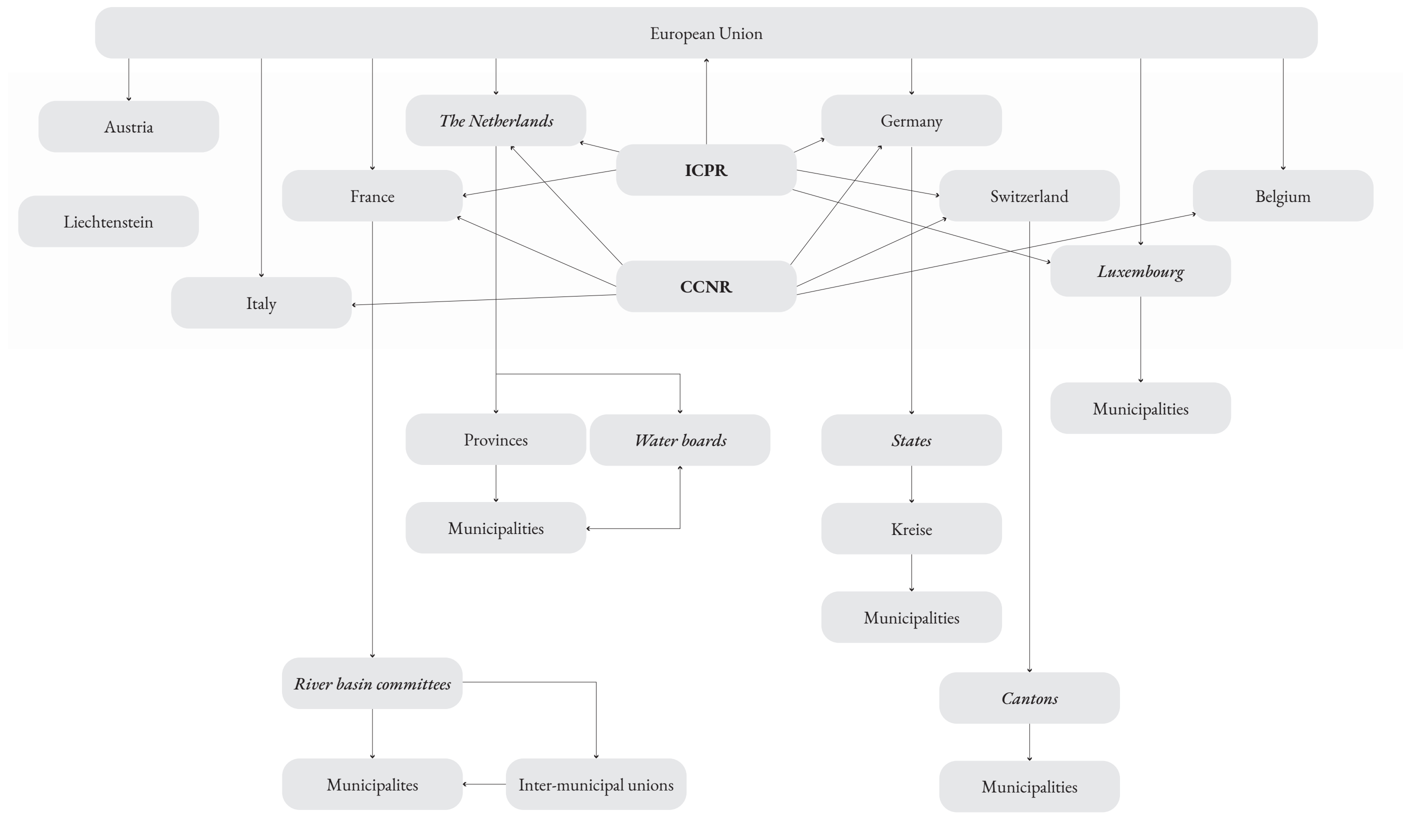
Illustration 14 | Monograph 'Accumulation: geopolitics: composition'
Source: by author

II.IV GEOPOLITICS: ALTERATION

The diagram on the right intends to clarify the governance structure of the whole basin. Three governing parties have basin-wide responsibility. Most countries within the basin are a member of the European Union. The EU has its own policies and regulations on water management, which helps bring coalition in the management of the basin. Switzerland is not part of the union, but its strong ties with the EU brings opportunities.

In 1816 the Central Commission for the Navigation of the Rhine (CCNR) was constituted to enforce the 1815 treaty on freedom of navigation on international waterways. Due to multiple problems, freedom of navigation became a reality in 1868. The members are Germany, France, The Netherlands, Belgium, Switzerland, and Italy. The commission ensures equal rights on shipping in the basin. (Arndt et al., 2009)

The second governing party is the International Commission for the Protection of the Rhine (ICPR). This organization was established in 1950 to combat the increasing pollution of the river. The ICPR's primary focus is pollution, flood risk, and ecological issues. All riparian states are members, including the European Union. The transboundary tasks of the ICPR correspond with the problem fields within this thesis and are, therefore, an exciting organization to study and collaborate with. (International Commission for the Protection of the Rhine, n.d.-a)



Accumulation : Geopolitics : Alteration

Rhine governance structure

AA	Powerfull transboundary organisations
AA	Govermental layers
AA	Prime national govermental layer
⟶	Direction of power

Illustration 15 | Monograph 'Accumulation: geopolitcs: alteration'
Source: by author

II.IV GEOPOLITICS: LIMIT

Today, there is extensive collaboration within the Rhine basin. The collaboration ranges from flood protection to energy production. The European Union, ICPR, and CCNR are potent examples of this collaboration. States of the Rhine have not always worked together this intensively. The figure on the right shows a timeline of events based on their collaborative level. International collaboration in the Rhine has been analyzed for the past two centuries. In the 19th century, there was a treaty on freedom of navigation, and bilateral dams were built, but intensive collaboration was not happening. The period around the second world war was characterized by very little collaboration; the river was mainly used for warfare. Two decades after the war, international collaboration was boosted by the formation of the ICPR and the EU. Since then, more and more collaborative programs have been set up.

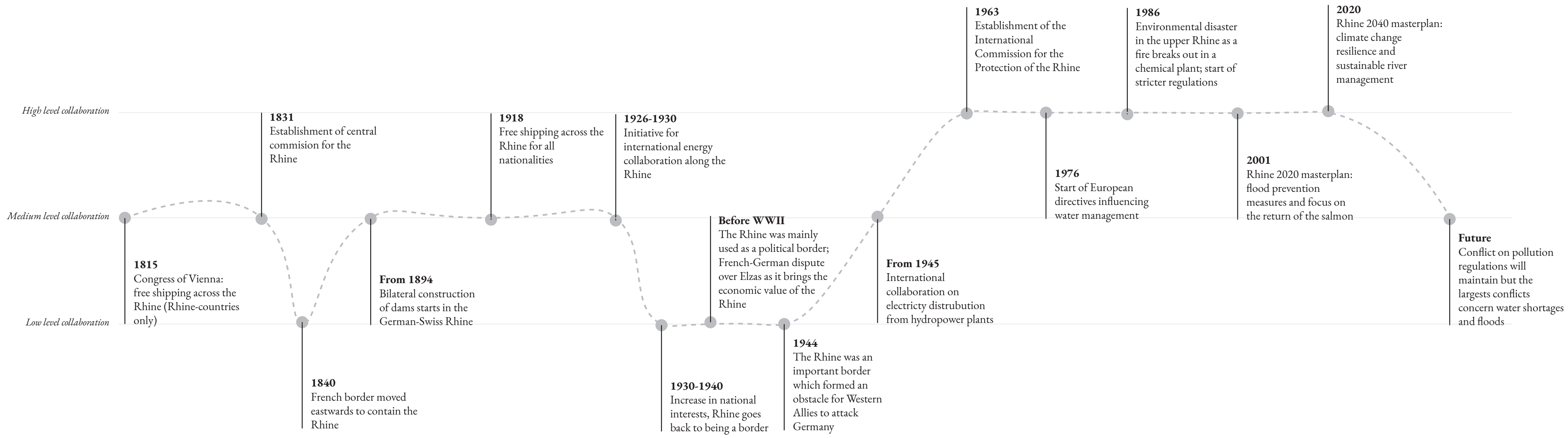


Illustration 16 | Monograph 'Accumulation: geopolitics: limit'
Source: by author

Accumulation : Geopolitics : Limit

Rhine historical collaboration

Major event for international collaboration

Image 9 | No water here means water elsewhere
Source: by author

II.V PROBLEM STATEMENT

IN THE RHINE BASIN, THERE ARE THREE WATER-RELATED PROBLEM FIELDS. THESE ARE FLOODS, POLLUTION, AND DROUGHT. THEY ARE THE CENTRAL PROBLEMS OF THIS RESEARCH. THESE PROBLEMS ARE DEVELOPING INTO A STATE OF CRISIS. SOME ELEMENTS ACCELERATE THESE PROBLEMS. WITHIN THIS THESIS, A SELECTION OF ELEMENTS IS MADE BASED ON SCIENTIFIC RESEARCH AND PERSONAL INTERESTS.

HUMAN-WATER RELATIONSHIPS ARE IN CRISIS. THE NATURAL WATER SYSTEM IS NOT CARED FOR PROPERLY BY HUMANS. THE RESULTS ARE THAT WATER THREATENS HUMANS IN MANY FORMS (FLOODS, DROUGHTS, POLLUTION). THEREFORE THE STATE OF THIS RELATIONSHIP IS ONE OF THE PRIMARY TARGETS OF THIS RESEARCH. SECONDLY, CLIMATE CHANGE IS CHANGING THE RULES OF WATER MANAGEMENT AS PERIODS OF DROUGHT AND EXTREME RAINFALL EVENTS WILL BECOME MORE LIKELY. LASTLY, ANTHROPIC ALTERATIONS OF THE RIVER SYSTEM HAVE INCREASED THE CHANCE OF FLOODS AND DROUGHTS, AND HAVE RESULTED IN THE LOSS OF HABITAT AND INCREASED POLLUTION.

Image 10 | Sculpture showing that humans are inseperable from earth
Source: van den Berg (2017)

III PROJECT FOCUS

.I PROJECT LOCATION

.II PROPOSITION

III.I PROJECT LOCATION

The northern Upper Rhine Valley is selected as the research location because it contains all relevant spatial factors found in the basin-wide problem analysis, within a relatively small area. Additionally, this is Germany's most prone area to droughts and the whole Upper Rhine Valley contains one of the two massive floodplains of the Rhine basin. These problems have specific forms of representation on this location, which is shown through multiple photographs before and after this page.

The project is divided into three typological locations. Area A is located in the floodplains of the Rhine but is nowadays protected by a dyke system. It primarily hosts agricultural lands. Area B is located on the slopes of the Taunus mountain range. It has multiple small streams, and the landscape alternates between villages and vineyards. Area C is partly located on flat land and partly on slopes. What marks this area is its diversity of agricultural typologies. These three locations and their problems related to water are representative of the whole Rhine Valley. Therefore, the design projects carried out here are seen as a pilot for the larger region.

The design phase entirely focuses on this region. However, the goal to aid downstream communities is strongly represented in the strategy.

0 10 20 km N

LEGEND

- Rhine water system
- Floodplains
- Local water system
- Cultivated landscape
- Urban landscape
- Topobathy: low > high

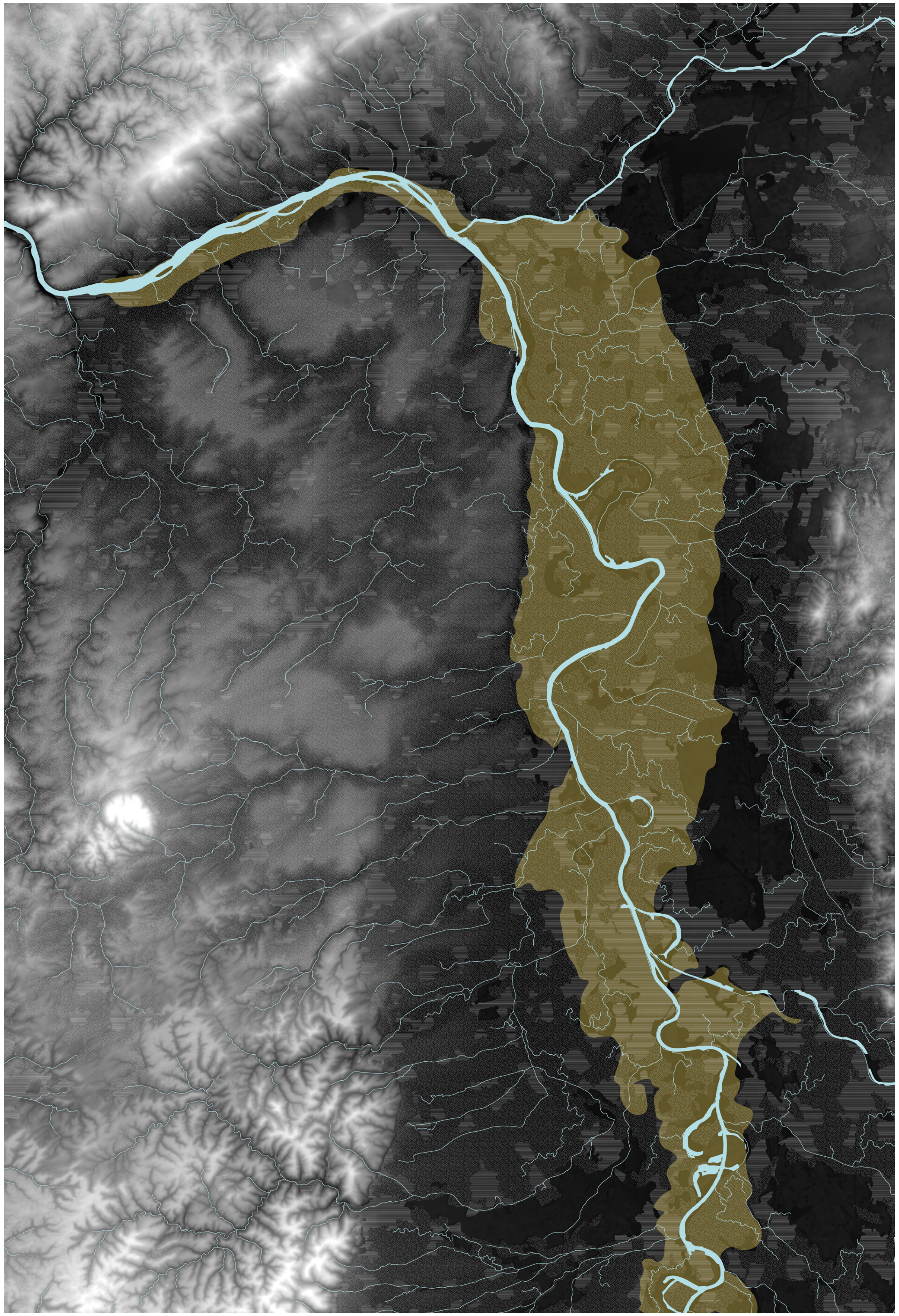


Illustration 17 | Project location in the Northern Upper Rhine Valley
Source: by author

Image 11 | Dried out sunflower field
Source: by author

Image 12 | Erosion prone vineyards
Source: by author

Image 13 | Small stream discharging run-off water to the Rhine
Source: by author

III.II PROPOSITION

UPSTREAM-DOWNSTREAM INTERDEPENDENCIES
Many measures have been taken to ensure water security in the Lower- and Delta Rhine, primarily focusing on flood prevention. The Room for the River project is an essential part of these measures. However, downstream communities are highly dependent on how water is managed upstream. Therefore, this research will focus on upstream interventions to prevent floods, droughts, and pollution downstream, while at the same time, these problems are tackled locally upstream. This relation between upstream and downstream is present on many scales, from basin-wide to the local scale, and this research takes all these scales into account.

CLEARANCE
The limits of large-scale engineering projects are known. Theoretically, extensive engineering works could protect people from floods. However, this method has many drawbacks. Environmental concerns are the most prominent drawback; every hard engineering work disturbs ecological habitats. Economic concerns are explained by the story of the little Dutch town of Valkenburg. Here, a small river runs through the city center, making it a popular tourist destination. Engineering works would conflict with the tourist industry. Therefore, many locals do not prefer it to engineer our way out of the flooding problem.

Therefore, the concept of clearance is introduced. This means all elements that lead to damaging accumulation (including the accumulation shown in the analysis) are taken away. If necessary, these elements are replaced by other elements that will not lead to damaging accumulation.

SOCIO-ECOLOGICAL SYMBIOSIS
There is a socio-ecological problem. Increasingly large engineering works affect people's perspectives on water. These fear-based designs cause a break between people and the natural world. Therefore, a method that deals with these challenges in an integrated manner would lead to a more satisfactory result. This research proposes the method of socio-ecological symbiosis as a paradigm to manage flood risk. This method entails a system where the symbiosis between humans and their environment is the starting point.

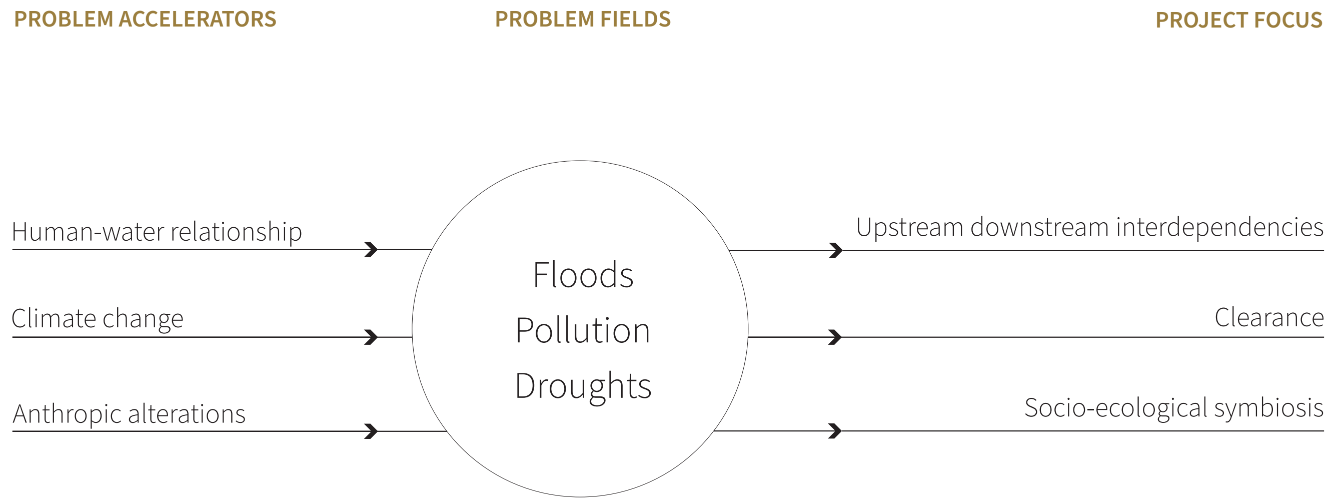


Illustration 18 | Conceptual framework
Source: by author

IV METHODOLOGY

.I THEORETICAL FRAMEWORK

.II RESEARCH FRAMEWORK

.III ANALYTICAL FRAMEWORK

IV.I THEORETICAL FRAMEWORK

UPSTREAM-DOWNSTREAM INTERDEPENDENCIES

The interdependencies between upstream and downstream communities become more tangible if explained as the fact that water always flows from high to low. This means that everything that is altered upstream that has anything to do with water can be noticed downstream. Seher & Löschner (2016) began their abstract with this sentence:

"RIVER FLOODS USUALLY DO NOT STOP AT ADMINISTRATIVE BORDERS."

This sentence summarizes what upstream-downstream interdependencies mean on a geopolitical level. Their research assesses a case study in which transboundary water management is applied to ensure a fair distribution of risk along the river. Chang & Leentvaar (2008) present a larger-scale study including Germany and The Netherlands. They suggest a trade-off system in which downstream communities financially support upstream communities for a higher level of river basin management.

These theories are considered within this research. However, other concepts to ensure fair risk distribution are assessed as well.

CLEARANCE

The concept of Clearance is developed in a joint effort of the research studio Transitional Territories, the studio within which this research is developed.

Joint statement on Clearance:
"Whereas Accumulation is descriptive of the status quo, Clearance presents ways to take a stance, to look for very different future and possible scenarios. Clearance allows us to explore alternatives and project future possibilities through design for the current and next generations. Clearance is about progress being reinterpreted. It is about finding operational ways to say farewell to the anthropocentric vision of endless growth and development as epitomes of wealth.

The urgency to act and to move away from accumulation processes is already starting to redefine the boundaries of the urbanism field. Clearance is not a solution-driven, nor a' one-size-fits-all' form of working, it is a situated practice. Clearance is about developing well-informed and context sensitive perspectives of what could be alternatives and responses to the global accumulated processes of extraction, displacement, and pollution. Clarence works with the fragile equilibrium capacity of the local by exposing critical areas in need of new imaginaries, either by bringing them out of their disruptive state or by completely bouncing forward, supported by new networks of ethical care.

The projects in the studio seek to take a strong position on these accumulated realities to direct them towards a sustainable state of co-existence. While these projects are diverse in their context and criticalities, they root their ethics in care for nature, sustainability, human and nonhuman lives and their coexistence through (trans-)formative, context-driven and situated design." (Transitional Territories Studio 2021-2022, 2022)

Illustration 19 | Artist impression of a landscape where all damaging accumulation is cleared and nature is flourishing
Source: Helmer (n.d.)

IV.I THEORETICAL FRAMEWORK

SOCIO-ECOLOGICAL SYMBIOSIS

The concept of socio-ecological symbiosis is presented in this research. Nevertheless, there is a broad theoretical underpinning to support the validity of this concept. The concept is based on both these theories and the problem analysis.

There is a bifurcation developing about the connection between humans and ecology. On the one hand, science fiction seems to adore a world where humans are the only organic matter, and everything else is clinical and controlled. However, there is also a movement that is rediscovering what nature means for our civilization. Literature on ecosystem services describes why humans and ecology should develop a harmonious connection. The definition of ecosystem services is clearly explained by Daily et al. (1997, p.3):

“ECOSYSTEM SERVICES ARE THE CONDITIONS AND PROCESSES THROUGH WHICH NATURAL ECOSYSTEMS, AND THE SPECIES THAT MAKE THEM UP, SUSTAIN AND FULFILL HUMAN LIFE.“

Gómez-Baggethun & Barton (2013) have done a valuation for ecosystem services in urban planning. This research supports the proposition of including ecosystem services in urban planning as it increases urban resilience. Knight & Riggs (2010) expand on these ideas by their proposition to introduce Nourishing Urbanism. This entails that the borders between the urban and non-urban world are blurred, and the urban population rediscovers how the power of nature nurtures them.

Comberti et al. (2015) take one step further. They suggest that not only ecosystems deliver services to humans, but that humans also (should) deliver services to ecosystems to prevent damaging practices. This theory comes close to the meaning of socio-ecological symbiosis, as ecosystem services are seen as an equal interaction between humans and ecosystems. Following this, Constanza (2020) argues that this equal interaction should be integrated into the valuation of ecosystem services and natural capital.

Water is the primary element this research is based on. Therefore, the exploration of ecosystem services in water management is relevant. Halbe et al. (2018) notice a paradigm shift in water management in which increasingly integrated flood risk management is used, including ecosystem services. The valuation of ecosystem services in the context of water is explored by Ding et al. (2014). They suggest a human-water harmony index to assess the relationship between humans and water. This builds on the problem analysis findings, which showed the human-water relationship has deteriorated recently.

Hankin et al. (2021) and Liquete et al. (2016) execute more detailed research and practical examples. They respectively show that nature-based solutions can contribute to large-scale retention areas and water purification. This data could specifically support the design of the floodplains pilot study.

Wheater & Evans (2009) explore how human land use has significantly impacted the hydrology of the land. This has increased flood risks and pollution. As a reaction to this problem, Delibas et al. (2021) describe another aspect of ecosystem services, the ecosystem services of the soil. Soil is an essential element in the other two pilot studies. This paper explains how soil ecosystem services could be essential in climate change mitigation.

To conclude, the book River Science: Research and Management for the 21st Century by Gilvear et al. (2016) is used as a reference for broadening knowledge about rivers.

Image 14 | Human world and natural world supporting each other
Source: by author

IV.II RESEARCH FRAMEWORK

RESEARCH QUESTION

HOW COULD WATER SAFETY DOWNSTREAM BE SUPPORTED BY UPSTREAM DESIGN INTERVENTIONS IN THE NORTHERN UPPER RHINE VALLEY, BASED ON METHODS IN WHICH SOCIO-ECOLOGICAL SYMBIOSIS AND CLEARANCE ARE CENTRAL?

ANALYTICAL SUB-QUESTIONS

AQ1. How can downstream hydrological consequences of upstream interventions be measured?

AQ2. Why is the northern Upper Rhine Valley a location of interest for this research?

DESIGN SUB-QUESTIONS

DQ1. How can upstream design interventions prevent pollution, floods, and droughts downstream?

DQ2. Which social-spatial alterations are needed in upstream communities, and how can communities upstream be persuaded to change their surroundings to aid downstream communities?

DQ3. How do the flood, drought, and pollution preventive measures spatially represent themselves on a regional and local scale?

DQ4. What synergistic water management approaches can be identified for the northern Upper Rhine Valley?

EVALUATIVE AND PROJECTIVE SUB-QUESTIONS

EQ1. How could the strategic masterplan be translated to other locations?

EQ2. What are the limits of the proposed strategic masterplan?

THEORETICAL SUB-QUESTIONS

TQ1. What are symbiotic socio-ecological water management methods, and what are their advantages?

RESEARCH APPROACH AND PHILOSOPHY

Data collection is primarily qualitative as data on all problem fields and accelerators is collected based on previous research and real-life events. This is unique data. In the analysis of the basin, quantitative data is used. This data is used to understand the Rhine basin and how the problems work here and to choose a research location. Research & design experiments are done; this is a form of quantitative data collection.

As qualitative data is collected, an inductive analysis is executed, which results in a theory. The aim is to understand a phenomenon instead of testing a hypothesis

The philosophy behind this research is interpretivism. I do not assume the reality is a stable being not needing interventions. The goal of this research is to decide whether or not an intervention should be done and how this intervention then represents itself in reality.

▲ *Image 15 | View on the Vineyard Streams from the Agroforestry Waterscapes*
Source: by author

IV.II RESEARCH FRAMEWORK

RESEARCH METHODS

Answering these questions needs a clear research plan. The following section explains the necessary steps and the methods that are used.

Symposium
The graduation studio will organize a symposium to showcase the monographic mappings. The students are divided into groups and have to establish a collaborative narrative. This reflection process could give input for the research process.

Location visit
After establishing an extensive understanding of the research location, a field trip will help to deepen this understanding. The trip's primary goal is to talk to local experts to gain specific knowledge, but the location's social state is also important. Qualitative data collection is done by photographs and memo's about the human experience.

Cartography
Spatial problem analysis is presented through maps, sections, and diagrams.

Literature research
Theoretical and practical knowledge is gathered through literature research which, together with the problem analysis, helps to build to the concept of the project.

Concept building
A concept is built through the problem statement and proposition. This is direct input for the strategy and design process.

Data collection - pilot studies
Throughout the design process, extra data collection is necessary to develop the concept into specific designs in three pilot studies.

Research by design
After establishing a solid base knowledge of the problems, theories, and location, the design phase can be started. The primary research method used is 'Research by design.' Theories and methods will be implemented in the case study. The specific circumstances of the location could lead to the adjustment of these theories and methods.

RESEARCH AIMS

These are the aims of this research:

- Define a strategy to prevent floods and pollution downstream by upstream interventions.
- Develop a prevention and adaptation strategy based on the harmony between humans and water.
- Develop a strategy that is simple to implement in other river basins.
- Integrate downstream prevention and local prevention and adaptation, which is extended to droughts
- Mitigate and adapt to climate change in the Rhine basin

EXPECTED OUTCOMES

Analysis
A rich cartographic set gives an understanding of the Rhine's water system and water management. This is started with 12 monographs and will be extended during the design phase with more focus on the northern Upper Rhine Valley. The monographs are divided into four lines of inquiry:

- Matter: where does water come from, and does it flow?
- Topos: how does the form of the land impact the water system?
- Habitat: how is the natural habitat disturbed by humans?
- Geopolitics: how does governance influence the state of the basin?

The concept of the analysis is the notion of accumulation, which is chosen by the graduation studio. This analysis gives a deeper understanding of the complexity of the territory. As the project has a synergistic approach, the analysis guides the selection process for the research location.

Problem statement
The problematization is based on personal interests, urgencies, and the scope of the graduation studio. The problem statement is regularly updated based on analysis, projections, and literature reviews.

Projection
Drawing upon the monographic analytic maps, projections are made per line of inquiry:
matter: the natural flood plains
topos: sustainable and water-regulating land-use
habitat: buffering and cleaning water
geopolitics: clearing damaging policies

The graduation studio has drafted the concept of the projections. The projection is a view of a post-accumulation world. The focus is on the clearance of processes or elements that lead to accumulation.

Design
Flood, drought, and pollution managing design interventions on a regional, local, and 1 to 1 scale.

Strategy
A strategic masterplan with design interventions and downstream effects. Including a rich understanding of upstream-downstream interdependencies.

Conclusion
The expected research output is a strategic masterplan for the northern Upper Rhine Valley. Additionally, a description of how to implement this strategy in other locations is expected to be made.

Evaluation
To conclude this research project, the process and outcomes will be evaluated. This will discuss how the research could be used and what further research is necessary or expected.

LIMITATIONS

The limitations of these methods are that they tend to result in only qualitative data. A lack of quantitative data, which could be obtained through modeling, brings doubts to the process. Research through quantitative models would be helpful to make the qualitative design ready for implementation. Therefore, I would suggest that if a similar project is executed in a professional environment, to use a combination of qualitative and quantitative research. Additionally, involving specialists in hydrology, ecology, agriculture, and sociology would help deepen the research.

IV.III ANALYTICAL FRAMEWORK

The analytical framework aims to explain how the analytical research, design interventions, and upstream-downstream measurements are done.

ANALYTICAL RESEARCH AND DESIGN
This research uses a multi-scalar approach. The strategical masterplan, the expected outcome of this research, will be developed on a regional scale (meso). However, specific design interventions often require a local scale (micro). When going more in-depth on these interventions, design on a scale of 1 to 1 (nano) becomes relevant.

UPSTREAM-DOWNSTREAM MEASUREMENTS
Upstream design interventions to prevent floods and pollution downstream are the focus of this project, together with socio-ecological symbiosis and clearance. The relationship between two points along the river is analyzed, researched, and altered. The stretch of river studied can differ in scale and expected results. Local (micro), regional (meso), and transboundary (macro) scales will be used to understand the effects of the upstream interventions.

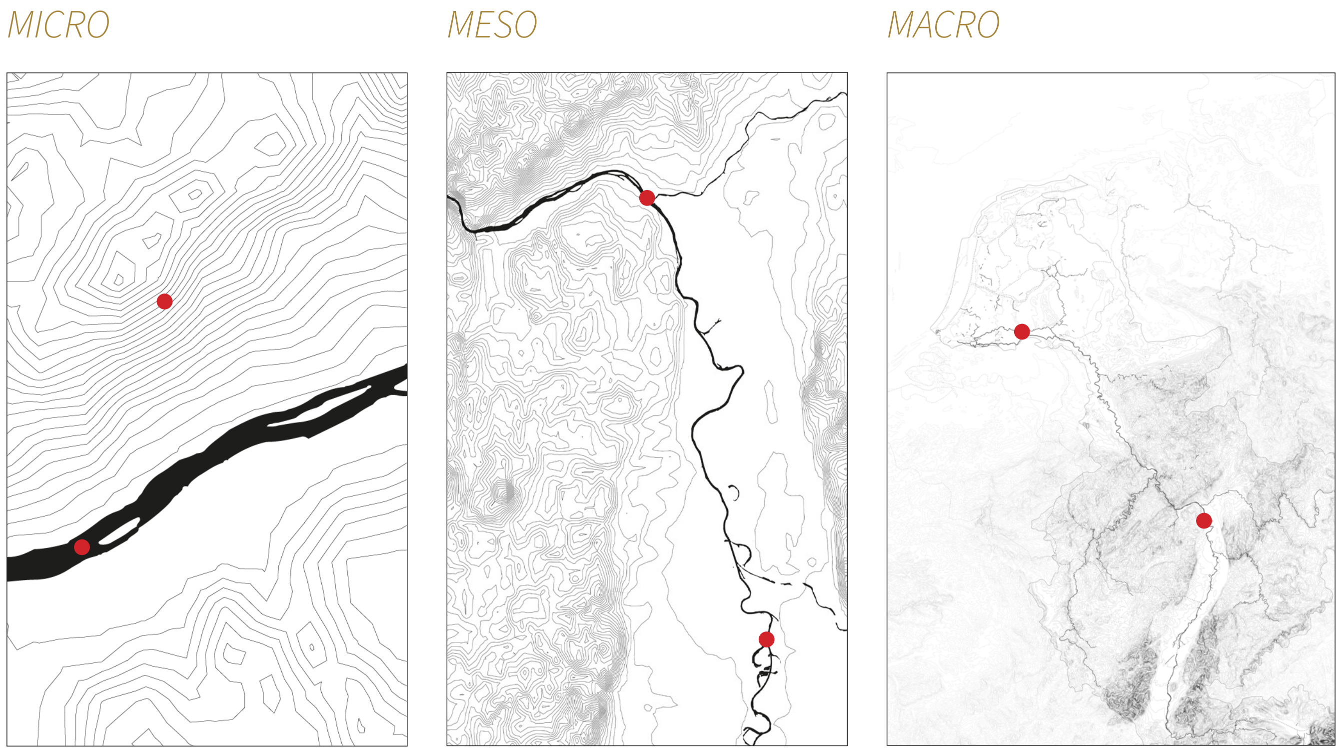


Illustration 20 | Upstream-downstream measuremnt scales
Source: by author

V PROJECTION

CLEARANCE MONOGRAPHS

V CLEARANCE

MONOGRAPH TAXONOMY

The monograph series *clearance* projects a future scenario in which the accumulation is cleared. It is built on the accumulation monograph series. Each line of inquiry is a projection based on the same line in the accumulation series. An overview of the series is given in illustration 21.

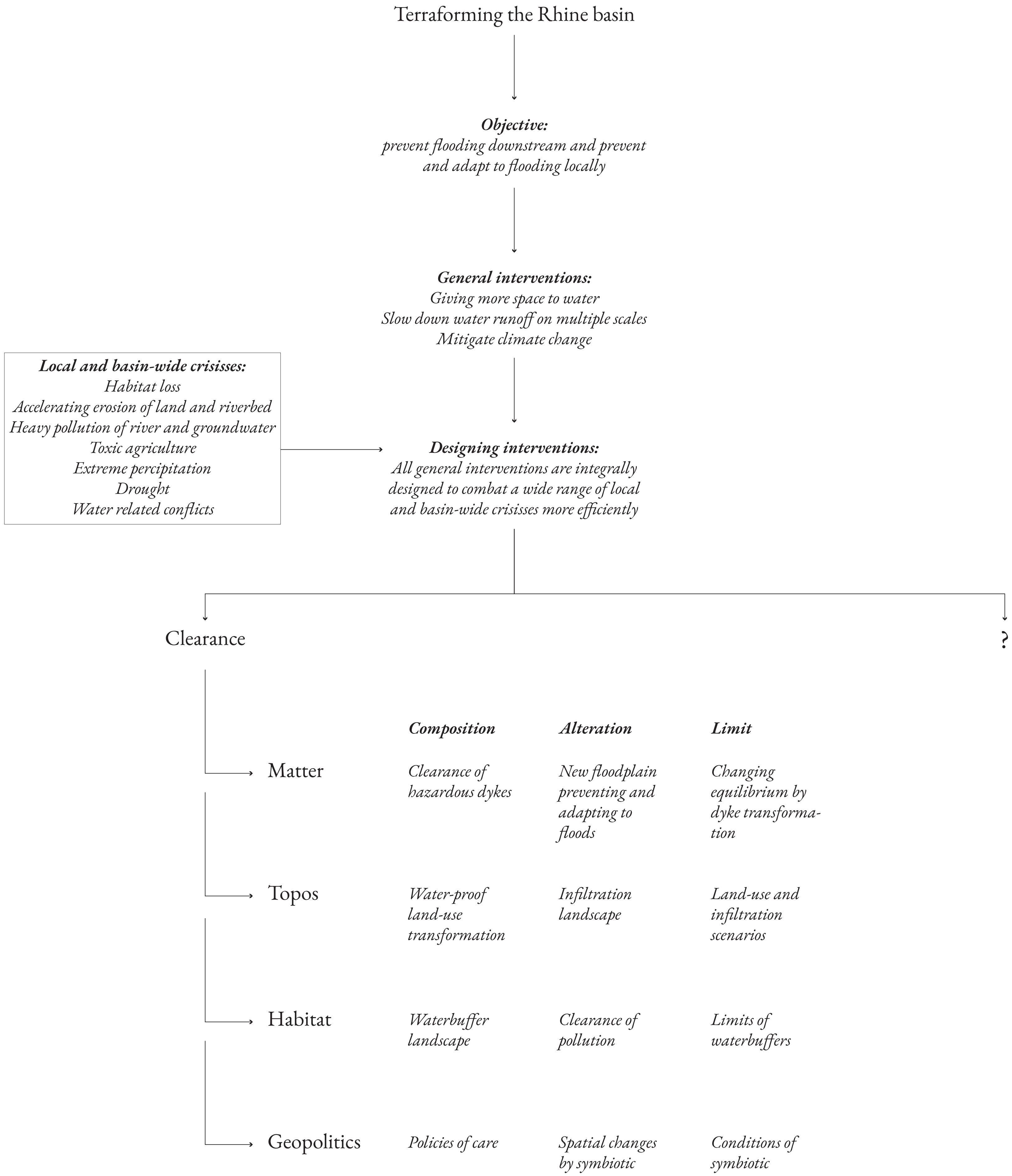


Illustration 21 | Taxonomy of Clearance
Source: by author

V.I MATTER: COMPOSITION

CATALOGUE OF MATTER

- Natural water system
- Dyke relocation
- Hybrid land uses
- Non-hybrid land uses

COMPOSITION

This composition explores how extending the floodplains of the Rhine Valley would look. By relocating dykes to strategic lines inland, defined mainly by natural heights, the Rhine is allowed to flood large patches of land. This means the water-controlling layer is cleared, and the natural landscape before human interventions is reinstated. However, the landscape and its uses have dramatically changed past centuries. So should this space be given back to nature altogether? This is not a realistic scenario as this would cut out an essential part of the regional economy and would mean an unprecedented relocation of people.

In reaction to that, hybrid urban- and cultivated landscapes are proposed. This entails that current land uses remain, but adapt to the water. What this exactly means is explored in the following pages.

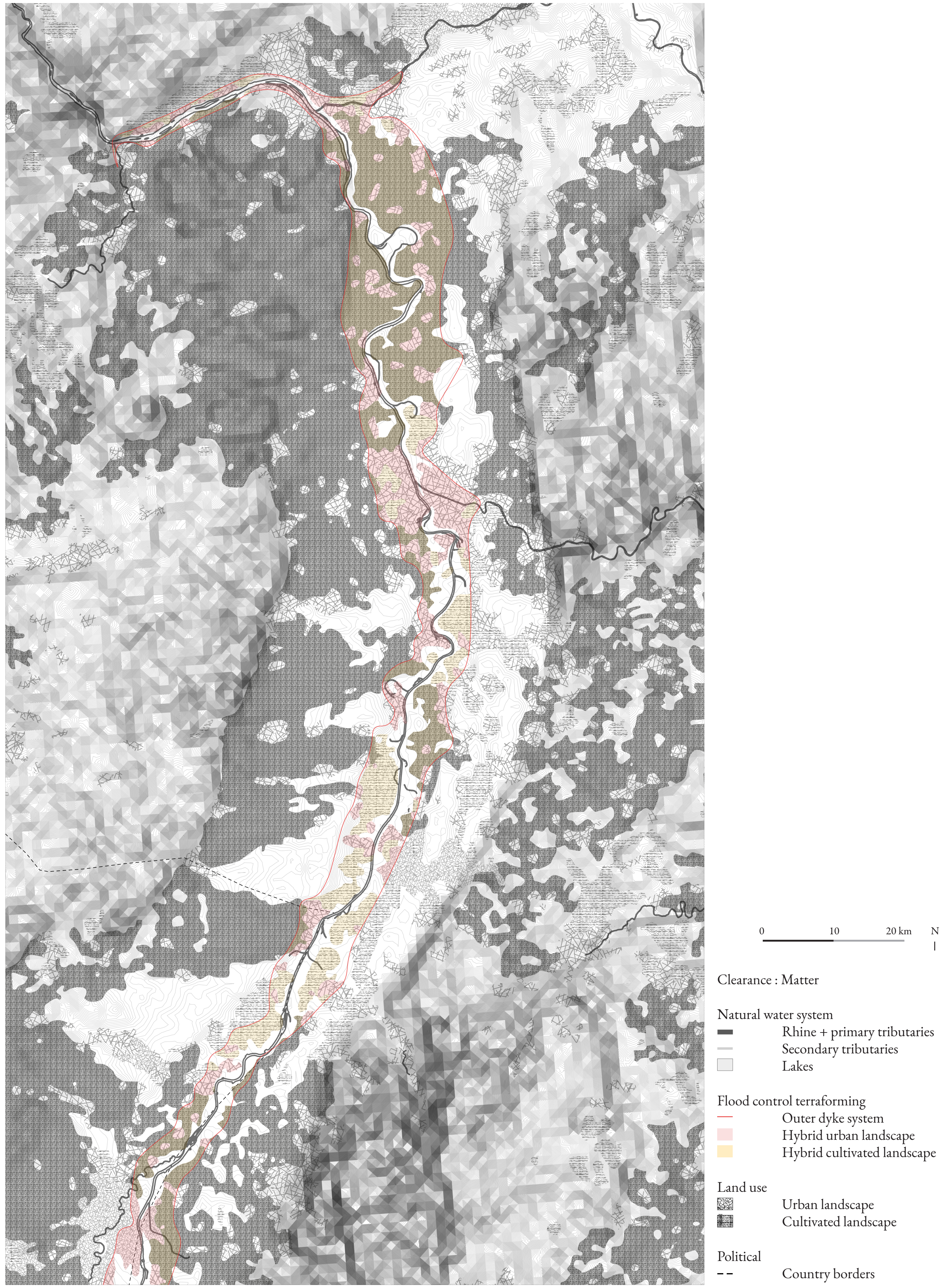
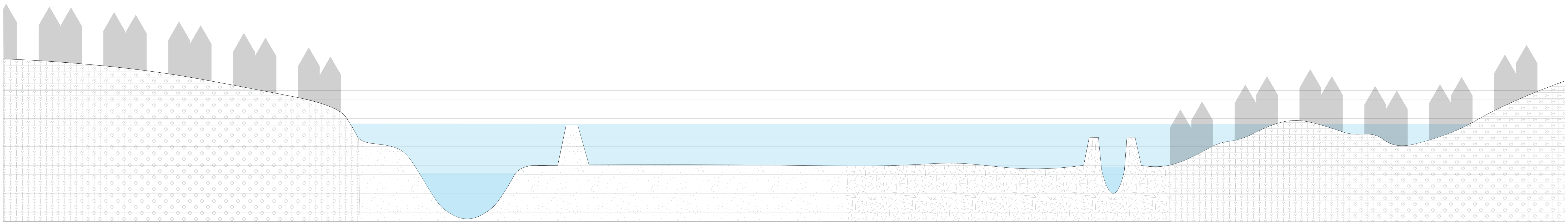
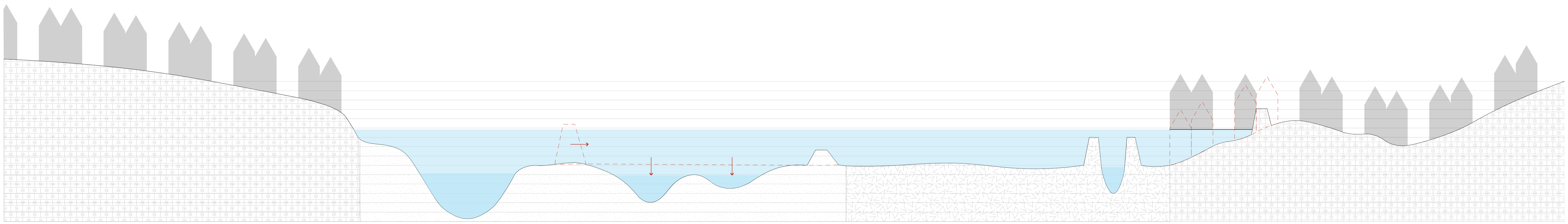


Illustration 22 | Monograph 'Clearance: matter: composition'
Source: by author

The schematic section below shows an example of how the floodplains could be transformed. Dykes are moved far inland, often located on natural heights or the edge of significant urban areas. Creating smaller water buffers in the flood plains increases the total buffering capacity and retains water for periods of drought. The increase in surface and volume of water means water is forced downstream less quickly, and local water levels decrease, preventing dykes or thresholds from overflowing





▲ *Illustration 23 | Monograph 'Clearance: matter: alteration'*
Source: by author

What are the limits of the clearance of dykes? Illustration 24 shows the probability of specific elements or occurrences depending on the percentage of cleared dykes. Three occurrences are likely to decrease:

- Large floods downstream
- High discharge peaks
- Devastating local floods

This decreasing trend is in line with to goal of the clearance. However, it also leads to a substantial decrease in the permanent functional use of the natural floodplains. This will have drastic consequences for the functioning and composition of this landscape. This decrease is explained by the strongly increased chance of small local floods. A positive side-effect of this operation is the increased size of valuable riparian habitats.

The design phase further explores transforming a permanent functional landscape into a dynamic hybrid one.

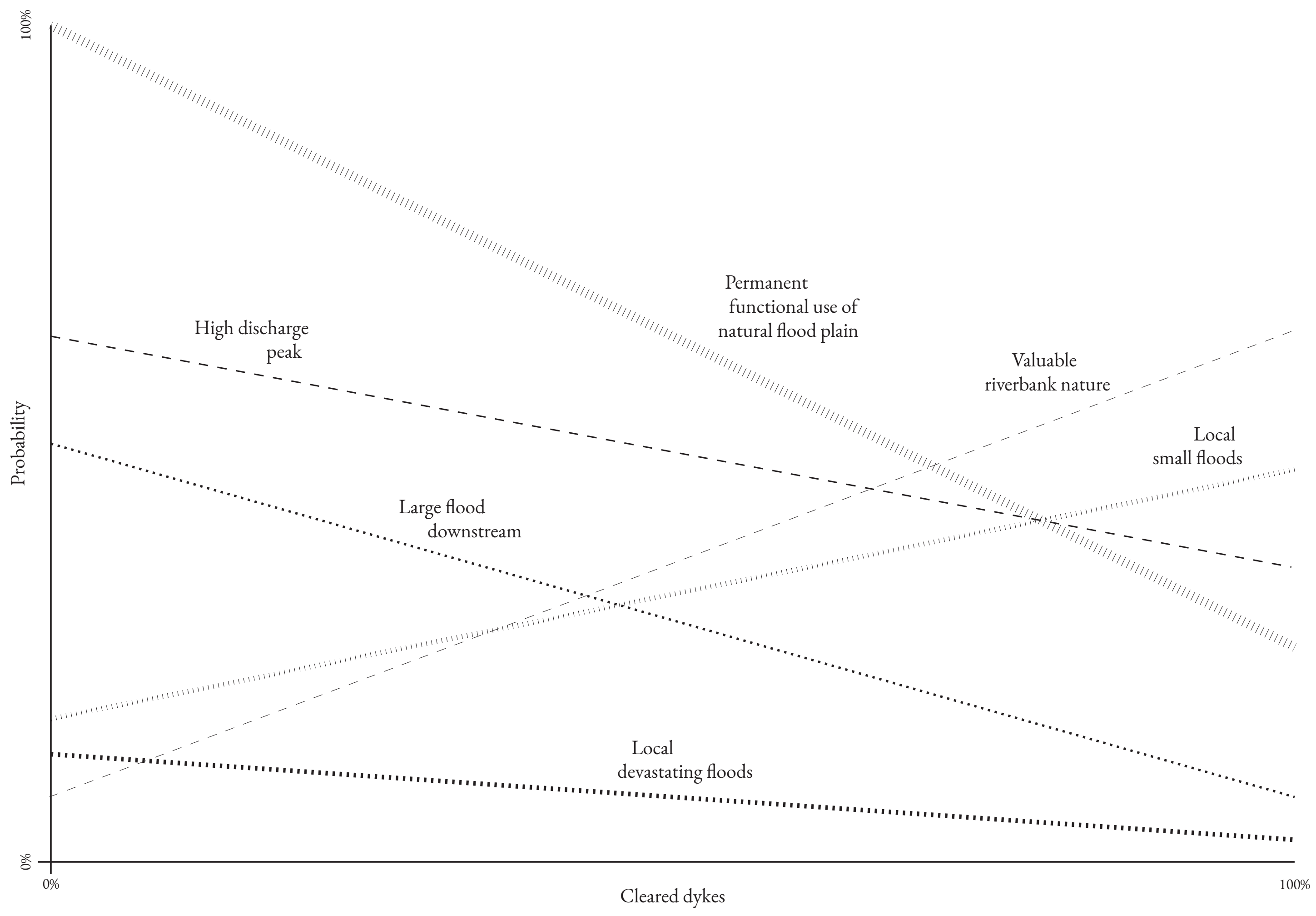


Illustration 24 | Monograph 'Clearance: matter: limit'
Source: by author

CATALOGUE OF MATTER

- Natural water system
- Current water absorption landscapes
- Future water absorption landscapes

COMPOSITION

This composition explores how the land use in the Mosel river basin could be transformed to decrease fast water run-off and increase water infiltration. This decreases local flash floods and peak discharges that could cause downstream floods.

Large parts of the area are covered by forest, which is already considered a water absorption landscape. This land use typology should be maintained. The land uses that qualify for transformation are located on steep hills, which significantly increase water run-off. Vineyards are the most extensive problematic land use. The wine culture is firmly instilled in the regional community. It is, therefore, a sector that is preferred to remain as vineyards need the microclimatic conditions of a river valley at this latitude. Therefore, vineyards should remain in their current locations.

Nevertheless, there is a chance to improve this landscape by changing the cultivation technique from conventional to biodynamic. Pastures located on slopes are transformed into forests as the amount of livestock is expected to decrease. This could go hand in hand with strategic land use transformation. Lastly, croplands undergo the same transformation as the vineyards as this sector is not expected to decline in volume.

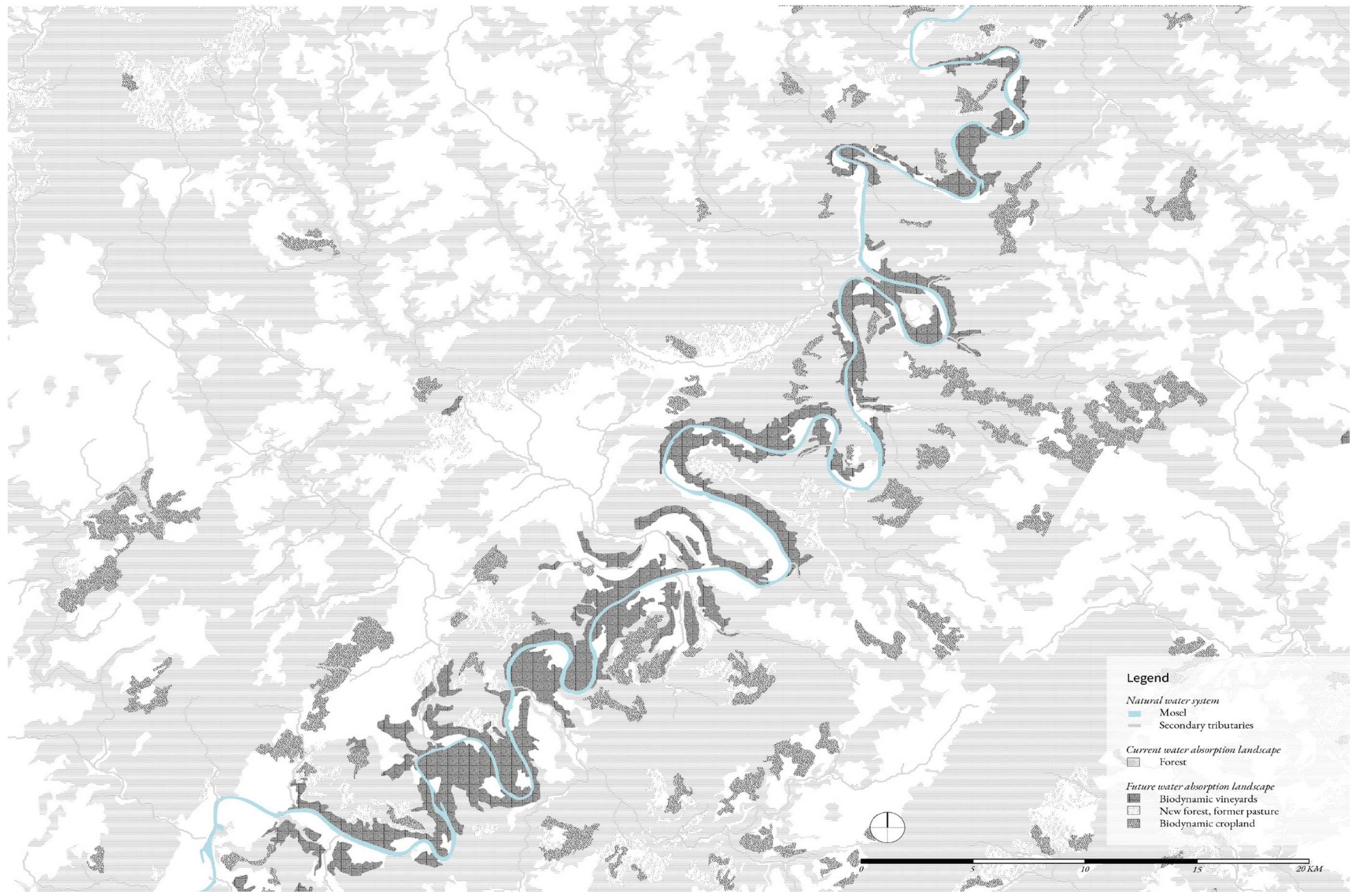


Illustration 25 | Monograph 'Clearance: topos: composition'
Source: by author

An example of what these transformations could mean for the balance between infiltration and run-off is shown on the right.

The maintained forest is slightly altered as forests in this area tend to have low diversity. Higher densities and diversity in species improve the soil's condition and increase the infiltration capacity. The most significant change is seen in the pasture, which is transformed into a forest. Trees and shrubs intercept water and anchor the soil, preventing erosion. This leads to better soil conditions and a substantial increase in infiltration. As the forest is located on a slope, there is more run-off than in a forest on flat land. The third alteration is a vineyard which transformed its cultivation technique into biodynamic. This means more ground cover and the addition of compost; this forms a water-regulating humus layer and, therefore, increases the infiltration of this land.

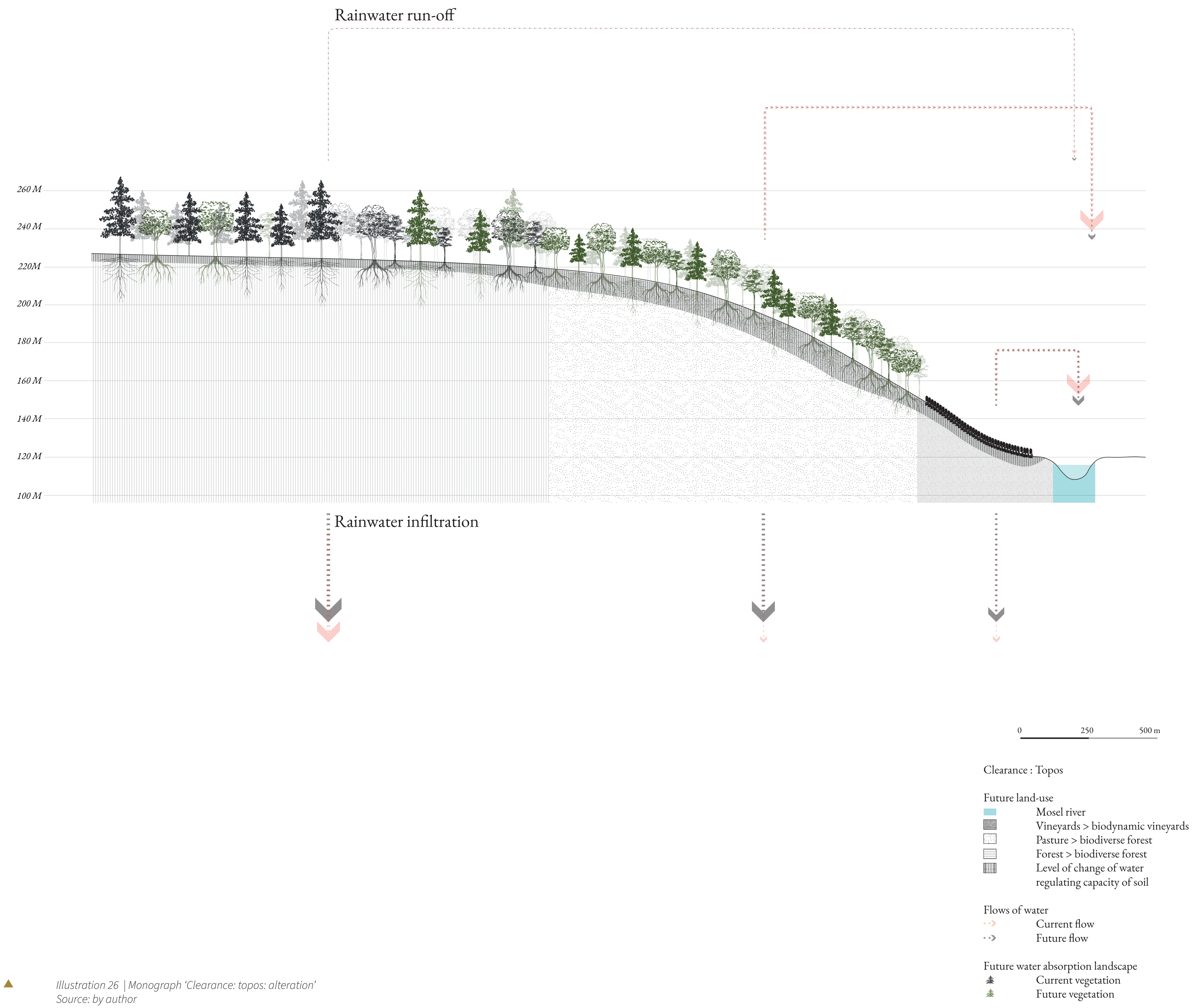


Illustration 26 | Monograph 'Clearance: topos: alteration'
Source: by author

There will be major changes in the water infiltration capacity of the land by 2100. The types of land use will change. More land is expected to be used for energy production and housing. The amount of wild nature is also preferred to grow. In contrast, agriculture is set to decrease its land use. Now it is using the majority of the land in the Rhine basin, but due to technological and methodic changes, food production can become more efficient. Additionally, in Western Europe, there is a transition toward diets containing fewer animal products; therefore, pastures are expected to disappear rapidly.

The second transition is the method of how water is dealt with in each type in land use. By transitioning towards bio-dynamic agriculture, the water regulating the capacity of the soil will significantly increase, leading to a higher resilience in the increasingly dry and extreme wet periods.

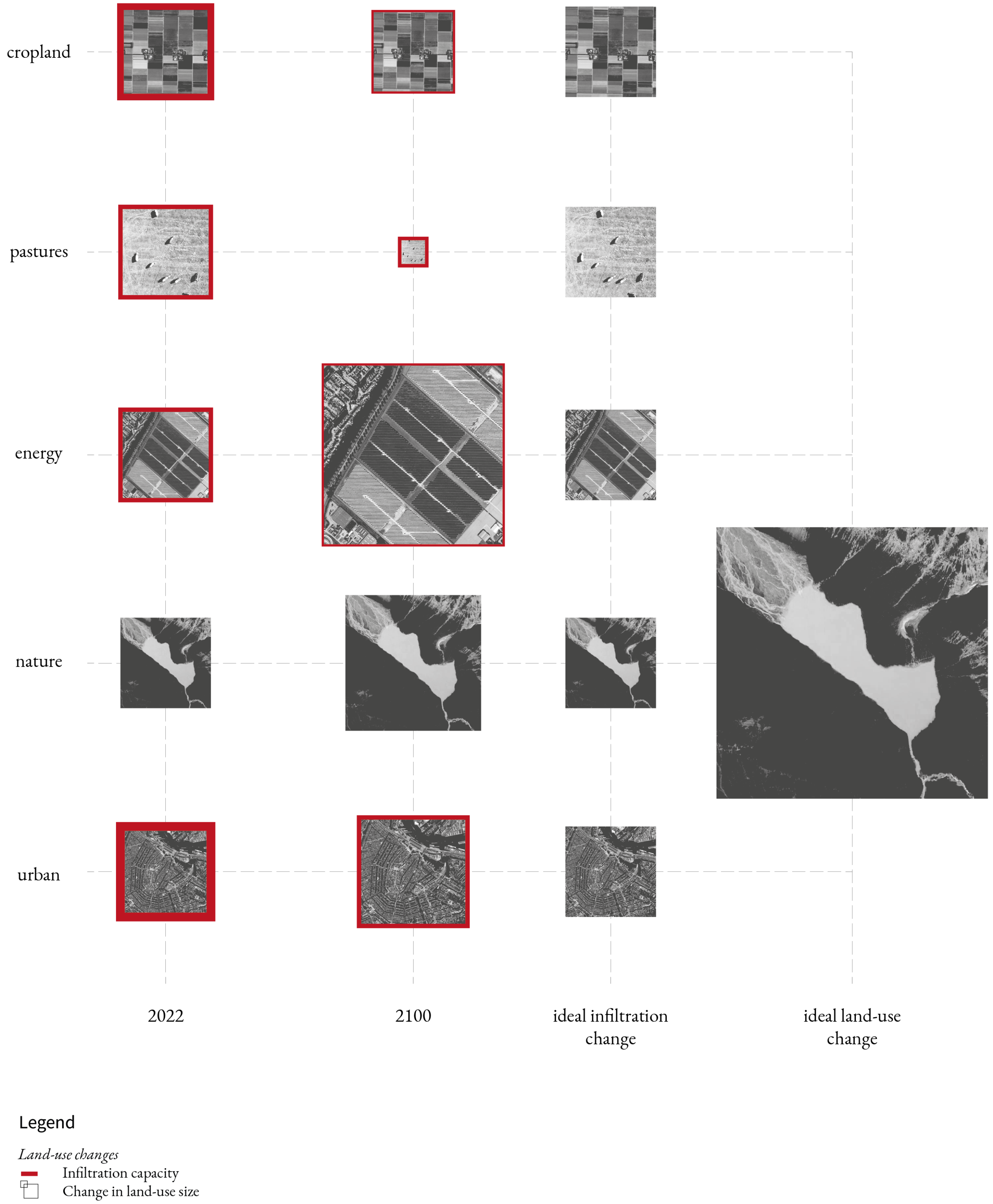


Illustration 27 | Monograph 'Clearance: topos: limit'
Source: by author

V.III **HABITAT:** COMPOSITION

CATALOGUE OF MATTER

- Natural water system
- Land uses in the floodplains

COMPOSITION

This composition explores all land uses within the natural floodplains of the Rhine Valley. It is a simplified display of the floodplains. The goal is to give an overview of the dimensions of each land use that falls under this transforming landscape.

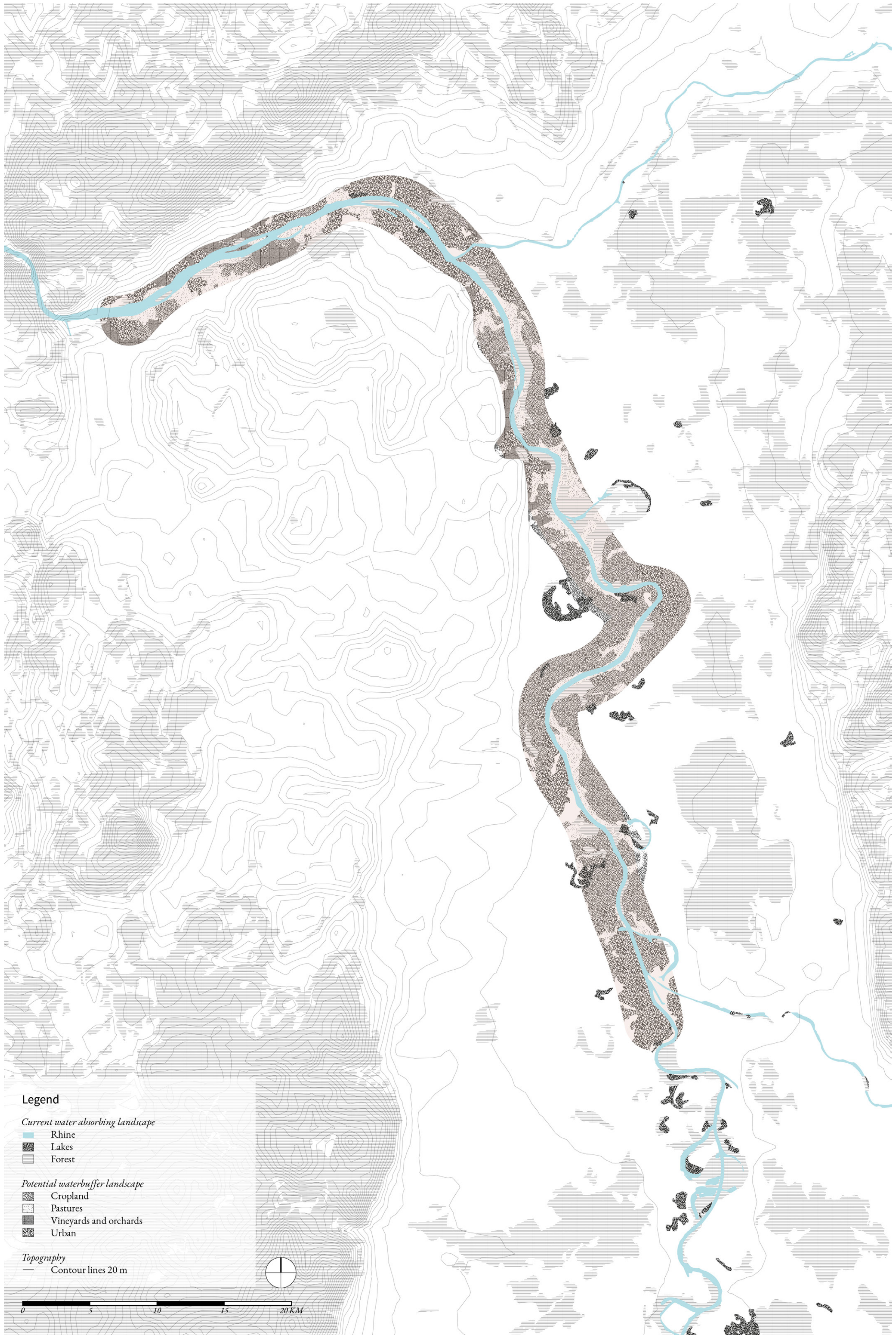
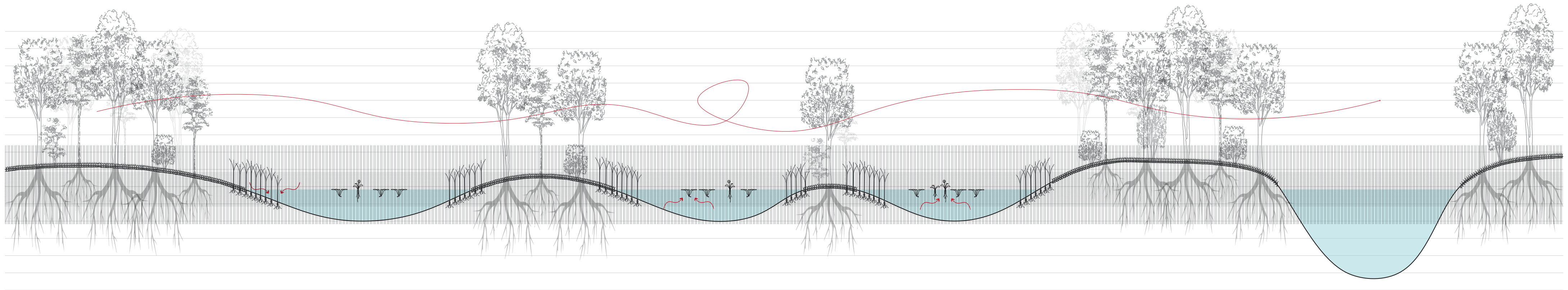


Illustration 28 | Monograph 'Clearance: habitat: composition'
Source: by author

V.III HABITAT: ALTERATION

The section on the right shows an example of how this territory could be transformed. Here the land has the new function of hosting water throughout the year. This increases the water buffer capacity during floods and mitigates droughts. Due to the altered landscape, the fluctuations of the water height become smaller. The land between the ponds is covered by natural vegetation resistant to floods. This dramatically increases biodiversity. The ponds also serve as filtration mechanisms as plants in the riparian zone have the capacity to filtrate the river water, increasing the Rhine's water quality.



0 250 500 m

Clearance : Habitat

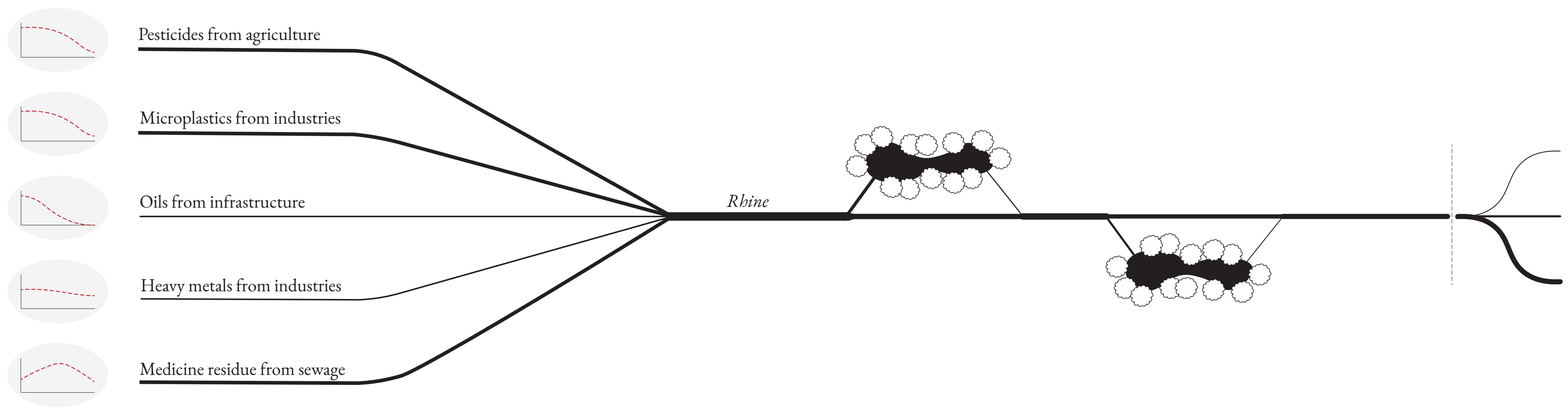
Water buffer
- Water
- Old standard fluctuations
- New standard fluctuations

Ecology
- Increased biodiversity
- Phytoremediation

Illustration 29 | Monograph 'Clearance: habitat: alteration'
Source: by author

Expanding on water pollution, this diagram shows the clearance of pollution. There are five primary sources of water pollution. Based on technological, societal, and governmental development, future trends show a decrease in most pollutants. Especially pesticides, microplastics, and oils are expected to largely disappear.

Water buffer wetlands along the Rhine are used to filtrate remaining pollutants. The effectiveness of these wetlands is limited as only a portion of the water flows through them, and the wetlands do not have the capacity to filtrate all pollutants.

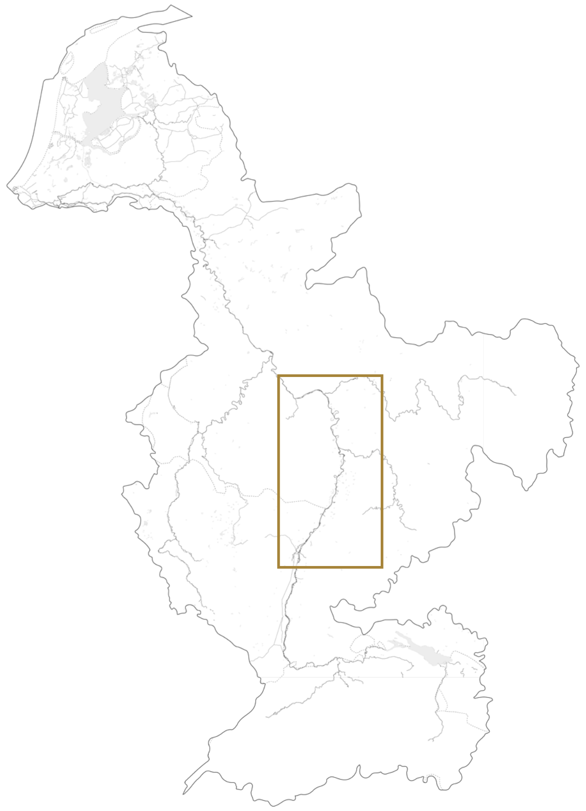


Legend

Clearance of pollution
Pollution future trends
Level of contamination
Water buffer wetland

Illustration 30 | Monograph 'Clearance: habitat: limit'
Source: by author

V.IV **GEOPOLITICS:** COMPOSITION



CATALOGUE OF MATTER

- Natural water system
- Policies of care

COMPOSITION

This composition explores how (geo)political actors could alter the future of the Rhine. A transboundary effort could have immense implications for future floods, droughts, and pollution risks.

This map shows what could happen if we acknowledge the upstream-downstream interdependencies and together work for a sustainable future for the Rhine. Water buffers throughout the basin will significantly decrease flood risks downstream, pollution, and the effects of local droughts. Eco-friendly dams ensure that the river once again becomes a connected habitat where fish and sediments can follow their natural course. Total bans on pesticide use and wastewater disposal into the river significantly decrease water pollution. Furthermore, a transboundary soil protection act could significantly increase the water regulating the capacity of the soil.

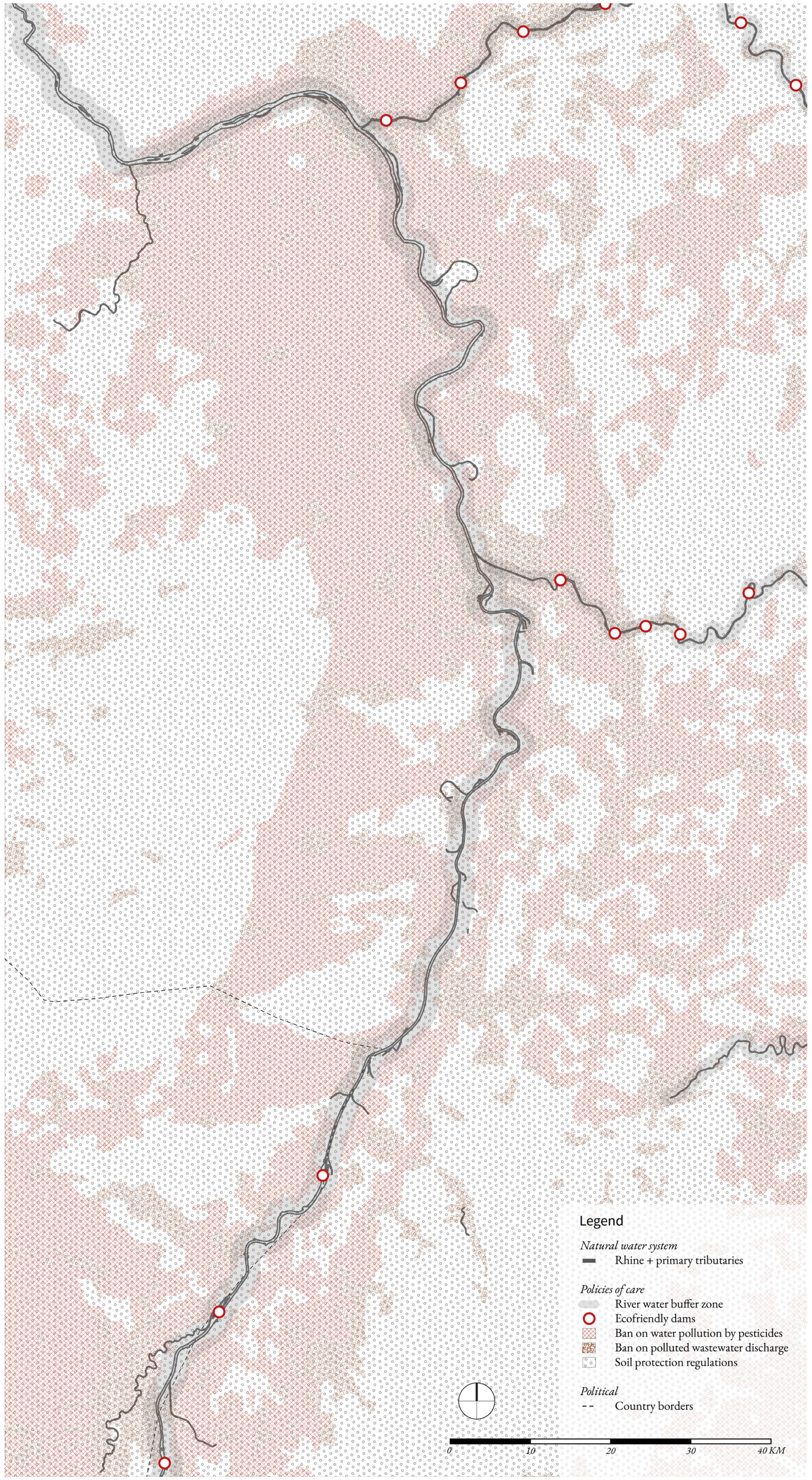


Illustration 31 | Monograph 'Clearance: geopolitics: composition'
Source: by author

This section visualizes the alterations mentioned on the previous page.

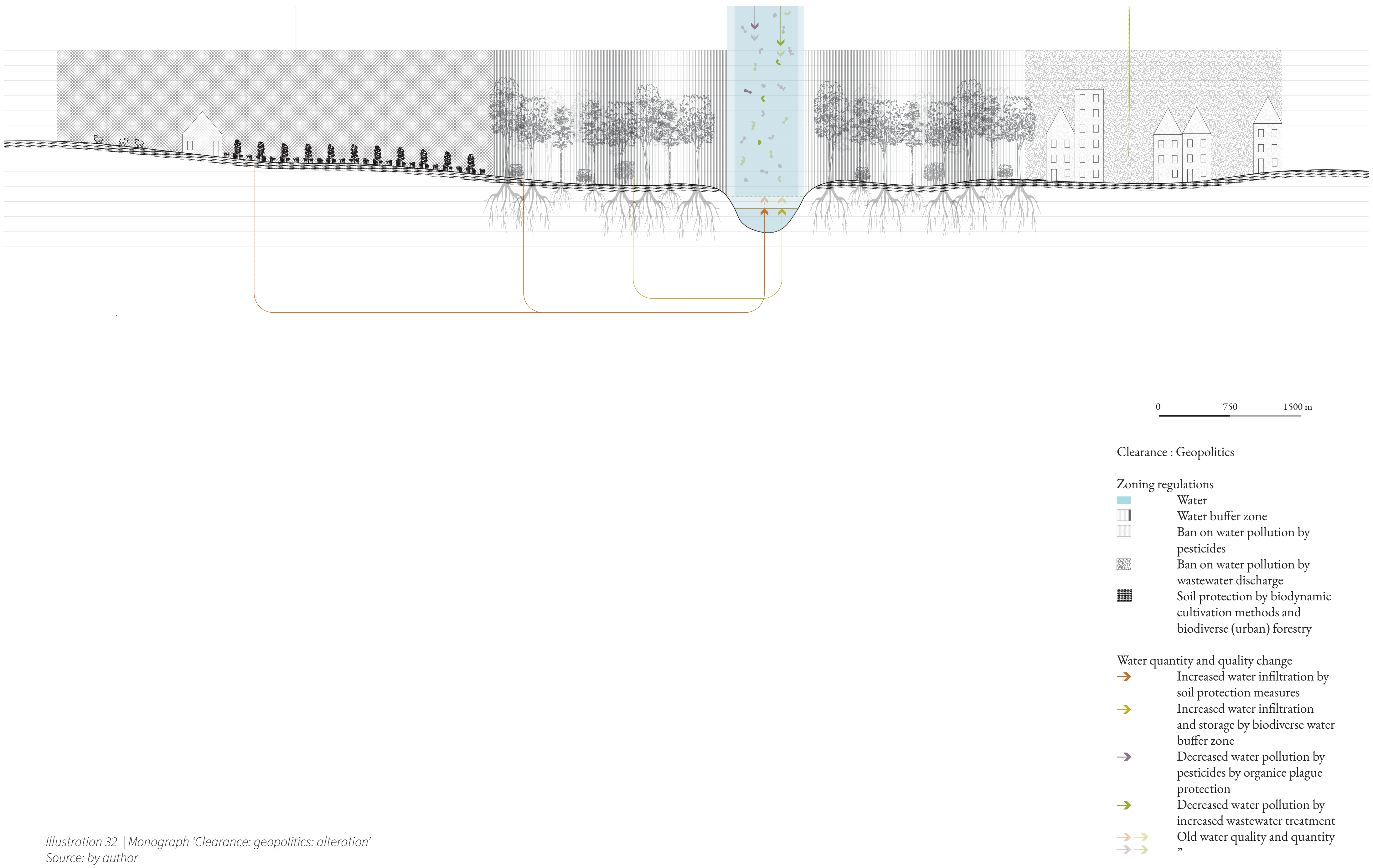


Illustration 32 | Monograph 'Clearance: geopolitics: alteration'
Source: by author

Transboundary cooperation is crucial for the sustainable development of the Rhine. Therefore, establishing a Rhine Union could be helpful. Currently, there are multiple basin-wide organizations; however, their capabilities are limited and separated into multiple institutions. Increasing the power of this central organ could lead to symbiotic governance. In light of the progressive ideas that are explored, these chances are necessary as well:

- Progressive national and regional politics
- Private-public cooperation or land expropriations
- Linking knowledgeables and farmers
- Centralization of German and Swiss water management.

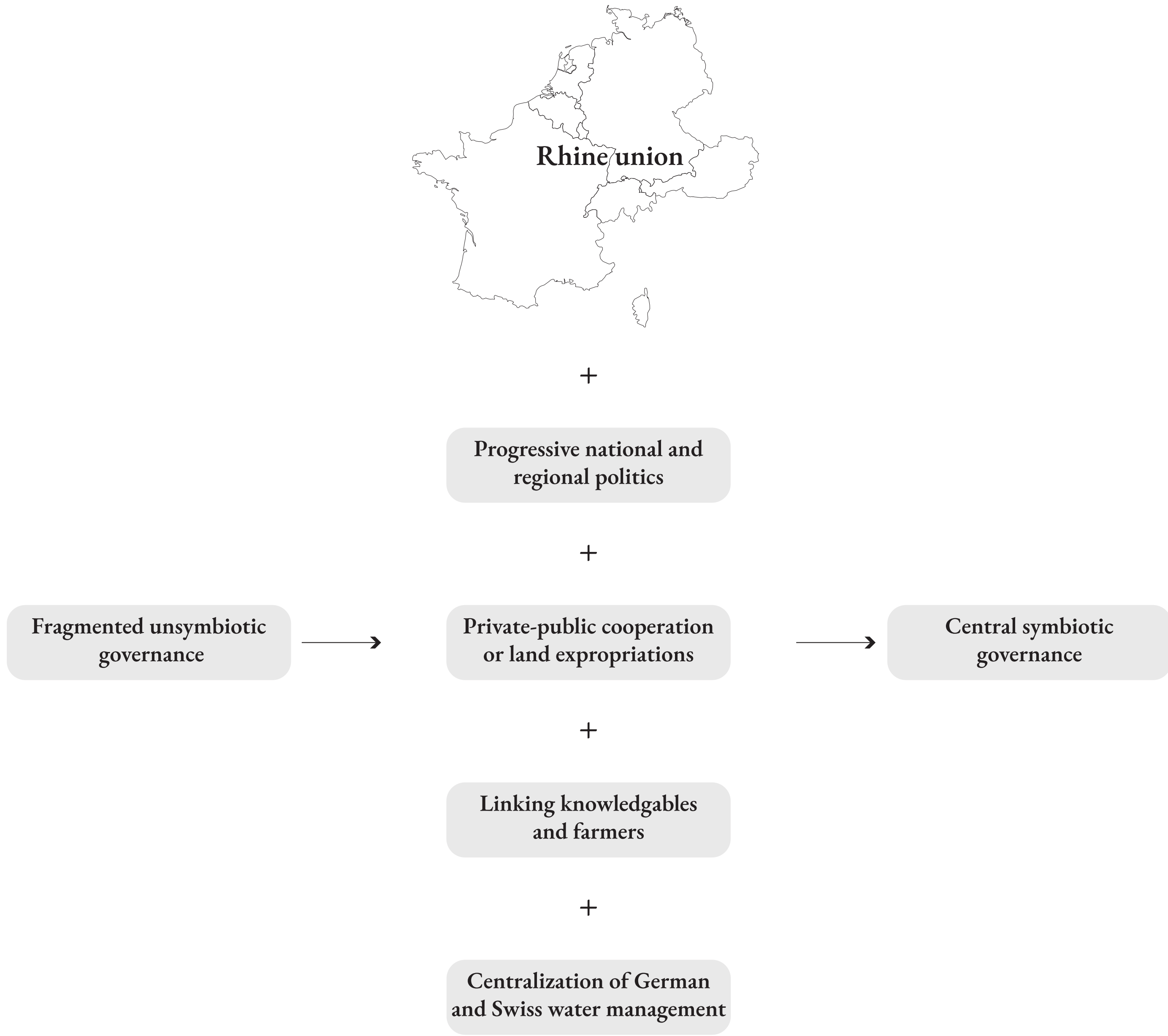


Illustration 33 | Monograph 'Clearance: geopolitics: limit'
Source: by author

V.V DESIGN ELEMENTS

Distilled from this projective exploration are three main design elements. They are acts of clearance and hold the potential to connect to the values presented in the proposition and theoretical framework.

LAND USE TRANSFORMATIONS
Historical changes in land use are partly responsible for floods and droughts. This can be counteracted by transforming land into a state with better water regulating capacity. Societal trends can be connected to this, like a decreasing meat consumption which would allow for a landscape with fewer pastures.

TERRAFORMING THE FLOODPLAINS
Dykes constructed closely to the riverbed force water to flow downstream quickly. This increases peak discharges and, therefore, the chances of floods downstream. Giving more space to the river could prevent floods both locally and downstream. This means floodplains are reinstated and could become a dynamic hybrid landscape for humans and nature.

BUFFERING WATER
River rectification and land use change have decreased the water buffering capacity of the land. Water buffers contain the potential to prevent floods and drought and could help clean the river and become a valuable habitat.

VI STRATEGY & DESIGN

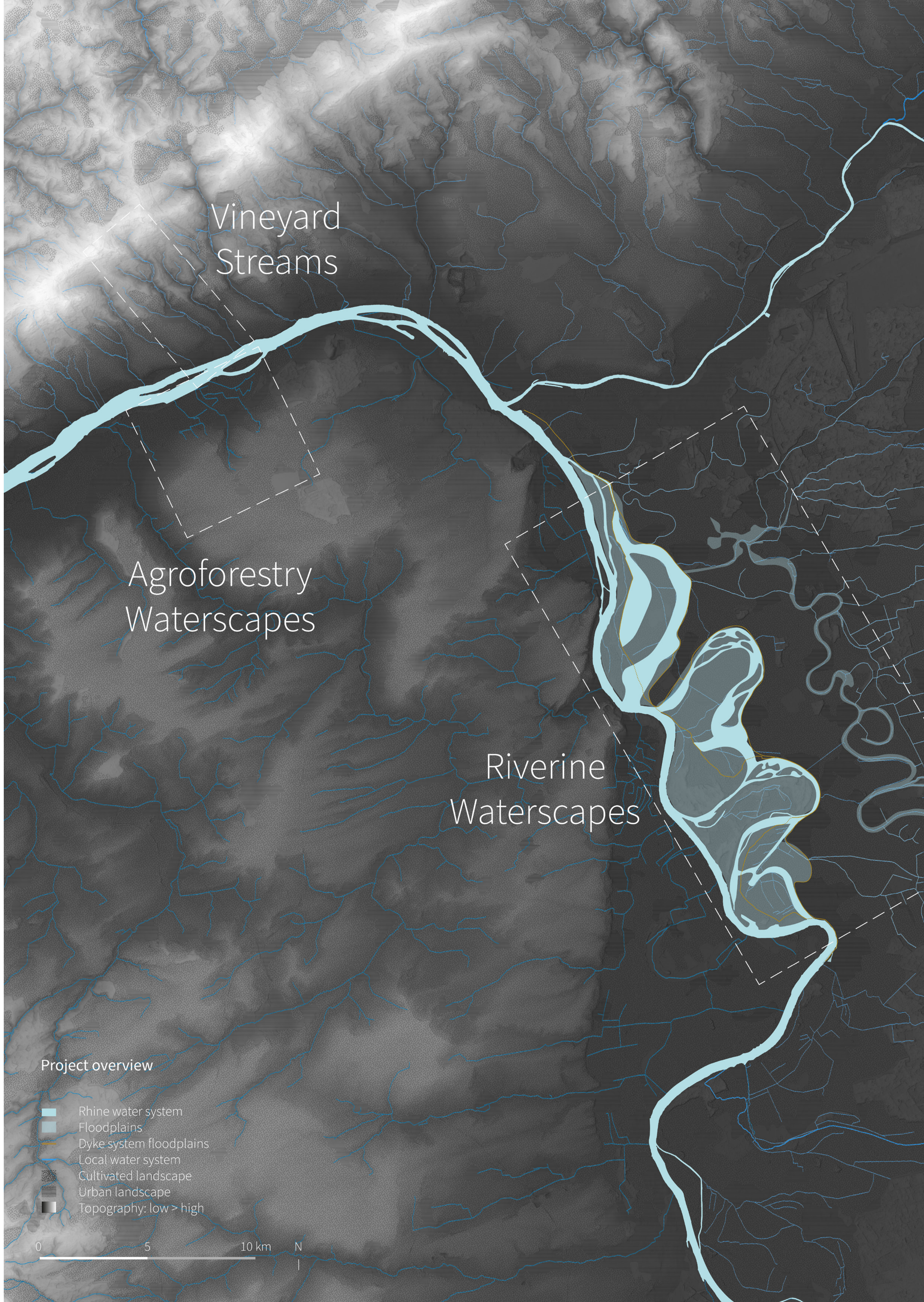


Illustration 34 | Project overview
Source: by author

Image 16 | Satellite image of Eltville am Rhein and landscape around the Kiedricher Bach. Source: Apple (n.d.-a)

VI.I VINEYARD STREAMS

Illustration 35 | analysis of the Vineyard Streams location
Source: by author

ELTVILLE AM RHEIN AND THE KIEDRICHER BACH

The first typological elaboration is given for a site signified by a small stream flowing through hilly terrain with an alternation of vineyards and villages.

The stream central in this design exercise is the Kiedricher Bach (dark blue line is illustration 35). It starts in the forests of the Taunus mountain range (northern part of image 16 and illustration 35). It flows downhill along the village of Kiedrich. Water is fed by the surrounding landscape consisting of forests and vineyards. Before entering the Rhine, the stream flows through the center of the small city of Eltville am Rhein (later referred to as Eltville). However, the stream is not visible here as it flows through underground pipes towards the Rhine. The capacity of these pipes is not made for extreme rainfall events, and it is a complex task to alter these pipes as the stream flows underneath more than 50 private properties. This situation has already led to flooded basements. In a village nearby someone has lost their life in a similar flooding. The Taunus mountain range is known to be a border between warm air from the Rhine Valley and cold air from the north. This leads to many thunderstorms, making the Kiedricher Bach system more vulnerable. Given this information, the municipality expects that the changing climate will have significant consequences for the future flood risk of Eltville. (appendix AI)

This means action is necessary to mitigate the effects of climate change to protect Eltville from floods.

0 0,5 1 km N

LEGEND

- Vineyards
- Streams
- Kiedricher Bach
- Rhine
- Urban area
- Other land use
- Shrubs
- Forest
- Roads
- Landscape contours

VI.I VINEYARD STREAMS

STRATEGY OF THE VINEYARD STREAMS

The main idea for the Vineyard Streams is to retain and filtrate as much water as possible before the stream enters the town of Eltville am Rhein. By retaining water throughout the landscape, several problems are addressed:

- Drought is mitigated as more water is available from retention areas and within the soil. Right now, there are not many alternative sources of water when rainfall is lacking.
- Flash floods are mitigated; flash floods emerge when much rain falls on arid soil. As more water is retained in the land, the soil dries out less quickly, so water can infiltrate better (partly) and prevent flash floods.
- Floods are mitigated; lower-lying areas are less prone to floods by heavy rainfall when there is sufficient upstream retention capacity.
- Biodiversity loss is prevented; mitigating extremes of water availability helps the survival of certain species.
- Biodiversity is enlarged; new landscape forms like ponds create space for new species to flourish.
- When this strategy is upscaled to many or all small streams, the water supply of the Rhine becomes more steady, so extreme low or high water levels are prevented, which prevents floods and droughts, and all the damages they bring, to communities downstream.

The water is also filtrated, and pollution is prevented at the source, so the water quality of both the streams and, when upscaled, the Rhine will improve. This results in a healthier habitat for humans, animals, and plants.

DESIGN IN THREE AREAS

The Vineyard Streams is divided into three areas to reach these goals and implement these main tools (illustration 36).

<u>I The Vineyard</u>

Area one is located within the vineyards and is characterized by steep slopes and erosion-prone soils. Three interventions are presented to reach the stated goals.

<u>II Retention Valley</u>

The second area is the middle part of the main branch of the stream, the Kiedricher Bach. This area is characterized by gentle slopes, fields, and small patches of forest. Here there is more space for larger-scale retention basins. The goal of this area is to retain all the remaining run-off water during extreme rainfall events before the stream enters the city.

<u>III Drainage City</u>

The last area is the city of Eltville am Rhein. Here the situation of the stream is relatively complicated. The stream is almost entirely located underground and partly underneath private properties. This makes it almost impossible to increase the capacity of the stream, and therefore the city is exceptionally prone to flash flooding. This is why in extreme rainfall events, all the water must be buffered before it enters the city. So the only concern that remains is discharging the water that falls within the city. There are two main interventions in this area.

OVERALL STRATEGY AND DESIGN

The original idea was to link these three recreational areas around the stream. However, due to difficulties with private properties in Kiedrich and especially Eltville, this turned out to be impossible. Now the best way to connect these three areas is by installing explanatory signs in each area, inviting people to check out the whole system. The advantage of a complete stream walk is that it helps people understand the system.

The later chapter about the strategic framework discusses how the specific strategy and design, and the lessons learned in the process, could be used in similar streams through the Rhine basin, so it helps to reach the large goal of protecting downstream communities from floods and droughts.

Illustration 36 | map of projects in the Vineyard Streams project
Source: by author

WINE CULTURE

The first detailed design proposal is produced for a challenging vineyard site close to the river Kiedricher Bach. The landscape has the extraordinary shape of a funnel. These two conditions have led to the choice of this location. Vineyards on steep slopes are very vulnerable to erosion and run-off water. Through the funnel, this water collects at the meeting point with the Kiedricher Bach. During extreme rainfall events, this joint becomes a bottleneck vulnerable to flooding. The fact that this joint is located on the edge of the village of Kiedrich makes it an extra pressing problem.

Therefore, the transformation is proposed to change this vineyard site to become a water retention landscape. This connects to this typological exercise's main challenge: retaining water throughout the landscape to prevent floods in Eltville am Rhein. As mentioned before, the clearance of vineyards is not a preferred action. This is a powerful wine-producing region called Rheingau. This means that wine is an essential part of the identity of the surrounding communities. This is seen in every village through the presence of multiple winemakers (images 17 to 20). Additionally, these steep hills are needed to produce high-quality grapes in this relatively northern wine region. This means the design exercise is to create a retention landscape within a vineyard.

Images 17 to 20 | Wine identity in local communities
Source: by author

VINEYARD DESIGN

The first intervention is focused on the farming technique. Biodynamic cultivation is the basis for this new technique as it focuses on improving the soil conditions by adding specific compost and more undergrowth, which results in an improved sponge capacity of the soil. This means the soil is better at letting water infiltrate, retaining water, and giving water back to the plants. Grape plants grow relatively well on rocky and dry soil, but a high-quality grapes can be produced by adding the proper nutrients through composting. The extra undergrowth and improved soil quality create a healthier habitat for insects and soil life. (Meissner et al., 2019)

The second intervention consists of hedges parallel to the contour lines of the landscape. These hedges will naturally form an elevation in the lanscape, creating a small trench through natural erosion and sedimentation. These trenches guide run-off water towards dedicated retention basins. Additionally, they can retain and let the water slowly infiltrate the ground. Apart from naturally forming and preserving the trenches, the hedges also boost biodiversity. Planting certain plants attract animals and insects to the vineyard; they can serve as natural plague protection. This extends the concept of biodynamic farming.

The last vineyard intervention is retention basins. Many vineyards, especially the vineyard in this pilot study, are located on steep hills, making large-scale retention basins challenging to create without significantly impacting the landscape. Therefore, a series of small ponds is introduced called the Retention Ladder. Each pond can retain a small amount of water, and when the limit is reached, it overflows into the pond below. These ponds, together with the trenches and sponge soil, have the capacity to retain all the water in a future extreme rainfall event (appendix AII).

0 50 100 m N

LEGEND

- Vineyards
- Hedges
- Vineyard trench
- Water ladder
- Kiedricher Bach (river)
- Landmarks
- Landscape contours
- Urban area
- Forest
- Roads

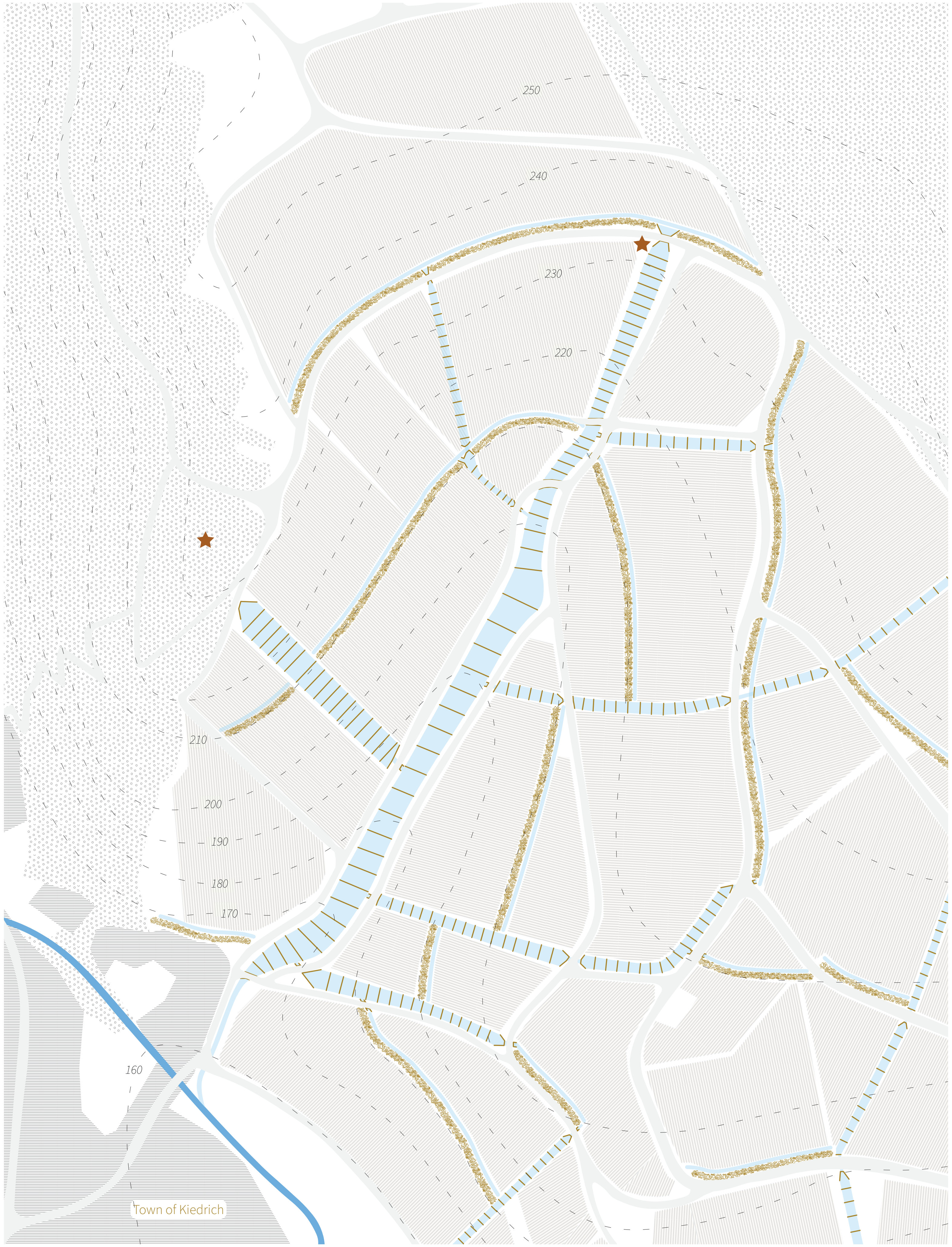


Illustration 37 | map of The Vineyard
Source: by author

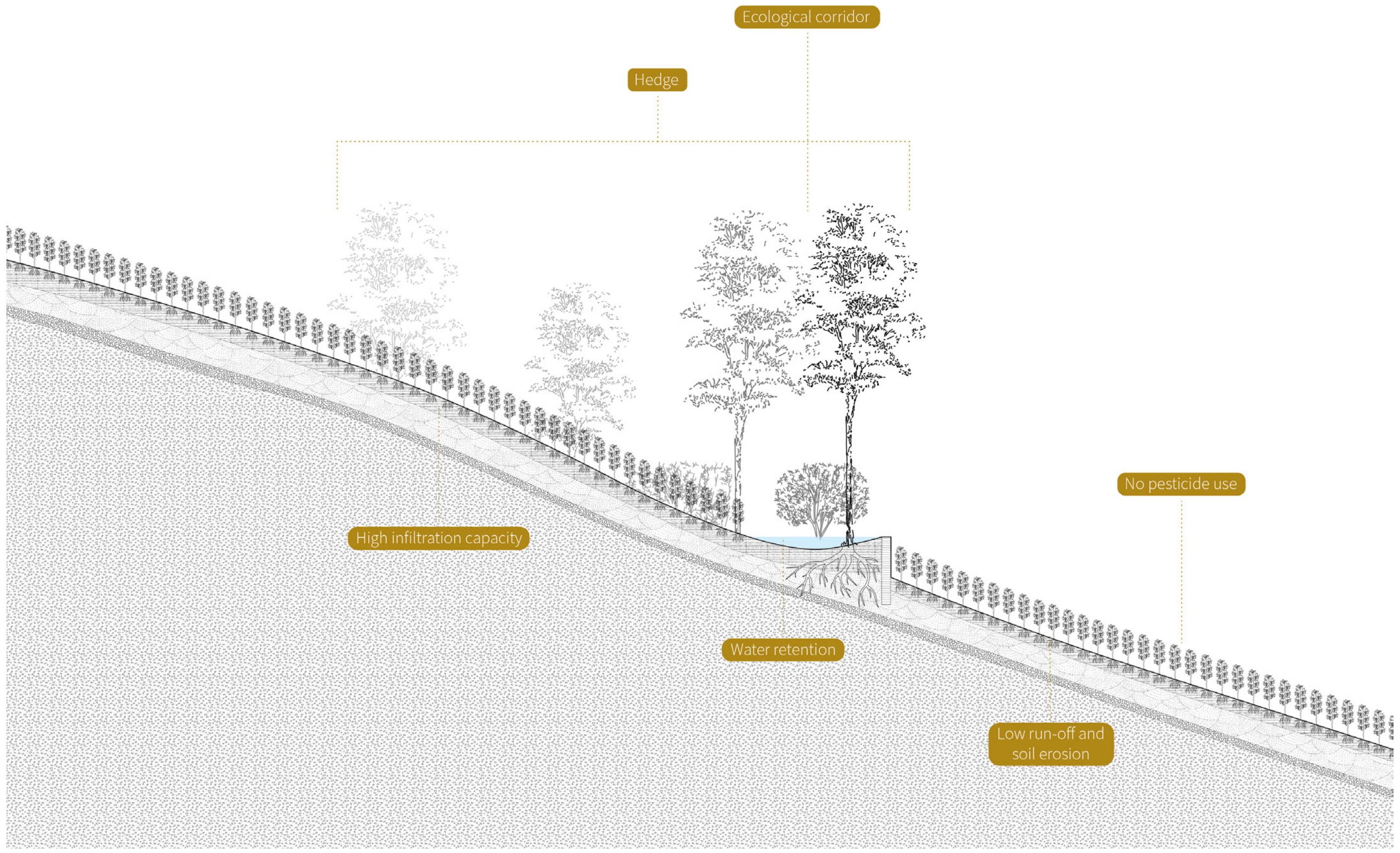


Illustration 38 | section of The Vineyard flood conditions
Source: by author

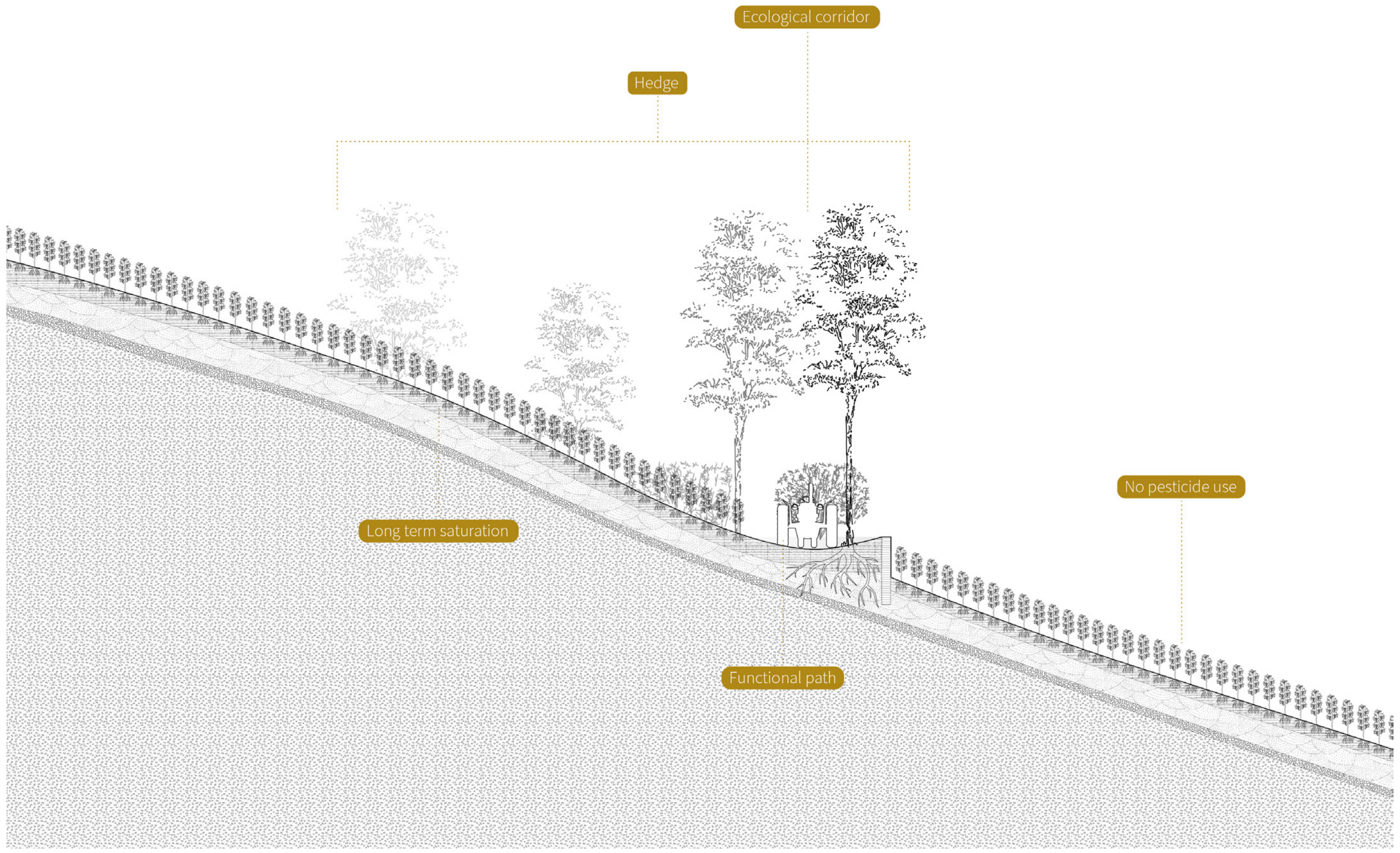


Illustration 39 | section of The Vineyard dry conditions
Source: by author

VINEYARD STREAMS: THE VINEYARD

WATER LADDER

The water ladder and the hedges bring a new cultural layer to the landscape. It forms rigid and formal lines, which serve as guides apart from their retention function. As it is incorporated into the existing rigid structure of the vineyards, it forms a balanced composition. Inviting people to visit these modern, nature-inclusive engineering works helps them to understand the water system. It aims to increase awareness about water's positive sides and dangers, thus enhancing the societal capacity to maintain a water-inclusive landscape. Therefore, making the new water system accessible and attractive to citizens is a crucial design strategy.

Along the water ladder, paths are designed and, where possible, accompanied by trees and other vegetation. The vegetation and water make recreational activities more comfortable as the microclimate is more temperate than without these elements.

One of the prominent landmarks in the whole Vineyard Streams project area is a ruin of an old castle (image 21). This is already a popular cultural site, invigorated by the formal water ladder, inviting people to walk uphill.

The water ladder's main branch is incorporated into the landscape. It uses the natural trench formed by the landscape; therefore, minimal changes are necessary. Only a series of small dams which can control to retain or let the water flow downstream is constructed. The smaller branches cannot use existing trenches in the landscape. As the soil is rocky, it is decided to build the retention basins on top of the current landscape. This decision aims to increase the infiltration rate within these small basins.

FINANCIAL COMPENSATION

Due to the proposed interventions, the total vineyard area and the number of grapes per plant will decrease (appendix AI). This could lead to diminished income for the farmers. Here a trade-off system is introduced. The farmers make a relatively high sacrifice to aid the downstream communities of Kiedrich, and Eltville am Rhein. This sacrifice could also support the farmers themselves. However, the most significant benefits are expected for the communities. Therefore, the community should reserve a yearly fund to financially support the farmers who are part of the Vineyard Streams project. Apart from the fact that this can be considered fair, it motivates farmers to become part of this project. This could initiate a more extensive transformation in the Rhine Valley region.

▲ *Image 21 | photo of vineyard in exiting condition*
Source: by author

▲ *Illustration 40 | vineyard in future condition*
Source: by author

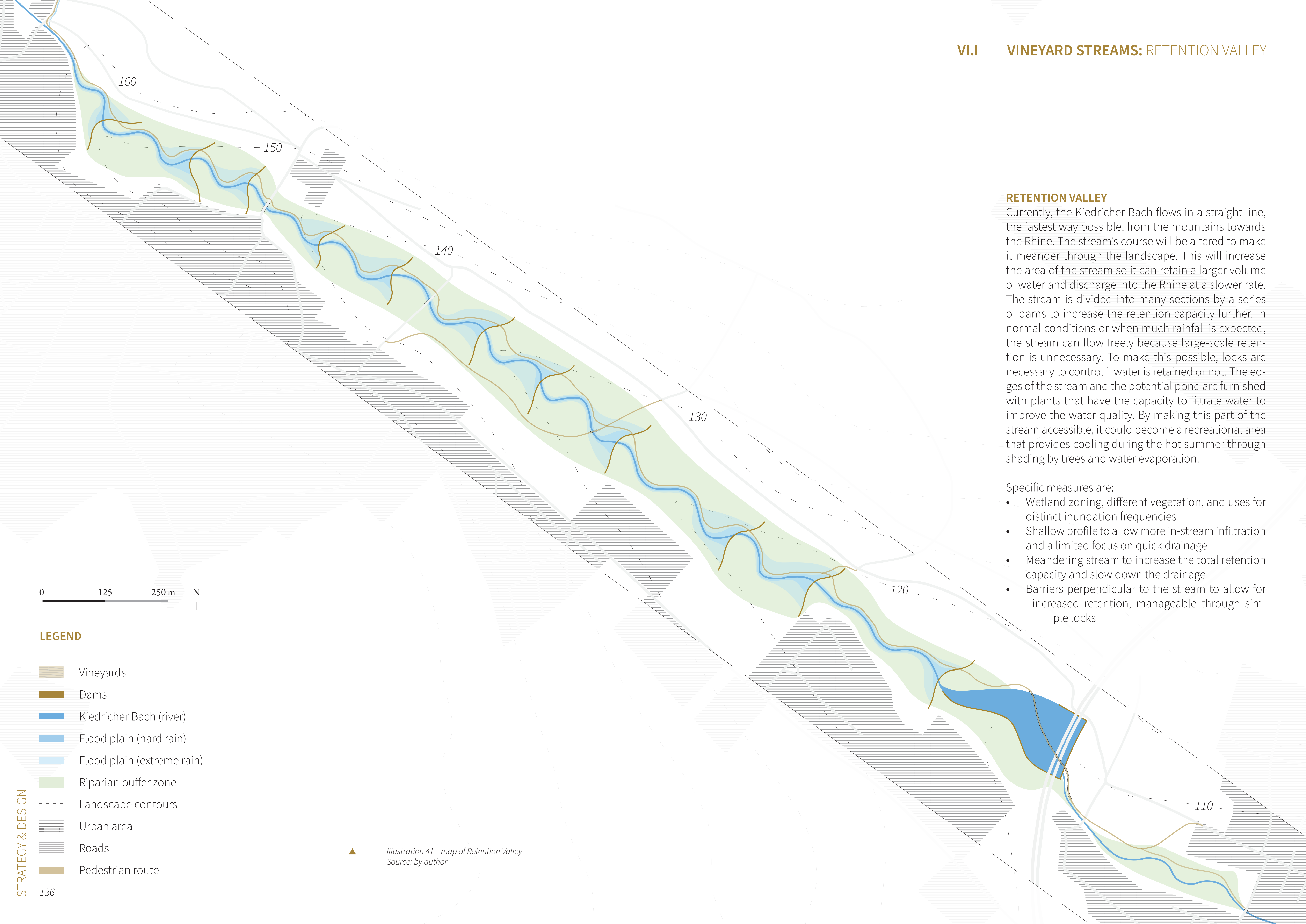


Illustration 41 | map of Retention Valley
Source: by author

RETENTION VALLEY

Currently, the Kiedricher Bach flows in a straight line, the fastest way possible, from the mountains towards the Rhine. The stream's course will be altered to make it meander through the landscape. This will increase the area of the stream so it can retain a larger volume of water and discharge into the Rhine at a slower rate. The stream is divided into many sections by a series of dams to increase the retention capacity further. In normal conditions or when much rainfall is expected, the stream can flow freely because large-scale retention is unnecessary. To make this possible, locks are necessary to control if water is retained or not. The edges of the stream and the potential pond are furnished with plants that have the capacity to filtrate water to improve the water quality. By making this part of the stream accessible, it could become a recreational area that provides cooling during the hot summer through shading by trees and water evaporation.

Specific measures are:

- Wetland zoning, different vegetation, and uses for distinct inundation frequencies
- Shallow profile to allow more in-stream infiltration and a limited focus on quick drainage
- Meandering stream to increase the total retention capacity and slow down the drainage
- Barriers perpendicular to the stream to allow for increased retention, manageable through simple locks

COMPOSITION

The dams are designed with the experience of visitors in mind. Therefore, dams will be low, with a maximum height of two meters. This height is chosen as it enables a total overview of the composition of dams. As the slope's steepness increases towards the mountain range, the overview is made possible. Together with the landmark ruin in the vineyard, this invites people to walk upstream and explore the whole water system of the Kiedricher Bach. Trees are placed strategically to ensure the visibility of this landmark.

This results in trees being located near the stream on the west bank and further from the stream on the east bank. Large trees on the west bank provide shade in the afternoon and evening on the river and the east bank. This form of strategically placing trees is also used in other locations throughout the Vineyard Streams project.

ECOLOGY

When zooming in, the ecological benefits of the design become more apparent. Apart from meandering, the form of the stream is altered from a canal profile to a wide shallow trench. The decreased depth means a decline in fast drainage, especially from groundwater. Further, the speed of the water flow is decreased, and the surface contact area has increased. This improves infiltration within the riverbed. Shallow wide trenches also have ecological benefits. New flora and fauna can flourish in the partly or permanently inundated land. This creates a green corridor from the mountains towards the edge of Eltville am Rhein. Low vegetation on the edges of the stream also holds the potential to filter the water, ensuring good water quality downstream.

The construction of a series of dams creates barriers for marine life. Therefore, most dams within the main branch of the stream are only closed in extreme rainfall events. After the event, the water is slowly discharged to the Rhine so the dams can be opened. The most downstream dam remains closed in every situation. Depending on further research from ecologists on potential migrating marine life in this stream, a fish pass could be constructed.

Excavation of the stream is necessary as the course is significantly altered from its current form. To ensure the stream's path remains within certain limits, trees and bushes are planted strategically to prevent soil erosion. Especially willows are able to strengthen the banks of rivers.

Illustration 42 | short section of Retention Valley flood conditions
Source: by author

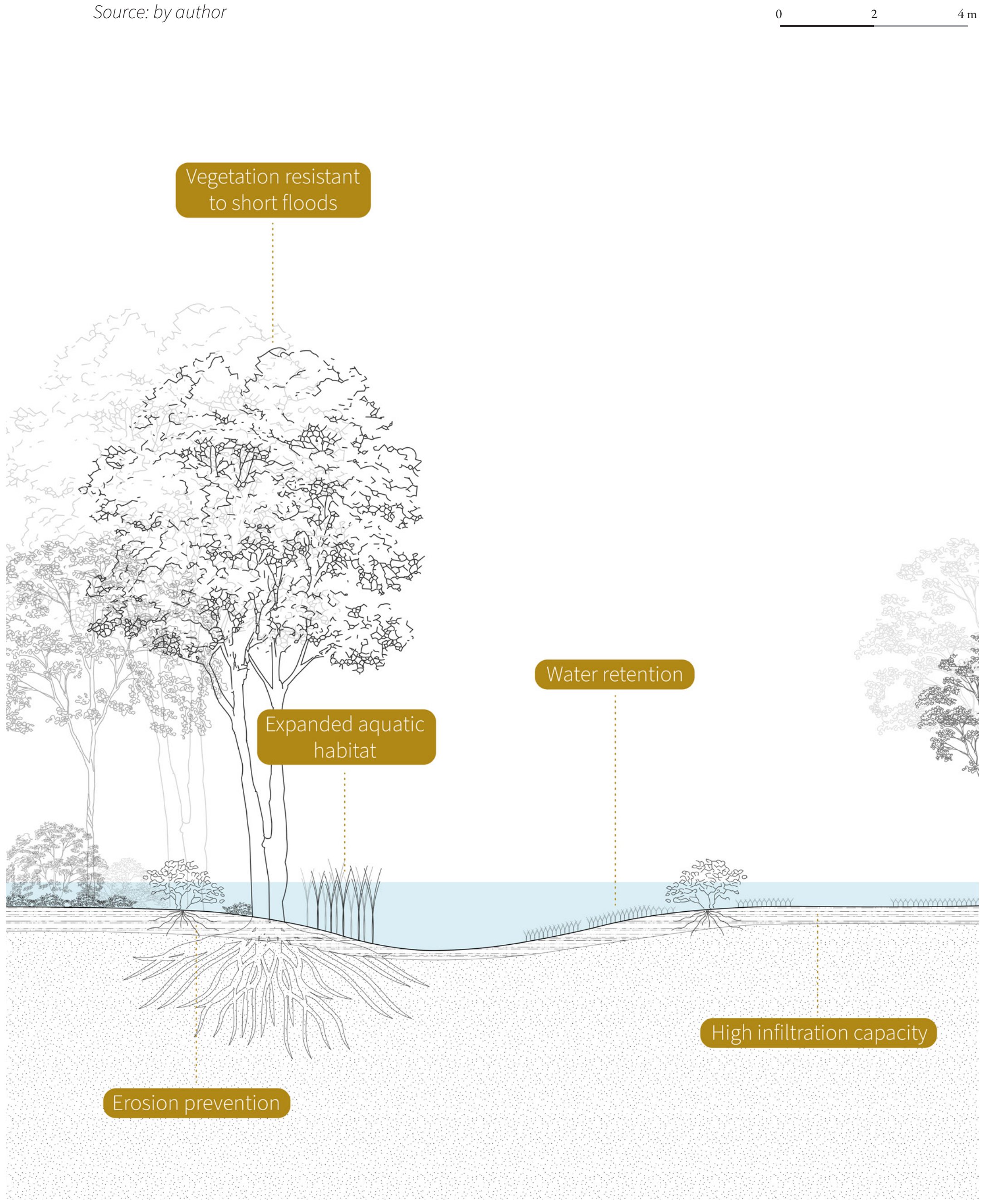


Illustration 43 | short section of Retention Valley dry conditions
Source: by author

THE HIGHWAY
A bottleneck from a recreational perspective is the highway underpass before the stream enters the city. The bridge's height is limited, creating a feeling of unsafety. Multiple scenarios were sketched to upgrade this place. Eventually, the chosen scenario is a large and permanent retention buffer. The whole area underneath the bridge is inundated, except for a small road. Also, a part north of the bridge is inundated as this was inevitable due to the form of the landscape. This creates a pond that could be used to cool down in the summer. The natural edge of this pond north of the bridge could function as a beach with vegetation. The pond is equipped with lights to create a sense of safety during the evening and night. A bridge hovers a few centimeters above the pond to form a pedestrian and cyclist connection between Eltville and the Retention Valley.

GOING UNDERGROUND
The Retention Valley ends when the stream goes underground in Eltville. The fact that the stream goes underground is inevitable, and as awareness of the water system is one of the main goals, this point is highlighted through design.

This location is the starting point from which the stream can be followed upstream without interruptions. Therefore, it is designed as an access point for multiple modes of transport. Parking space for cars and bicycles is designed 300 meters north of where the stream goes underground. There is a tiny pavilion with toilets, tourist information, and a café at the parking. From there, only pedestrian access to the underground entrance is possible to prevent disruption of the surrounding neighborhood. Glass panels are placed on top of the end of the stream so people can walk on it and have the stream flowing underneath their feet while reading information about the water system.

Illustration 44 | map of Drainage City
Source: by author

ELTVILLE AM RHEIN

Through the effort in The Vineyard and Retention Valley, the city of Eltville is protected from excessive amounts of water entering the city via the Kiedricher Bach. Therefore, the focus on the city can shift towards the urban quality of water and extreme rainfall within the city. Run-off water from rainfall tends to flow towards the stream due to the form of the landscape. Due to the low capacity of the underground stream, run-off water can only enter the stream at specific locations. To control the flow of water in the city during extreme rainfall, a strategy is made for a drainage network. This is visible in illustration 44 as 'Drainage street profiles.' These street profiles are altered to accommodate water and direct it to the Kiedricher Bach in a controlled manner.

In the Northern part of the city, the stream flows underneath more than 50 private properties; therefore, interventions are too complicated here. The city center located against the Rhine brings more opportunities. The exact location of the drainage pipes is unknown (also by the municipality), but here, there is an opportunity to open up the stream. Due to height differences, it cannot be fully opened. The stream is brought above ground in two sections to enhance its drainage capacity and improve the urban quality. Two essential functions are to mitigate the urban heat island in the context of climate change and improve the city center's recreational aspect.

0 100 200 m N

LEGEND

- City river access
- Kiedricher Bach (river)
- Underground river
- Drainage street profiles
- Pedestrian route
- Landscape contours
- Buildings
- Roads
- Railway

DRAINAGE STREET PROFILE
Street profiles are designed with three ideas in mind:

- Control the water flow to the Kiedricher Bach
- Temporarily retain water to prevent peak discharges
- Improve the urban quality of the street

They are also designed for three scenarios: dry, wet, and extreme wet conditions. In dry conditions, the street profile is accessible for pedestrians, cyclists, and cars (one-way). Between the road and the sidewalk, a wadi is proposed. The wadi has mixed vegetation, which mitigates the urban heat island and expands the urban ecological habitat. Depending on the initial conditions, there might be water in the wadi.

In wet conditions, the primary function of the wadi is to collect rainwater run-off from houses and streets. As most streets are located on slopes, small dams are installed to retain small amounts of water.

The water collecting function is expanded to the road in extreme wet conditions. Therefore, the street is temporarily not accessible by (low-lying) cars. This increases the drainage capacity and prevents local flooding. The small dams cause a decline in the peak discharge towards the Kiedricher Bach.

CITY CENTER STREAM
Regarding the goal to mitigate the urban heat island, the opened-up stream is accompanied by vegetation where possible, as this brings an extra cooling effect. It is challenging to incorporate the stream into the small street profiles in the center. To prevent a lack of space for pedestrians and terraces in the main shopping street, the stream is partly covered by penetrated metal sheets. This gives the experience of the stream as it is audible. Another small street connects the city center and the Rhine. In this street, less space is necessary for movement, so accessibility to the stream is possible. The stairs that lead to the water provide a resting place with a view of historic buildings, including a church.

An additional benefit is that people can improve their relationship with water as bringing it above ground makes changes in discharge easier to grasp. When people understand water better, they might become less afraid of it. This fear is present due to the 2021 deadly flooding event elsewhere in the country and past fatalities in nearby streams.

Image 22 | Satellite image of Wackernheim and surroundings
Source: Apple (n.d.-c)

WACKERNHEIM AND SURROUNDINGS

The second typological elaboration is given for a site signified by a multitude of agricultural practices with a belt of orchards and vineyards on sloped land.

The village and its agricultural surroundings in this design exercise is Wackernheim. It is located on a slope on the edge of a plateau with a height of approximately 200 meters. The slope continues downward on the village's north and west sides, where vineyards, orchards, and forests are alternated. On the south and east sides, the land is relatively flat and is used for orchards and croplands. The landscape is signified by hard borders between urban and agricultural uses and drought, visible through dead trees, dried-out crops, and dusty soils. Dry conditions make an area prone to soil erosion and flash floods.

Illustration 45 shows a complex patchwork which represents distinct land uses. Orchards and croplands are currently the most extensive agricultural practices. Forest cover follows the patchwork pattern which means it is divided in small indivudual pieces and not forming any kind a valuable corridor. On the slopes, especially vineyards and orchards are found.

0 0,75 1,5 km N

LEGEND

- Rhine
- Stream
- Vineyard
- Orchard
- Cropland
- Pasture
- Urban area
- Main roads
- Railway
- Forest
- Nature reserve
- Topobathy: low > high
- Landscape contour

Illustration 45 | Analysis of Agroforestry Waterscapes
Source: by author

STRATEGY OF THE AGROFORESTRY WATERSCAPES

The main idea of the Agroforestry Waterscapes is to retain as much water as possible in the landscape, significantly improve the biodiversity and improve the connection of the community to nature, water and agriculture. This addresses previously discussed problems in this way:

- Land-use transformations towards nature-inclusive practices mitigate extreme drought. This leads to more forest and open-water cover, which significantly improves the landscape's retention capacity, and the water evaporates less quickly through the increased vegetation.
- Drought in the whole region is mitigated if this pilot project is upscaled towards the whole region. More forest cover and water retention can alter the regional climate towards more sustained rain showers.
- Lack of biodiversity is mitigated by giving more space to nature and nature-inclusive living and farming and ensuring protected natural areas are connected, forming valuable green-blue corridors through the region.
- The lousy relationship of humans with water is improved as nature and water become a more significant part of people's daily life, simply by making it more visible and by focussing on water- and nature-inclusive practices in education.
- When scaling up this pilot project, water discharge is more equally divided throughout the seasons in the region, leading to a decline in fluctuations in the total river discharge and therefore preventing floods and droughts in downstream communities.
- Local floods are mitigated as the landscape's ability to retain water increases, communities around local streams are less likely to flood, and by integrating nature-inclusive urban design into the landscape, communities are also protected from micro-floods (local floods not caused by a stream but by micro-scale rainfall)
- Extensive agricultural practices are introduced as this is required to transform the land into an agroforestry waterscape. Extensive agriculture is more nature-inclusive, which improves biodiversity and cuts out most forms of pollution that affect communities, opening up the way to integrate food production and living. This leads to an improved understanding of people where their food comes from, how nature works, and how valuable it is, but also how water is part of this vulnerable equation.
- The water quality improves in two ways: most water polluting practices in agriculture are cut out, like pesticide use, and the increased vegetation filtrates water it encounters. This leads to better water quality on a local scale, but when the project is scaled-up, it positively impacts the water quality of the whole Rhine.

LAND-USE PLANNING AND DESIGN EXERCISES

This project comprises one design exercise about integrating urban, agricultural, and natural functions to increase the harmony between these functions, focusing on the symbiosis between people and water. The other part is a land-use planning exercise that aims to transform the land use into a more natural- and water-inclusive landscape.

<u>Land-use transformation</u>

My position on this exercise is that it is a rational planning exercise in which the planning is based on several rules, which are discussed below.

- Rule one: protected nature zones need to be connected to form green-blue corridors throughout the region
- Rule two: steep hills are not suitable for arable land
- Rule three: patches of arable land cannot be larger than a certain threshold that is still being investigated. It needs to be alternated with nature-inclusive land use for optimal water management and natural plague protection
- Rule four: a buffer zone around streams in required forming a natural corridor and slowing down water discharge, with an exception for existing urban areas
- Rule five: open-water retention buffers need to be optimized to be shaded as much as possible. This prevents high levels of evaporation and improves the water quality
- Rule six: urban functions should be prevented in areas that could potentially flood in extreme rainfall events
- Rule seven: the current land use is used as the base to prevent as much resistance as possible while reaching the optimal result
- Rule eight: vineyards remain on the slopes as they need these growing conditions and form an essential part of the identity of this region

<u>Integrated land-use</u>

This exercise focuses on function edges, where urban, nature, water, and agriculture meet. Two exemplary urban edges are selected. Area four is located on a slope and is currently a place where orchards and housing meet. Area five is located on a plateau and is currently a place where arable land and housing meet. There are two design challenges here; how does the urban landscape connect to the agricultural and natural landscape? Furthermore, how do the agricultural and natural (including water) landscape provide urban functions while also functioning properly on itself? These questions come forward from the goal of bringing people closer to nature, water, and food production, improving the knowledge about these elements and the relationship between people and these elements.

The main goal is to improve the relationship with water, but at the same time, we can combine this with other elements. This leads to a landscape that has much more to offer than before. The natural landscape has something to offer for food production and directly to humans through recreation and education. The agricultural landscape has something to offer to nature (again including water) and humans directly (mainly in the form of education). Educating people about how food production can go hand in hand with nature, water management, and biodiversity preservation helps people to understand and respect the sector; it also becomes more accessible for local participation and a local circular economy. The human landscape is consequently better integrated into other elements. Adding human structures into the natural landscape helps humans enjoy this landscape while at the same time, these structures restrict people from going beyond; therefore, the natural landscape is relatively unharmed. By improving and expanding protected natural structures throughout the region, the natural landscape and all its benefits become more accessible for many communities.

Integrating living, food production, and nature is supported by a ban on fast traffic from these edges, and a good network for pedestrians, cyclists, and comparative forms of transportation. Building houses in the forest does not enforce a proper connection between the human, agricultural and natural landscape. Agroforestry already eliminates most limiting factors for this connection but does not automatically enforce it. If the natural landscape is accessible from the edges with the human landscape, it feels inviting for people to enter this world instead of making them fearful of the wilderness. It also makes it simply more convenient. The hard edge needs to become a soft edge. Open nature and open water, especially along the edges, give a sense of security because people can observe their surroundings. A wide street profile transforming into open nature and eventually more wild nature makes it more accessible.

To give insight into how this diverse functional landscape looks like, conceptual visuals of each landscape configuration are made.

VI.II AGROFORESTRY WATERSCAPES

DEFINITION OF AGROFORESTRY

In 1996, Leakey defined *agroforestry* as:

"A DYNAMIC, ECOLOGICALLY BASED, NATURAL RESOURCE MANAGEMENT SYSTEM THAT, THROUGH THE INTEGRATION OF TREES IN FARM- AND RANGELAND, DIVERSIFIES AND SUSTAINS SMALLHOLDER PRODUCTION FOR INCREASED SOCIAL, ECONOMIC AND ENVIRONMENTAL BENEFITS."

Since then, the concept has been further developed and more strictly defined. This project uses three typologies that fall under the definition of agroforestry: food forests, silvopastures, and alley cropping. In this project, the goal of agroforestry is the regeneration of the soil and its ecosystem services. Healthy soil with a thick humus layer has good water regulating capacity, making the ecosystem more resilient to floods and droughts. The soil acts as a large retention buffer.

FOOD FOREST

A *food forest* is an agricultural system in which the structure of a young natural forest is copied, and the plants produce food for humans (Crawford, 2018). Like a young and healthy forest, food forests have many vegetation types. Oostwoud et al. (2019) define nine distinct layers in their book:

1. High trees
2. Small trees
3. Climbers
4. Bushes
5. Herb layer
6. Ground cover
7. Roots and bulbs
8. Water plants
9. Mushrooms, mycelium, mycorrhiza

There are two main ways of designing food forests: linear and romantic (Oostwoud, 2022). Linear food forests are focused on efficiency, and romantic food forests are more similar to forests and have a higher recreational quality. In this project, food forests on the edges of urban areas are designed as romantic food forests to attract people. Mixing urban life and food production increases awareness about food and nature.

SILVOPASTURE

Silvopastures are an agroforestry system in which livestock, trees, and forage are integrated (Jose, 2019). This expands the biodiversity of common pastures and mimics natural forests with abundant grazing animals. In this project, silvopastures are used to improve pastures' ecological and hydrological qualities and make land use more efficient.

ALLEY CROPPING

Alley cropping is an agroforestry system in which croplands are alternated with rows of trees or hedges (Kang & Wilson, 1987). This alternation increases biodiversity and can attract natural enemies to protect crops. The hedge- or tree rows improve the hydrological conditions of conventional cropland. As large-scale croplands are not possible within a food forest system, this is an excellent alternative to make efficient production possible.

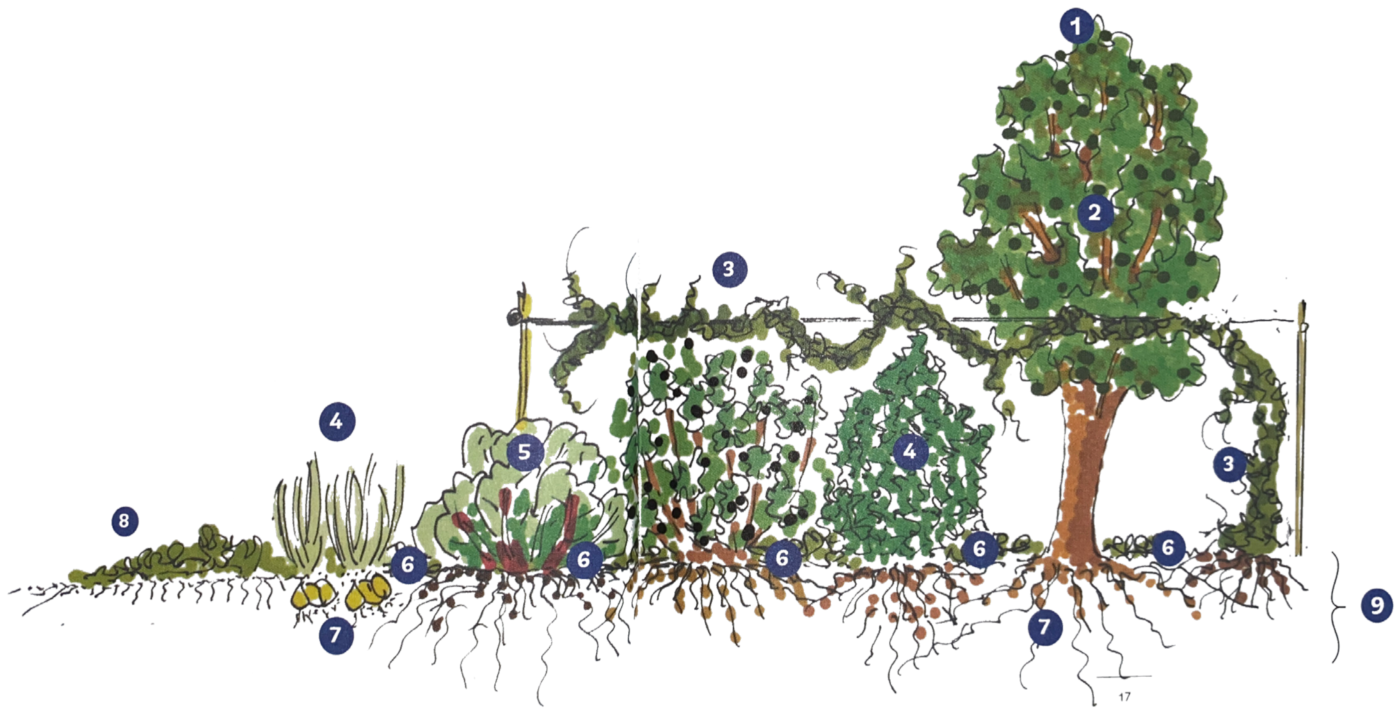


Illustration 46 | The nine layers of a food forestry system
Source: Oostwoud et al. (2019)

LAND USE TRANSFORMATION

Based on the set of rules, the transformation of land use is carried out. Patches of forests are connected, forming ecological corridors, mainly located on sloped lands to enhance the soil's infiltration capacity. The remaining slopes will become food forests alternated with existing vineyards, further improving the infiltration capacity of the land. Flat land is suitable for a wider range of agricultural typologies. Orchards are transformed into food forests or silvopastures. Fields are transformed into alley cropping, food forests, or silvopastures. Croplands are transformed into alley cropping. The following pages elaborate on these future land uses and their integration. The red boxes show the areas which are examined.

0 500 m 1 km N

LEGEND

- Rhine
- Stream
- Vineyard
- Silvopasture or food forest
- Alley cropping or food forest
- Food forest
- Urban area
- Main roads
- Railway
- Forest
- Nature reserve
- Topobathy: low > high
- Landscape contour

Illustration 47 | Map of Agroforestry Waterscapes
Source: by author

VI.II AGROFORESTRY WATERSCAPES

CURRENT TREE SPECIES

The future landscape of the Rhine Valley will be much richer in the amount and diversity of plants and trees. Understanding the current ecological habitat gives a starting point for looking into the future. The trees included in the list are all native and widespread exotic tree species. For the project, it is relevant what the required soil types, moisture levels, and flood resistances are for each species. Therefore this information is added to the overview. In each design exercise, certain trees are used to support the design, and this overview helps in the decision-making process as it shows which trees are most likely to flourish in certain conditions. More information about the aesthetic, shading, and natural plague defense might be needed in the exercises.

FUTURE TREE SPECIES

Native and other common species are under variating pressure from invasive exotic species, the changing landscape, and the changing climate. An example is the accelerating mortality rate of certain coniferous species, especially the Picea Abies (Norway Spruce) seems vulnerable to long periods of drought. Deciduous trees are more resistant to drought as they let their leaves fall, lessening the evaporation and retaining more water. Additionally, coniferous trees cannot defend themselves well in drought conditions, making them more vulnerable to plagues. In recent years the European spruce bark beetle has caused many coniferous trees to die. Nevertheless, also broadleaved trees are vulnerable to droughts. More frequent floods and increasing temperatures are also linked to the disturbance of forests.

Mitigating climate change and locally adapting to climate change could help to maintain the native species. However, it must be accepted that the conditions are changing, and certain species will become less common. Therefore further research by ecological experts is necessary to set a path to the future of the German ecological habitat. This could mean species less vulnerable to droughts, high temperatures, and certain plagues will be introduced. This could positively affect humans, animals, other tree species, and food production. As still to be researched, it falls beyond this project's scope. Therefore, native and common exotic species are generally used in the designs. Introducing new exotic species could have unforeseen negative consequences on the existing habitats and therefore need careful consideration.

Trees (scientific name)	Trees (english name)	Soil type					Soil moisture					Habitat characteristics	Density, Crown base
		Clay	Loess	Loam	Sand	Peat	Wet				Dry		
Acer campestre	Field Maple	X	X	X	X				X	X		Bees, Butterflies	Dense, Medium
Acer monspessulanum	Montpelier Maple	X	X	X	X				X	X	X	Bees, Butterflies	Dense, Low
Acer opalus	Italian Maple		X	X	X				X	X		Bees, Butterflies	Dense, Low
Acer platanoides	Norway Maple	X	X	X	X				X	X		Bees, Butterflies	Dense, High
Acer pseudoplatanus	Sycamore	X	X	X	X			X	X	X		Bees	Dense, Medium
Alnus glutinosa	Common Alder	X		X	X		X	X	X			X	Semi-open, Low
Alnus incana	Gray Alder	X		X	X		X	X	X	X	X	X	Semi-open, Low
Betula pendula	Silver Birch			X	X	X				X	X	Butterflies	Semi-open, Medium
Betula pubescens	Downy Birch			X	X	X		X	X			Butterflies	Semi-open, Medium
Carpinus betelus	Common Hornbeam	X	X	X				X	X	X		X	Dense, Low
Fagus sylvatica	Common Beech			X	X	X			X	X		X	Dense, Low
Fraxinus excelsior	Common Ash	X	X	X				X	X			X	Semi-open, Medium
Malus sylvestris	Wild Apple			X	X				X		X	Birds, Bees, Butterflies	Semi-open, Medium
Populus nigra	Black Poplar	X	X	X	X		X	X	X			Butterflies	Semi-open, Low
Populus tremula	Aspen	X	X	X	X	X	X	X	X	X	X	Butterflies	Semi-open, Medium
Prunus avium	Wild Cherry	X	X	X	X			X	X			Birds, Bees, Butterflies	Semi-open, Low
Prunus padus	Bird Cherry	X	X	X	X		X	X	X			Birds, Bees, Butterflies	Semi-open, Low
Pyrus pyraster	Wild Pear			X	X			X	X	X		Birds, Bees	Semi-open, Medium
Quercus petraea	Durmast Oak			X	X				X	X	X	Birds, Butterflies	Semi-open, Medium
Quercus pubescens	Downy Oak			X	X			X	X			X	Semi-open, Medium
Quercus robur	Common Oak	X	X	X	X			X	X	X	X	Birds, Butterflies	Semi-open, Medium
Salix spec.	Willow	X	X	X	X	X	X	X				Bees, Butterflies	Semi-open, Medium
Sorbus aria	Whitebeam		X	X	X				X	X		Birds, Bees	Semi-open, Low
Sorbus aucuparia	Mountain Ash		X	X	X	X		X	X	X	X	Birds, Bees, Butterflies	Semi-open, Low
Sorbus domestica	Service Tree		X	X	X	X			X	X	X	Birds, Bees, Butterflies	Semi-open, Medium
Sorbus torminalis	Wild Service Tree	X	X	X	X	X		X	X	X		Birds, Bees, Butterflies	Open, Medium
Tilia cordata	Small-leaved Lime	X	X	X	X			X	X			Bees, Butterflies	Semi-open, Low
Tilia platyphyllos	Large-leaved Lime	X	X	X	X	X		X	X	X		Bees, Butterflies	Semi-open, Medium
Ulmus glabra	Scotch Elm	X	X	X	X		X	X	X			Butterflies	Dense, Medium
Ulmus laevis	European White Elm	X	X	X	X			X	X			Butterflies	Open, High
Ulmus minor	Field Elm	X	X	X	X		X	X	X			Butterflies	Semi-open, Medium

Illustration 48 | Native broadleaved tree species in Germany
Source: FSC® Deutschland (2018), Roeleveld et al. (2014), Van den Berk Boomkwekerijen (n.d.) | adapted by author

Trees (scientific name)	Trees (english name)	Soil type					Soil moisture					Habitat characteristics	Density, Crown base
		Clay	Loess	Loam	Sand	Peat	Wet				Dry		
Abies alba	European Silver Fir	X	X	X	X				X	X		X	Dense, Low
Larix decidua	European Larch	X	X	X	X			X	X	X		X	Open, Medium
Picea abies	Norway Spruce			X	X	X		X	X	X		X	Dense, Low
Pinus cembra	Arolla Pine	X	X	X	X	X			X	X		Birds	Semi-open, Low
Pinus mugo x rotundata	Mountain Pine	X	X	X	X	X			X	X		X	Dense, Low
Pinus sylvestris	Scots Pine	X	X	X	X	X			X	X	X	Birds	Semi-open, High
Taxus baccata	Common Yew	X	X	X	X				X	X		Birds, Bees	Dense, Low

Illustration 49 | Native coniferous tree species in Germany
Source: FSC® Deutschland (2018), Van den Berk Boomkwekerijen (n.d.) | adapted by author

Trees (scientific name)	Trees (english name)	Soil type					Soil moisture					Habitat characteristics	Density, Crown base
		Clay	Loess	Loam	Sand	Peat	Wet				Dry		
Aesculus hippocastanum	European Silver Fir	X	X	X	X	X		X	X	X		Bees	Dense, Medium
Pseudotsuga menziesii	Douglas Fir	X	X	X	X	X			X	X	X	X	Open, High

Illustration 50 | Common exotic tree species in Germany
Source: Deutsche Wildtier Stiftung (n.d.), Van den Berk Boomkwekerijen (n.d.) | adapted by author

VI.II AGROFORESTRY WATERSCAPES: URBAN AGROFORESTRY

This is the first detailed view of the Agroforestry Waterscapes. Here a combination of an urban area and agriculture is seen. The agricultural practices of 2022 are completely transformed for sustainable agroforestry agricultural practices.

In this area, all three leading agroforestry practices are represented. On the southwest part of the map, there is a 'romantic' food forest. As it is on the edge of an urban area, recreational value is integrated into the design. North of the food forest, an orchard is transformed into a silvopasture, meaning a diverse orchard that is at least partly inhabited by livestock. The primary agroforestry practice in this area is lane cropping. The large wheat fields remain but are alternated with rows of other vegetation. Its goal is to increase the diversity and health of the soil and to host natural enemies for plagues wheat is vulnerable to. The rows are orientated along the height contours of the landscape to intercept run-off water from the croplands. Wadis are introduced at the edges of the lane crops to retain more run-off water. The edge of the urban area is carefully designed to increase the agricultural land's recreational value and enhance the connection between urban life and food production.

The red lines show the scope of the impression on the following page.

0 50 100 m N

LEGEND

- Romantic food forest
- Regular food forest
- Alley cropping
- Silvopasture
- Shrubs
- Trees
- Large trees
- Open water
- Wadi
- Houses
- Roads
- Pedestrain paths
- Landscape contours

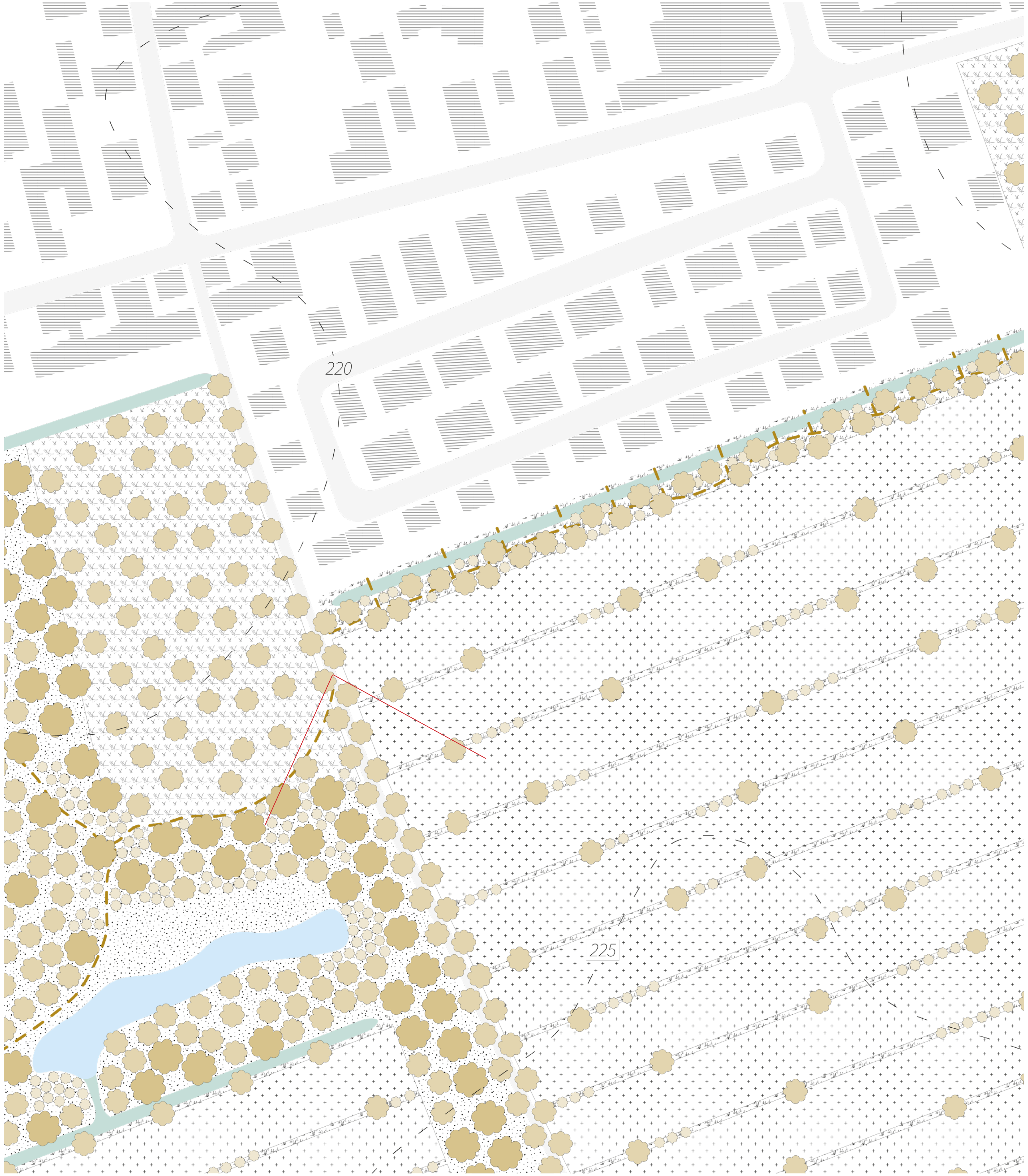


Illustration 51 | map of Urban Agroforestry
Source: by author

NATURAL ENEMIES IN ALLEY CROPPING

Food forests and silvopastures bring great diversity to the agricultural landscape. Nevertheless, they are less suitable for one-year crops like wheat. Many crops will not grow well in shaded conditions in food forests or on pastures with livestock. Therefore the third type of agroforestry is introduced: *alley cropping*. The idea is to create lanes of crops alternated with lanes of trees and bushes. This dramatically enhances the croplands' biodiversity and plays a vital role in the hydrological system. If lanes of trees and bushes are placed parallel to height contours, they can intercept run-off water from the croplands, creating a natural wadi and increasing infiltration and retention.

By making this lane structure, larger patches of wheat are present so they can receive enough sunlight and remain easy to harvest with modern machines. Enhanced biodiversity can play a vital role in protecting croplands. First, identifying what crops will be planted in an area is necessary. It is helpful to choose crops with similar enemies, which can cause plagues. After identifying these enemies, the next step is to identify the natural enemies of the enemies of this crop. These natural enemies each have a natural habitat, mainly in the form of certain plants. By planting these plants in the lanes around the crop patches, the cropland can be protected without the need for chemicals that hurt the environment to a larger extent.

An example of this concept is explained below. The crop in this example is wheat (Triticum Aestivum), as this is the most common crop in the project location. These are the common plagues wheat is vulnerable to (MijnTuin.org, n.d.):

- Multiple fungi
- Cereal leaf beetle (Oulema melanopus)
- Wheat weevil (Sitophilus granarius)
- Rose-grain aphid (Metopolophium dirhodum)
- Bird cherry-oat aphid (Rhopalosiphum padi)
- Barley root-knot nematode (Meloidogyne naasi)
- European cyst nematode (Heterodera avenae)
- Saddle gall midge (Haplodiplosis equestris)

These are specific types of enemies which have particular types of natural enemies. This results in a long and incomprehensive list of natural enemies and their habitats. However, a species often has another species as a natural enemy. For example, birds and ladybirds are predators of aphids, so also of the specific aphid that wheat is vulnerable to. Therefore, the list below states the general natural enemies of the enemy species, unless more specification is necessary:

- Natural enemy of Saddle gall midge: Ichneumonidae (Hulshoff & Nijveldt, 1968).
- Natural enemy of European cyst nematode: Arthrobotrys irregularis, Rhizoglyphus echinopus (CABI, n.d.).
- Natural enemy of Barley root-knot nematode: no information
- Natural enemies of Aphids: Ladybugs, Hoverfly larvae, Lacewing larvae, Predatory midge larvae, Parasitic (Parasitoid) wasps (various species), Earwigs, Predatory beetles, Birds (Royal Horticultural Society, n.d.).
- Natural enemies of the Wheat weevil: Theocolax elegans. (CABI, n.d.)
- Natural enemies of Cereal leaf beetle: Ground beetles, Ladybugs, Damsel bugs (Kheirodin, n.d.).
- Natural enemies of fungi: improving overall soil quality and diversity (Halsall, 2019).

Some natural enemies are very specific insects which can make the planting scheme unnecessary complex. Therefore, the focus is on common species who eat a larger diversity of wheat enemies. The overall soil quality is improved by increasing the diversity of vegetation in the croplands. Ladybugs are attracted by birch trees and a wide variety of flowers and herbs ([Pamela-Anne], 2019). Birds are attracted to multiple trees, especially fruit producing trees like the wild apple and wild cherry. This results in a lane of flowers and herbs alternated with specific trees, which are pruned often to prevent too much shade on the wheat.

Image 23 | Current agricultural landscape near Wackernheim
Source: by author

Illustration 52 | Future agroforestry landscape near Wackernheim
Source: by author

VI.II AGROFORESTRY WATERSCAPES: URBAN FOREST

This is the second detailed view of the Agroforestry Waterscapes. A combination of an urban area, agriculture, and the forest are seen here. The agricultural practices of 2022 are entirely transformed into sustainable agroforestry agricultural practices and forests.

The northern zone of this map is a part of the protected nature corridor. Here orchards and croplands have been transformed into a biodiverse forest, hosting many native and common German species which can flourish in dry conditions, one of the main problems of this area. The forest is only accessible via multiple paths, allowing citizens to enjoy nature without disturbing animals. Most agricultural grounds here are located on slopes, making alley cropping and silvopastures unsuitable. Therefore food forestry is the primary agricultural practice. Most food forests are designed with efficiency and the demanded diversity in mind.

Nevertheless, surrounding land use, like remaining vineyards and urban areas, are taken into account to avoid conflicts and strengthen each other.

0 50 100 m N

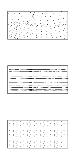
LEGEND

- Romantic food forest
- Regular food forest
- Alley cropping
- Vineyard
- Forest
- Nature reserve
- Shrubs
- Trees
- Large trees
- Wadi
- Houses
- Roads
- Pedestrain paths
- Landscape contours

Illustration 53 | map of Urban Forestry
Source: by author

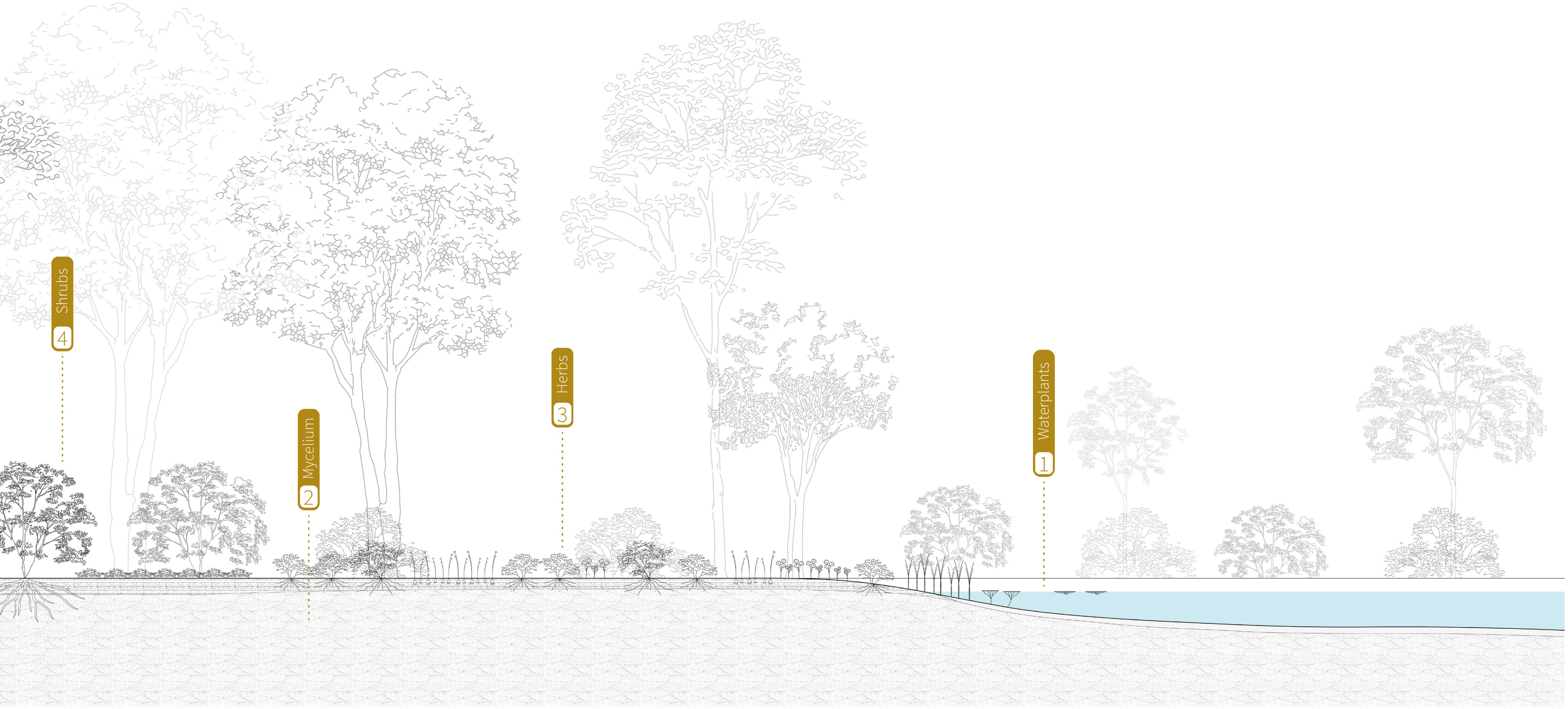
Illustration 54 | section of the edge or urban and food forestry land use
Source: by author

SOIL LEGEND



This is a section of the romantic food forest located on the edge of the urban area of Wackernheim (red line A in overview map). It represents all the layers commonly found in this type of agriculture. The design is made from a recreational perspective. This means it should be pleasurable to walk through the forest. The houses adjacent to the forest each have individual access. A zone of approximately 15 meters wide is free of bushes. From the houses towards the forest, people encounter a zone of bulbs, herbs, and climbers, then a zone of low and high trees with ground cover. This design ensures people have a good overview of this zone, making it more pleasurable to enter and explore.

As the forest starts developing, slowly organic matter will accumulate on the ground, creating a healthy humus layer that hosts a diverse range of subsoil lifeforms. This humus layer is essential for the water-regulating capacity of the soil. More water is infiltrated and retained during heavy rainfall events, and more water is available for the plants during droughts. As all these vegetation layers are mixed, practically no sunlight will directly shine on the soil, significantly reducing evaporation, but also plants in lower layers are protected from the sun's heat.


Shrubs
4
Mycelium
2
Herbs
3
Waterplants
1

FOREST VIEWPOINT

One of the prime qualities of this area is the view of the Taunus mountain range on the other side of the Rhine. This quality could be lost by transforming these croplands into a diverse forest. Therefore, one of the paths leads to a viewpoint, slowly unveiling the magnificent views. (red lines B in overview map)

Image 24 | Current agricultural landscape near Wackernheim
Source: by author

Illustration 55 | Future forest landscape near Wackernheim
Source: by author

VI.III RIVERINE WATERSCAPES

Image 25 | Satellite image of Leeheim and its surrounding old meanders of the Rhine
Source: Apple (n.d.-b)

OLD MEANDERS OF THE RHINE

The third and last typological elaboration is given for a site signified by flat agricultural lands where old meanders of the Rhine are visible.

In image 25 and illustration 56, large parts on the east bank of the Rhine are former floodplains. Therefore, the forms of old meanders are found throughout this landscape. Nowadays, the majority of these floodplains are protected by dykes. Consequently, the plains are now permanently used for living and food production. On the east side of the large meanders, smaller meanders are visible. This is an active small stream that discharges into the Rhine through these floodplains. Only one old meander is still part of the river system. It highlights itself in green in the satellite image as the island it forms is a protected nature zone.

0 2,5 5 km N

LEGEND

- Rhine river system
- Hessen water system
- Main road network
- Topobathy: high - low
- Croplands
- Pastures
- Vineyards
- Urban areas
- Current dyke system
- Forests

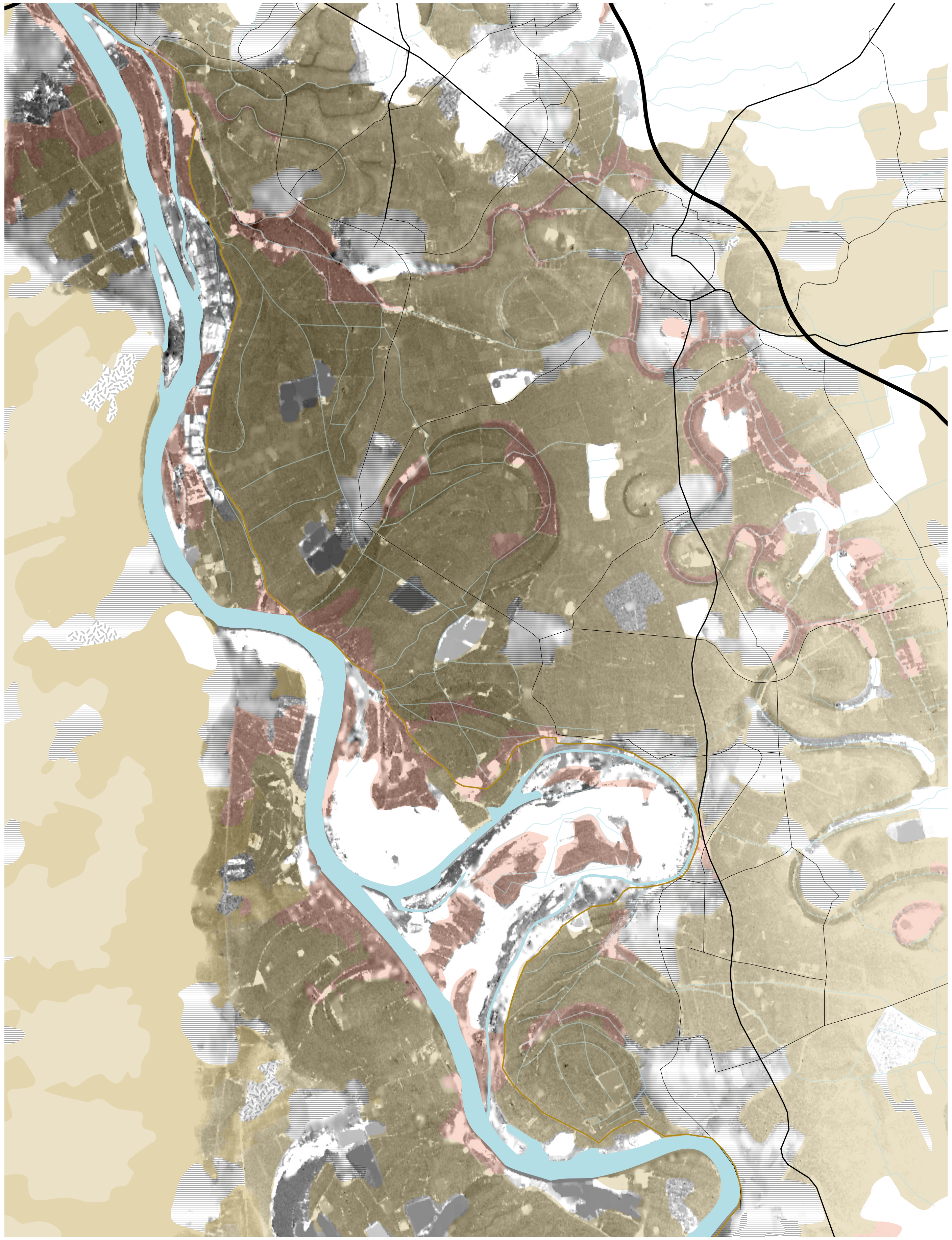


Illustration 56 | Analysis of the floodplains
Source: by author

VI.III RIVERINE WATERSCAPES

STRATEGY OF THE RIVERINE WATERSCAPES

The main idea of the Riverine Waterscapes is to retain large amounts of water from the Rhine and filtrate this water. By retaining river water, a number of problems are addressed:

- Extreme high discharges are mitigated downstream of this retention buffer as a large volume of water is stored here till after the high water peak
- Extreme low discharges are mitigated as retained water is slowly discharged into the main channel of the Rhine
- Filtrating plants decrease water pollution throughout the floodplains
- Local floods are less likely as giving more space to the water decreases water levels and, therefore, is less likely to overflow dykes or threshold height contours.
- Local droughts are mitigated as retained water gives more freedom to irrigate vulnerable landscapes.

Apart from these problems, the Riverine Waterscapes also give new qualities to the area:

- Recreational value during normal and low water discharges
- Ecological value as slow flowing and partly shallow waters are the ideal breeding ground for marine life (fish and aquatic plants)
- Ecological value as new partly inundated nature is developed, extending the riverine habitat
- Agricultural and economic value as it allows for new types of production landscapes, partly inundated and aquatic

DESIGN OF THE RIVERINE WATERSCAPES

The floodplain is divided into four hydrological typologies. The composition of these typologies is based on the current landscape (land use, height, and historic landscape structures).

First, the design for the whole system is elaborated. It shows where the reintroduced meanders are located and which ground will fall under the new floodplains. Further land use, evacuation routes, and inflow from local rivers are touched upon.

Secondly, a zoom-in on one part of a reintroduced meander is made. Here the possibilities of the four hydrological zones are explored.

REINTRODUCING THE MEANDERS

Storing large amounts of water requires a large area that is allowed to flood. To make this possible, the old meanders of the Rhine are reintroduced. Due to their height, they will contain water year-round. The islands this creates will also become part of the floodplains and are allowed to flood whenever high discharges present themselves. The meanders given back to the river are strategically chosen to have minimal impact on the current functions of the region. There are multiple houses and farms that will be vulnerable to flooding, but villages remain safe from water. The map in illustration 57 shows the future maximum designed inundated landscape.

During high peak discharges, these floodplains will be completely inundated. This causes difficulties with discharging local rivers into the Rhine system. This could be done with a pumping station. However, this does not connect to the project's goal as it is not a nature-based solution and increases pressure on downstream communities. Therefore, storing water locally before it enters the floodplains is a more suitable solution. This is done with three strategies:

- Local rivers are assigned their own floodplains.
- The strategy of the Vineyard Streams is implemented in small streams of this region.
- The strategy of Agroforestry Waterscapes is implemented throughout this region.

The dyke system is expanded to make the reintroduction of the floodplains possible. New dykes are constructed on the edges of the meanders to protect urbanized and cultivated land further inland. However, the old dyke system remains as it makes controlled water management possible by introducing locks. Later in this chapter, elaboration is given on this strategic choice.

Due to the implementation of all three typological projects presented in this research, extremely high water levels are expected to be lower than the current predictions. However, this does not imply there is a zero percent chance that the Rhine will flood areas beyond its floodplains in the future. Therefore, the population in lower-lying areas needs to be prepared for such an emergency. Illustration 58 shows the leading road network of the region. Not many alterations to this network are made as it allows efficient evacuation from all villages towards the higher-lying areas in the east and north. To maintain the accessibility of this network in a catastrophic event, the main roads need to be heightened to meet a yet-to-be-calculated threshold.

The land use in areas that remain safe from the water will undergo a similar transformation as shown in the Agroforestry Waterscapes project. The following pages show how the floodplains function in different hydrological conditions.

0 2,5 5 km N

LEGEND

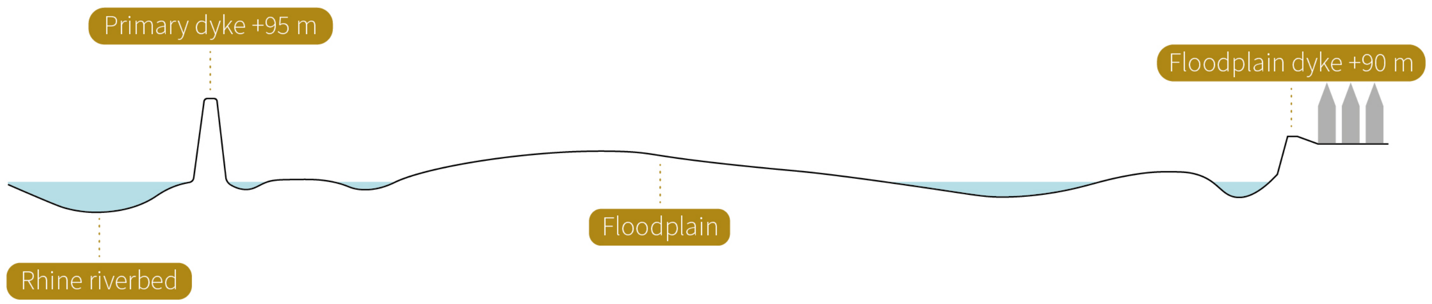
- Rhine river system
- New Rhine floodplains
- Local floodplain
- Urban area
- Water flow
- Lock
- New dyke
- Old dyke

Illustration 57 | Schematic map of the reintroduction of the meanders
Source: by author

LOW WATER

For a low discharge scenario, it is relevant to assess the extent of the permanently inundated areas. This assessment determines where functions that require permanent inundation should be located. Local water managers can set a minimum water height by closing the locks if the water level is forecasted to decline. This decreases the impact of droughts locally and gives clear boundaries for spatial designs, which leads to more design possibilities.

SECTION AA'



0 2,5 5 km N

LEGEND

- Rhine river system
- New Rhine floodplains
- Hessen water system
- Main road network
- Topobathy: high - low
- Urban area
- Lock open
- Lock closed
- New dyke
- Old dyke

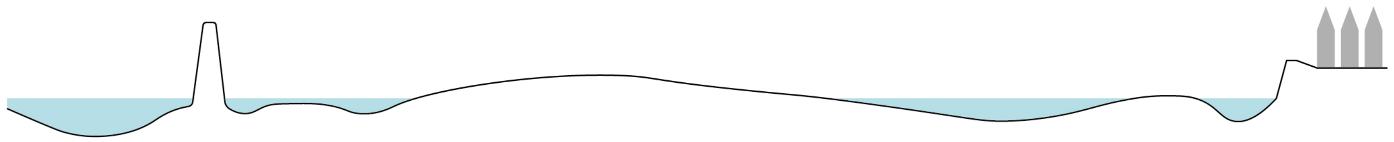
Illustration 58 | Map of the reintroduction of the meanders - low water
Source: by author

VI.III RIVERINE WATERSCAPES: REGIONAL

AVERAGE WATER

An average water level scenario is relevant to assess how the floodplains operate and are experienced during large parts of a year. This scenario sets the boundaries for functions requiring dry land but resistant to short or long floods. The water edges in this scenario are where most fluctuations in water level are noticed. This creates a dynamic ecological habitat and is therefore designed as a protected ecological zone. This zone is valuable to marine life and has the power to remediate water quality. This scenario is also used for designs of recreational areas, as they will often function in this condition but are resistant to floods.

SECTION AA'



0 2,5 5 km N

LEGEND

- Rhine river system
- New Rhine floodplains
- Hessen water system
- Main road network
- Topobathy: high - low
- Urban area
- Lock open
- Lock closed
- New dyke
- Old dyke

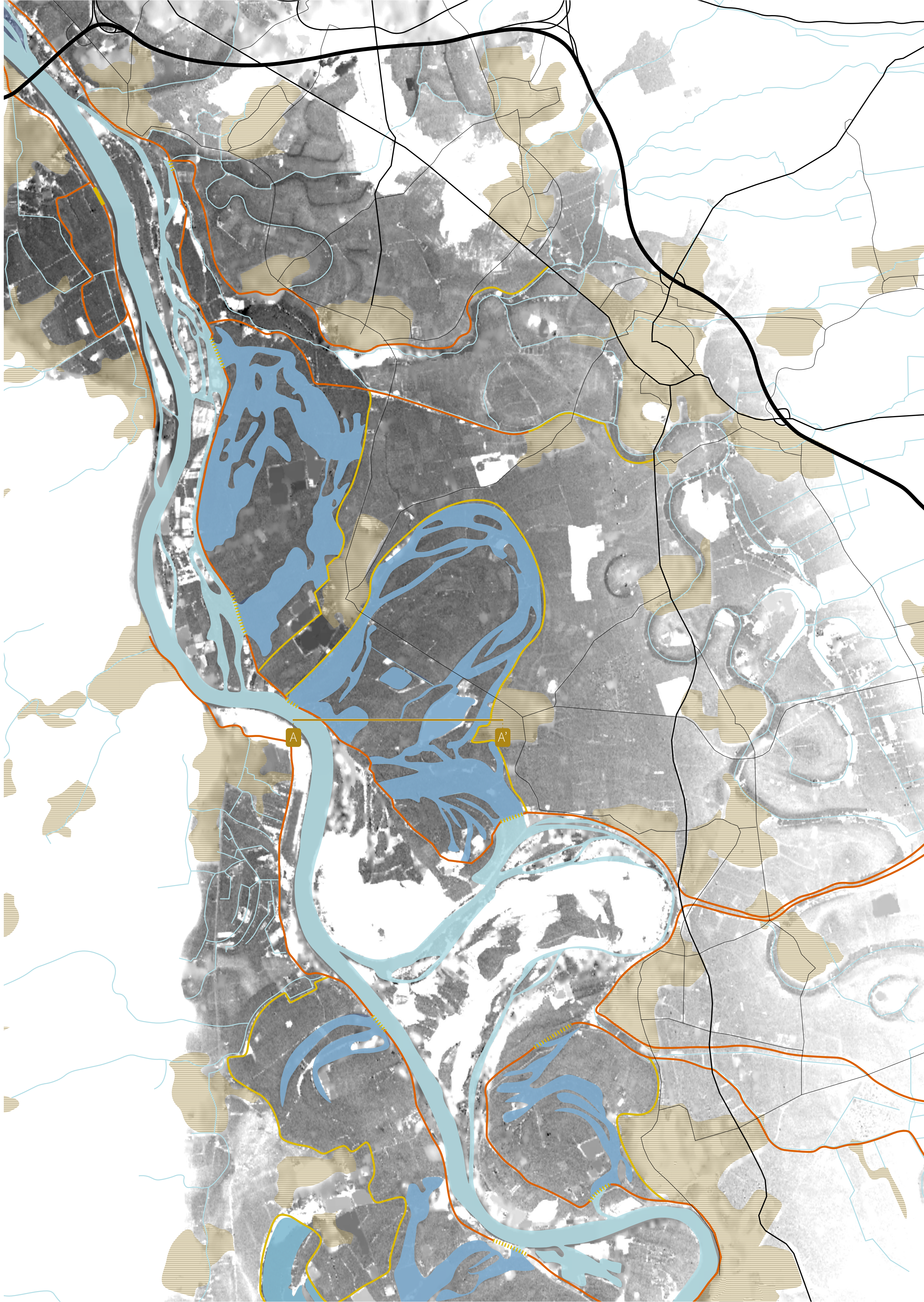


Illustration 59 | Map of the reintroduction of the meanders - average water
Source: by author

VI.III RIVERINE WATERSCAPES: REGIONAL

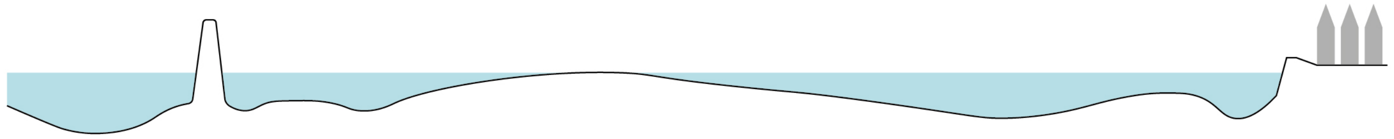
TEN-YEARLY HIGH WATER

On average, large parts of the floodplains will be flooded every ten years. In this scenario, the water level is between the minimum and maximum threshold, so the water can freely flow through floodplains. The lock of an existing emergency floodplain on the west bank remains closed as it is designed as a buffer for extreme water discharges. Also, the lock of the local water system is closed; otherwise, the Rhine water would penetrate deeply inland and flood multiple villages. This means the local water system cannot discharge its water. Therefore, this system has its own floodplain. If new calculations show longer flood durations or higher local discharge levels, a pumping station could be installed to prevent flooding beyond this floodplain.

The strategies presented in the Vineyard Streams and Agroforestry Waterscapes are implemented in the permanently dry areas to decrease water accumulation in the floodplains and decrease fluctuations in discharges.

This scenario helps distinguish between functions resistant to short floods and long floods. Non-permanently inundated land which is flooded in this scenario is ideal for functions that are resistant to long floods. Areas of the floodplains that remain dry in this scenario are ideal for functions resistant to short floods.

SECTION AA'



LEGEND

- Rhine river system
- New Rhine floodplains
- Local floodplain
- Hessen water system
- Main road network
- Topobathy: high - low
- Urban area
- Lock open
- Lock closed
- New dyke
- Old dyke

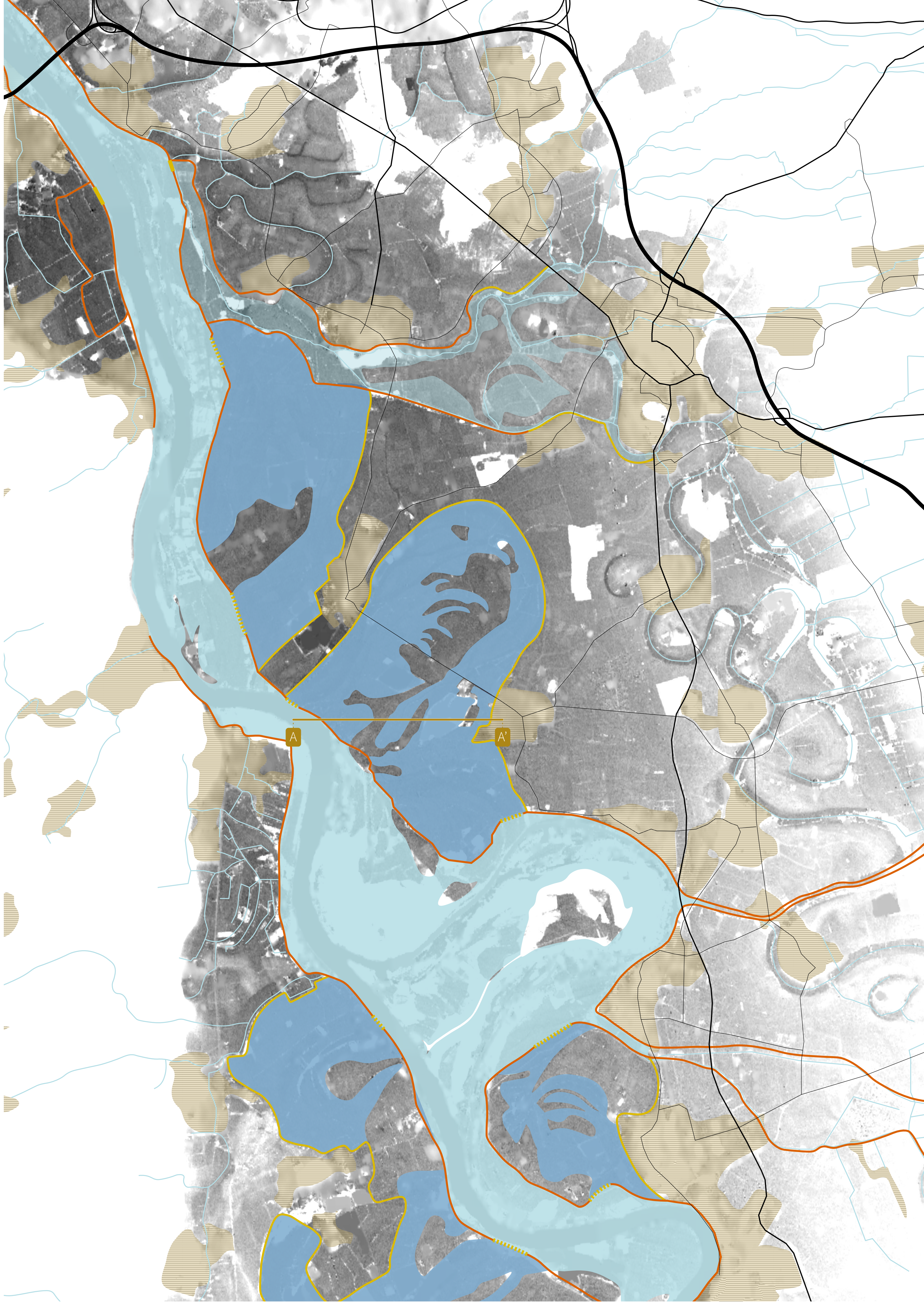


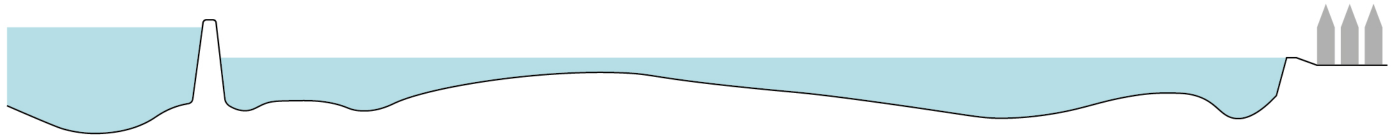
Illustration 60 | Map of the reintroduction of the meanders - high water
Source: by author

EXTREME HIGH WATER

In events of extremely high water levels, which are currently expected once in ten thousand years, all locks are closed as the water levels have exceeded the maximum thresholds of the floodplains. This means the water level in the main branch of the Rhine will be higher than in the floodplains. Only the lock of the emergency floodplain on the west bank is opened, as the dykes here are designed with a higher maximum threshold. As it is likely that such a flooding event will have a longer duration, more water is expected to accumulate in the local floodplain. Like the current situation, one local canal and one local river are not protected by locks. This decision was made to maintain aquatic transportation. These systems quickly reach a height above the expected maximum water levels. The lower-lying vulnerable areas are protected by dykes. Floods with a return period of one hundred years are also expected to flood the floodplains completely. In this case, the expected water levels are below the maximum threshold, which means the locks could remain open.

In the following pages, an elaboration is given on the design of the four hydrological zones and their edges. The assessed area is located in the red box shown in illustration 61.

SECTION AA'



0 2,5 5 km N

LEGEND

- Rhine river system
- New Rhine floodplains
- Local floodplain
- Hessen water system
- Main road network
- Topobathy: high - low
- Urban area
- Lock open
- Lock closed
- New dyke
- Old dyke

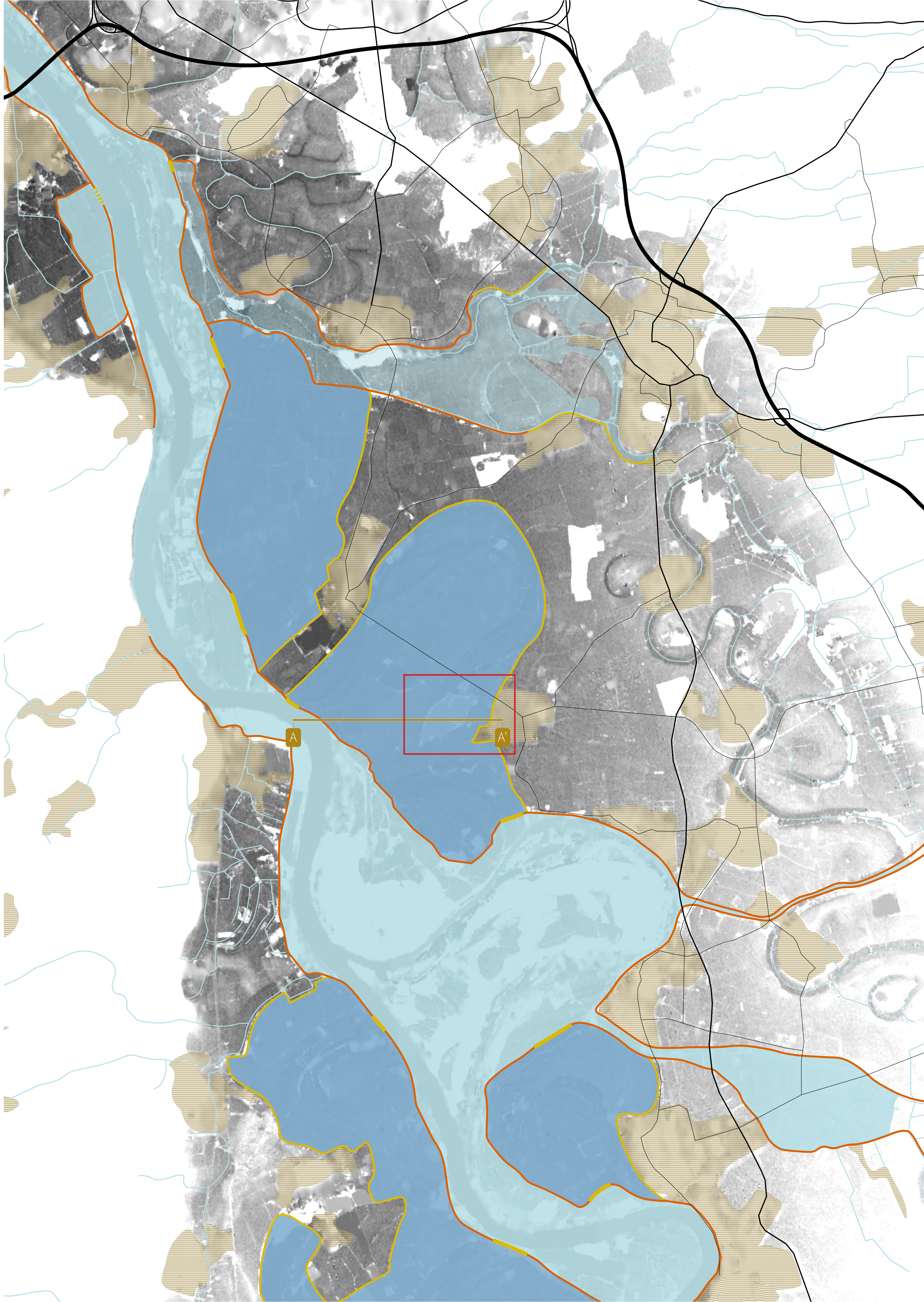


Illustration 61 | map of the reintroduction of the meanders - extreme high water
Source: by author

LEEHEIM FLOODPLAIN CURRENT SITUATION

The map on this page is a zoom-in of the floodplain area adjacent to the village of Leeheim. The area west of the village of Leeheim is part of the future floodplains. Croplands and pastures characterize the floodplains. However, this area hosts a wider variety of functions. There are three large ponds, two used for aquatic recreation and one for sand extraction. The broader surroundings use the recreation area. Additionally, there is a water sanitation plant and a sports park servicing Leeheim.

As shown in the previous pages, old meander structures are visible on topobathic maps. In the satellite image of this area, these structures are also visible.

Illustration 62 | Map of Riverine Waterscapes - Leeheim
Source: by author

VI.III RIVERINE WATERSCAPES: LOCAL

FLOODPLAIN PLAN

The four zones of flood frequency are shown by shades of blue, where the brightest blue is permanently inundated. These zones are based on the existing form of the landscape and multiple strategic interventions discussed in the implementation section. The planological map on this page gives an overview of which function could be hosted by each flood zone in the context of the Leeheim floodplain. This is an example to other parts of the floodplains showing the possibilities. Nevertheless, other areas could function differently; for example, larger floating neighborhoods which are not necessarily connected to existing villages are possible. How each floodplain is designed depends on specific local needs in time and space. The following pages show impressions of how the future floodplain could look in different flood scenarios and how they could function.

DRY LAND

The village of Leeheim and the surrounding land to the north and east are protected by a dyke. Therefore, this land is suitable for all functions that are not resistant to floods. Two of these functions are ground-based houses and industry, and croplands. The floodplains are not suitable for croplands as floods are most likely during the start of the growing season. Therefore, the density of croplands on permanently dry land will increase. These croplands should follow the concept of agroforestry, so the technique of alley cropping is used.

In theory, the lands protected by dykes are still prone to floods. Reintroducing the floodplains and other measures throughout the region will make this chance smaller. However, it is impossible to say there is a zero percent chance of a flood sometime in the future. Therefore, consciousness about the risks of floods and a strategy of what to do during floods are essential to develop.

Illustration 63 | Planological map of Riverine Waterscapes - Leeheim
Source: by author

0 150 300 m N

LEGEND

Agroforestry	Aqautic urban area	Houses
Forestry	Recreational center	Roads
Forest	Sportpark	Bridge
Bird reserve	Permanently inundated	Underground parking
Recreational area	10 yearly inundation	Pedestrain paths
Aquatic energy / food production	100 yearly inundation	Dyke

PERMANENTLY INUNDATED

This zone has a range of functions that are floating on the water. The central lake on the map currently has a recreational function, which will remain as this is a flexible function that can temporarily be stopped when water levels become too high. Additionally, the base camp of the recreational area is located on land, which only floods when water levels are very high. This means it could stay; however, alterations are needed. Buildings at this camp should either be resistant to flooding, meaning they can flood without causing significant damage, or they should be temporal buildings that can be removed when very high water levels are expected.

The old meander that flows close to the village will become a residential area with two small floating neighborhoods. These neighborhoods are vital in connecting the village and the floodplains. This is a place to enjoy the qualities of the flooded landscape and could serve as a base camp for tours or other recreational activities throughout the floodplains. Between the floating neighborhoods and the land-based neighborhoods, a dyke is located to prevent flooding in the village. This dyke is relatively low on the village side as the village is already located on higher grounds. Therefore there is a visual and physical connection between the village to the floodplains. Other large patches of permanently inundated land could host economic functions through energy production and aquaculture.

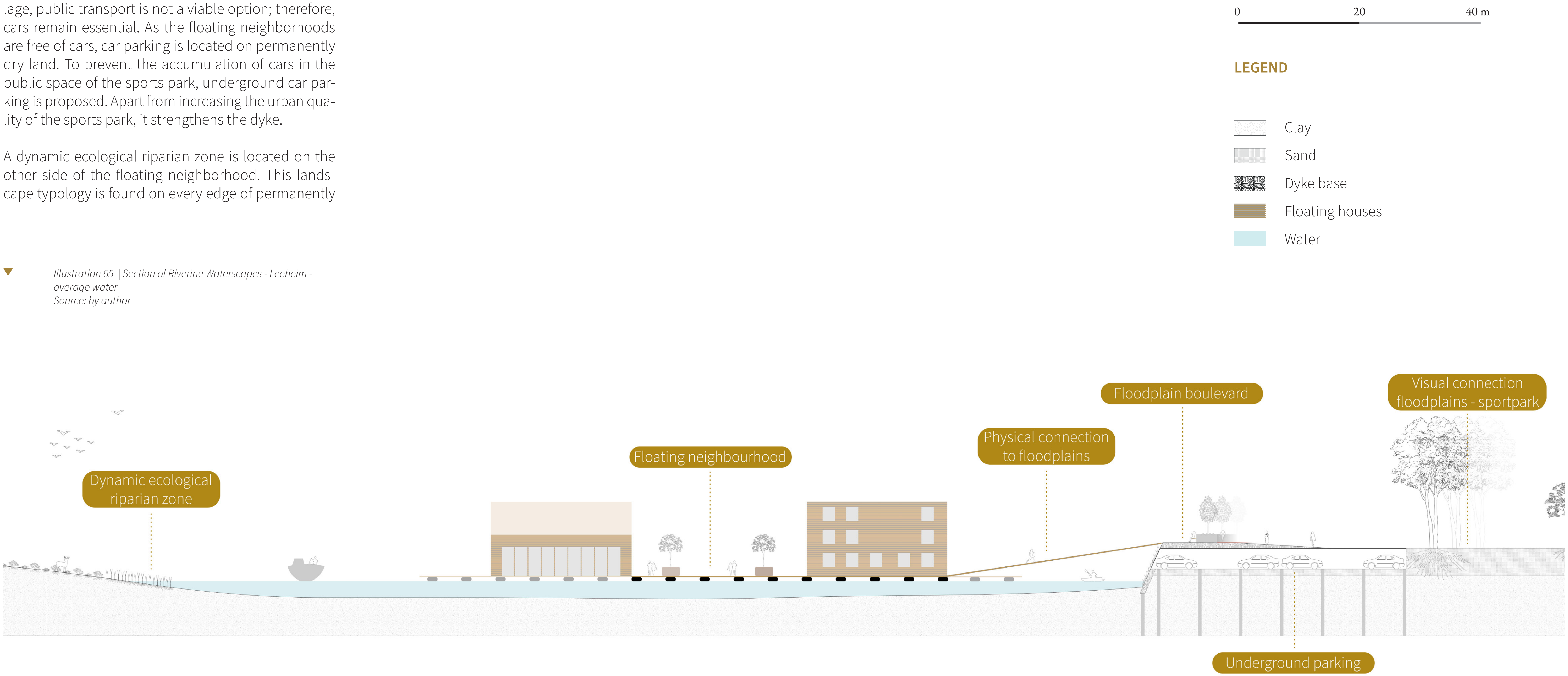
Illustration 64 | Impression of Riverine Waterscapes - Leeheim - average water
Source: by author

SECTION BB'

The section below shows the connection between the sports park north of Leeheim and a floating neighborhood. As the village is located on higher ground, a dyke structure is barely visible. One-meter-high concrete slabs are placed on the ground level to ensure flood safety in extreme flood events. This is used as an urban design element, containing plants and small trees, benches, trash bins, and lights. Multiple openings are made to ensure a physical connection to the floating neighborhoods. Due to the location of this village, public transport is not a viable option; therefore, cars remain essential. As the floating neighborhoods are free of cars, car parking is located on permanently dry land. To prevent the accumulation of cars in the public space of the sports park, underground car parking is proposed. Apart from increasing the urban quality of the sports park, it strengthens the dyke.

A dynamic ecological riparian zone is located on the other side of the floating neighborhood. This landscape typology is found on every edge of permanently inundated areas except where it borders a dyke. These are ideal breeding grounds for marine life and host a rich biodiversity as fluctuations in water level create a wetland typology. Ecologists can plant and maintain these zones to ensure the growth of specific plants with the capability to filter pollutants in surface water. This increases the water quality.

Illustration 65 | Section of Riverine Waterscapes - Leeheim - average water
Source: by author



HIGH WATER (ONCE IN 10 YEARS)

Land vulnerable to floods yearly is more complex to remain of economic importance. This land can potentially have ecological importance, especially the edges with the permanently inundated land, as this is a wetland habitat. This habitat could host a large diversity of life and plays a crucial role in the phytoremediation of water, as aquatic plants filtrate water. Potential economic functions are forestry and livestock. Currently, these lands are not widely used for livestock and milk- and the meat sector is expected to decline in Western Europe. Therefore forestry is chosen as a viable function. There are multiple native and common trees in Germany which survive long-term floods. In general, these trees are not suitable for food production, especially the wood of these trees is valuable. Conventional forestry has a low ecological value, as they are often grown in monocultures. One of the project's goals is to increase the ecological value of the land. Therefore, a diverse type of forestry is suggested where multiple species are mixed. This leads to continuous forest cover as harvesting thins the forest. This also makes the forests more resistant to plagues.

Mixed forestry on yearly inundated land might sound difficult for harvesting with heavy machinery. Tree species can be strategically grouped to lead to diversity and harvesting efficiency. Floods are most likely to happen during spring, so at this time of the year, harvesting is not possible. However, this is not necessarily a problem as the winter season is most suitable for harvesting as trees are resting (Schira, 2018) and soil disturbance is minimal (Kulak et al., 2019). In this season, the land is more likely to be dry and accessible by heavy machinery.

The impression on the following page shows the connection from the sports park to the floating neighborhood in a high water situation. The floating neighborhood remains functional and accessible in all high-water situations.

Illustration 66 | Impression of Riverine Waterscapes - Leeheim - high water
Source: by author

0 150 300 m N

LEGEND

Inundated land

Dry land

Illustration 67 | Impression of Riverine Waterscapes - Leeheim - high water
Source: by author

Illustration 82 | Impression urban floodplain connection
Source: by author

EXTREME HIGH WATER (ONCE IN 100 YEARS)

Lands within this zone are located on higher altitudes and, in the case of some farms, protected by a smaller dyke. Farms located at higher altitudes or protected by small dykes must consider that they could flood in extreme flooding events. Farms at lower altitudes will disappear with the reintroduction of the floodplains.

More plants are suitable to grow on lands that experience short floods. Therefore, the diversity in potential functions is higher. Diverse forests, food forests, silvopastures, and fields for birds are possibilities. The diversity of a food forest or silvopasture is lower in these conditions as many plants cannot sustain short floods. However, many plants can also cope with these conditions, as the inventory in the appendix shows (illustration AIII).

0 150 300 m N

LEGEND

Inundated land

Dry land

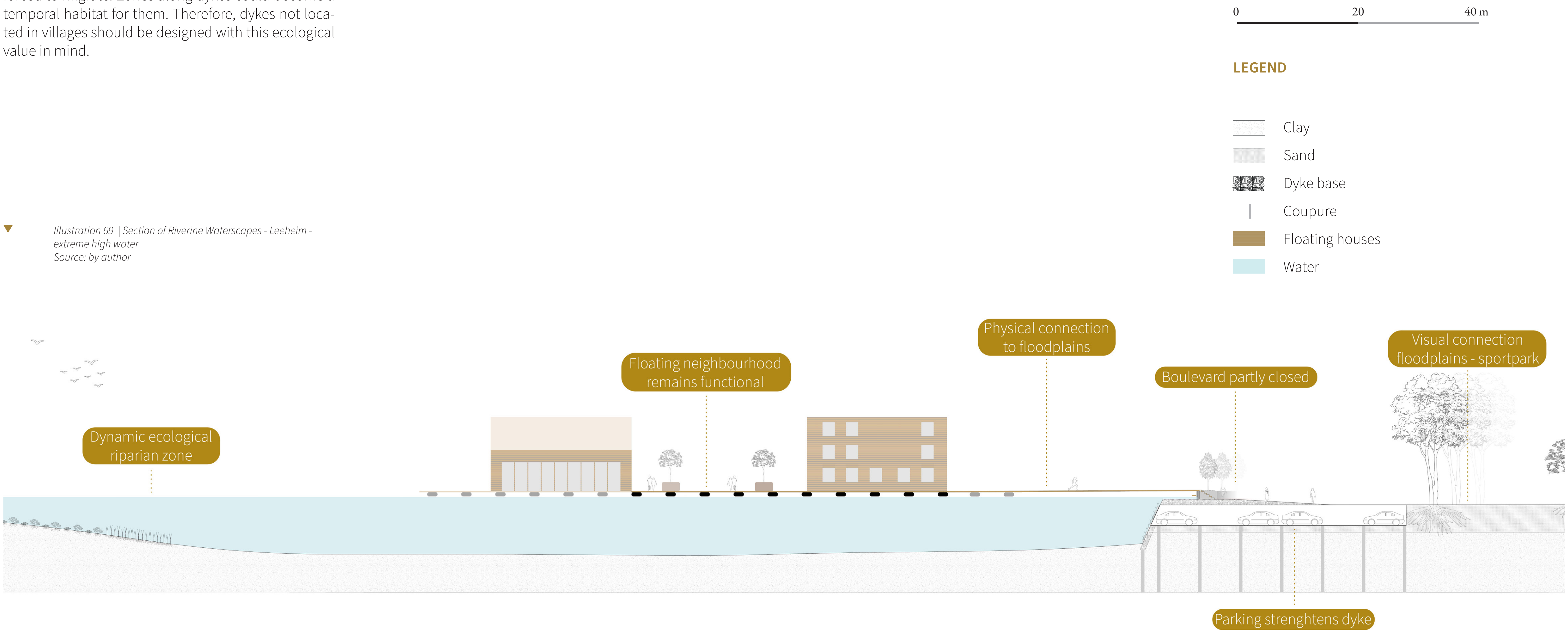
Illustration 68 | Impression of Riverine Waterscapes - Leeheim - extreme high water
Source: by author

SECTION BB'

In extreme high water situations, the maximum water level is reached. Therefore, locks to the floodplains are closed, and the water level in the main branch of the Rhine could rise further independently. To ensure flood safety, coupures are closed between the concrete slabs. A sloping path and stairs are installed to remain accessibility to the floating neighborhoods.

The riparian ecological zone is temporarily flooded in this scenario. As these plants are resistant to floods, this will not lead to much damage on a short term. Organisms dependent on this wetland typology are forced to migrate. Zones along dykes could become a temporal habitat for them. Therefore, dykes not located in villages should be designed with this ecological value in mind.

Illustration 69 | Section of Riverine Waterscapes - Leeheim - extreme high water
Source: by author



SECTION CC'

The three sections on this page show three land-use typologies based on inundation probability. As it is decided that maximum water levels are controlled, the main road crossing this meander is heightened to guarantee accessibility unless an unforeseen flood event occurs.

Illustration 70 | diverse forest on 10-yearly inundated land
Source: by author

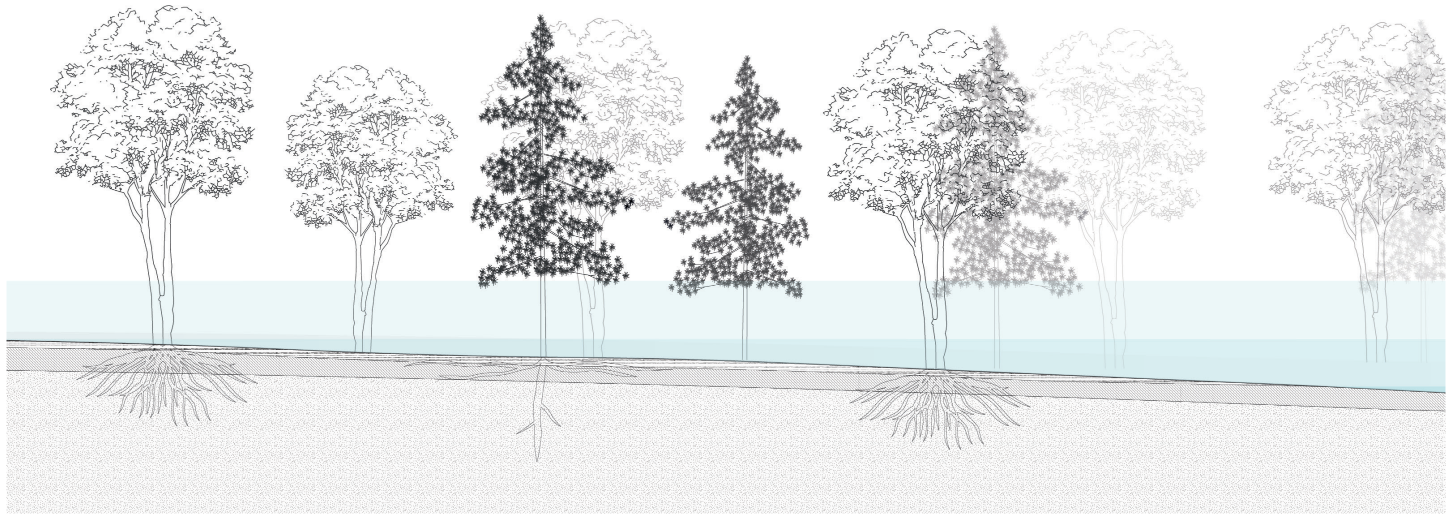


Illustration 71 | forestry on yearly inundated land
Source: by author

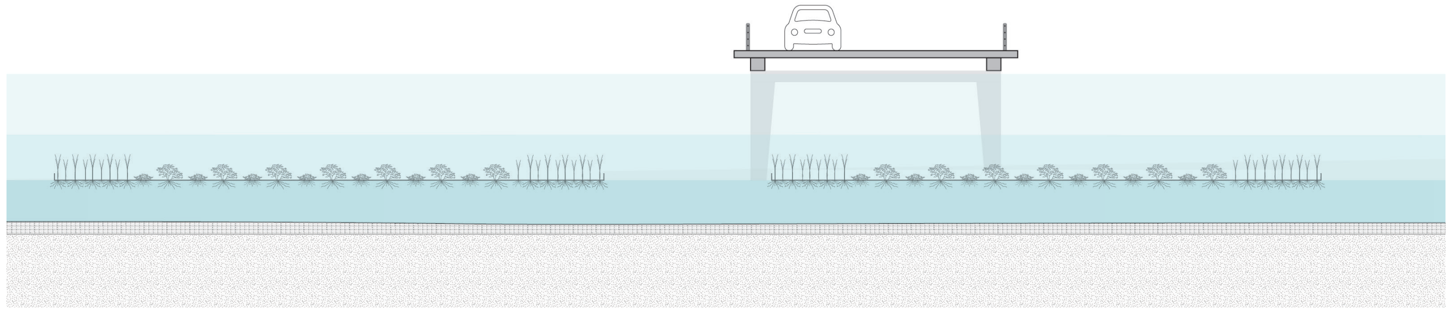


Illustration 72 | aquaculture on permanently inundated land
Source: by author

PROJECT PLANNING

The floodplains are divided into four sections. The implementation of each section can work independently. Therefore, certain sections can be put into use at an earlier stage than others. Due to specific challenges in each floodplain, it is expected that there will be significant differences in completion times. Due to this project's complexity, a year of completion is difficult to determine at this stage.

The first step is to continue developing the strategy and design of each floodplain in collaboration with local governments, experts, the ICPR, and civilians. Bringing all involved stakeholders to the table ensures a more smooth implementation process and strengthens the human-nature symbiosis. As the wishes of most parties are heard and integrated as much as possible, potential protests will be limited. However, as this proposal means the terraformation of the land, societal resistance is an important aspect to take into account.

The second step is the construction of a trade-off system. This large-scale intervention is beneficial for the local community as potential damage related to water security decreases. However, the absolute decrease in potential damage in downstream communities is much more significant. This means an upstream community is drastically changing its surroundings to support downstream communities. A trade-off system ensures the costs and benefits are fairly distributed throughout the communities as downstream communities financially support upstream communities. An agreement on a trade-off system is essential to progress with the implementation of the project. There is also a local distinction to be made. Parties outside the floodplains mainly benefit from this project and are, therefore, similar to downstream communities within this trade-off system.

The third step is to make an inventory of the wishes of current residents and agricultural businesses regarding the floodplains. Are they willing to leave (voluntary expropriation), not willing to leave (mandatory expropriation), or willing to transform to future-proof agriculture (customized expropriation). This inventory affects the speed and form of implementation.

STAKEHOLDERS

These three steps are dependent on the whishes of all involved stakeholders. An inventory of the stakeholders helps to understand the potential conflicts and symbiotic opportunities. These are the primary stakeholders of the Riverine Waterscapes project:

- Residents of the floodplains
- Agricultural business in the floodplains
- Other businesses in the floodplains
- Residents surrounding the floodplains
- Agricultural businesses surrounding the floodplains
- Other businesses surrounding the floodplains
- Governmental organisations (local, regional, national and european)
- International Commision for the Protection of the Rhine
- Downstream communities (including residents, bussinesses and governments)
- Nature and wildlife
- Future generations

INTERESTS

Three main types of interest concerning the inundation of the floodplains are identified: floodplains to be inundated, floodplains to remain dry, and partially inundated or conflicting interests.

The residents and non-agricultural businesses of the floodplains generally prefer the floodplains to remain dry as this will not lead to the expropriation of their land and buildings. Businesses and residents which are not firmly bound to their current situation are expected to be more open to change. They are supported to move outside the floodplains by the local go-

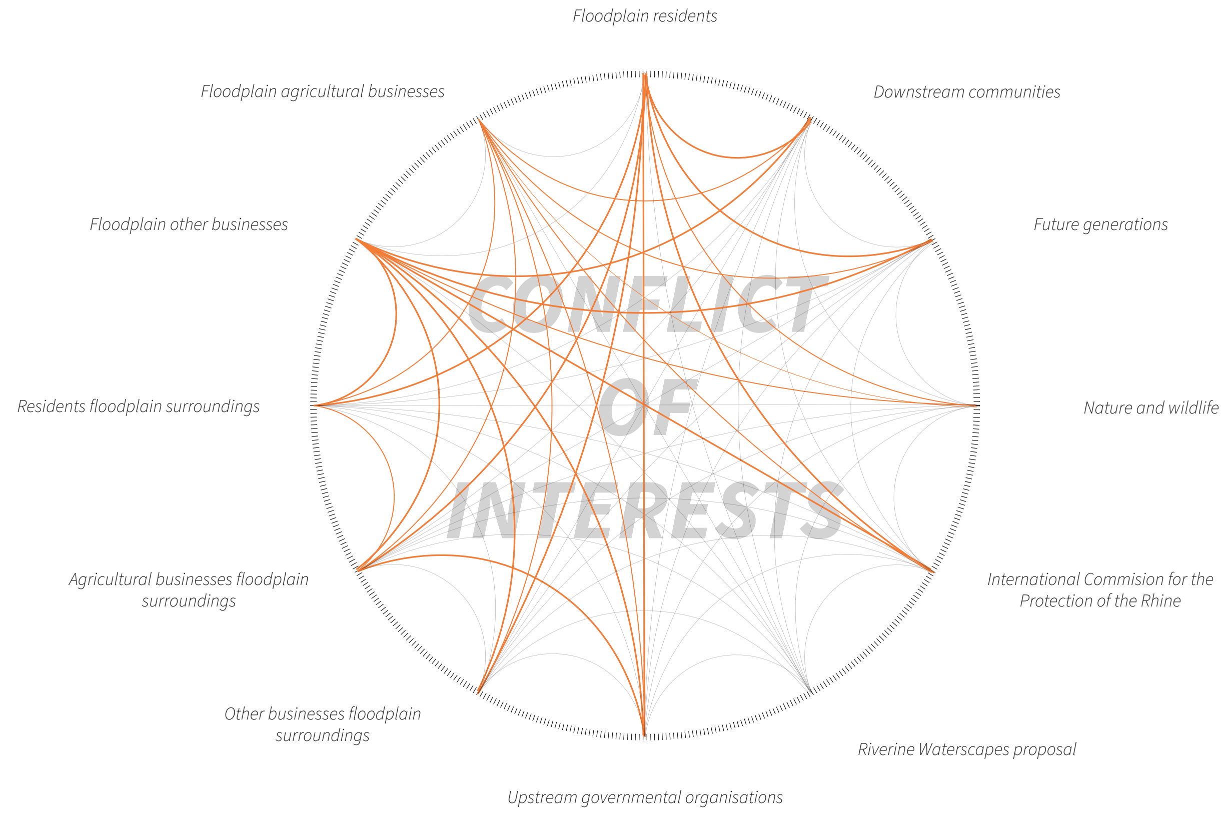


Illustration 73 | Stakeholder analysis: conflict of interests
Source: by author

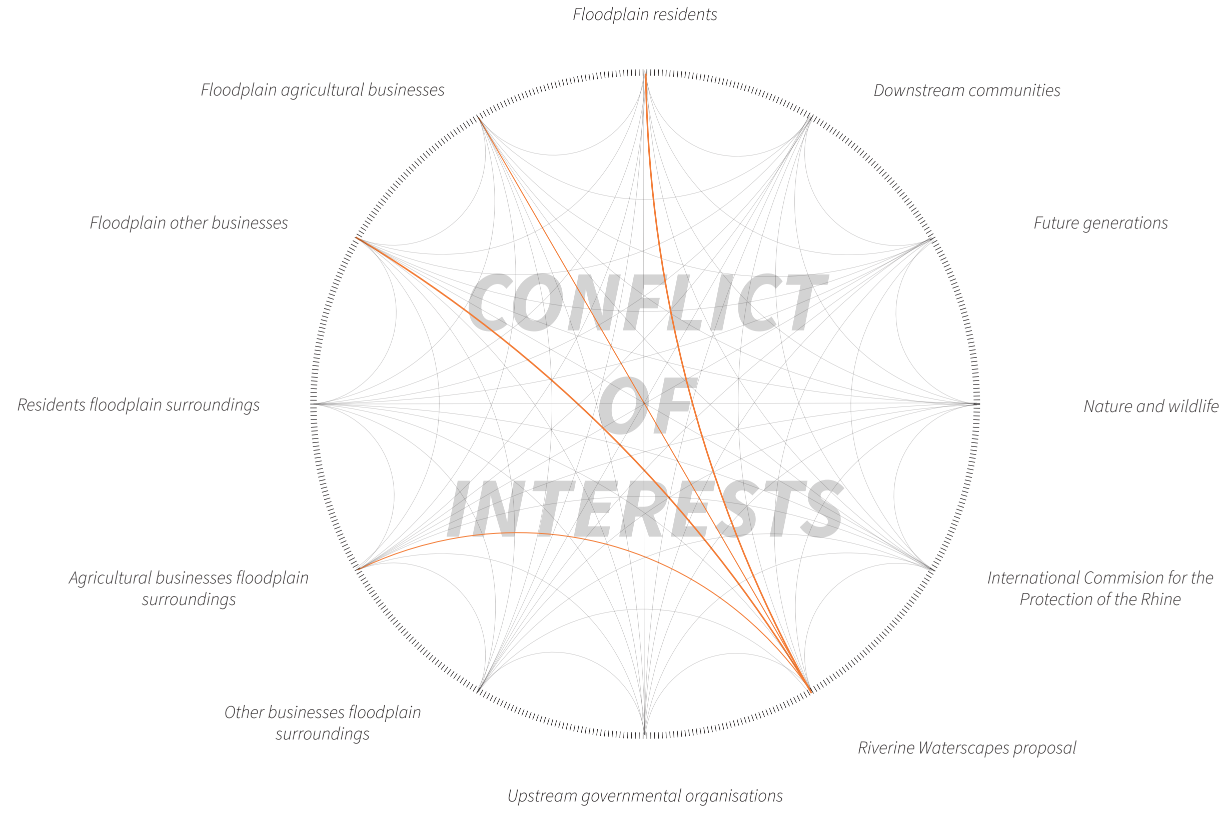


Illustration 74 | Stakeholder analysis: conflict of interests project
Source: by author

vernment. Residents of the floodplains also have the option to relocate within the floodplains as multiple floating neighborhoods are constructed. As the floating neighborhoods could only be installed when water is introduced to this area, and ground-bound buildings need to be demolished at this point, temporal residence outside the floodplains is necessary.

Agricultural businesses in the floodplain have a similar position as the residents. However, much space for agricultural practices will remain. As the practices change to aquaculture, agroforestry, and forestry, these businesses are forced to drastically transform their businesses to remain operational within the floodplains. Above that, the residence, including all buildings, must be adapted to temporal floods or moved outside the floodplains.

All other identified parties are expected to support the inundation of the floodplains as this increases their water safety as the chances and severity of floods, droughts, and pollution decrease. An overview of the interests of each stakeholder is given in the appendix (illustration AIV)

ROADBLOCKS AND PREVENTING CONFLICTS

There are three primary types of societal resistance possible concerning this project. The first is resistance from residents and business owners of the floodplains. Their houses, land, and businesses are expropriated or drastically transformed. Parties that choose to transform to fit within the plans of this project should receive financial compensation for their transformation process and increased flood risk. This financial support could be accompanied by expert support, increasing the willingness to follow this track and prevent resistance. Other parties must be expropriated either voluntarily or mandatory. Again they should receive financial compensation for their losses, allowing them to finance residences and businesses outside the floodplains. Parties that undergo mandatory expropriation could slow down the implementation phase. Legal procedures are one of the possibilities if these parties do not agree with the amount of financial compensation or the expropriation itself. Eventually, there is the risk of cancellation of the project either for financial or other reasons.

The second resistance type is formed by landowners surrounding the floodplains and users of the floodplains. This could also lead to legal procedures if these parties are unwilling to let their surroundings dramatically change with the primary purpose of protecting downstream communities. However, resistance from this group is expected to be less severe as they are not subject to expropriations and experience a reduced flood and drought risk.

The third form of societal resistance comes from downstream communities. They could refuse a financial trade-off system for multiple reasons. As the scale of downstream communities is large (millions of landowners), the financial impact on the individual scale is low, especially considering the increased water security, which leads to risk reduction. Therefore, this type of societal resistance is the least concerning.

SYMBIOTIC OPPORTUNITIES

The project itself focuses on the symbiosis between nature and humans. A stakeholder analysis is made to analyze to what extent this symbiosis is present in the current proposal.

Illustration 76 shows that the project brings symbiotic opportunities to most stakeholders. The most substantial opportunities are for agricultural businesses in the floodplains, residents surrounding the floodplains, nature and wildlife, upstream governmental organizations, and the ICPR. The project does not yet hold much potential for non-agricultural businesses. However, there are opportunities considering energy production, recreation, and agricultural technology

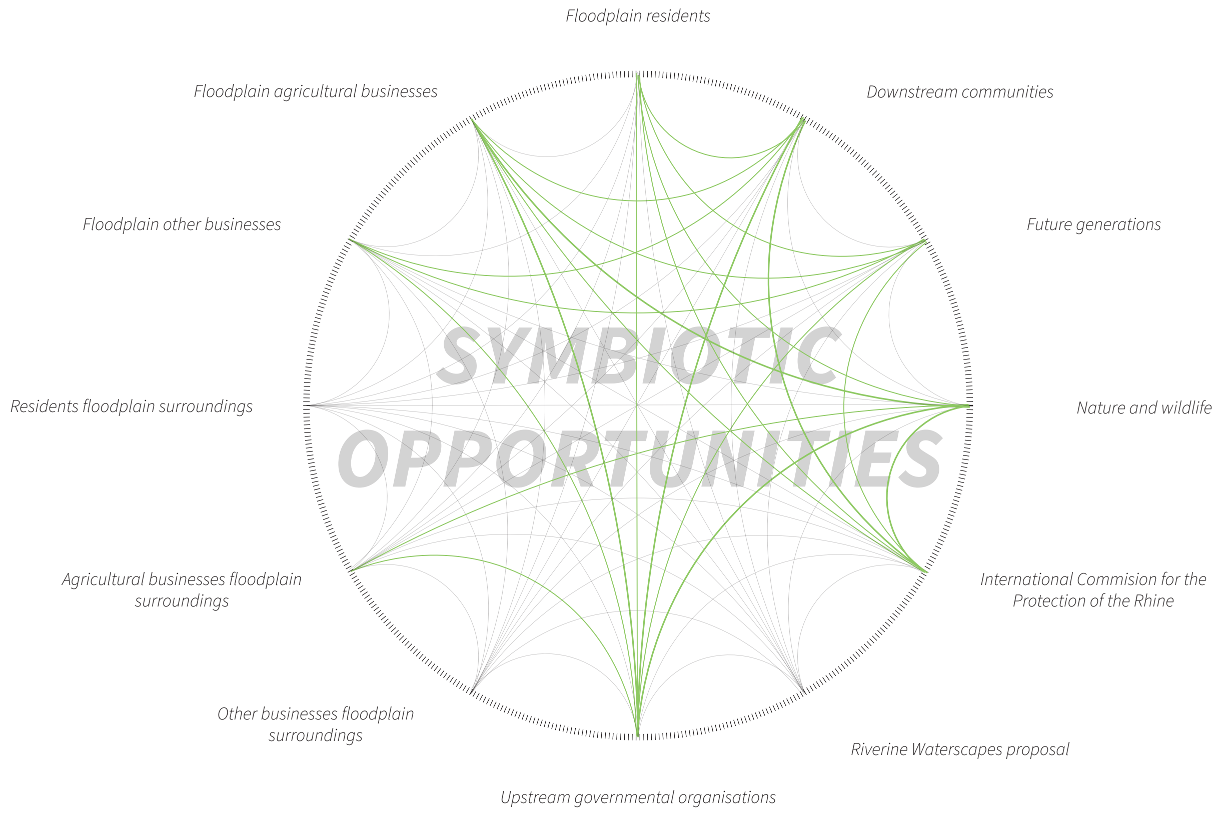


Illustration 75 | Stakeholder analysis: symbiotic opportunities
Source: by author

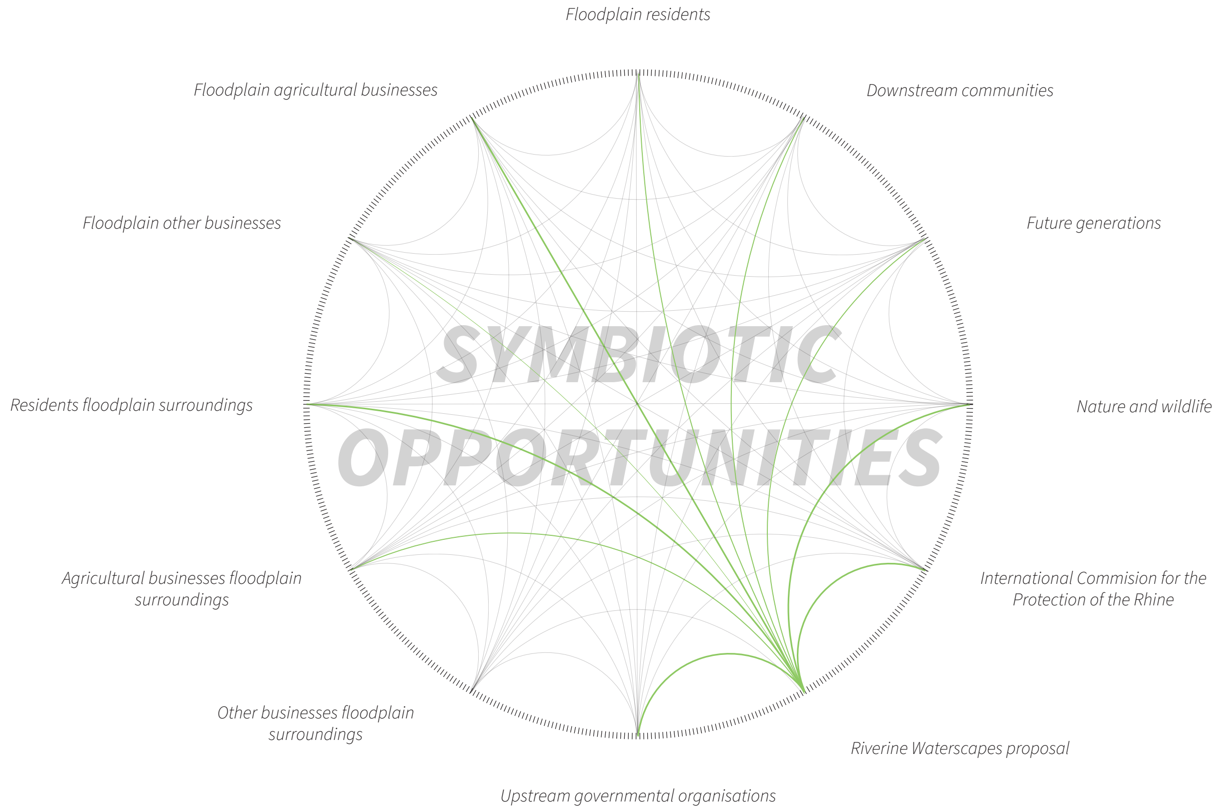


Illustration 76 | Stakeholder analysis: symbiotic opportunities project
Source: by author

that could be explored.

Between stakeholders themselves, this project aims to merge the interests of currently opposing parties. Downstream communities, future generations, nature and wildlife, and the ICPR hold symbiotic opportunities by working together with upstream residents and businesses through upstream governmental organizations. This collaboration is a mixture of water management, knowledge exchange, and financial support.

IMPLEMENTATION PLANNING

When the first three steps are completed, the project's implementation phase is initiated. The fourth step is to make a detailed implementation plan. The construction of this planning implements the project's core values, and circularity is an additional essential value.

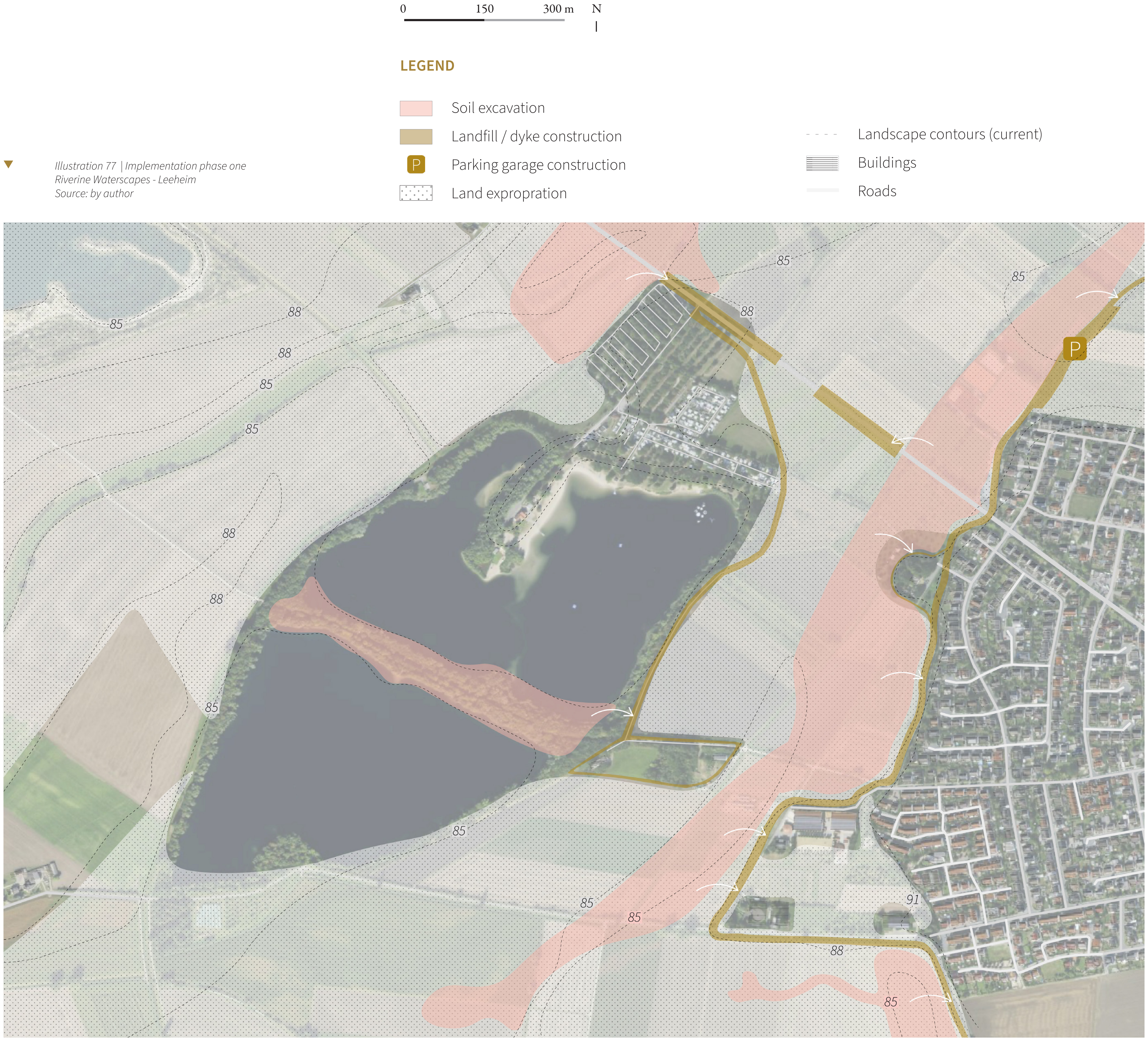
The fifth step is the terraformation of the floodplains. Demolition of buildings within the future permanently inundated land, waterway excavation, and dyke construction will happen simultaneously. When the landscape formation is completed, construction of the landscape design is started.

The sixth step is to open up the floodplains to the Rhine and permanently introduce water into this landscape. In this phase, functions that need permanent inundation, like floating neighborhoods, are constructed.

IMPLEMENTATION PHASE ONE

Floating neighborhoods and aquatic transportation need guaranteed inundated waterways. Therefore, at some points, the soil needs to be excavated. This raises the question of whether this practice is harmful to the environment as soil life is disturbed. This disruption is happening already by flooding this land, so excavation should have limited additional damage. In fact, this soil can be used to construct the new dyke system. This means the excavation and dyke construction is a circular process. External material might be necessary

Illustration 77 | Implementation phase one
Riverine Waterscapes - Leeheim
Source: by author



to ensure dyke strength and is undoubtedly necessary for the construction of locks.

A land expropriation scheme is rolled out to make this excavation possible and prepare for the land use transformation of the whole floodplains. Agricultural lands that will be permanently flooded in the future or be transformed into bird reserves and forestry are expected to be expropriated. Lands which transform within the dry agricultural sector are less likely to be expropriated. Land expropriation is a challenging process that leads to much societal resistance. Therefore, with every unique land owner in the floodplains, negotiating the necessity and the terms of expropriation is necessary.

IMPLEMENTATION PHASE TWO

When the preferred landscape form is reached, the spatial design is implemented. Expropriated buildings are demolished, and new infrastructure is constructed. This includes a motorcycle bridge between the villages Leeheim and Geinsheim and locks in the old dyke system. A new sports park is constructed outside the floodplains as the old sports park was located in a future permanently inundated area. Land use transformations not requiring inundation are also implemented in this phase. Aquatic energy production, aquaculture, and floating neighborhoods require permanent inundation and are therefore constructed after water from the Rhine is introduced in the floodplains.

Illustration 78 | Implementation phase two
Riverine Waterscapes - Leeheim
Source: by author

VII UPSCALING

VII UPSCALING TO THE RHINE BASIN

This chapter explains to what extent symbiotic water management is possible in the Rhine basin. This is relevant as the pilot projects are designed to reach local symbiotic water management by local projects and basin-wide symbiotic water management by implementing this strategy throughout the basin. The following pages show in which parts of the basin implementing these pilot projects is possible. The inventory is separated into three parts, as each pilot project has specific requirements. Further, the chapter discusses how these pilot projects can be translated to other locations.

Areas not marked in this inventory still have the possibility to host symbiotic water management, but it would manifest itself in a different form than the three typological pilots.

VII.I VINEYARD STREAMS

UPSCALING VINEYARD STREAMS

This project is based on three characteristic landscape elements: the vineyard, the small stream, and the city. The city itself has not been a central focal point in this study, so upscaling this marginal intervention is irrelevant. Nevertheless, the city becomes a relevant element in combination with the stream and vineyard.

This means the following steps are taken:

- Vineyards on slopes with at least a 2% incline are identified
- Small streams on slopes with at least a 2% incline are identified
- Urban areas downstream of vineyards and including a small stream connecting the two elements are identified

IMPLEMENTATION

The vineyard and the stream are independent elements. They could function with or without the other elements if their representative designs are implemented.

The implementation of the vineyard strategy is separated into two elements; transformation to biodynamic cultivation and construction of retention buffers. These two elements can be implemented independently. Biodynamic cultivation is expected to be the first transition completed on most sites as it requires fewer resources than the construction of retention buffers. Transforming the cultivation technique requires a strong business plan, and it takes multiple years until this transformation leads to the wanted result. Where transformation to biodynamic cultivation can be implemented per parcel, retention buffers will function better on a multi-parcel scale. As the retention buffers are small, the construction phase is not expected to impact business operations significantly. The main challenge is forming a communal implementation plan; all involved vintners (vineyard owners) must agree to this intervention and the corresponding financial construction.

For the implementation of the small streams strategy, an analysis is necessary for each case to determine if the landscape is suitable for this intervention. In some cases, water retention might not be necessary if upstream land can absorb enough water and capacity problems in downstream urban areas are limited.

RESULTS

Any small stream or set of vineyards can be transformed independently. When a single set of vineyards is transformed, it primarily positively affects local water- and climate resilience. In urban areas located downstream of vineyards connected by a small stream, every completed step decreases the pressure on the urban water system. When the whole catchment area of a small stream is transformed, optimal local water- and climate resilience is reached as well as in the urban areas downstream of this small stream.

As there are many relevant small streams and vineyards in the Rhine basin, a single local catchment area is expected to have minimal impact on water- and climate resilience in downstream communities along the Rhine. As the transformation percentage slowly increases, the effects will become measurable on this large scale.

Finally, upscaling the Vineyard Streams project leads to decreased chances and impact of flash floods and local droughts, improved water quality in small streams and the Rhine, and mitigation of extreme fluctuations of small streams and the Rhine.

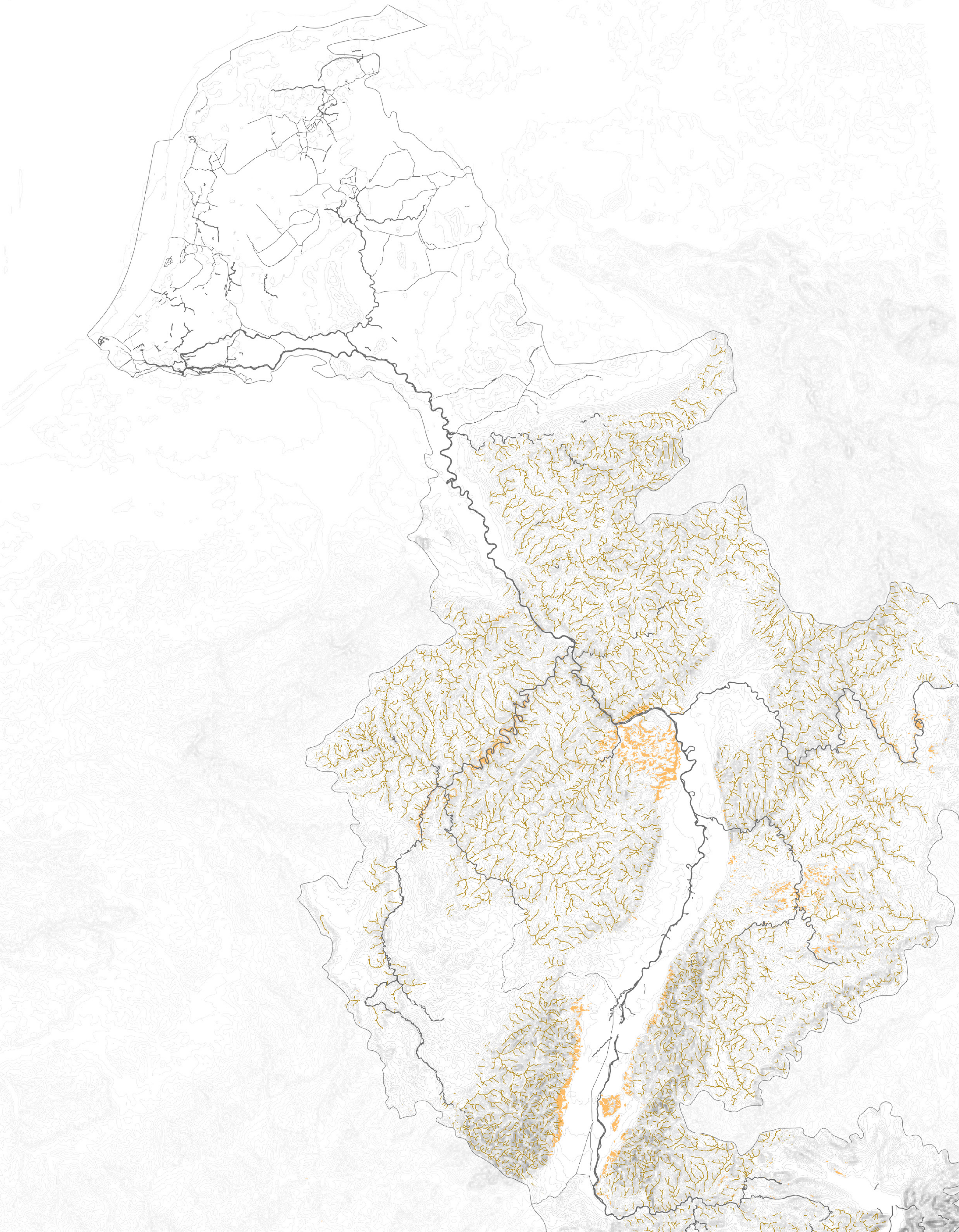
Further research is needed to understand the ecological qualities of the small water retention buffers. It brings new ecological qualities. Nevertheless, in specific cases existing ecological qualities could be harmed.

0 50 100 km N

LEGEND

- Rhine river system
- Canals
- Vineyards
- Small streams
- Rhine basin border
- Landscape contours

Illustration 79 | Upscaling the Vineyard Streams project
Source: by author



VII.II AGROFORESTRY WATERSCAPES

UPSCALING AGROFORESTRY WATERSCAPES

This project concerns the total land use transformation of agricultural lands. Agricultural forms not considered are vineyards and indoor agriculture (horticulture and livestock factories). All other agricultural lands, independent of their context, are transformed into agroforestry waterscapes.

IMPLEMENTATION

The implementation of this strategy is expected to be gradual. The nature of this proposal creates the possibility for implementation on the scale of a single farm or parcel. There are two relevant groups in this process; conventional farmers and future farmers.

Conventional farmers need to transform their agricultural business to the principles of agroforestry waterscapes. This process can take much time as the following steps must be taken. First, the farmer needs to decide to transform their business. This decision can be based on personal conviction, a strategic business plan, or rules forced on farmers by governmental organizations. Secondly, the land needs to be transformed. This is expected to be a gradual process to ensure business continuity.

Future farmers are defined as people who start a new agricultural business and do not have an existing business to transform. They can immediately create Agroforestry Waterscapes on their newly acquired land. This means the process of land transformation could happen at a faster pace.

0 50 100 km N

LEGEND

Rhine river system

Canals

Agroforestry Waterscapes

Rhine basin border

Landscape contours

Depending on favorable business conditions and governmental plans, the implementation process could be slower or faster. Nevertheless, all agricultural land will slowly transform into Agroforestry Waterscapes, making the Rhine basin more resilient to water-related problems and climate change.

RESULTS

Any agricultural land transformed to the principles of Agroforestry Waterscapes has positive local results. As this type of land use is more resilient to droughts and extreme rainfall, these extreme weather events result in less damage to plants and animals than conventional agricultural methods. Local water and air quality are also improved as more plants are available, which can filter water and air from pollution, and no chemicals are used anymore in food production.

As the share of Agroforestry Waterscapes of the total agricultural area increases, this transformation's large-scale (basin-wide) effects become measurable. Extreme fluctuations of the Rhine are mitigated as the land buffers most water which then slowly drains into the river system. Simultaneously, the water quality of the Rhine improves. However, this partly depends on pollution from urban areas and industrial processes.

This means extremely low water levels are prevented, so the river remains easy to navigate for ships and marine life. It also leads to greater availability of drinking water, water for industrial processes, and water for irrigation. Water demand for irrigation is also expected to decrease as all agricultural lands have larger local water buffers. On the other hand, extremely high water levels are prevented; therefore, flood risk is limited without heightening dykes. This also limits periods in which the river is unsuitable for recreation and transportation. Lastly, better water quality creates a healthier marine habitat, makes drinking water cheaper to filter and safer to drink, and makes recreational activities healthier.

This large-scale transformation means losing currently culturally and ecologically valued agricultural landscapes. Therefore, further design research could explore how current landscape values could become intertwined with Agroforestry Waterscapes.

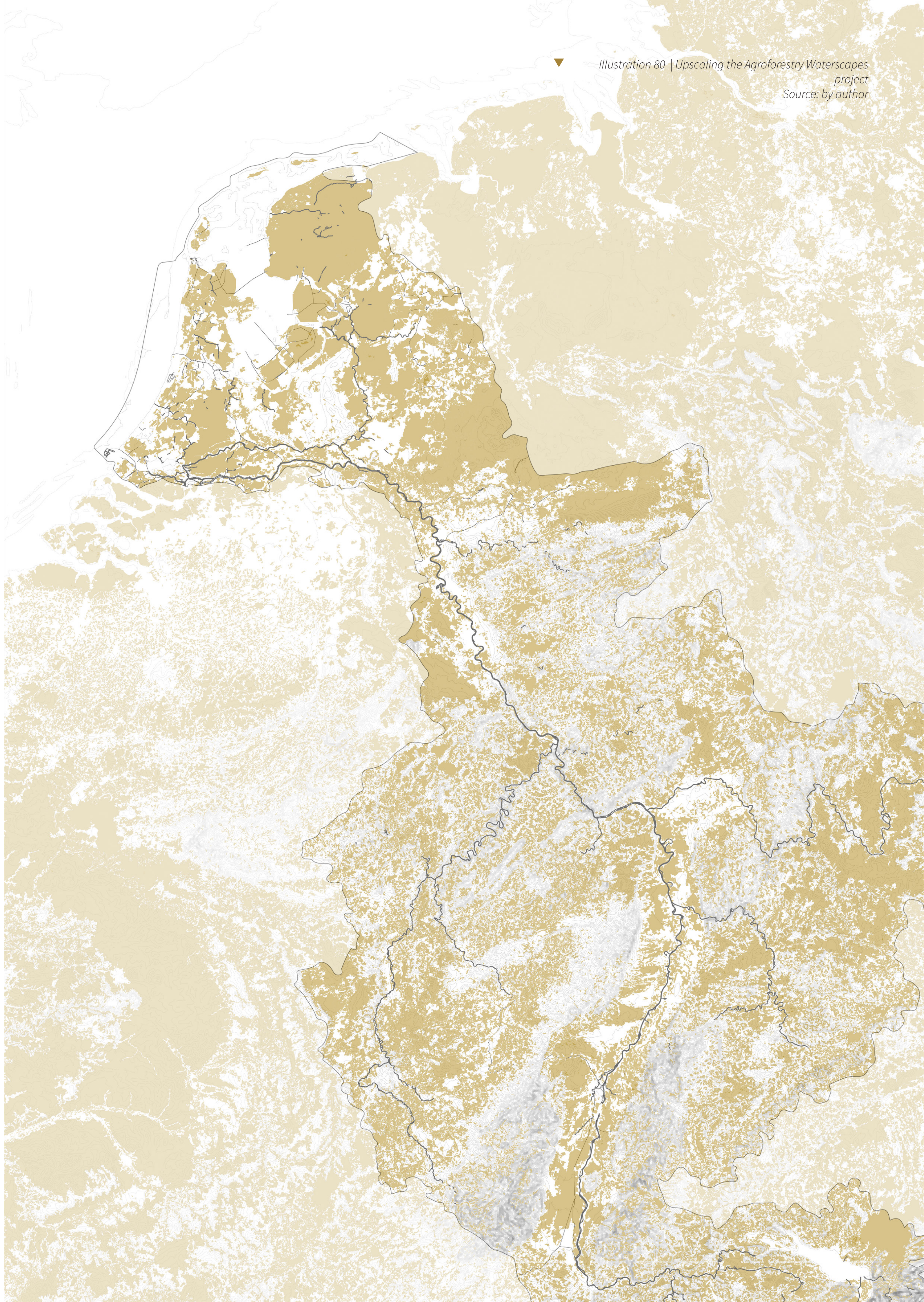


Illustration 80 | Upscaling the Agroforestry Waterscapes project
Source: by author

VII.III RIVERINE WATERSCAPES

UPSCALING RIVERINE WATERSCAPES

This project concerns the (re)creation of floodplains of the Rhine. Here water can flood large areas to prevent extreme peak discharges downstream. Retaining this water until dry periods gives the possibility to mitigate the effects of droughts locally and in the river itself. Within these floodplains, there is a wide range of functions currently. All potential floodplains in an extreme flooding event are of interest. When (re)creating these floodplains, for each section, a cost-benefit analysis has to be made to decide what function should be given back to the river in return for greater water safety. Illustration 81 is based on a general cost-benefit consideration. All functions with a high density of buildings are not suitable for flooding as the damage of these properties' deconstruction is often larger than the decline in potential damage by water.

IMPLEMENTATION

These floodplains can be separated into sections, ideally the size of an old river meander. These meanders are often still visible as shallow trenches in the landscape. This natural elevation difference makes these places ideal for water retention with minimal human interventions. How this implementation process works per floodplain section, is described in the Riverine Waterscapes project. On a larger scale, different management options should be considered. The floodplains in the Riverine Waterscapes project follow the dynamics of the river until a maximum and minimum height. When reducing flood risk, flattening the discharge peak is the goal. When the floodplains are already filled with water before the peak arrives, the flood risk remains high, although lower than without floodplains. Therefore, multiple floodplains should be strategically managed. They should be opened when the peak discharge arrives. These floodplains are less dependent on existing meanders in the landscape as the water levels are high immediately. Here the natural dynamics and ecological value are less important as it functions as an emergency system.

RESULTS

When one section is implemented, it will slightly decrease the flood risk locally and downstream on a small scale. The water quality will especially improve within the floodplain itself. Local droughts are primarily managed by local water management. However, as more water is retained in floodplains upstream and within the landscape through the Vineyard Streams and Agroforestry Waterscapes projects, extremely low water discharges are mitigated. This leads to more water availability within a specific floodplain during droughts.

As more floodplains are (re)created, flood risk (Lammersen et al., 2002), droughts, and poor water quality become less likely. The extent of this risk reduction depends on the location of the floodplain compared to where most interventions have been made. For example, if Nijmegen in The Netherlands is taken as a reference point and most interventions have been completed in Germany, a significant risk reduction is expected. However, risk reduction is limited when most interventions are made downstream of this city. For large-scale effects, large-scale implementation is necessary.

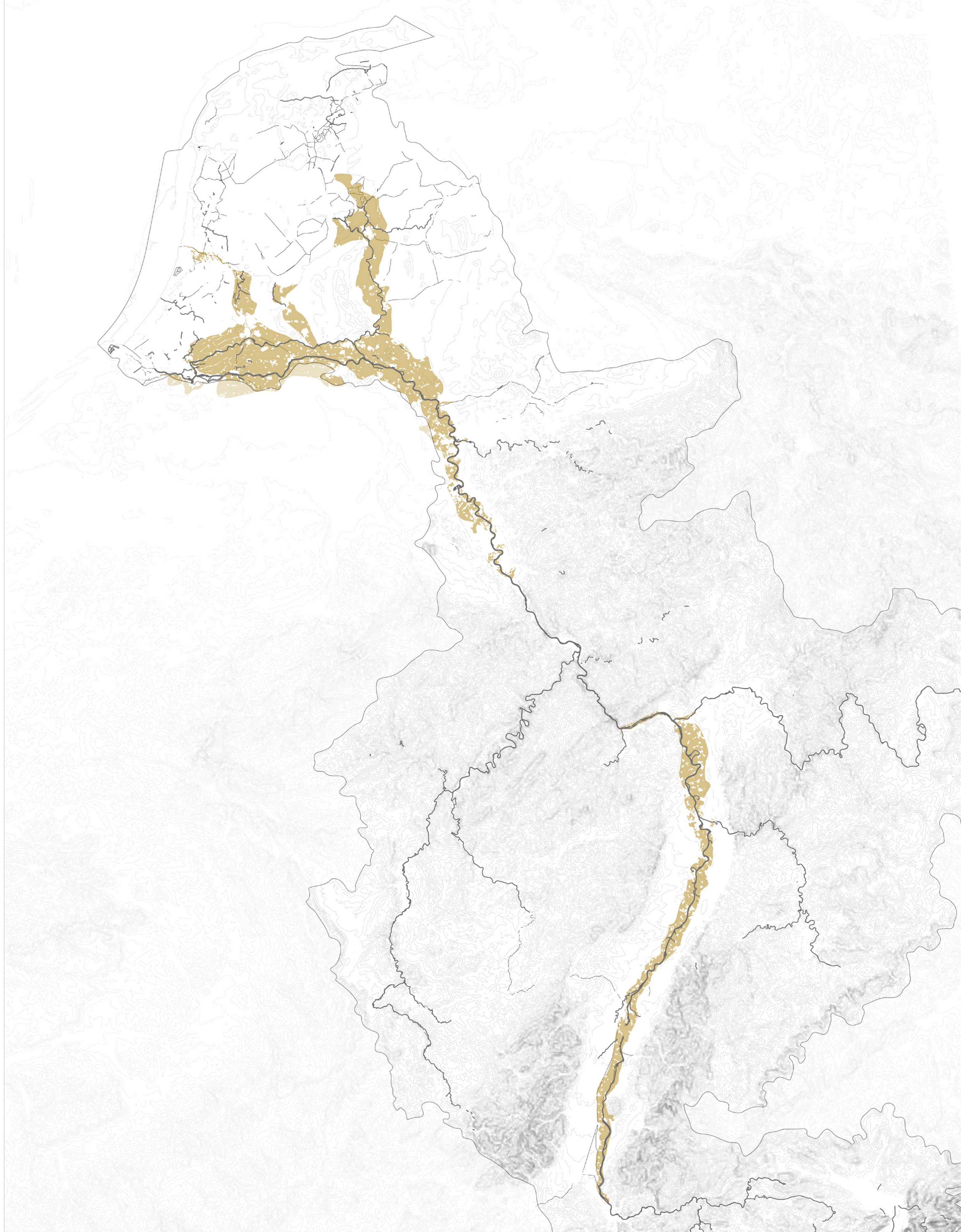
An important topic that needs further research is whether there is an ideal balance between the number of reintroduced floodplains and water security benefits from the perspective of water management, finances, and socio-cultural systems. The economic implications should be determined when deciding which floodplains to reintroduce. Additionally, cultural and ecological values in both scenarios (reintroducing floodplains or not) are essential to consider. If an area has highly valued economic, cultural, or ecological elements, transforming it could be a step back for the region. This is a reminder that integral water management means not only integral solutions but also a holistic view of the complex systems of a region.

0 50 100 km N

LEGEND

- Rhine river system
- Canals
- Riverine Waterscapes
- Rhine basin border
- Landscape contours

Illustration 81 | Upscaling the Riverine Waterscapes project
Source: by author



VII.IV DISCUSSION ON UPSCALING

Every pilot project concerns different parts of the Rhine basin. In total, areas suitable for transformation to symbiotic water management cover large parts of the Rhine basin. If these projects are implemented on such a large scale, the landscape will significantly differ from its current situation. An enormous transformation like this can be referred to as terraformation. This term means the transformation of a planet to make it habitable for a particular species. Without this intervention, the Rhine basin could become an unsuitable location for human population, considering the basic needs humans need to thrive.

Restoration of ecosystems is an existing paradigm in Western countries. Often large amounts of money are spent on clearing damaging engineering projects. This money is earned back indirectly through ecosystem services (K. Tockner et al., 2016). In all projects in this thesis, ecosystem restoration is a combined effort with shaping the future food production industry, climate mitigation, and symbiotic water management. Combining these aspects leads to a cost-effective approach.

The potential size of upscaling of these projects raises the question of the limits to upscaling. As discussed before, upscaling is theoretically limited by unsuitable landscape typologies. There is no theoretical limit for transforming all suitable landscapes as the projects do not lead to damaging accumulation. A common concern in water management is upstream communities keeping all water for themselves, leading to shortages downstream. An example is a mega-dam under construction in Ethiopia, prompting a conflict with countries downstream (Maru, 2020). The Vineyard Streams project has a limited capacity, and the Agroforestry Waterscapes project rests on natural dynamics, which are difficult to steer.

On the other hand, the Riverine Waterscapes project has a large retention capacity. Due to the design, these buffers can only be filled when water levels are high. Additional extensive infrastructure is needed to lead to potential downstream water shortages. Therefore, this project is not a risk in itself. Practical limits are more restricting. As millions of parties could be involved throughout the basin, there is a significant chance of delays or cancellations of projects.

Given the scale of these interventions, the implementation is expected to span multiple decades. The pace of this change depends greatly on societal and political willpower. Innovations in water retention and agroforestry techniques play an important role as this could stimulate business opportunities in relevant sectors like food production. Innovations could also change design opportunities for individual projects. Different types of design solutions are welcome and do not have to weaken the project as long as the goals and values of this project remain part of future designs and strategies. This means the project could be expanded with new goals or values depending on future challenges and viewpoints. Allowing flexibility in a large-scale project is essential to ensure its continuity in the future.

It is impossible to promise that this project will prevent all damage from floods, droughts, and water pollution, nor is it possible to claim that it will lead to perfect biodiversity and relationship between water and humans. There is scientific proof that this project's individual elements positively impact the problem fields, as mentioned at the beginning of this thesis. Therefore, it is most realistic to frame this project as a significant step towards water safety, increased biodiversity, and a healthy relationship between humans and water.

The extent to which these problems are solved depends on various uncertain factors. There is much uncertainty about climate predictions, how these systems are maintained and developed, and other relevant water management strategies. In the research set up, a question was formulated about how the results of upstream interventions can be measured. This thesis has not been able to answer this question. Further research in collaboration with hydrology experts is necessary to set up a modeling and measuring system to give experts and governments insight into how specific interventions alter hydrological aspects. Such a system could also form scientific input to a trade-off system.

An exemplary relevant water management strategy is the sea level rise in the Dutch delta. The strategy concerning this issue could significantly impact how water from the Rhine is discharged into the North Sea, which alters water safety in this area.

VIII CONCLUSION & DISCUSSION

The research shows how the theoretical concepts of upstream-downstream interdependencies, clearance, and socio-ecological symbiosis could lead to a integral and sustainable water management approach in which the balance between humans and nature is restored. The theoretical foundations, problem analysis and location-based conditions have shown to hold a broad range of solutions. The three pilot projects are merely examples of how this combination of factors could lead to a future-proof design and answer the research question: *How could water safety downstream be supported by upstream design interventions in the Northern Upper Rhine Valley, based on methods in which socio-ecological symbiosis and clearance are central?*

VINEYARD STREAMS
The project about the Kiedricher Bach and Eltville am Rhein is an example of how small streams in mountainous terrain can be managed to prevent devestating flashfloods as seen in Germany in July 2021. It also shows how droughts and pollution can be mitigated.

Here upstream-downstream interdependencies are most important on a micro scale. Nevertheless, when this pilot project is upscaled to locations with similar conditions throughout the region, together they have significant influence on a larger extent of downstream communities. A list of interdependencies central in this project:

- The vineyards to Kiedrich
- The vineyards to Eltville am Rhein
- The Retention Valley to Eltville am Rhein
- Neighbourhoods in Eltville am Rhein to the center of the city
- The whole system of the Kiedricher Bach to downstream communities along the Rhine

This design shows that socio-ecological symbiosis is not necessarily the same as nature-based solutions. A combination of nature-based solutions and engineering works is presented as the research by design process showed that this was the optimal solution to the adressed problems.

The primary limits of this project are social resistance to land expropriations and disagreements about financial compensation for these expropriations and cultivation technique transformation. As this water retention system is not wholly passive, active management and maintenance are necessary. Over time, this management system could deteriorate. In this case, the new cultivation technique is the only system that remains functional. Above that, it could be possible that this system increases local flood chances if not adequately managed.

AGROFORESTRY WATERSCAPES
The pilot project in the village of Wackernheim and its surroundings is an example of how land use transformations towards a nature-inclusive and human-inclusive use, can lead to sustainable water management.

The erosion- and run-off prone land use is transformed to uses which improve the water-regulating capacity of the soil and above ground. Apart from mitigating flashfloods and droughts, it clears pollution common in food production, it significantly improves biodiversity, and it increases the awareness and connection between humans, water, nature, and food production.

This approach has broader positive effects than the Vineyard Streams project. When this strategy is implemented throughout the Rhine Valley region, local droughts are mitigated on a regional scale, local and larger downstream floods are mitigated, water quality of the river system is improved, biodiversity expands, and the harmony between people and their surroundings is improved.

The willingness limits the implementation of transformation in the agricultural sector and governmental organizations. Through sustainable policies, damaging agriculture can be phased out. Once the agricultural transformation is completed, the system only requires active management by agricultural businesses. They are stimulated by the urge to keep their businesses functional. On the governmental side, these sustainable policies must remain in place to prevent backward development.

RIVERINE WATERSCAPES
The project about the reintroduction of the floodplains is an example of how giving more space to the Rhine mitigates floods, droughts, and pollution.

The dynamic yet controlled flooding of these plains complety change how this land is used. Large-scale agricultural practices make place for new activities and new forms of cultivation. The four proposed zones show the possibilities this dynamic system brings.

The relationship between people and water is strenghtent in multiple ways:

- There is a strong visual and physical connection between villages and the floodplains and the functions it hosts.
- Fear-based design makes place for water-inclusive design.
- The floodplains bring new recreational, economic, and residential possibilities

This project is large-scale in itself but could be implemented on multiple locations throughout the Rhine Valley, which would significantly decrease discharge fluctuations throughout the Rhine.

As extensive expropriation is necessary for this project, it could limit its implementation. The process of expropriation on this scale mainly limits the project in time. However, financially it could lead to the cancellation of the project. For every transformed floodplain section, a calculation is necessary to determine all costs, including financial compensations and all benefits through increased water security. Apart from this calculation, the willingness of downstream communities to support this trade-off system determines the continuation of the project.

FINAL REMARKS
In the beginning phase of this thesis, trade-off systems, including financial compensation, were expected to be necessary to answer the sub-research question on how to persuade upstream communities to change their surroundings to aid downstream communities. Eventually, upstream interventions have been shown to bring many opportunities to improve local spatial qualities and mitigate local water-related problems, apart from their downstream benefits. This focus on local upstream improvements makes a financially driven trade-off system less necessary. However, the Riverine Waterscapes project has shown that financial compensations for imbalanced interventions are still relevant.

IX REFLECTION

IX REFLECTION

SOCIETAL RELEVANCE

We are experiencing an enormous environmental crisis affecting how we live and work. The accumulation of damaging matter from the modern world is changing the planet. Climate change is just one of the consequences. The urbanized and cultivated landscapes in riverine territories are experiencing these problems firsthand, and water is often the means through which we experience this. Floods, droughts, and pollution are the main water-related crises. Examples are:

- The floods in the Rhine and Meuse in July 2021 which caused many deaths and a lot of damage to buildings and agricultural lands.
- The droughts throughout the Northern hemisphere in the summer of 2022 which damaged nature, crops, and energy production and facilitated deadly heat waves.
- The pollution of the Rhine, making it less suitable for drinking water and damages marine life.

All this damage that is caused by water has an enormous societal impact:

- People and businesses could temporarily lose their access to energy which can cause dangerous situations and interrupt essential processes.
- People could lose access to food and drinking water, which is physically and mentally damaging.
- People could become homeless as their houses are damaged beyond repair.
- People could eventually die because of these water crises.
- Nature could be severely impacted, which could eventually disturb processes of societal importance.

Therefore, there is a need for a changing understanding of how we live, work and use space in riverine territories. The project aims to reach sustainable and integral water management with a focus on water quantity and quality. It constitutes to the greater goal to let us and future generations live a comfortable and healthy life without fear of floods, drought, or pollution. The word 'integral' implies that this sustainable water management is dealt with in symbiosis with solutions to other pressing environmental problems, like the decline in biodiversity and the decline in awareness of how water works and what it means to society.

ADVANTAGES AND LIMITATIONS OF THE CHOSEN METHODOLOGY

The main methods applied in this research are literature research, problem analysis, and research by design. The advantages of these methods are that they gave a deep understanding of the general problems and why they were occurring. It allowed me to understand the processes behind these problems, and that made it possible to make successful alterations in these processes to mitigate the problems. Research by design has been essential for this process as it gave me a better understanding of how certain alterations would work in a specific context. It also helped examine if the chosen alterations led to the preferred results.

The limitations of these methods are that they tend to result in only qualitative data. For this specific research, this did not pose a problem as qualitative results were the primary goal. However, a lack of quantitative data, which could have been obtained through modeling, did bring doubts to the process. Research through quantitative models would have been helpful to make the qualitative design ready for implementation. Therefore, I would suggest that if a similar project is executed in a professional environment, to use a combination of qualitative and quantitative research. Additionally, involving specialists in hydrology, ecology, agriculture, and sociology would help deepen the research.

PROBLEMS IN DATA COLLECTION

One of the problems encountered in data collection was the question to which level of detail the data would be relevant to the project. An example is the design of the floodplains. One goal of this design was to prevent local and downstream floods. To know exactly how to prevent these floods through the chosen method, a detailed hydrological model would be needed with the input of information that is unavailable. The amount of space to give to the water and the height on which certain functions should be located to be safe from floods depends on climate variables, the number of other floodplains that will be realized, and the effects of large-scale land transformation and water retention. All these elements have insecurities that make them difficult to calculate with.

It is not the goal of this project to tell precisely how big a retention area should be and on which height certain functions are considered safe from floods. The goal is to show general solutions to the problems at hand, which entail a certain level of realism through general calculations or scientific proof. This vision of how the future landscape could look is a concept that can be built upon. If a design were to be implemented by a governmental organization, further elaboration (through modeling) would be necessary to set the exact configuration of the design.

POSSIBILITY TO GENERALIZE THE RESULTS OF THE RESEARCH

Generalizing the results of this research is one of the project's goals and is further elaborated in chapter 7. The project contains three design typologies that work together to reach the primary goal. These typologies are all connected to a specific type of landscape. These types of landscapes can be found throughout the Rhine Valley region, and therefore the results can be upscaled to these locations. Outside the region, similar types of landscapes can be found as well. However, the exact conditions of the landscapes, which become apparent through problem analysis, will determine if these locations are suitable for the design concept or not.

ETHICAL ISSUES AND DILEMMAS

There are two significant ethical dilemmas I encountered in this research. The first is found in the concept of the project. Initially, the project's main goal was to protect downstream communities from floods, droughts, and water pollution by implementing upstream interventions. The problem here is the societal capacity to deal with a significantly changing landscape for the good of others (downstream communities). This discussion led me to reframe the concept of the project. Now, the goal is the protect both local (upstream) and downstream communities by implementing upstream interventions. Moreover, in light of upscaling this research results, a community considered upstream in one design could be considered downstream in another design. Therefore, the societal capacities to deal with this change are supported by implementing the results on a large scale.

The second ethical problem is found in the specific design. Land expropriation might be necessary to make particular design elements possible, depending on land-owners' willingness to cooperate. This dilemma is likely to cause disturbances in the project process through social resistance. Here I argue that the project's goal has large-scale societal and environmental effects, which generally weigh higher than the rights of these land-owners to maintain their lands. However, each case should be assessed individually to understand the exact effects of that specific land expropriation, and to make a decision that can be considered fair.

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A APPENDIX

A.I INTERVIEW SUMMARIES

INTERVIEW WITH KERSTIN RUDLOFF FROM THE MUNICIPALITY OF ELTVILLE AM RHEIN

This is a summary of the conversation with Kerstin Rudloff from the municipality of Eltville am Rhein during a short excursion to the Kiedricher Bach and surroundings:

The conversation starts at the municipal office where some maps of the area are discussed. In 2005 a large-scale land consolidation started to make the vineyards larger and more efficient.

The Taunus mountain range protects Eltville am Rhein from cold northern winds. This mountain range is considered a weather boundary between warm air from the south of the Rhine Valley and cold air from the north. This causes relatively, compared to surrounding regions, many heavy thunderstorms with hail and potentially tornados. This makes Eltville am Rhein extra sensitive to climate change. These storms have already caused problems in the past as basements flooded, which led to a death in a nearby community. In general this area is very dry and is not good in retaining water in the soil. Also vineyards encounter this problem.

The Kiedricher Bach is part of a programme to improve the quality of small streams. The main responsibility for this programme is for the Hessischen Landgesellschaft (HLG). A risk study has been done on the stream which showed the importance of interventions. The European water directive is important for these projects, one reason is their financial support.

The municipality is working on the renaturation of multiple small streams and has plans for retention basins. Another stream in the municipality, the Sulzbach, has already finished a renaturating project in 2008. More recently the renaturation of a 450-meter stretch of the Walluf (another small stream) was finished. A second bed is constructed, following the original (meandering) path of the stream. The riparian zone is planted with flowers, partly exotic, and this is mowed and taken away frequently to maintain this vegetation.

In the vineyards, multiple retention basins are constructed, for some of which vineyards had to disappear. There is a plan to let animals graze here to maintain the land, this helps the functioning of the basins.

In the city there are problems with the water quantity. The Kiedricher Bach flows underground through Eltville am Rhein. The pipe's capacity is too low. Bringing the stream above ground is a impossible task as it is too expensive. Underground capacity extension is also difficult as many houses are located on top of the stream. Therefore, they are trying the retain the water in the landscape before it enters the city.

The municipality uses the process of land consolidation to retrieve lands around the streams to execute their projects. This process takes a lot of time. On many places the city owns just small stretches, and other parts are owned by a large amount of distinct people.

Since the floods in Ahr in the summer of 2021 people are very sensitive to the topic of flash floods. Before that event, they did not realize this was a problem. Nevertheless, people still think the interventions are too expensive, although risk studies are showing the necessity.

One of the final remarks is the fact that much knowledge about land management in relation to water and ecology was lost in the world wars. This has increased the socio-ecological disbalance. The young generation has a renewed interest and understanding of the value of a ecology and the planet.

INTERVIEW WITH URBAN KAUFMANN FROM WINE-GUT KAUFMANN

This is a summary of the conversation with Urban Kaufmann during the visit to his biodynamic vineyard. It is a translation from a complicated conversation in english, dutch, and german:

The soil in his vineyard works as a sponge, it can absorb and deposit water well. When the soil is too wet the grapes could burst. Drought is for this specific vineyard not an issue due to groundwater seepage.

On specific sites they use the moon calander, a common practice in biodynamic cultivation. Applying this to all vineyards is too complicated as it requires much work and other factors like weather conditions are more important to take into account. It is difficult to say if the wines made from sites which follow the moon calander are of better quality just because this practice.

He still uses machines fifty percent of the time. No animals are grazing in his vineyards as there is no space for them and mowing is done at the same time as machines are used for other purposes.

Compost preps are bought as it requires too much time to produce it themselves. Specific compost preparations are used for specific problems that are encountered. For example, yellow leaves is a sign of a iron shortage. Netles are a good ingredient to combat this problem.

The forests of the Taunus mountain range protects the vineyards from cold northern winds. The Rhine reflects sunlight to the site a serves as a warmth basin which results in a temperate climate.

Overall, the biodynamic vineyard looks similar. Often the quantity of grapes is less but the quality is higher.

A.II VINEYARD STREAMS CALCULATION

EXTREME RAINFALL RETENTION CAPACITY

- Rainfall rate: 100 liter per square meter per hour.
- Rainfall rate per second: 100 / 3.600 = 0,02778 liter per square meter.
- Amount of square meters of subbasin: 285.000.
- Amount of water per second: 285.000 x 0,02778 = 7916,67 liter per second = 7,916 m^3 per second
- Assumed maximum speed of riverwater: 7 meters per second.
- Size of river section to estimate river level: 7,916 m^3/s / 7 m/s = 1,13 m^2

Elements that could make the necessary river section bigger are: even higher percipitation, decreased speed due to less steep slopes or objects blocking the water. Also the two streams coinciding with each other is a relevant factor. This happens in the town of Kiedrich and that is an important reason the minimize the water that reaches the town by extending the time before the full field capacity is reached or redirecting water around the town.

The three emergency channels have a capacity of 0,48 m^2. Due to the slope and constant sidewards inflow the speed of water will probably be much lower (~2 m/s). So its discharge would be around 1 m^3/s in that case. That's 1/8 of the total discharge. Enlarging the section of the emergency channels could lead to more significant changes in the discharge at Kiedriech.

- Total subbasin area until potential retention area is 10,19 km^2.
- 0,48 km2 of this is built up area of which the infiltration rate is solely dependent of the sewage system.
- 0,63 km2 of this is pasture, with a much lower infiltration capcity depending on the soil properties.
- 0,45 km2 of this is vineyard, infilitration capacity depending on soil properties and slope.
- 8,63 km2 is forest.

In percentages:
Forest: 84,7%
Urban: 4,7%
Pasture: 6,2%
Vineyard: 4,4%

The average forested land has a infiltration capacity of 335 to 671 mm per hour, however, this can be less or more depending on local factors including forest density and soil properties. A extreme heavy rainstorm has a precipitation rate of about 100mm per hour, which means soil runoff would be unlikely in forested land. The german record is 200 mm in one hour. In case of the worst-case climate scenario, this part of Europe will warm by an extra 4,5°C. Each degree in warming can hold 7% more moisture in the air. This leads to a potential rainfall rate of 271 mm per hour. Which is 271 liter per square meter.

Forest: 8.630.000 m2 x 271 = 2.338.730.000 liter. An estimated 10% (in principle there is no surface run-off in forests but the field capcity is lower than 271mm in large areas, however the soil can temportarily hold more water durig rainfall, but this makes it likely that the interflow results in run-off as well relatively quickly (European Environment Agency, 2015)) of this will be surface run-off which is equal to 233.873.000 liter.

Urban: 480.000 m2 x 271 = 130.080.000 liter. An estimated 70% (a combination of attached single family homes and streets from Values of Runoff Coefficient (C) for Rational Formula (n.d.)) of this will be surface run-off which is equal to 91.056.000 liter.

Pasture: 630.000 m2 x 271 = 170.730.000 liter. An estimated 20% (based on löss soil, more sandy than heavy in the table, but on the high side of sandy pastures because of the slopes (Values of Runoff Coefficient (C) for Rational Formula, n.d.)) of this will be surface run-off which is equal to 34.146.000 liter.

Vineyard: 450.000 m2 x 271 = 121.950.000 liter. An estimated 40% of this will be surface run-off which is equal to 48.780.000 liter (Cerdà et al., 2018).

The total hourly run-off is 407.855.000 liter = 407.855 m3. This would require a resevoir of 3 meters deep and 368 meter long by 368 meter wide. If the stream profile in the city is 2m² and the speed is very high at 7 m/s then it has the capacity to discharge 50.400.000 liter but this amount will probably come from the basin-part south of the potential resevoir. This basin-part is 2.610.000 m2 large x 271 liter = 707.310.000 liter with a run-off coefficient of approximately 50%. Which results in a problematic 353.655.000 liter. Of this 6/7 should be retained.

Total area of subbasin: 187.000 m2.
Forested: 62.000 m2 x 271 liter = 16.802.000 liter x 0,1RC = 1.680.200 liter runoff
Vineyard: 125.000 m2 x 271 liter = 33.875.000 liter x 0,4RC = 13.550.000 liter runoff
Total runoff: 15.230.200 liter

The goal is to retain as much water as possible in the subbasin to reduce the size of the central retention area.

To minimize the impact on the landscape the retention areas are limited in depth. Standing water in dryer periods is also not ideal for the water quality (although proper planting can deal with this, but it will warm up too much) and therefore water flow should be possible then. A minimum impact basin could have a depth of 0,5 meters. 15.230 m3 of retention area is required. With a depth of 0,5 meter this results in an area of 30.460m2. Within the small stream and the vineyards a retention area of maximum 15.000m2 is measured. So maximum 50% of the runoff could be retained. By transforming the vineyards from a convential farming method to biodynamic farming, the runoff could be reduced by 75%, leading to a total runoff of 5.067.700 liter Cerdà & Rodrigo-Comino, 2021). As the average pond depth is kept at 0,5 meters, the total required area would be approximately 10.000 m2. The existing stream has a maximum area of 6.000m2. The biggest existing stream in the vineyards is 1.500m2. Other exisiting streams have an area of 1.800 m2. Then there is a remaining 700m2 (350m3) which could be retained by the paralel vineyard retention areas. The depth of these retention areas is smaller but they have a larger total area so 350m2 should not form a problem.

The stair retention

The first stair consists of 21 steps. Each step has a height difference of approximately 1,4 meters. The total lenght is 118 meters so each step has a lenght of approximately 5,6 meters. The width is approximately 12 meters. So the total area is 1.416 m2. With an average depth of 0,5 meters this results in 708 m3, which is equal to 708.000 liters. The basin of this ladder has a maximum runoff of 2.258.333 liters. So the ladder would be able to retain 1/3 of all the water. If the depth is increased to 1,5 meters, 100% of the surface runoff could be retained by this ladder, but this would have a more significant impact on the landscape and would be less valuable biodiversity wise.

VINEYARD LOSS

The next question is how much vineyard area will be lost due to the paralel rentention areas. These retention areas have a total lenght of approximately 1400 meters and a width of about 5 meters. This is a total area of 7000 m2. The vineyards have an total area of 125.000 m2, but what is effectively vineyard is about 105.000 m2. 7000m2 is a 6,7% loss of vineyards. A reduction of the retention profile might be possible. Some of the retention areas a located next to an existing road where there is already 3 meters leftover space (250m length). There is also one existing stream which could transport water to the water retention in the larger stream (250m lenght).

A.II VINEYARD STREAMS CALCULATION

New calculation:
250m x 2m
900m x 5m
= 5000m2 = 4,7% vineyard reduction. The municaplity can pay a compensation fee to these farmers as they have the benefit via less costs for flood damages.

Vineyards with a run-off coefficient of 0,1 need to infiltrate, in an extreme scenario, 243mm of water. For most vineyards this fits in the current field capacity. For forests and some vineyards the field capacity is significantly lower (140mm - 220mm) and then already present water needs to be substracted. However, during the rainfall itself the soil is capable of holding more water than its field capacity. On top of this the addition of only 1% organic material in the topsoil increases the field capacity with 25mm. Added organic material in the topsoil is part of the biodynamic farming method. For forests it is a bit more complicated. Extra research should discover how this organic layer can be increased, possibly by sustainable and biodiverse forest management.

A.III RIVERINE WATERSCAPES TREES

FLOOD RESISTANT TREE SPECIES

In the floodplains, there are different conditions vegetation should be resistant to. As four zones of flood frequency are introduced, the native and common tree species are judged on their flood resistance. The permanently inundated zone is not suitable for any native or common trees. Sweetwater mangroves are found elsewhere in the world. This means that experts could decide to introduce them to the Rhine Valley ecosystem. For the yearly inundated zone, trees are judged if they can sustain long-term floods. For the ten-yearly inundated zone, trees are judged if they can sustain short-term floods. For the permanently dry zone, other factors then flood resitance are important. The diagram on the right shows an overview of flood resistance per tree species.

Trees (scientific name)	Trees (english name)	Soil type					Soil moisture					Flood resistance		
		Clay	Loess	Loam	Sand	Peat	Wet				Dry	No	Short	Long
Acer campestre	Field Maple	X	X	X	X				X	X			X	
Acer monspessulanum	Montpelier Maple	X	X	X	X				X	X	X	X		
Acer opalus	Italian Maple		X	X	X				X	X		X		
Acer platanoides	Norway Maple	X	X	X	X				X	X			X	
Acer pseudoplatanus	Sycamore	X	X	X	X			X	X	X			X	
Alnus glutinosa	Common Alder	X		X	X		X	X	X					X
Alnus incana	Gray Alder	X		X	X		X	X	X	X	X			X
Betula pendula	Silver Birch			X	X	X				X	X	X		
Betula pubescens	Downy Birch			X	X	X		X	X				X	
Carpinus betelus	Common Hornbeam	X	X	X				X	X	X			X	
Fagus sylvatica	Common Beech			X	X	X			X	X		X		
Fraxinus excelsior	Common Ash	X	X	X				X	X				X	
Malus sylvestris	Wild Apple			X	X				X		X		X	
Populus nigra	Black Poplar	X	X	X	X		X	X	X					X
Populus tremula	Aspen	X	X	X	X	X	X	X	X	X	X			X
Prunus avium	Wild Cherry	X	X	X	X			X	X			X		
Prunus padus	Bird Cherry	X	X	X	X		X	X	X					X
Pyrus pyraster	Wild Pear			X	X			X	X	X			X	
Quercus petraea	Durmast Oak			X	X				X	X	X	X		
Quercus pubescens	Downy Oak			X	X			X	X			X		
Quercus robur	Common Oak	X	X	X	X			X	X	X	X		X	
Salix spec.	Willow	X	X	X	X	X	X	X						X
Sorbus aria	Whitebeam		X	X	X				X	X		X		
Sorbus aucuparia	Mountain Ash		X	X	X	X		X	X	X	X		X	
Sorbus domestica	Service Tree		X	X	X	X			X	X	X	X		
Sorbus torminalis	Wild Service Tree	X	X	X	X	X		X	X	X		X		
Tilia cordata	Small-leaved Lime	X	X	X	X			X	X				X	
Tilia platyphyllos	Large-leaved Lime	X	X	X	X	X		X	X	X		X		
Ulmus glabra	Scotch Elm	X	X	X	X		X	X	X					X
Ulmus laevis	European White Elm	X	X	X	X			X	X					X
Ulmus minor	Field Elm	X	X	X	X		X	X	X					X

Illustration A1 | Native broadleaved tree species in Germany
Source: FSC® Deutschland (2018), Roeleveld et al. (2014), Van den Berk Boomkwekerijen (n.d.) | adapted by author

Trees (scientific name)	Trees (english name)	Soil type					Soil moisture					Flood resistance		
		Clay	Loess	Loam	Sand	Peat	Wet				Dry	No	Short	Long
Abies alba	European Silver Fir	X	X	X	X				X	X		X		
Larix decidua	European Larch	X	X	X	X			X	X	X		X		
Picea abies	Norway Spruce			X	X	X		X	X	X		X		
Pinus cembra	Arolla Pine	X	X	X	X	X			X	X		X		
Pinus mugo x rotundata	Mountain Pine	X	X	X	X	X			X	X		X		
Pinus sylvestris	Scots Pine	X	X	X	X	X			X	X	X		X	
Taxus baccata	Common Yew	X	X	X	X				X	X		X		

Illustration A2 | Native coniferous tree species in Germany
Source: FSC® Deutschland (2018), Van den Berk Boomkwekerijen (n.d.) | adapted by author

Trees (scientific name)	Trees (english name)	Soil type					Soil moisture					Flood resistance		
		Clay	Loess	Loam	Sand	Peat	Wet				Dry	No	Short	Long
Aesculus hippocastanum	European Silver Fir	X	X	X	X	X		X	X	X			X	
Pseudotsuga menziesii	Douglas Fir	X	X	X	X	X			X	X	X	X		

Illustration A3 | Common exotic tree species in Germany
Source: Deutsche Wildtier Stiftung (n.d.), Van den Berk Boomkwekerijen (n.d.) | adapted by author

RESIDENTS OF THE FLOODPLAINS
Interests:
- Floodplains to remain dry

Possibilities:
- Relocation to floating neighbourhood or outside the floodplains
- Floodplain recreation

AGRICULTURAL BUSINESSES IN THE FLOODPLAINS
Interests:
- Prevent complete inundation
- Prevent droughts

Possibilities:
- Transformation to aquatic agriculture or agroforestry

OTHER BUSINESSES IN THE FLOODPLAINS
Interests:
- Floodplains to remain dry

Possibilities:
- Relocation outside the floodplains

RESIDENTS OF THE FLOODPLAIN SURROUNDINGS
Interests:
- Floodplains to be inundated
- Dry agriculture transformed to agroforestry

Possibilities:
- Relocation to floating neighbourhood
- Floodplain recreation

AGRICULTURAL BUSINESSES IN THE FLOODPLAIN SURROUNDINGS
Interests:
- Floodplains to be inundated
- Dry agriculture to remain

Possibilities:
- Relocation and transformation to aquatic agriculture
- Transformation to agroforestry

OTHER BUSINESSES IN THE FLOODPLAIN SURROUNDINGS
Interests:
- Floodplains to be inundated

Possibilities:
- Explore aquatic business oppurtunities

UPSTREAM GOVERNMENTAL ORGANISATIONS
Interests:
- Floodplains to be inundated
- Transformation to aquatic agriculture and agroforestry

Possibilities:
- Increase value of the floodplains (ecological, economical, recreational)

DOWNSTREAM COMMUNITIES
Interests:
- Floodplains to be inundated

Possibilities:
- Trade-off system to support and sustain the project

FUTURE GENERATIONS
Interests:
- Floodplains to be inundated

Possibilities:
- Aquatic recreation and business opportunities

NATURE AND WILDLIFE
Interests:
- Floodplains to be inundated
- Floodplains to remain dry with nature development

Possibilities:
- Dry nature development outside the floodplains
- Aquatic (partly) nature development in the floodplains

INTERNATIONAL COMMISSION FOR THE PROTECTION OF THE RHINE
Interests:
- Floodplains to be inundated

Possibilities:
- Increasing water quality through aquatic plants and nature-inclusive agricultural practices
- Increasing water safety throughout the Rhine basin

SYMBIOTIC WATERSCAPES