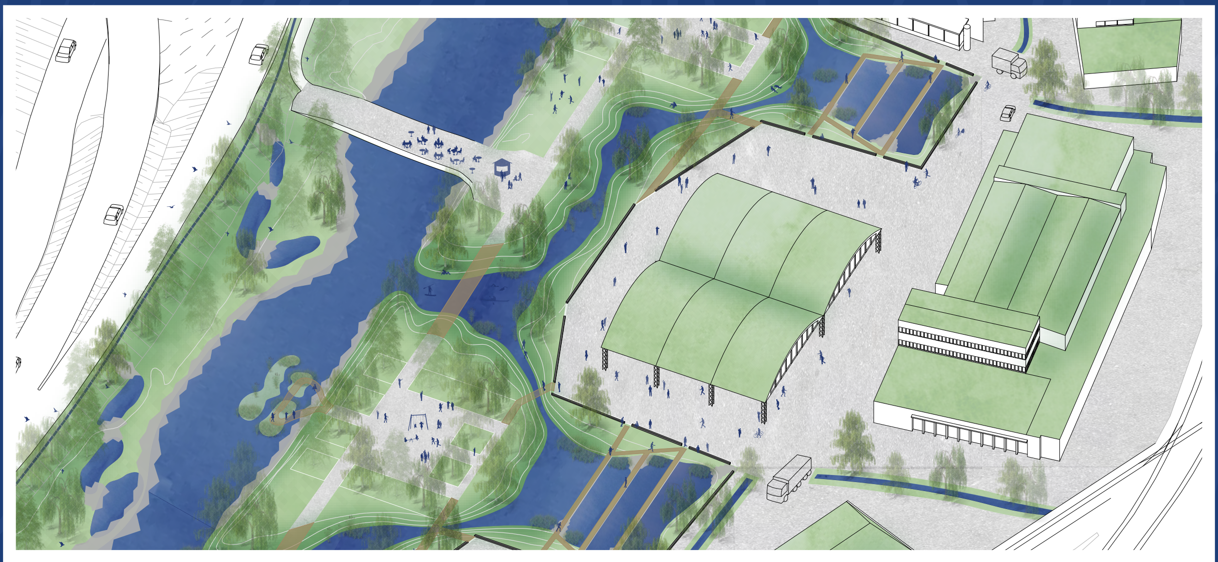
REINVENTING WATERSCAPES



Transforming (r)urban landscapes to improve water quality and access to water with ecosystem services

Master's thesis 2025
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Chalmers school of Architecture
Department of architecture & Civil Engineering

Examiner: Nils Björling
Supervisor: Louise Didriksson

Reinventing Waterscapes

Transforming (r)urban landscapes to improve water quality and access to water by combining regulating and cultural ecosystem services

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Architecture and planning beyond sustainability

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Examiner: Nils Björling
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Thank you,

Louise, Nils, and fellow students for helping me along the winding path that is a thesis, and for all the interesting discussions and feedback on my work.

To my family and friends, for supporting me when I've been stressed and doubted my process.

And finally, to everyone who has listened, and hopefully will continue to listen, when I ramble on about water and spatial planning.

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ABSTRACT

Can ecosystem services and design strategies for community engagement be used to mitigate human impact on aquatic environments? In this thesis the main catchment area of the river Göta älv in Sweden and specifically the sub-catchment area between lake Vänern and the sea has been investigated as a case study to understand how spatial development in key locations can be used to reduce harmful impact on freshwater bodies. Investigations have also been done on how spatial transformation for improving the chemical and ecological status of freshwater can also contribute to social welfare in urban environments.

The investigations have been done on different scales. Mapping on a regional scale defined key locations to intervene in the sub-catchment area, but also what problems relates to spatial transformation and what has to be solved within other fields. One of these locations where then selected as an example of how spatial transformation on a smaller scale can look like to improve water status. The transformation is also a critical reflection of how urban expansion have been relating to water historically. To support the design of the key location different principles for spatial water purification have been developed.

All stages of the project were supported by evidence-based design with different methods such as literature reviews, interviews, GIS analysis and generative design. Theories around social ecological urbanism and participatory design was used to support the project. Ecosystem services have been used to frame the project and understand the relation between ecological and social aspects of spatial planning around water.

The most important outcome of the theses has been to distinguish how architects and planners can approach similar projects that intends to support better water quality. Mainly in the design phase it has also been important to clarify how spatial planning for healthy status of freshwater bodies can be beneficial even for people and where synergies occur.

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BACKGROUND

BACKGROUND & CONTEXT

Land and sea use change and direct exploitation such as the expansion of farmlands, urban areas and infrastructure account for over 50% of global impact on freshwater since 1970. This has led to a loss of 84% of freshwater species. As usage of fertilizers on fields increase run-off water also brings nutrients out into freshwater and ultimately the sea producing more than 400 zones globally with reduced levels of oxygen leading to decrease in biodiversity, called dead zones (IPBES, 2019).

Runoff water caused by precipitation is also a problem in most urban environments. Cities generally consist of lots of hard surfaces, such as concrete and asphalt, which are the main causes for this phenomenon. When water is pouring down on these surfaces it is not infiltrated in the ground. Instead, all the toxins produced within the city such as plastic waste, toxins from roads and pesticides are flushed into nearby aquatic environments. Generally urban runoff is not treated in any way often leading to acute toxicity to aquatic environments. In the long run this does not only affect ecosystems but also the seafood that we consume and recreational possibilities etc. (Lapointe et al, 2022).

The thesis focuses on the river Göta älv. Historically there have been a lot of industries along the river causing toxification with for example quicksilver and chromium. However, since the 70s new laws have been implemented to reduce these substances and industries are forced to clean their runoff water meaning environmental qualities in this aspect has become much better. Today the main problems instead are runoff water for urban environments and widening of the sewage system during heavy rains flushing micro-organisms and toxic particles into the river, but also runoff water from agriculture causing high levels of nitrogen and phosphorus (Göta älvs vattenvårdsförbund, 2015).

Göta älv, belongs to the largest main catchment area in Sweden occupying 1/10 of the country but also parts of Norway. It contains the third biggest lake in Europe, Vänern. The circulation of water in Vänern takes 8-9 years and many toxins and nutrients sink to the bottom or are consumed by plants in the lake (Havsmiljöinstitutet, 2019). This is why the main focus for this project is what happens between Vänern and the sea. The main catchment area and sub-chatchment focus area can be seen in figure 1.

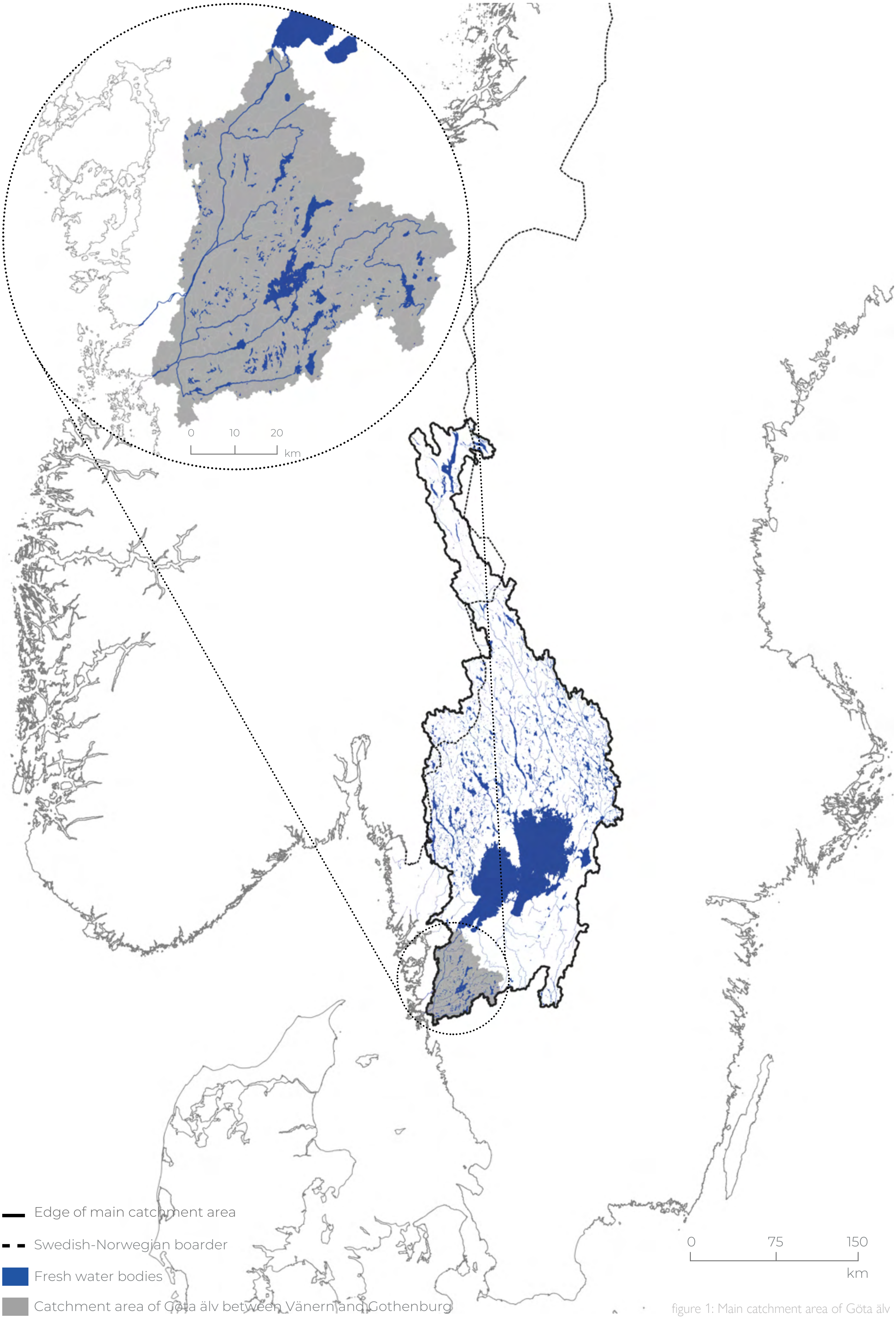


figure 1: Main catchment area of Göta älv

AIM AND SCOPE

The overall aim of the thesis is to investigate how urban development can improve the status of water bodies by understanding, valuing, and implementing ecosystem services. The specific context of Göta Älv will be investigated. This is done both on a large regional scale, an urban scale and a smaller site-specific scale based on theories around social ecological urbanism.

On a regional scale the main catchment area of Göta älv and especially the part after Vänern is investigated to understand in what ways spatial transformation can support better water quality. The identified measures are then evaluated based on how well they are linked to urban development. Measures that can be supported by urban development are investigated further to help identify a key location as an example of spatial transformation for better water quality.

The key location and problems found in the regional scale is developed on a more detailed scale to understand how spatial development can contribute to mitigate identified environmental problems. On this scale a gradual implementation of ecosystem services is investigated to understand how participatory design through placemaking can generate new habitats to improve water status.

The solutions on the smaller scale in the key locations are finally investigated in relation to how they connect to the nearby urban environment. In this stage particular focus is put on how these spaces can also contribute to a sustainable social transformation within an urban environment.

RESEARCH QUESTION

Main research question

How can regulating and cultural ecosystem services guide rurban development to improve the chemical and ecological status of water bodies in a defined sub catchment area of Göta älv?

Sub research questions

What measures for better water quality can be applied in a selected urban key location and what needs to be done in other parts of the region?

How can regulating ecosystem services be combined with cultural ecosystem services and in that way create accessible and multifunctional recreational spaces close to water in cities?

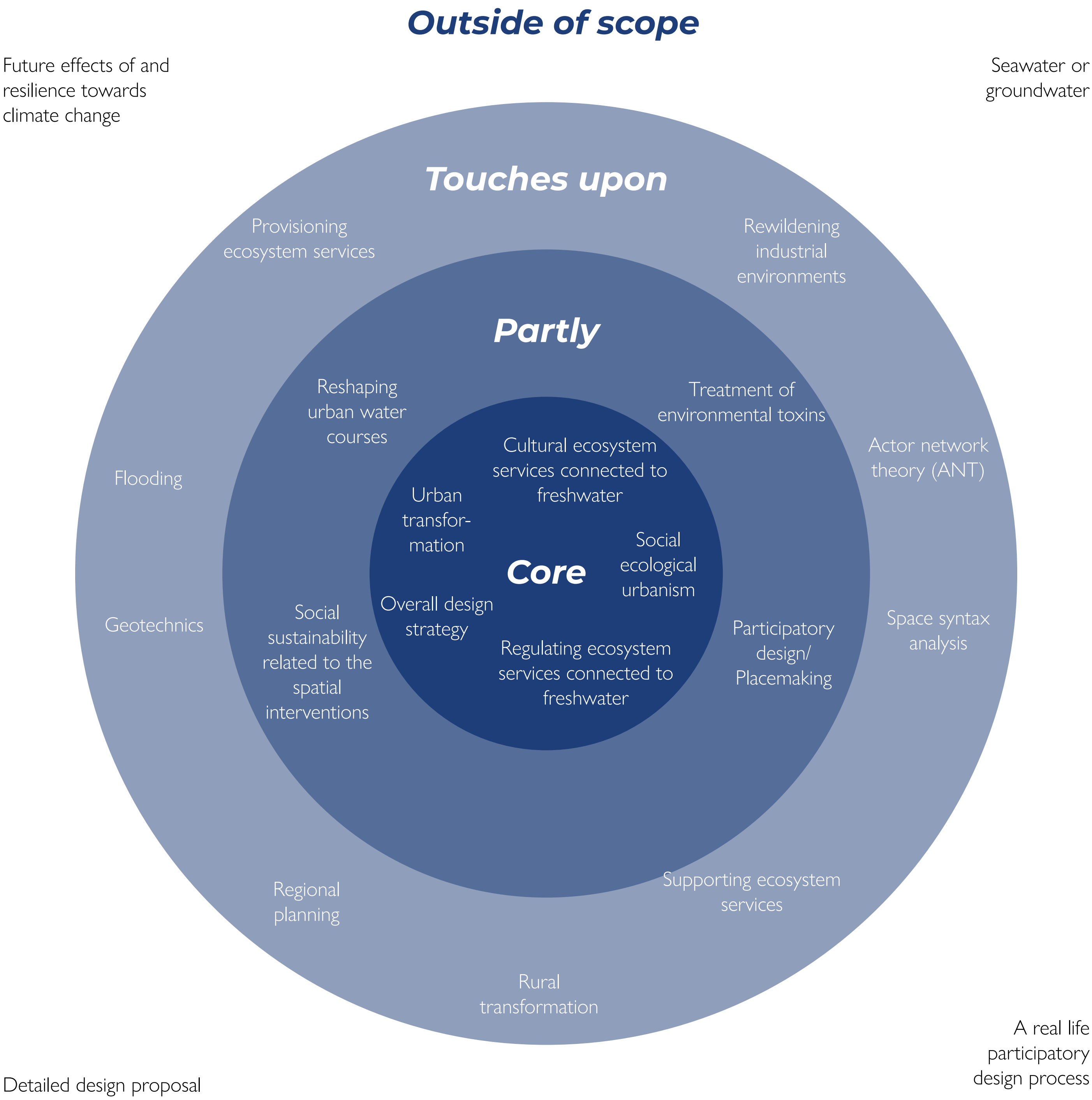
How can an urban environment and former industrial area transform into a natural environment with regulating and cultural ecosystem services?

FRAMEWORK

DELIMITATIONS

The diagram on the following page shows subjects that have come up throughout the process that could have a connection to the project. The aim is to establish a hierarchy and give an understanding of what is the most important aspects of the project.

In general, the project is on a planning level at different scales trying to understand the relation between improved water status and spatial transformation by investigating ecosystem services. The result is an overall design strategy that easily could be adapted to other locations rather than a specific fully developed design proposal


Outside of scope
Future effects of and resilience towards climate change
Seawater or groundwater
Touches upon
Provisioning ecosystem services
Rewildening industrial environments
Partly
Reshaping urban water courses
Treatment of environmental toxins
Cultural ecosystem services connected to freshwater
Flooding
Actor network theory (ANT)
Urban transfor-mation
Social ecological urbanism
Core
Overall design strategy
Geotechnics
Social sustainability related to the spatial interventions
Regulating ecosystem services connected to freshwater
Participatory design/ Placemaking
Space syntax analysis
Regional planning
Supporting ecosystem services
Rural transformation
A real life participatory design process
Detailed design proposal

METHODS & TOOLS

The project is based on a mix between research and design where research is mostly used to define problems and framing the project while the design is used to creatively combine research, references and design strategies into a site-specific project. The pragmatic worldview is emphasized using mixed methods to reach there.

As described in the aim the project touches upon different scales, each of them exploring specific things. This allows different methods to be used in different phases of the project. In general, all of the stages are in some degree influenced by evidence based design and exploratory research which grounds the design choices in different aspects of research or analysis. Experts in the specific field have been interviewed as a complement to research.

On the regional scale q-gis analysis supported by the right literature help to find key locations to intervene. The analysis in q-gis is mostly carried out through looking at existing data and combining it to find overlaps. Information and geodata about water status and possible measures for better water quality is mostly gathered from WISS (Water Information System Sweden).

For the development of the selected key location, Marieholm and Partihallarna in Gothenburg, ecosystem service case studies are used to understand how the outcome of research on the regional scale can be translated into spatial transformation. Based on this together with findings in the regional mapping design principles for better water quality is developed. The design principles are then used to develop a site specific proposal of how urban transformation can contribute to better water quality

When returning to the urban and regional scale, space syntax analysis in q-gis is used to understand how the development of the key location increase accessibility to green areas and in that way cultural ecosystem services. The regulating ecosystem services are analysed based on how well the implementation of the developed design strategies works.

To communicate and reflect on the outcome, different types of illustrations will be important throughout the project with emphasis at later stages.

INTERVIEWS

Martin Knape
February 11, 2025 (digital interview)
Strategic environmental planner at the City of Gothenburg. involved in the work on blue-green corridors and currently working on how Mölnndalsån can be improved through better riparian zones.

Per Torstensson
March 31, 2025 (phone interview)
Limnologist at the Biosphere Office and the naturum (visitor center in nature) Vattenriket, Kristianstad.

William Hogland
April 1, 2025 (digital interview)
Professor in environmental- and ecotechnology conducting research on water and material flows in urban environments, phytoremediation, and landfilling- and leachate treatment.

Mats Karlsson
April 10, 2025 (in-person interview)
Associate Professor at Chalmers University of Technology, Department of Geology and Geotechnics.

Maria Greger
April 24, 2025 (digital interview)
Associate Professor in Plant Physiology at Stockholm University. Her research includes phytoremediation in soil and water, especially involving metals, metalloids, and the influence of silicon on plant metal uptake.

THEORETICAL & METHODOLOGICAL FRAMEWORK

Social ecological urbanism (SEU)

Social ecological urbanism proposes a shift in current worldviews and planning principles. Instead of thinking about humanity and nature as separate entities it emphasizes synergies between the built environment and nature. This should be done by understand ecosystems as an important piece in urban planning processes. Not only by maintaining and keeping existing ecosystems but also by altering them and adding new ones. In that way the objective is that cities could play an important role in managing habitats to support biodiversity but also as places for people contributing to social wellbeing (Barthel et al., 2013).

Social ecological urbanism also acknowledges that climate change is a fact. By understanding the relation between urban development and ecosystems the idea is that cities can become more resilient to future effects of climate change (Barthel et al., 2013).

When engaging in social-ecological projects it is important to work interdisciplinary. Architects need to develop ideas for urban development based on ecosystem services in close collaboration with experts in other fields (ex ecologists). To develop means for interdisciplinary collaborations it is important to use a shared written and/or visual language where scientific knowledge within one field can be transferred to and communicated within other fields. (Barthel et al., 2013).

Social ecological urbanism in the project

The thesis is based on ecosystem services which is presented more in depth later in the theory chapter. Since the aim is to investigate urban environments more in depth this is the most evident link to social ecological urbanism. The intention is that the specific focus on ecosystem services in and around water will showcase new ideas of what social ecological urbanism could look like in practice and how it can be used for investigating a very specific part of urban planning.

By using interviews as a method, the aim is to start developing an interdisciplinary collaboration where the ideas from this architectural project can be combined with knowledge from experts in other fields. Since this project must be delimited it will not be possible to engage fully in the kind of interdisciplinary collaborations that are needed in a real social ecological project. However, the idea is to showcase the potential if similar projects would be taken further.

Participatory design

Participatory design and especially co-production intends to bring people such as professionals and users closer by establishing new networks and design strategies. Allowing different stakeholders to contribute to development based on their own experience and objectives. (Lee et al., 2024)

To achieve this, it is important to understand existing flows which in turn can reframe the project and affect the outcome. (Brass et al., 2011). Seven steps that can help co-production is to establish which actors could be part of the project, what the reason for co-production is, what the different actors can contribute with, in which phases of the project co-production occurs, in what way co-production is implemented in the project and how the context relate and enhance the co-production. (Lee et al., 2024)

Participatory design in the project

Participatory processes will be left on a more theoretical and strategic level in the thesis. This means real life participatory elements such as workshops and dialogues will not be part of current work. However, the outcome of the design will support the use of co-production if the project would be taken further by investigating possibilities for placemaking.

Placemaking

Placemaking is not by itself considered as an architectural theory but springs from theories developed by Jane Jacobs and William H. Whyte in the 60s. They advocated for a shift in urban planning where people and the function of a place should be prioritized over connectivity and transportation that at the time was the dominating urban transformation. (Ungvarsky, 2025)

Placemaking can be divided into the four categories, standard, strategic, creative, and tactical. The most relevant strategy in this project is the strategic which not only intends to create one or several specific spaces for people but also a long-term strategy for one area where interventions in specific places have positive effects for improving the area in general in the long run. (Ungvarsky, 2025)

Placemaking will be used as a tool to guide the design part of the project in a way that could support participatory processes if the project was realized. It will showcase how small interventions in a specific site can increase the connection between people and water, raising awareness about questions around water management. In that way the intention is to establish strong communities that can affect planning processes on a strategic level to improve the status of waterbodies.

Ecosystem services

Ecosystem services can be defined in different ways but are often used to describe the function and importance of ecosystems for people. The Swedish environmental protection agency (Naturvårdsverket) defines ecosystem service as follows. (Naturvårdsverket, 2024).

"Ecosystem services are all products and services that the ecosystem gives humanity and that contributes to our welfare and quality of life" (Naturvårdsverket, 2024, para. 3, [own translation]).

Although definitions around ecosystem services have gained much attention recent years it is not a new phenomenon. Through history communities have tried to define the benefit ecosystems can have on humanity. It has not been uncommon that the environment has had religious meaning. During the past decades many attempts of classifying ecosystems have been carried out. Many of them centres around the physical components of the ecosystem, the function of these components and how they benefit people. (Danley & Widmark, 2016)

According to the most established classification of ecosystem services, Millenium ecosystem assessment, ecosystem services can be divided into four categories based on the function they give humanity: supporting, provisioning, regulating and cultural (Naturvårdsverket, 2017).

Supporting ecosystem services

Supporting ecosystem services provide indirect benefits but are fundamental for all other categories and are in one way or another included in all the other (Naturvårdsverket, 2024). It can for example include provisioning of spaces for different species and the regulating capacities that different ecosystems have (Naturvårdsverket, 2017).

Provisioning ecosystem services

Provisioning ecosystem services are the ones that provide humanity with raw products for production (Naturvårdsverket, 2024). It can for example be the ability of healthy ecosystems to produce food and bioenergy but also clean water for consumption (Naturvårdsverket, 2017).

Regulating ecosystem services

Regulating ecosystem services are the ones that help to control our living environment and provide humanity with functioning and healthy spaces (Naturvårdsverket, 2024). The ability of greenery to clean air and water but also to protect from extreme weather such as storms and heatwaves are examples of this category (Naturvårdsverket, 2017).

Cultural ecosystem services

Cultural ecosystem services are the once that create spaces for recreation and experiences for people (Naturvårdsverket, 2024). These spaces can lead to better possibilities for physical activity and recuperation but are also supposed to educate and create a local cultural identity (Naturvårdsverket, 2017).

Spatial relations of ecosystem services

To understand the relation between where the ecosystem service is produced and where the benefits of it is most prominent the term ecosystem service flows is often used. Ecosystem service flows are divided into six categories based on their geographic relation. These are globally location-dependent, locally location-depended, directed flows, on site, detached and related to movement of the user.

- Globally location-dependent ecosystem services produce benefits for people wherever they are produced as for example carbon capture. (Naturvårdsverket, 2017).

- Locally location-dependent ecosystem services need proximity to where the benefit is expected to be noticeable but not a specific site. Examples of this is pollination and temperature control. (Naturvårdsverket, 2017).

- Directed flow ecosystem services lead to benefits in a certain direction, for example upstream or downstream. (Naturvårdsverket, 2017).

- On site ecosystem services provide benefits on site and could for example be household food production or shading. (Naturvårdsverket, 2017).

- Detached ecosystem services could be beneficial in a different site by transportation and are therefore not dependent on a specific site. This also includes food production but on a more commercial scale. (Naturvårdsverket, 2017).

- Ecosystem services related to movement of the user is mostly connected to the flow of people to and from a site where an ecosystem service is produced and mostly refer to cultural ecosystem services (Naturvårdsverket, 2017).

Ecosystem services in the project

The two categories of ecosystem services that will be developed most in the project are the regulating and cultural since the aim is to develop new methods of how urban planning can create multifunctional green spaces that support water status and biodiversity. However, when working with these, especially the regulating services, long term effect could support the provisioning and supporting services as well. Interventions in one site is probably not enough but if many similar projects were implemented in the regional context the long-term effect would be better water quality and habitats for animals. That could both secure access to fresh water (provisioning) but also a more resilient and stable overall ecosystem in the future (supporting)

The main ecosystem service flows that will be explored in the project are locally location-dependent, directed flows, related to movement of the user and on site flows. However, the project will probably be beneficial for the other flows as well. Directed flow services mostly related to how the ecology in the water of the specific selected site can have an impact further down-/upstream in the catchment area. Locally location-dependent services can both be used to investigate how the implementation can support biodiversity but also how they affect the micro-climate and well-being of people in the local context. By analysing accessibility to the specific site for the ecosystem services flows related to the movement of people will be understood. Lastly the spaces created in the design proposal will for example generate recreational spaces and shading providing the area with on site flow ecosystem services.

Actor network theory (ANT)

To get a theoretical understanding of how ecosystems relate to interdisciplinary and participatory design processes and in that way also to social ecological urbanism actor network theory (ANT) can be helpful. ANT originates from the 80s and social constructionist perspectives which put emphasis on that people and social processes shape society. However, when social processes started to be used interdisciplinary within many fields process evolved to include not only human elements but also non-human elements. This was the starting point of ANT which argues that societal development is based on complex networks of both human and non-human actors. (Michael, 2017))

Theoretical and methodlogical relations in the project

ANT can be used in the project to combine all theory into a theoretical framework. Ecosystem services exists naturally but if this architectural project would be realized different human actors have to cooperate and understand non-human actors and natural processes. In this way a complex network of relations and power dynamics appear. The diagram on the following page (figure 2) tries to visualize how all the theories could come together to start establishing this network. Social ecological urbanism mostly relates to the ecosystem services while participatory design relates to the actors. The actors are also crucial in making the project interdisciplinary. The diagram should not be seen as a finalized product, rather as a document that could be extended to constantly elaborate the relations between ecosystem services and actors if the project would be realized.

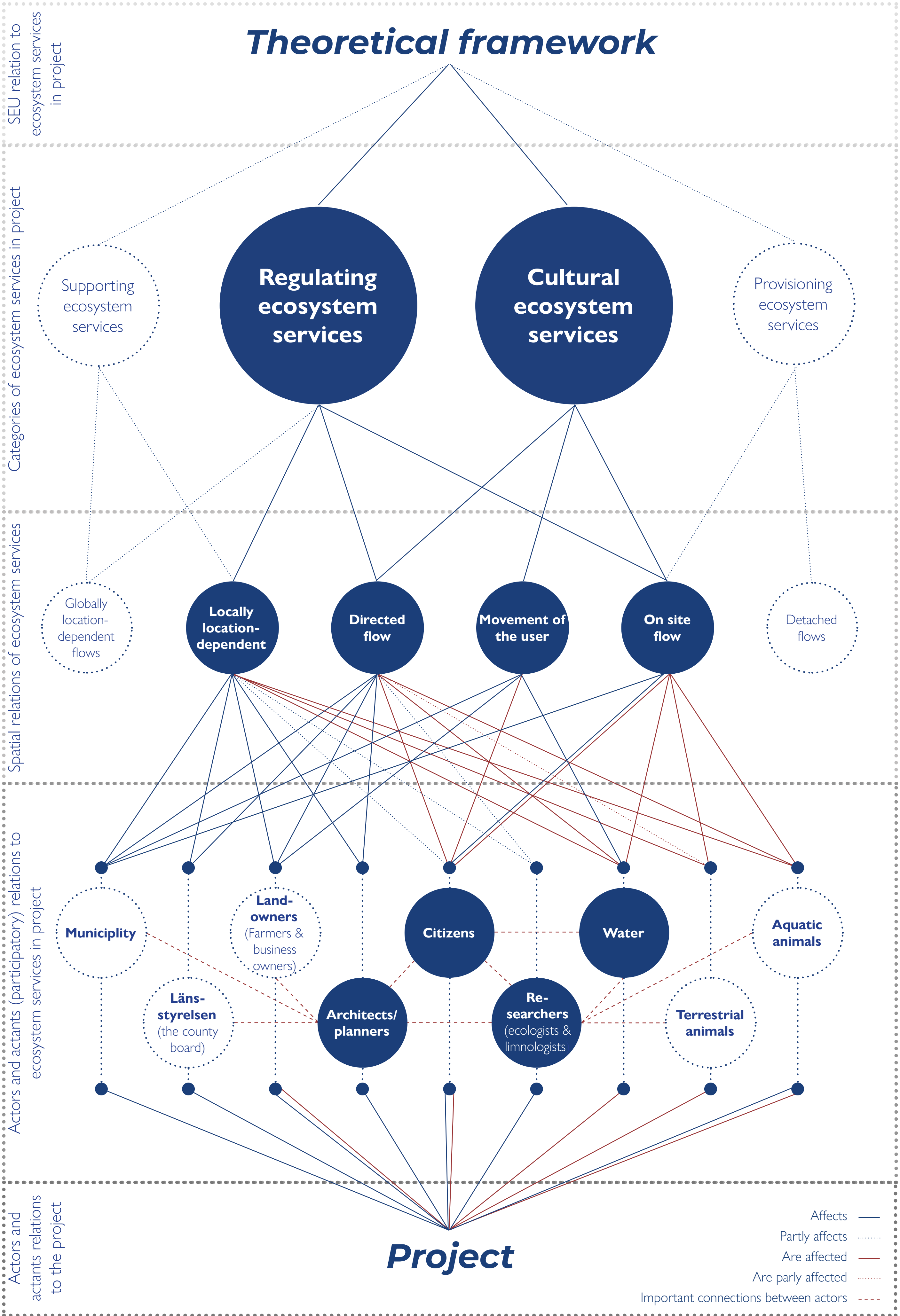


figure 2: Diagram of relations between theories used in project and the project

REGIONAL MAPPING

WATER STATUS & REGIONAL MEASURES

To get an understanding of the current situation of water bodies in the region but also to find key locations to interview spatially the defined sub-catchment area has been studied through maps provided by WISS (Water Information System Sweden) (Länsstyrelsernas WebbGIS, 2024).

Chemical status

In *figure 3* chemical and ecological status (and potential) is visible. The chemical status refers to specific threshold values and substances that cannot be exceeded. The status for ground water and surface water is defined in different ways. This thesis only investigates surface water, where threshold values and substances (around 45) are set on a European union level.

In Sweden WISS is responsible for the measuring and classification. For watercourses that do not reach good status measures need to be implemented. This is why *figure 3* also shows when good status should be achieved.

Quicksilver and Polybrominated diphenyl ethers (PBDEs) end up in watercourses because of precipitation and are excepted from the visualisation since they exceed levels in every water course in Sweden. (Länsstyrelserna, n.d.-a)

Ecological status and potential

The ecological status is a measurement of the status for animals and plants in watercourses and is affected both by physical changes but also substances such as environmental toxins. Watercourses are classified high, good, or moderate based on these measurements. Watercourses that have been heavily modified is instead classified based on there potential. The potential is divided in the same classes but the ecology in a watercourse that is classified by potential does not need to reach as high ecological qualities as the once categorized with status. (Länsstyrelserna, n.d.-b). In the sub-catchment area of Göta Älv it is only the river itself that is classified with ecological potential as seen in *figure 3*.

Measures for better water quality

Based on these classifications WISS has then come up with possible measures for each waterbody in the sub-catchment area. These are indicating more in detail what must be done to reach both a good chemical and ecological status (and potential) in specific locations (Länsstyrelsernas WebbGIS, 2024).

On the following spreads most of the measures proposed for the area are briefly presented to get an understanding which of them relates most to spatial transformation. Even though the thesis focuses on urban areas measures for rural areas are also presented to get a full understanding of what measures are needed on a regional scale.

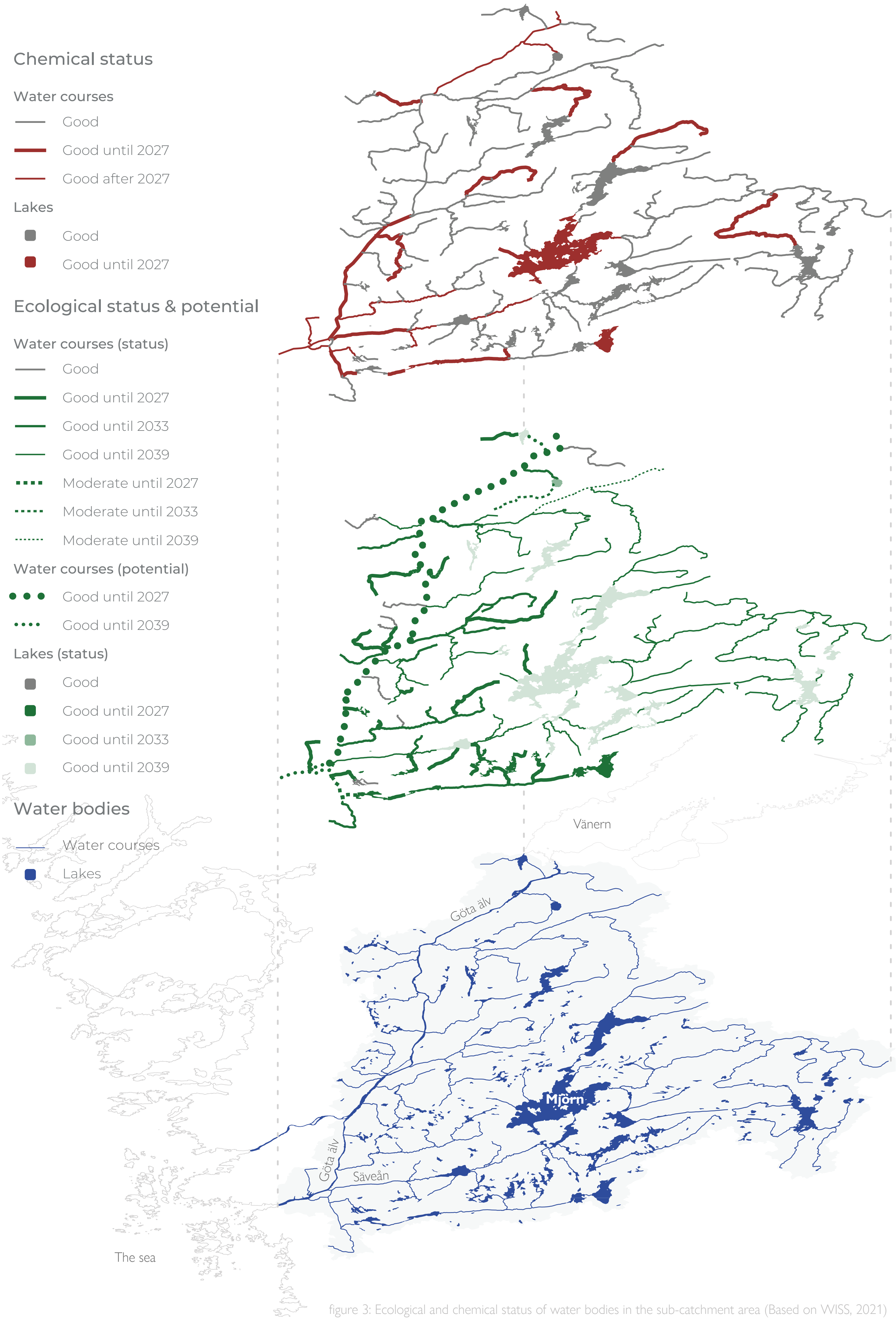
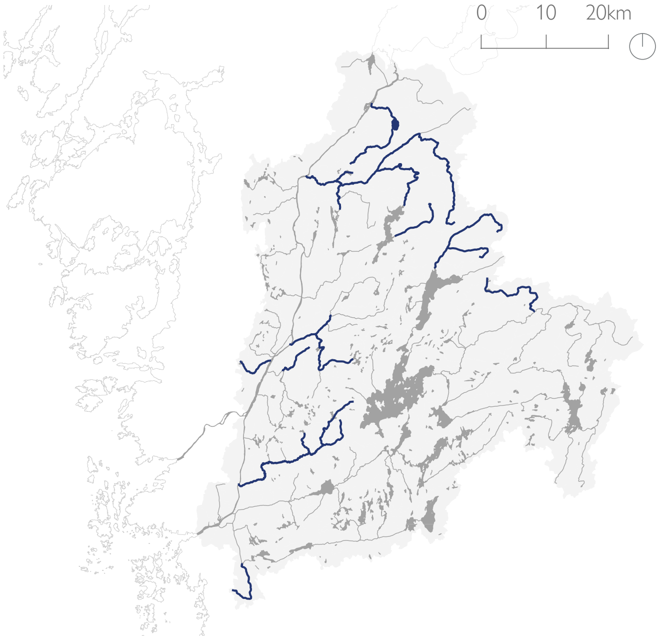


figure 3: Ecological and chemical status of water bodies in the sub-catchment area (Based on VISS, 2021)

Wetland for better water quality

To gain more buildable and agricultural land many wetlands have been lost. However, since they support biodiversity, regulate water flow, keep water in the landscape, and can clean water from nitrogen, phosphorus, pesticides, and other environmental toxins they are crucial for good aquatic environments. (Naturvårdsverket & fiskeriverket 2008) To reach its full potential however, they need to be quite spacious. (Petersson et al, 2021) Therefore they are mostly considered in rural locations as supported by the proposed measures seen in figure 4. The floodplain, the area next to a watercourse that temporarily gets flooded, can also perform similar qualities in a smaller scale. (Naturvårdsverket & fiskeriverket 2008). Because of the many benefits of wetlands, the thesis will investigate how qualities of wetlands can be allowed to take place in urban environments.

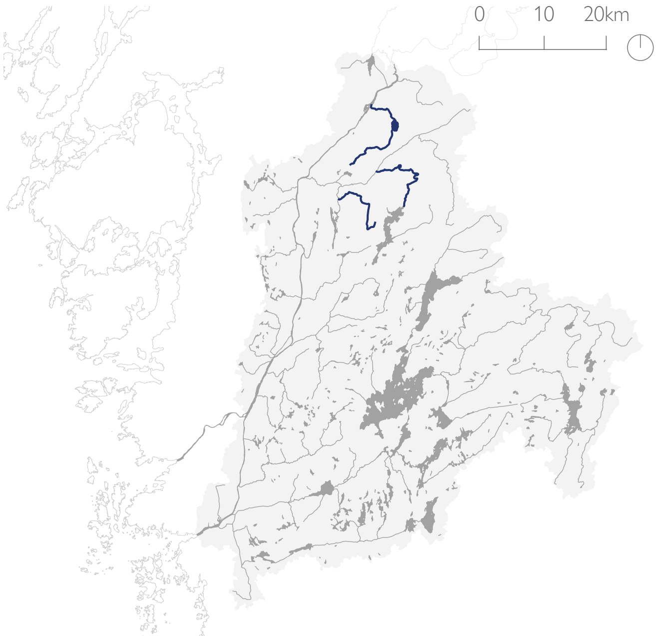


Proposed measures - Lakes
Proposed measures - Water courses

figure 4: Proposed sites: Wetland for better water quality. (Based on WISS, 2021)

Structure liming

Structure liming is a method where calcium rich materials are mixed into soil on farmlands to bind phosphorus in the ground. Except for decreasing the outlet of phosphorus into nearby water it also increases the stability of the ground and enable roots to grow easier resulting in better harvest (Jordbruksverket, 2023). Even though this method is better in some places, in particular fields with clay-rich soil, it does not require spatial transformation and will not be develop further in the thesis.



Structure liming - Lakes
Structure liming - Water courses

figure 6: Proposed sites: Structure liming (Based on WISS, 2021)

Protection zone on agricultural land

Protection zones on agricultural land is supposed to decrease surface runoff, erosion and leakage of particles and nutrients from agricultural land by for example leaving parts of fields untouched to reduce risk of erosion or adding plants filtering runoff water. By looking at already existing maps provided by the Swedish board of agriculture (Jordbruksverket, 2025) farmers can identify areas on their fields where a protection zone could be introduced. Farmers can then receive financial aid from the government to do required implementations (Jordbruksverket, 2025). This measure is very site specific for rural environments and clear methods to deal with it already exists. That means it will not be a key measure in the thesis even though similar methods could be used if the possibility occurs.

Protection zone - Lakes
Protection zone - Water courses
Locally adapted protection zone - Lakes
Locally adapted protection zone - Water courses

figure 5: Proposed sites: Protection zones on agricultural land (Based on WISS, 2021)

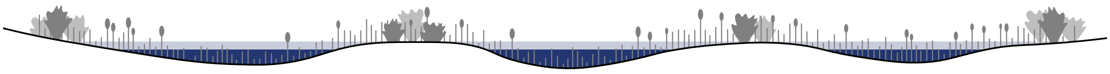


figure 7: Wetland

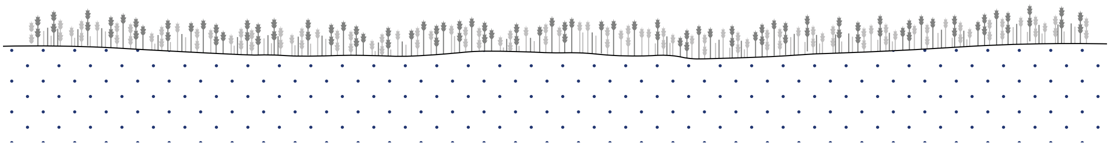


figure 8: Agricultural field with structure liming

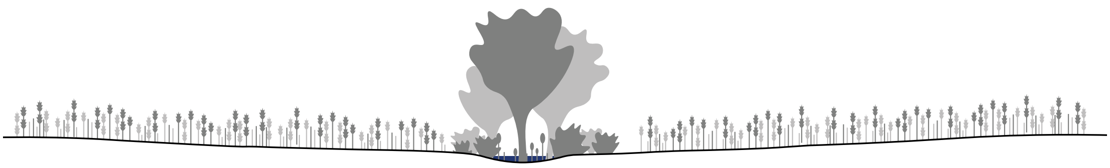


figure 9: Agricultural field with a protection zone

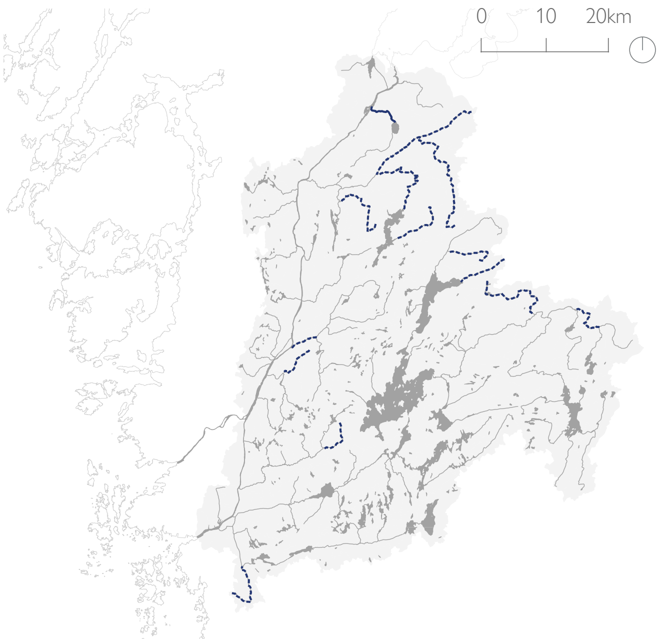


figure 10: Proposed sites: Riparian zones in agricultural environments (Based on WISS, 2021)

Riparian zones in agricultural environments

Riparian zones are important for the ecological status and biodiversity in and around water bodies. Next to agriculture it is divided in two categories, locally adapted, and ecologically functioning. The locally adapted zone is a compromise with agriculture that does not occupy as much valuable agricultural land. Even though locally adapted zones may not have an impact on the classification it leads to some infiltration of nutrients and toxins and can work as a bridge for animals traveling between water and land. (VISS, aug 2021) An ecologically functioning riparian zone however should be at least 15 meters wide on both sides with at least 10 meters of untouched nature. This leads to shadowing, filtration of nutrients and fallout etc. which both can change the ecological classification of the water body and increase biodiversity (VISS, 2016). Riparian zones will be investigated further in urban environments.

— Ecologically functioning riparian zones agriculture - Water courses
---- Locally adapted riparian zones, agriculture - Water courses

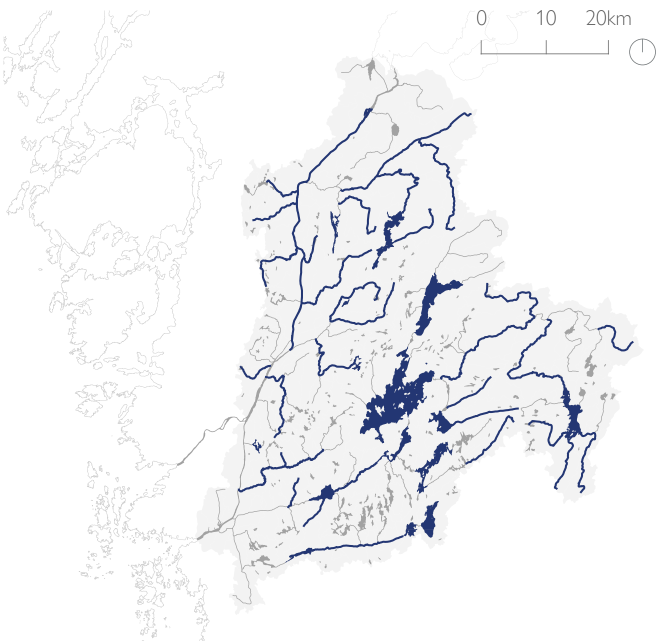


figure 11: Proposed sites: Measures for reduced impact of forestry (Based on WISS, 2021)

Measures for reduced impact of forestry

Measures to reduce impact of forestry aims at reducing the amount of nutrients that end up in nearby water but also at casting shade on waters keeping a more stable temperature, especially when a forest is clear cut. (skogsstyrelsen, 2014) To do this a riparian zone should be introduced by either leaving trees closes to the water or planting new greenery with better qualities for a more functional riparian zone in the future. (VISS, oct 2021). Forestry will not be investigated further but in what way shading can be used in urban environments to improve quality of water will be important in the project.

Measures for reduced impact of forestry - Lakes
— Measures for reduced impact of forestry - Water courses

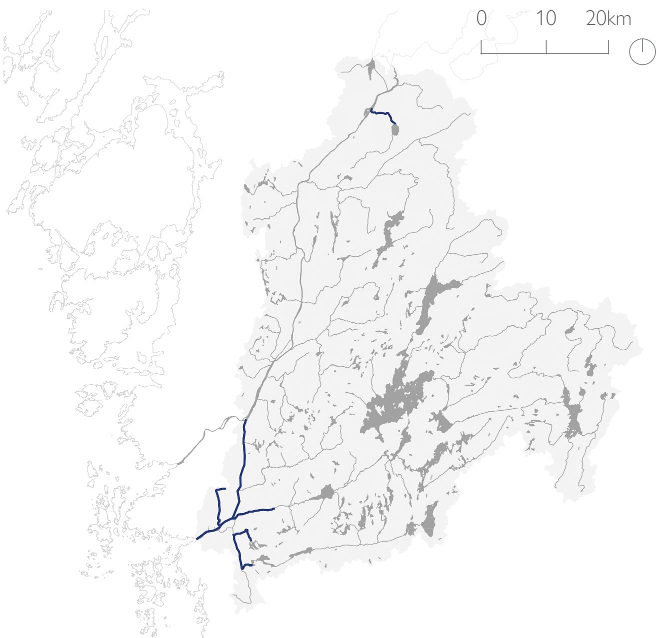


figure 12: Proposed sites: Riparian zones in urban environments (Based on WISS, 2021)

Riparian zones in urban environments

Riparian zones are one of the most divers biotopes. Measures to recreate more natural riparian zones and floodplains along urban watercourses can help the reduction of nutrients and toxins, reduce effects of run-off water from cloudburst, lower water temperatures due to shading caused by greenery and increase biodiversity. However, since urban areas have been excluded from laws around waterline protection in Sweden it is hard to fully recreate riparian zones that can transform the ecological status of watercourses to good. (WSP, 2021) If it's not possible to reach a good ecological status just by recreating the riparian zone other habitat management actions can be used as a complement (VISS, nov 2021). Riparian zones in urban environments and especially how these can be combined with other measures will be a key part of the investigation in the project.

— Riparian zone urban environments - Water courses

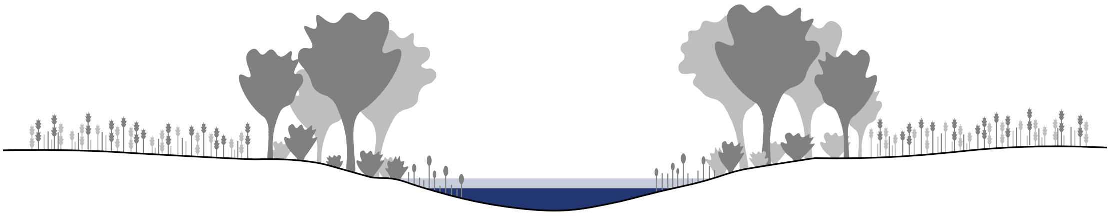


figure 13: Riparian zones in a agricultural environment

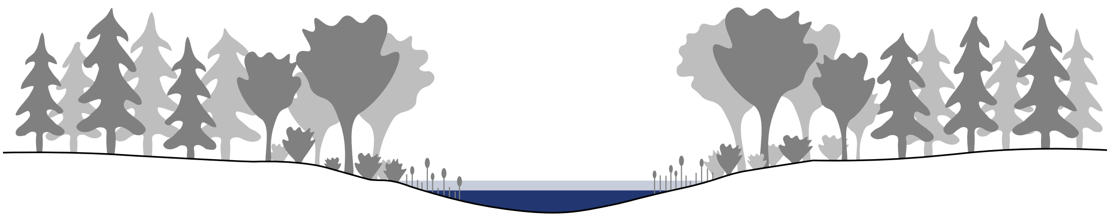


figure 14: Measures for reduced impact of forestry

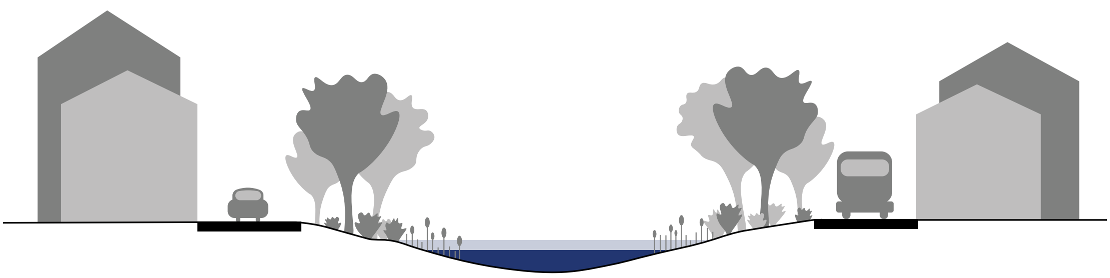


figure 15: Riparian zones in a urban environment

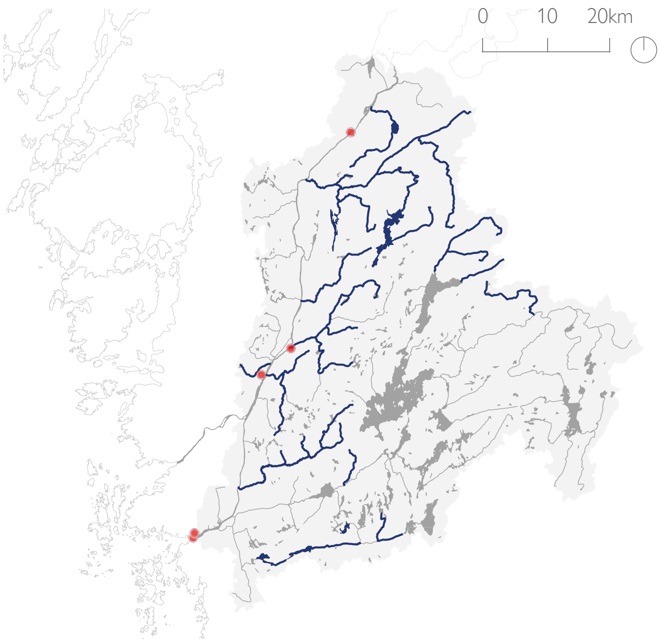


figure 16: Proposed sites: Reduced impact of waste water (Based on WISS, 2021)

Reduce impact of wastewater

Wastewater management primarily take place in water treatment plants or smaller sewage treatment systems. It reduces outlet of substances such as nitrogen and phosphorus, chemicals, environmental toxins and micro plastics. (Naturvårdsverket, n.d.) When too much water reach treatment plants, untreated water is directly flushed into aquatic environments. The treatment plant in Gothenburg, Ryaverket, only receives just above 40% wastewater, the rest is mainly storm water. (Göteborgs Stad, 2023). Urban planning cannot directly deal with treatment plants but with the right storm water management such as greenery and infiltration water reaching treatment plants will decrease. This also leads to synergies such as biodiversity and more stable temperatures in cities (Klimatanpassningen, 2023). Development of treatment plants will not be part of the project but investigations of storm water management in direct relation to water bodies could reduce the stress on treatment plants.

Reduce impact waste water - Lakes
Reduce impact waste water - Water courses
Water treatment plants

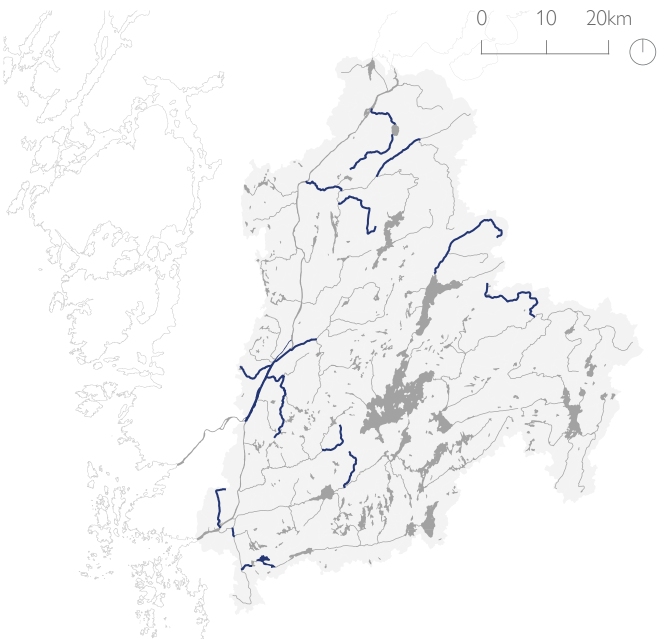


figure 17: Proposed sites: Storm water management (Based on WISS, 2021)

Stormwater management

To reduce outlet of nutrients and toxins storm water treatment need to be included better in planning processes. (VISS, 2019) As presented under reduce effect of wastewater, greenery and natural infiltration should be increased in cities to treat storm water directly instead of sending it in pipes to treatment plants or directly out into nearby water courses. figure 17 shows water-courses that are directly impacted by storm water. According to WISS there are a lot of possible ways to deal with storm water within the city. The most common one is directly translated from Swedish as a wet pond. If these kinds of ponds where implemented, they would roughly have to occupy 1 hectare for every 50 hectare of city. (VISS, 2019). Storm water management will be investigated in relation to water courses but not on the overall strategic level that might be needed to fully solve the problem.

Stormwater management - Lakes
Stormwater management - Water courses

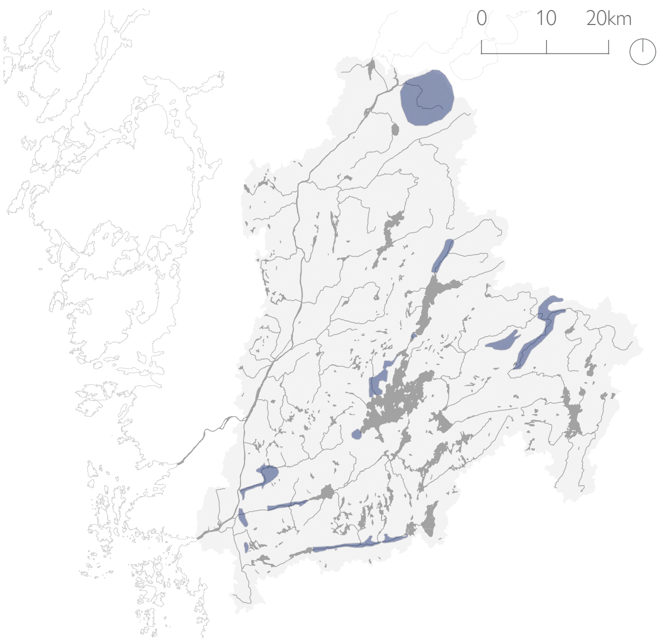


figure 18: Proposed sites: Ground water protection in regard to traffic (Based on WISS, 2021)

Groundwater protection in regard to traffic

In figure 18 where specific measures for traffic is pointed out it mostly regards possible accident on a specific road that might lead to chemical pollution in nearby groundwater (VISS, may 2021). However, according to mapping on the most trafficked roads in Gothenburg carried out in 2020 around 60% of the storm water coming from these roads is directly flushed out into water recipients. Around 30% is led to Ryaverket treatment plant where oils, metals and other toxins are causing problems in the maintenance and hinder use of special filters designed to capture nutrients for reuse in agriculture. To prevent this better storm-water treatment with for example greenery and infiltration is needed. (Göteborg stad, 2023). The thesis does not investigate ground water however if highly trafficked roads occur on the selected site close to water it will be crucial to understand how to reduce the effect of them in the near by water course.

Groudwater sources in need of protection from heavily traficated roads

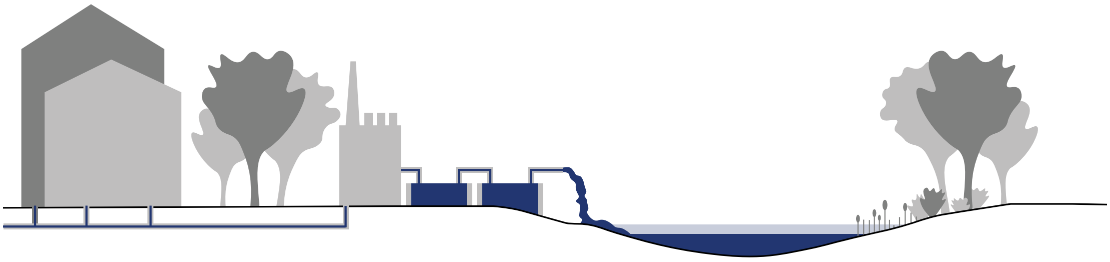


figure 19: Treatment of waste water

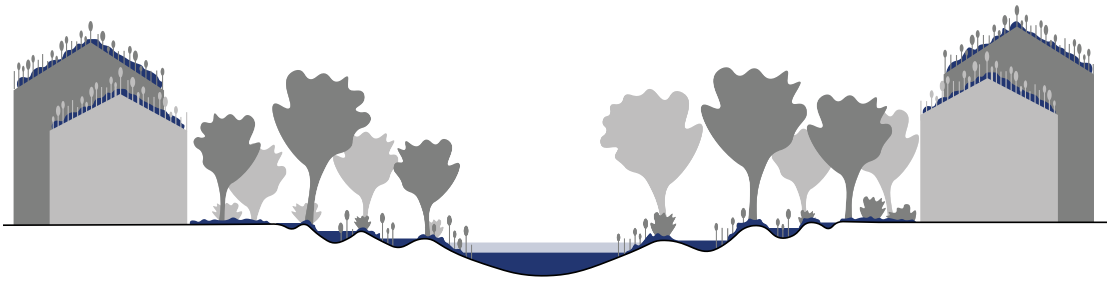


figure 20: Storm water management

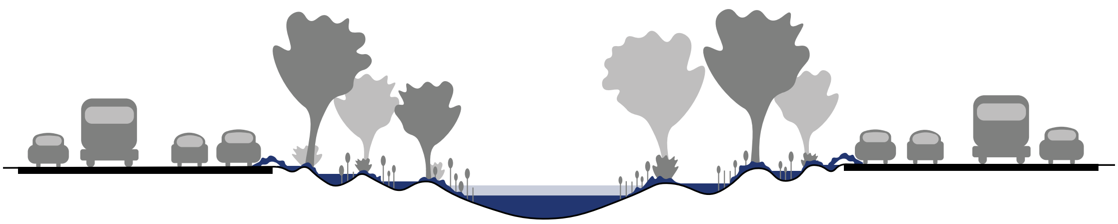


figure 21: Treatment of storm water from traffic

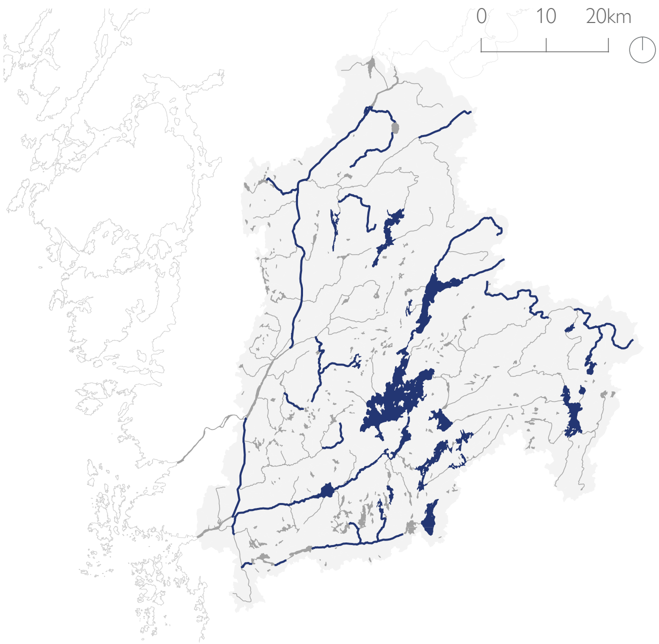


figure 22: Proposed sites: Habitat management (Based on WISS, 2021)

Habitat management

Human impact on water courses has in many places cut of tributaries and water has been channelized into straight streams with unnatural edges. Together with that, natural elements such as stones, gravel and tree trunks has been removed causing worse ecology and qualities for meandering fish. However, by placing stones and logs in water etc. the flow of water will be more uneven but slower in average creating better conditions not only for fish but also insects and reducing risk of flooding (Trafikverket, 2017-a). As seen in figure 22 measures for habitat management has been proposed both in rural and urban environments. This is one of the measures that relates most to site specific spatial transformation and ways to create more natural and varying conditions both in and around water should be considered.

Habitat management - Lakes

Habitat management - Water courses

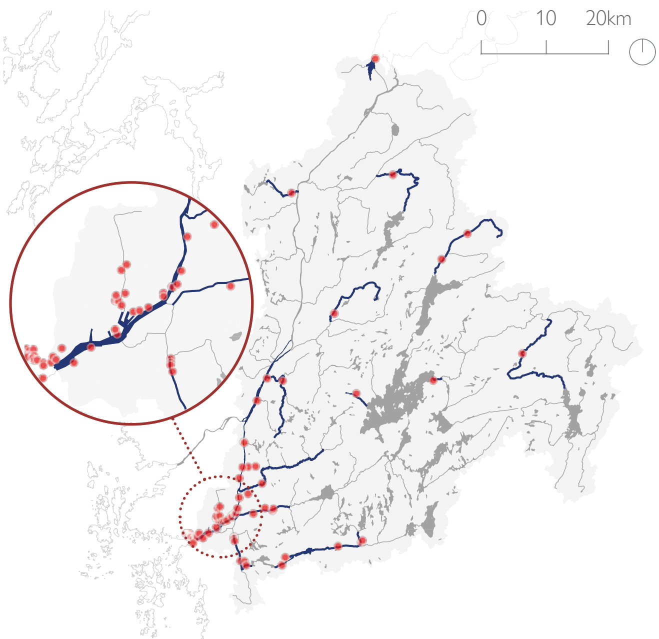


figure 23: Proposed sites: Treatment of environmental toxins (Based on WISS, 2021)

Treatment of environmental toxins

Contaminated land is a result of expansive industrialization in the 20th century and includes plots of land, lakes, buildings, and infrastructure that contains hazardous substances. Often these substances are kept in the same place but if they spread into nearby water, they can affect ecosystems and people in a much larger region. As presented in the background current problems with hazardous substances in Göta älv is limited. However, as seen in figure 23 there is a lot of contaminated land near water courses in the whole region, especially Gothenburg. This means there is a risk of these substances spreading (naturvårdsverket, 2024). With phytoremediation, a method to treat contaminated land with greenery, it could be possible to either, remove, break down, or bind these substances harder (KSLA et al, 2022). If the selected site contains or could contain environmental toxins it is important to investigate this further.

Lakes close to site with environmental

Water courses close to site with environmental toxins

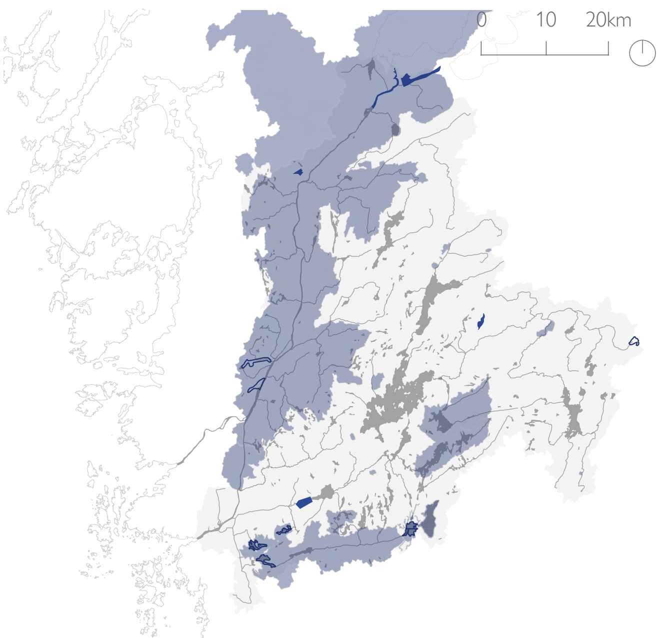


figure 24: Water protection areas (Based on WISS, 2021)

Water protection areas

The purpose with a water protection area is to secure access to healthy fresh water both now and in the future in specific places that are or could be used as fresh water sources. The area itself is an administrative measure but it implies specific protection that has impact on the built environment (Naturvårdsverket, 2011). For this thesis is good to be aware of the water protection areas but the focus will be on measures to increase the quality of water in general and not only in the protected areas.

Water protection areas

Establish new water protection areas

Revise existing water protection areas

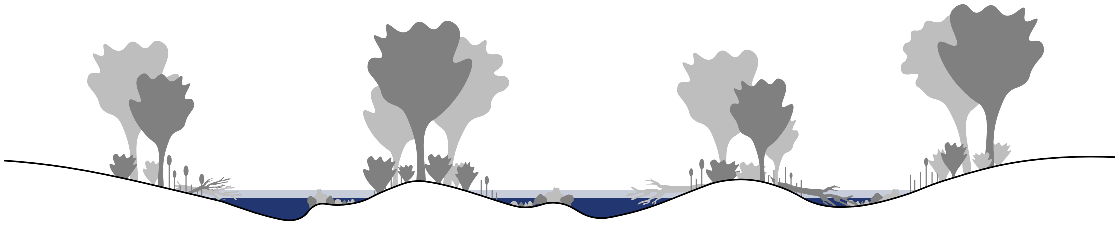


figure 25: Habitat management

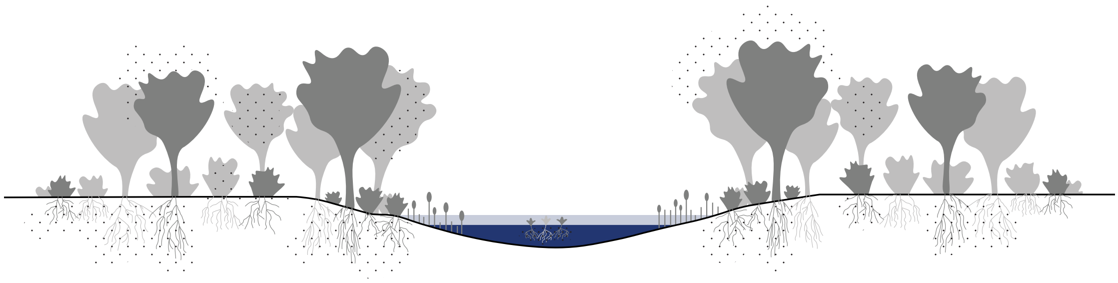


figure 26: Treatment of environmental toxins

SITES FOR SPATIAL TRANSFORMATION

The different proposed measures have different impact on physical planning. Based on the investigation of all measures eight of them have been identified as extra important to consider when identifying locations for spatial transformation.

These eight are:

- 1: Wetlands for better water quality
- 2: Protection zone on agricultural land
- 3: Riparian zone in agricultural environments
- 4: Impact of forestry
- 5: Riparian zone in urban environments
- 6: Stormwater management
- 7: Habitat management
- 8: Treatment of environmental toxins

The rest are:

- Structure liming
- Reduce effect of waste water
- Ground water protection in regard to traffic
- Water protection areas

Even though the four remaining measures have been identified as less important in spatial transformation, influences from all of them can be used for how the project and other similar project are carried out.

During investigations of a specific site later in the thesis it will be crucial to explore how all or many of the proposed measures can be combined. Especially since the intention is to investigate how they can be introduced in more densely populated environment, where different interests have to work together, and the space required to turn the status of watercourses into good with only one measure might not exist.

Based on the eight measures that have been identified as the most important in spatial transformation all the watercourses in the sub-catchment area have been mapped regarding how many measures have been proposed. By overlaying this information with urban areas and localities in the sub-catchment area six spaces have been detected (see figure 27). The chemical and the ecological status of the water bodies in all these locations also need to be improved. This means these spaces could both transform to support the aquatic environment with ecosystem services at the same time as the proximity to people increases the potential of interventions to become meeting spaces where the local community can engage in and learn about local water bodies.

1. Stallbackaån - Trollhättan:

- Propsed measures: 1, 2, 3, 5, 6 & 7
- Chemical status: Good after 2027
- Ecological status: Good until 2033

2. Säveån - Gamlestaden:

- Propsed measures: 5, 7 & 8
- Chemical status: Good after 2027
- Ecological status: Good until 2039

3. Mölndalsån - Kvarnbyn:

- Propsed measures: 5, 6, 7 & 8
- Chemical status: Good until 2027
- Ecological status: Moderate until 2027

4. Mellbyån - Sollebrunn:

- Propsed measures: 1, 2, 6, 7 & 8
- Chemical status: Good until 2027
- Ecological status: Good until 2039

5. Lärjeån - Angered/Kortedala:

- Propsed measures: 1, 2, 4 & 8
- Chemical status: Good after 2027
- Ecological status: Good until 2033

6. Mölndalsån - Landvetter:

- Propsed measures: 2, 4 & 7
- Chemical status: Good until 2027
- Ecological status: Good until 2033

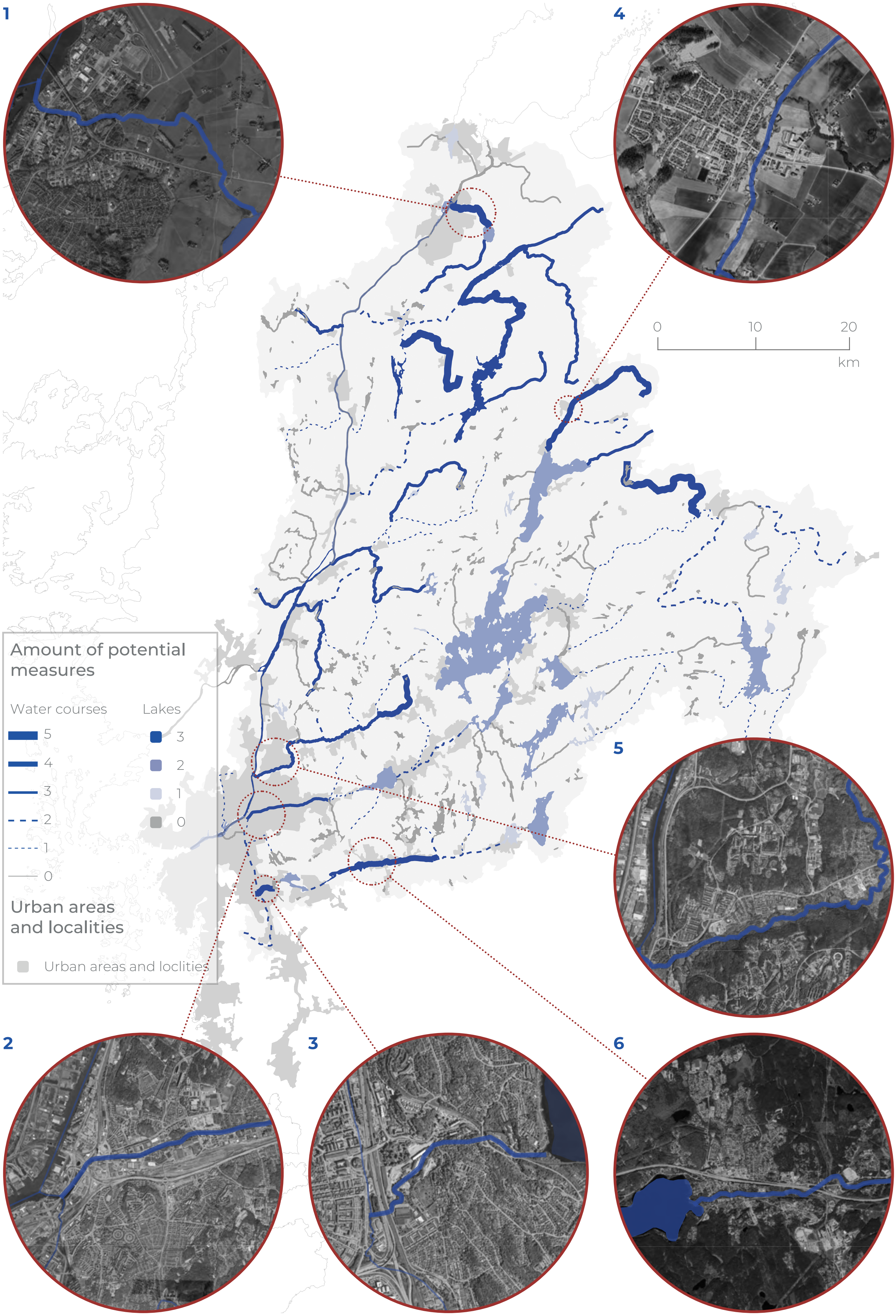


figure 27: Possible areas for project based on amount of proposed measures for better water quality and urban areas/localities

SITE ANALYSIS

BACKGROUND TO MARIEHOLM & PARTIHALLARNA

Because of the many proposed measures for better water quality in and the central location of Säveån in the city of Gothenburg this location has been selected as the site for a deeper investigation of how a specific location can transform to support a clean aquatic environment.

The city of Gothenburg is aiming at revitalizing Gothenburg as a harbour city and reconnecting the citizens and everyday life with water. To do so they want to connect the city with activities along and on the river, Göta älv, by introducing new meeting places with greenery that promotes sustainable living and increases accessibility to water. Urban runoff should be treated and stored in a creative and playful way in for example parks and playgrounds with emphasis on promoting biodiversity. (Göteborg stad, 2012)

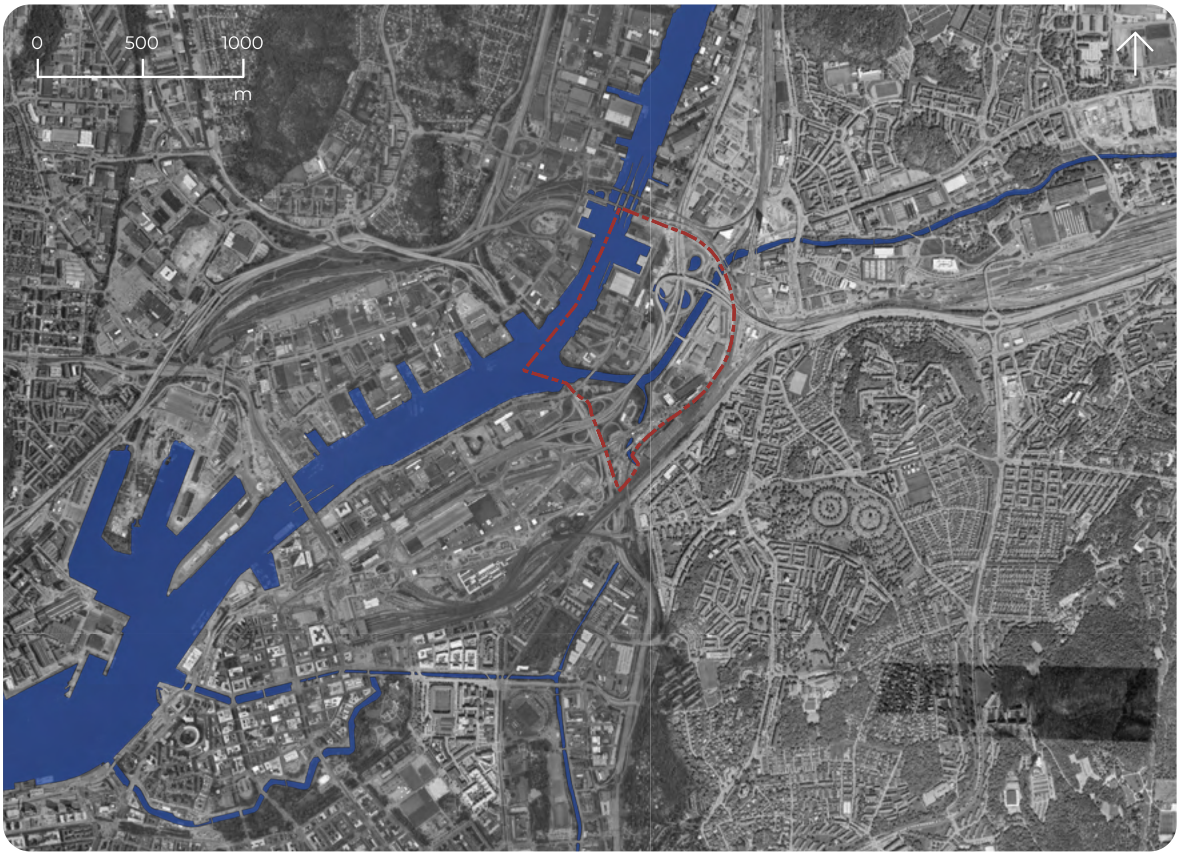
The site where Säveån flows into Götaälv, around Marieholm and Partihallarna, is important for the overall development of the east part of Gothenburg. Even though the specific site is not mentioned in depth in the comprehensive plan of Gothenburg it is placed in what is planned to be the intermediate city (mellanstaden) on the edge towards the inner city. More specifically it is placed in the eastern intermediate city which covers all Örgryte-Härlanda, Gamlestaden, Kortedala and Bergsjön. Gamlestads Torg which is right east of the selected site is also pointed out as one of the three most important future nodes in the city. (Göteborgs Stad, 2022)

Currently this part of the city is cut off by infrastructure such as highways and railroads. The aim is to decrease impact of this kind of infrastructure and instead increase the areas connection to other parts of the city, especially the inner city, by developing public transportation, walking and biking possibilities. This will also be crucial for the planned expansion of the inner city into the east intermediate city with around 13.000-15.000 housing units. (Göteborgs Stad, 2022)

Many parts of the east intermediate city also lack sufficient parks and green areas. The comprehensive plan highlights the importance of creating new green areas and develop the green corridors reaching out of the city connection the green infrastructure on a regional scale. It is also crucial to develop ecosystem services, in particular connected to big infrastructure and industry areas along Säveån and Götaälv. The accessibility for people to reach these streams is also important and a bigger district park enabling people to reach Göta Älv easier is desired. (Göteborgs Stad, 2022)

The selected site seen in figure 28 has potential to develop in line with the comprehensive plan as a pioneering example of how urban development can support aquatic environment. At the same time, it could work as a key location to connect different parts of the city and increase the accessibility to water and green areas.

Currently the site is car dominated and crossed by large highways that both act as boarders and cause sound pollution. Water is close all over the area even though it is hard to reach because of different barriers. On the following pages analysis of the site has been done regarding how the site relates to water and the urban fabric. This works as a base for the design part of the project and points out the importance of working with social and ecological aspects intertwined.



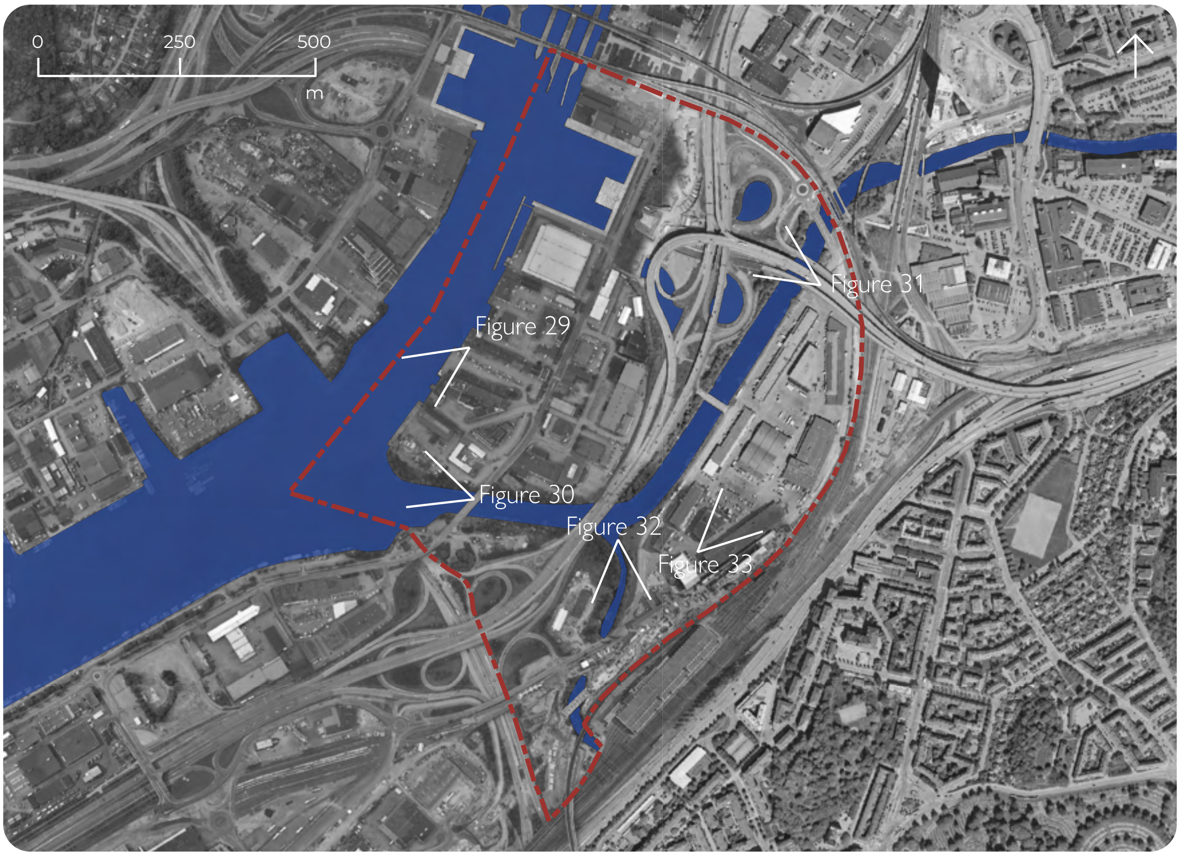


figure 28: Selected site


figure 29: Boarders to the water at Marieholm


figure 30: Outlet to Götaälv


figure 31: Highway bridge crossing the area and Såveån


figure 32: Gullbergsåns outlet to Säveån


figure 33: Partihallarna

Historical relation to water

As seen in figure 34 which showcase information from a map from around 1790 overlayed with current conditions the river front has gone through big changes because of urbanisation. In 1790 vast areas of the river front were covered by wetlands and the outlet of Säveån into Götaälv looked more like a small river delta. This poses questions of if it is possible to go back to more natural conditions where water is allowed to occupy more space, which in turn can help implementing many of the proposed measures on the regional scale.

Water 1790
Wetland 1790

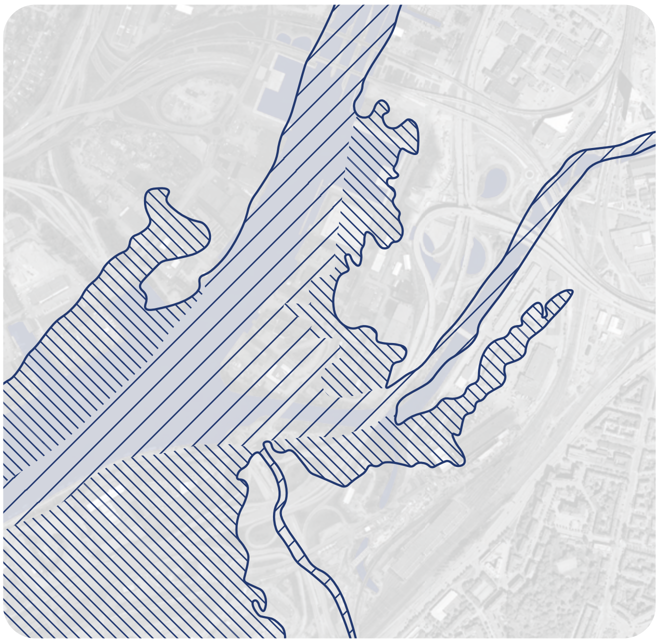


figure 34: Approximate waterline and wetlands around 1790 (based on Göteborgs stad)

High water protection and stormwater paths

Gothenburg risk flooding both from sea level rise and heavy downfall. Advised levels for protection from the sea is currently +2,5 m based on a +1,5 m higher sea level during a 200-year storm and a marginal of +1 meter for effect of waves and future sea level rise. Since the normal sea level is expected to rise between 0.3-0.6 m until 2100 the 2,5 m limit might need to be raised to advised levels of around 2,8-3 m at the selected site. (Stadsbyggnadskontoret, 2019). Currently the riparian zone in the area reaches around 1,5 m above sea level and most of the area is below 2 m above sea level (see figure 35). This means the riparian zone needs to be raised around 1,5 meter to protected from floods. In the light of current discussions of how municipalities in Sweden still tent to build in areas in risk of flooding (Sveriges radio, 2025) it is relevant to propose a development where in the future the area can withstand flooding instead.

High water barrier needed
Stormwater paths
1.5 m a.s.l
2 m a.s.l
Low point under 1.5 m a.b.s

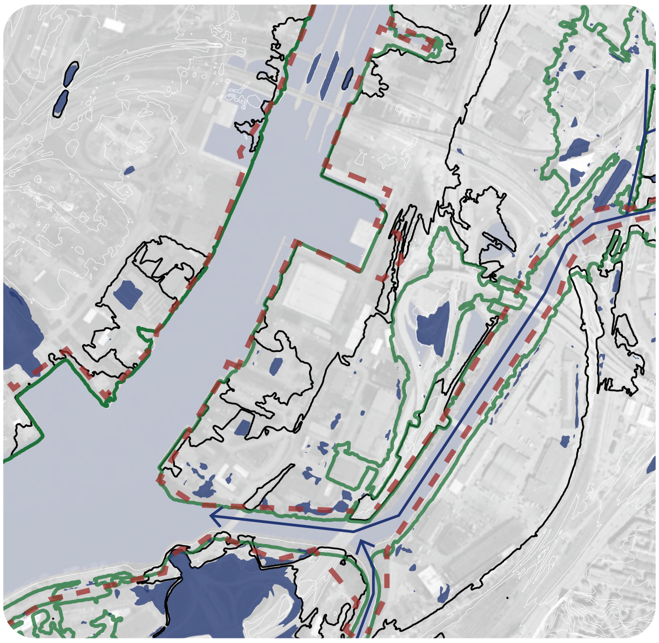


figure 35: Sea level rise/high water protection and storm water pathways

Soil conditions and depth

Most parts of the selected site sit on a layer of above 50 meters of clay. As a result of urban expansion former wetlands connected to the river have been filled up (see figure 34). In a geotechnical report from the expansion of Slakthusmotet in Marieholm the depth of the filling material was measured to between 0.5-2.5 meter where traces of asphalt, metal, wood, glass, porcelain and brick was identified. (Trafikverket, 2017-b). Assumptions of similar conditions in all the area can therefore be made. Most likely the filling material and especially the surface layer contain pollutants presented under chemical, ecological and sources impacting status. These pollutants are better treated on land and the risk of spreading them by leading water into the area is high. (Karlsson, interview, 10 April 2025).

Filling material
Post glacial clay
Glacial clay
Bedrock

Soil depth in meters
< 50
30-50
20-30
10-20
0-1

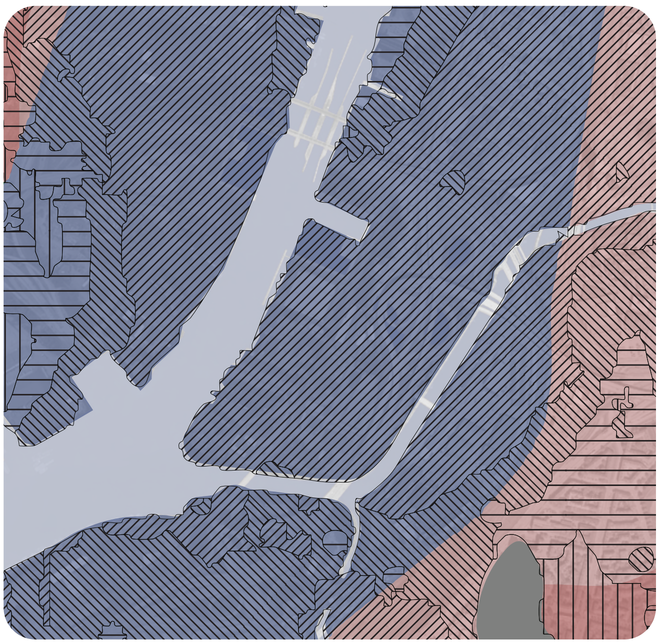


figure 36: Soil conditions and depth

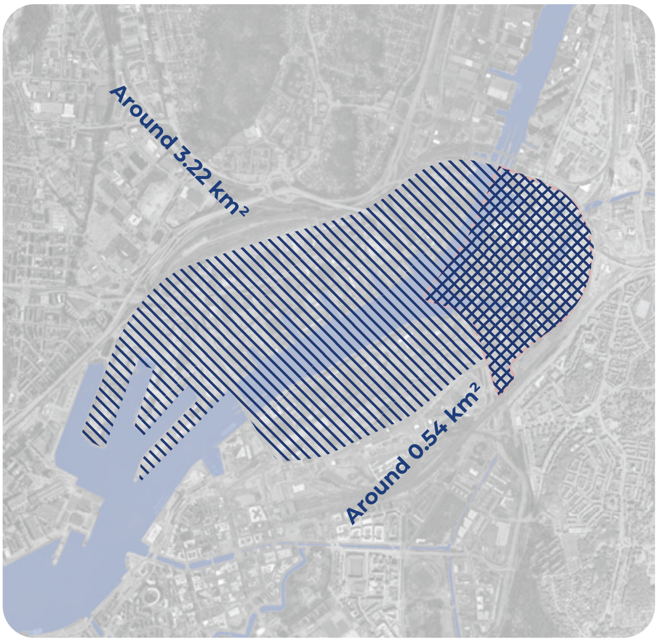


figure 39: Size of park and area needed for treatment of all phosphorus

Needed size for treatment of pollutants

Measures for reduced level of phosphorus also lead to reduced level of heavy metals and other particle-bound substance, especially if plants and filters are included in the cleaning process, which means it is often used as a reference substance (Göteborgs Stad, 2019). The map to the left (figure 39) shows the estimated size a natural treatment wetland would need to be to remove all the phosphorus that flows from Säveån into Göta älv. The estimate is based on comparisons with Johannisbergs Wetland Park in Västerås. it is 14.5 hectares, with a water area of 6.9 hectares, and is estimated to remove 450 kg of phosphorus/year (Mälarenergi, n.d). Every year, approximately 10 tons of phosphorus flow into Göta älv from Säveån (Göta älvs vattenvårdsförbund, 2015). This means a wetland park designed to treat all phosphorus would need to be around 322 hectares, with a water surface area of around 153 hectares. This justifies that the selected area could turn into a more natural area for different ecosystem services. However, it is also clear that other interventions along Säveån are needed.

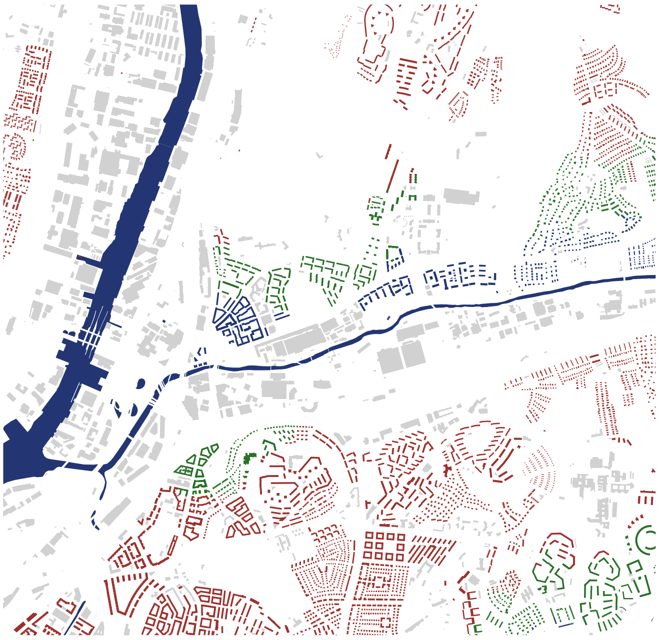


figure 37: Distance from housing to accessible water

Distace to accessable water

As the city aims to connect Gamlestaden and the surrounding east intermediate city better with water (Göteborgs Stad, 2022) it is necessary to understand how the site relates to its surroundings. Even though Partihallarna and Marieholm is situated close to many watercourses most of the neighbouring areas lack close access to water (figure 37). With the right connections to these areas such as Bagaregården to the southeast, the site could connect people better to water. What is not visible in the analysis (figure 37) is the spatial qualities of the site. These have been investigated during site visits instead. even though the area is right next to water there are many barriers such as fences, roads and unkept greenery that limit the possibility to access water even on site.

Dictance in meters
0-500
500-1000
< 1000
Other buildings

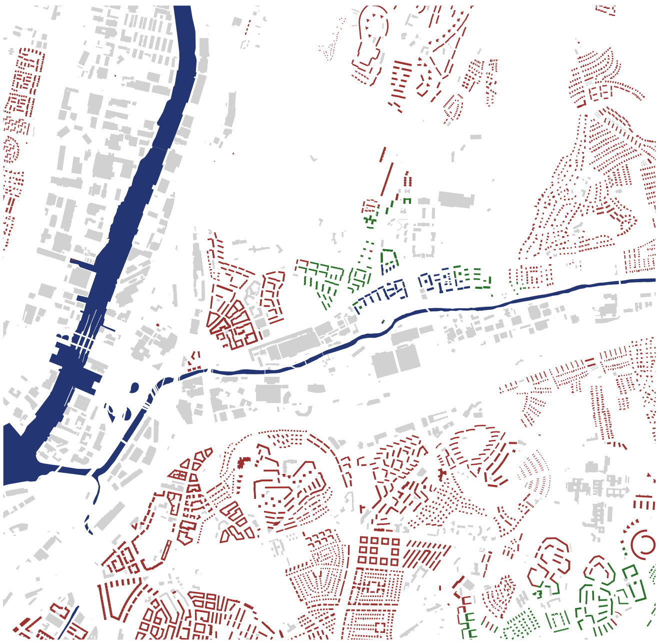


figure 38: Distance from housing to parks next to water

Distance to parks next to water

Even though it is possible to reach many parts of Säveån many of these places lack sufficient cultural ecosystem services and recreational possibilities. This was observed during a site visit along the water course where not only access to water but also, parks and seating areas etc. was mapped. Currently there is only one place along the river where an accessible and developed park exists which is visible in the analysis (figure 38). If the selected site would be developed as a park together with better connections to surrounding areas the accessibility to parks next to water would increase drastically.

Dictance in meters
0-500
500-1000
< 1000
Other buildings

Connectivity to and from the area

Analysis on angular betweenness on a 5 km scale (figure 40) shows the likeliness that people move (mostly by bike) on each street to reach all other streets within 5km. Most movement will occur on streets with high values. Both in Partihallarna and Marieholm the values are lower than in neighbouring areas. The analysis show that it is not easy to move to and from the area by foot or bike. This was also perceived during sitevisits. However, since the area is situated in the middle of the city center and the east intermediate city (Göteborgs Stad, 2022) it has potential to bridge these parts of the city and in that way attract more people to the water.

Highest 1%
Next 2%
Next 7%
Next 10%
Next 15%
Next 25%
Lowest 40%
Water

figure 40: Angular betweeness on a 5 km scale

Walkability in and around the site

Analysis on angular integration on a 1 km scale (figure 41) shows how many streets you reach from each street within 1 km walking distance. High values mean that the street is better integrated on a local scale and indicates if there are many or few people walking in the area. The integration of the Partihallarna and Marieholm is currently very low which was also observed during site visits. However, the areas around the site are better integrated which means it would be possible to add new connections to the site to increase walkability. Connections especially towards Gamlestaden in the northeast, Bagaregården in the southeast, Gullbergsvass in the southwest and between Partihallarna and Marieholm could make the site a more natural part of the urban fabric.

Highest 5%
Next 5%
Next 5%
Next 10%
Next 25%
Next 25%
Lowest 25%
Water
Connections that should be increased

figure 41: Angular integration on a 1 km scale

Chemical & Ecological status

The chemical status of Säveån approximately between the outlet into Göta älv and Partille is failing to achieve good. To high levels of Bromo diphenyl ether, mercury and its compounds, fluoranthene, and different kins of polyaromatic hydrocarbons (benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene have been identified (VISS, 2023). Investigations will be conducted of how these substances could be reduced using phytoremediation.

Although the ecological status in Säveån between the outlet into Göta älv and Partille is moderate there is a lot of things that can be done to improve it. Because of hydro power the water flow varies a lot affecting the ecological status negatively. There is also a lack of natural environments for animals. 47% of its nearby environment is either covered by agriculture or hard urban surfaces and 56% of the riparian zone is occupied by developed or used land (VISS, 2023).

Sources impacting status

There are several sources impacting the chemical and ecological status of Säveån. Urban run-off, transportation, atmospheric deposition, hydrological alteration, and physical alteration of riparian zones area currently the main sources affecting the stream. Except for the chemicals that impact the status today these sources risk contaminating Säveån with copper, PFOS, pressure PAH and pressure metals. In addition to this possible future contamination from contaminated sites such as abandoned industrial areas could be tributyltin compounds, chromium, copper, irgarol/cybutryn, doxins, PFOS, aclonifen, pressure PAH and pressure metals (VISS, 2023). How phytoremediation on land and water could be used to limit the ability of these substances to spread should be investigated further.

DESIGN PRINCIPLES

PRINCIPLES FOR SPATIAL WATER PURIFCATION

Based on the identified measures for better water quality from the regional mapping and the specific conditions of the site five principles for spatial water purification for the project have been developed. They are not necessarily only connected to the measures proposed for Säveån but also other measures that could have an impact on water quality in an urban environment. This is done both to explore how measures that are mostly considered to be suitable for rural environments such as wetlands can be part of urban development but also to enable the outcome of the project to be applied where other measures have been proposed. Except descriptions of how spatial transformation should occur the benefits of each principle is elaborated further to understand the capacity spatial transformation can have for supporting the status of water bodies.

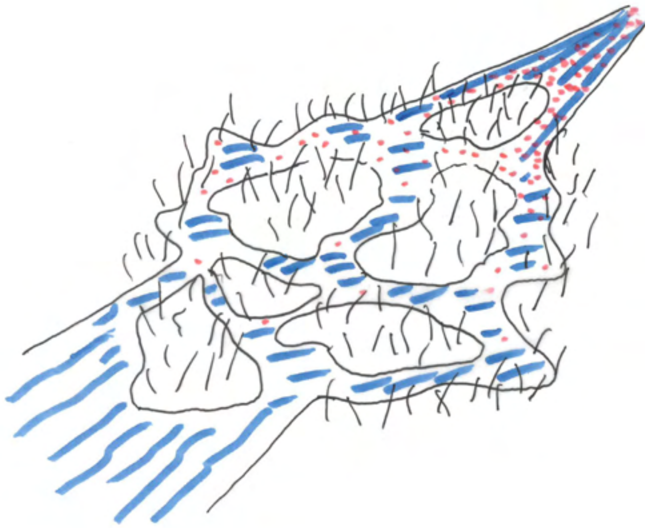


figure 42: Urban wetlands

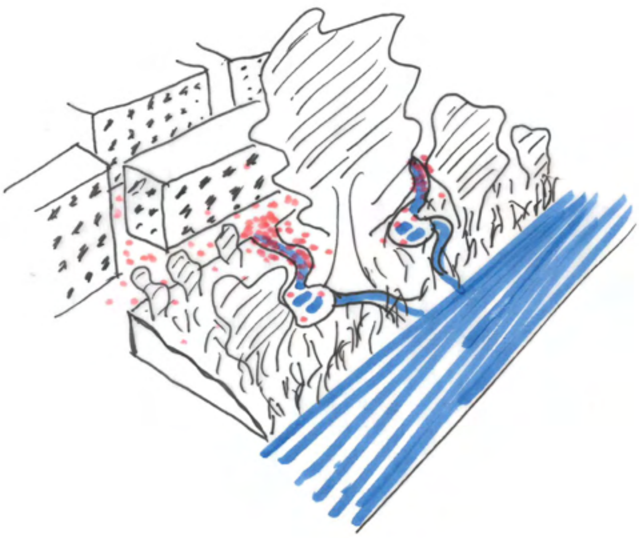


figure 43: Functioning riparian zones with shading

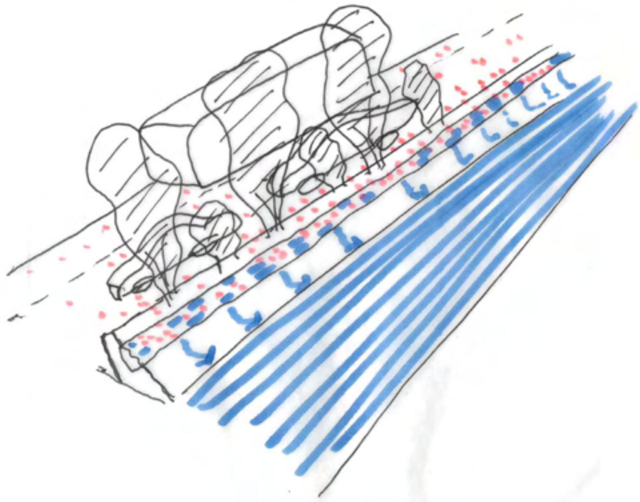


figure 44: Stormwater treatment from roads and the city

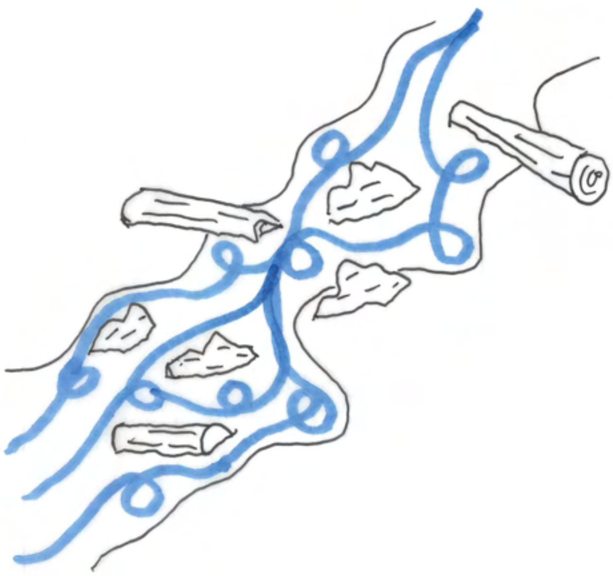


figure 45: Habitat management

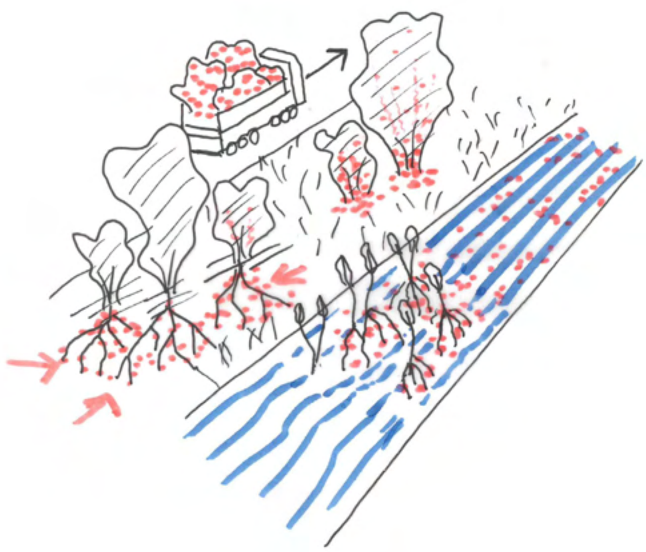


figure 46: Phytoremediation

URBAN WETLANDS

Since wetlands mostly are proposed in rural locations by WISS it is not proposed as a measure for Säveån. However urban sprawl, contamination from run-off water and barriers in water courses are threats to wetlands just as much as agriculture. Furthermore, the benefits functioning wetlands provide cities are many. Except for their capacities of purifying up to 90% of accumulated substances from run-off water they can increase biodiversity, reduce heat island effect, clean polluted air, store carbon, protect from flooding and increase resilience to climate change. (Alikhani et. al, 2021)

It is necessary that run off water is not led to already existing natural wetlands since that might affect the natural and chemical composition of it. This should instead be done in artificial manmade wetlands. However, to many pollutants in wetlands could cause a trap for traveling animals even in artificial wetlands ultimately affecting biodiversity. This could be avoided if they are managed correctly (Alikhani et. al, 2021). Other design strategies such as riparian zones might reduce the direct impact on Säveån which probably will reduce the risk of wetlands causing a trap for traveling animals.

Urban wetlands in practice

Urban wetland restoration can consist of artificial additions to the existing environment or up keeping of natural habitats and can both be permanent and temporal (Alikhani et. al, 2021). A relevant example of an artificial addition is the National Aquarium Harbour wetland. It is an artificial island in the harbour of Baltimore made of recycled plastic mats providing habitats for dozens of native species but also recreational spaces for people. By compressing water into shallow channels this artificial wetland also manages to mimic conditions in natural wetlands. (Ayers Saint Gross, 2024).

Johannisbergs wetland park in Västerås has a more natural appearance. It is placed in the outskirts of the city and naturally cleans the water from the stream Kappelbäcken from metals and other toxins before it reaches lake Mälaren. Except for the purification it also supports biodiversity and creates a recreational and educational space for people in the city. (Topia landskapsarkitekter, 2021) For this kind of more natural wetlands, it is important to identify low points in the landscape to work with spaces where water naturally gather. This can be done by analysis in the software Scalgo live (SCALGO,n.d.-a).

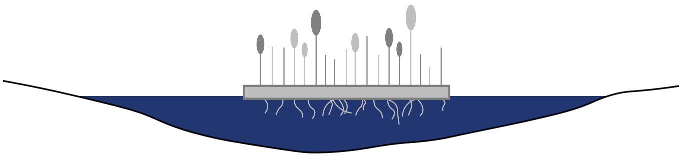


figure 47: Floating wetland

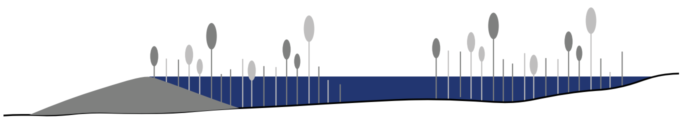


figure 48: Create wetland by damming at low point

FUNCTIONING RIPARIAN ZONES WITH SHADING

A functional riparian zone reduces input of nutrients and erosion to water, enables greenery to cast shade on watercourses which controls temperatures and increase diversity in the water, allows organic material and insects to end up in watercourses and creates a humid micro climate. (Naturvårdsverket & Fiske-riverket, 2008)

As presented in the measures for better water quality shading of water can benefit the ecological status of water courses since it lowers the water temperature. This is dependent on a more natural development of the riparian zone.

Functioning riparian zones in practice

When designing a riparian zone, it is important to create a wetland looking zone that temporarily can get flooded along the edge to the watercourse. That can reduce to input of nutrients further by for example turning nitrogen into harmless gas but also create a diverse habitat that temporarily gets flooded. It is also important that most of the waterline, especially the southern side of the stream, is covered by greenery in different levels that cast shade on at least 60-80% of the water. In that way the diversity of the watercourse is increased and the number of fish increases drastically but it also reduces the risk of the watercourse becoming overgrown. Trees and bushes also improve the ability to filter nutrients within the watercourse up to 20 times and water coming from land with 40% compared to a riparian zone that is just covered by grass or meadow. Lastly it allows a natural input of organic materials, insects and woody debris that are the foundation for a stable ecology in the water.

The city of Gothenburg aims at recreating riparian zones with a width of around 6 meters in urban environments. (M. Knape, teams meeting, 11 February 2025). However, to develop a fully functioning zone the width needs to be between 15-20 as presented in the regional mapping.

To reduce the input of nutrients further, especially nitrogen it is good if the riparian zone is planned in two layers. One that constantly casts shade on the watercourse and one that can be harvested to remove the nutrients taken up by plants. (Naturvårdsverket & Fiskeriverket, 2008)

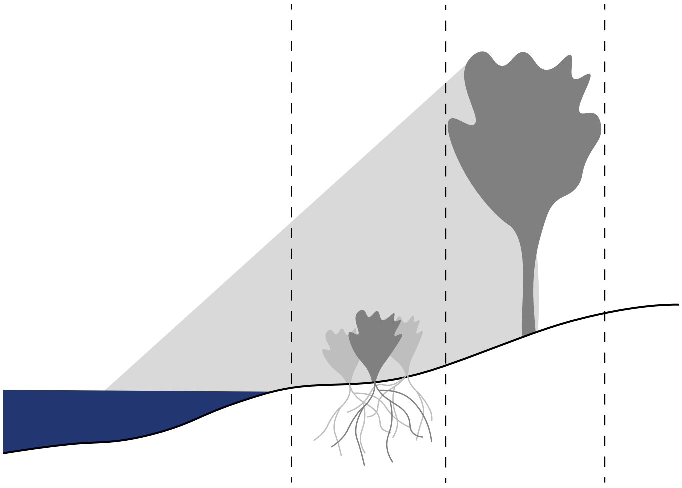


figure 49: Zoning of riparian zone

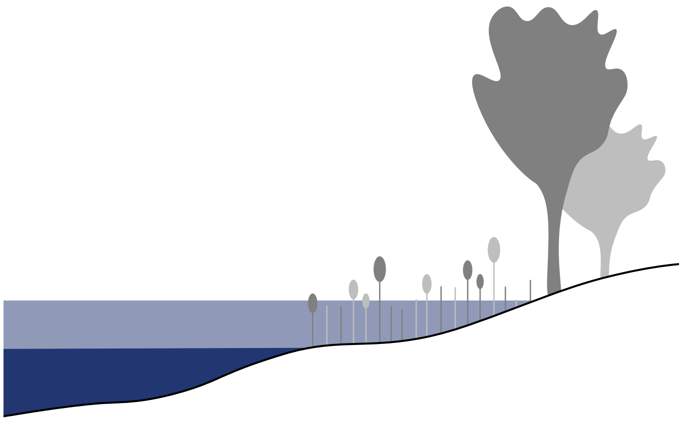


figure 50: Temporarily flooded riparian zone

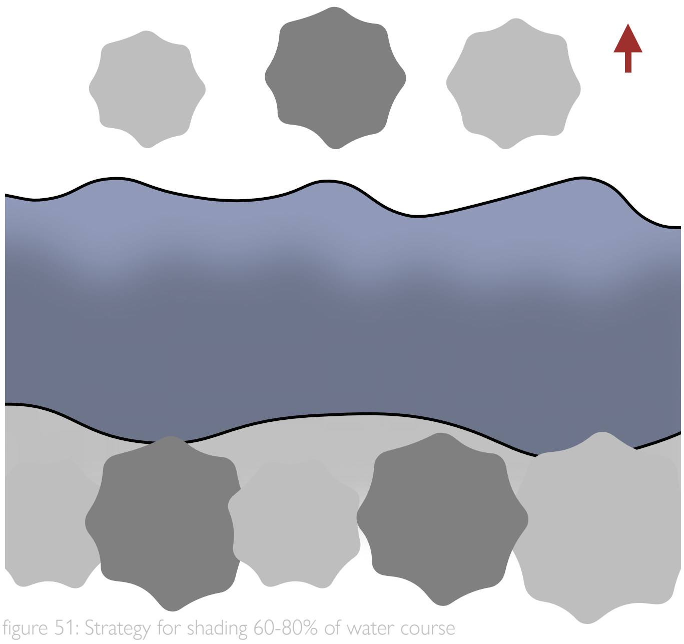


figure 51: Strategy for shading 60-80% of water course

TREATMENT OF STORMWATER FROM ROADS & THE CITY

The selected area is surrounded by highways. Highways generally cause worse ecological and chemical status because of outlet of exhaust and ware material from asphalt, tiers, and breaks (Mooselu et al. 2022). Metals such as lead, zink and copper and organic substances in different forms of hydrocarbons cause toxification of aquatic environment an effect human end ecological health. These attach to small soil particles (suspended soils) also coming from road ware which increases pollution on aquatic environments further. Levels of phosphorus and nitrogen can also increase from run of water from roads causing eutrophication. During winter road salts can cause increased salinity and enable heavy metals that have attached to small soil particles to move more freely (Trafikverket, 2018). In the regional mapping it was identified that 60% of the stormwater from the most trafficked roads in Gothenburg is directly flushed into nearby water bodies. This means it is not only crucial to understand how to treat run of water from the city but also from highways.

Treatment of stormwater in practice

Currently the most common way to treat run off water from highways is firstly through infiltration into road shoulders, vegetated side ditches or road embankments. Secondly through wetlands and ponds with sedimentation. Third through centralized infiltration facilities and basins for sedimentation and lastly through a combination of different measures. (Mooselu et al. 2022).

To remove as many pollutants as possible from storm water a combination between infiltration and sedimentation is needed. Firstly, the water should be infiltrated in road shoulders or grass ditches that can remove up to 25% of suspended soils and 20% of metals. These should lead the water to sedimentation ponds that can remove up to 90% of suspended soils, 65% of phosphorous and 60% of metals. The efficiency of these ponds increases if they are longer, and they should be 1-2% of their catchment area. Finally by leading the water into a larger wetlands pollutants that are dissolved in the water can be cleaned more efficiently. These pollutants can also be removed by filtering water though sand or gravel banks at the outlet of each sedimentation pond. For the system to work efficiently careful maintenance especially by removing sediment is needed. However, a larger and combined system can reduce maintenance frequency and costs. (Trafikverket, 2018)

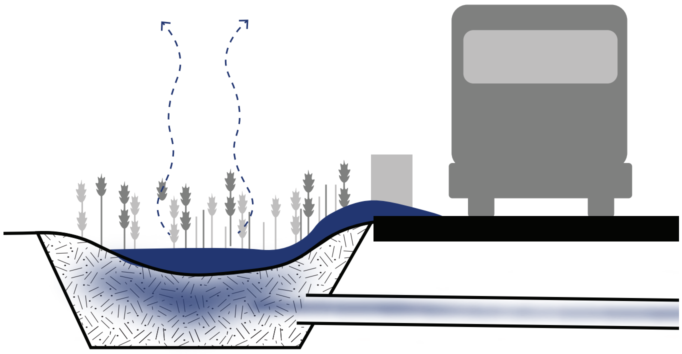


figure 52: Vegetated side ditch

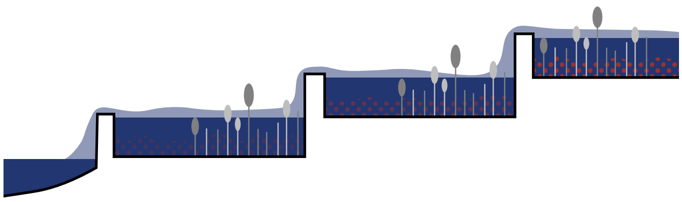


figure 53: Sedimentation and infiltration ponds

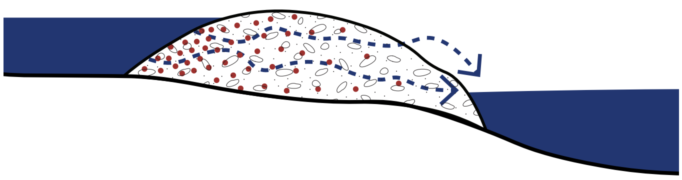


figure 54: Gravel and sandbank for infiltration

HABITAT MANAGEMENT

Through time water courses have been heavily modified to gain more space for agricultural land, forestry and urban development. This includes removal of natural meandering patterns by straitening water courses and removing stones, tree trunks and other natural material in and around the water to get more usable land. This has led to increased erosion, less landscape aesthetic values, less biodiversity and decreased nitrogen retention (plants ability to transform nitrogen into harmless gas, binding it to the ground or transforming it biologically in wetlands) (Naturvårdsverket & Fiskeriverket, 2008).

To regain these ecosystem services, it is important to recreate natural conditions. Some examples are summarized below. It is important to remember that measures only in a short part of a water course does not impact much and if similar measures are not done in big parts of the water course it might counteract implemented measures (Naturvårdsverket & Fiskeriverket, 2008).

Meandering

Meandering watercourses are a natural process that occurs when the riparian zone is not occupied with materials protecting from erosion. It occurs because of natural stream conditions when water courses are not straightened. Water flows faster in the outer curve than the inner curve. This leads to erosion and a steeper riparian zone in the outer curve while the inner curve turns into a shallow sand or gravel banks. (Prominski et al, 2017)

Open up tributaries

A common way to increase biodiversity and reduce risk of flooding is to open a tributary (secondary channel) or a side lagoon which can work as a spawning ground for fish (Naturvårdsverket & Fiskeriverket, 2008).

Changing the profile

By letting the riparian zone occupy more space the watercourse is narrowed but also creating less steep riparian zones. This means land closes to water temporarily gets flooded causing wetland conditions (Naturvårdsverket & Fiskeriverket, 2008).

Introduction of biological material

Reintroduction of stones and tree trunks into watercourses is also important. However, if most of the stones are removed erosion will make it hard for added material to stay. To tackle this, it can help to build up sand or gravel banks with bigger stones. The stones should measure 0.6-1.5 meters in width or no more than one fifth of the overall width of the watercourse. It is good if the stones are visible in low tide but are covered by water when flows are higher so that material coming from upstream doesn't get stuck (Naturvårdsverket & Fiskeriverket, 2008).

Habitat management in practice

To make straightened water courses meander or open up tributaries different strategies can be used. The most drastic is to remove riverbed reinforcement allowing the river to naturally erode and expand into the riparian zone and land next to it. To control movement of streams and in that way where erosion will occur disruptive biological elements and added bed loads can be place in strategic positions within the water course. To further emphasise the transformation the ground can be excavated artificially even though that is more expensive. (Prominski et al, 2017)

To extend the riparian zone into the water course different kinds of embankments such as large stones, tree trunks or different kinds of groynes (small peninsula) can be placed in the water. The groynes can be both above or below water and made by stone or organic material. For organic gryones living woven willow can be planted to function as a pioneering species for other species to later naturally establish. (Prominski et al, 2017)

It is good if the introduces material is biological material that comes from the watercourse or the area close to the watercourse to limit the risk of unwanted species and substances spreading in the water. (Prominski et al, 2017)

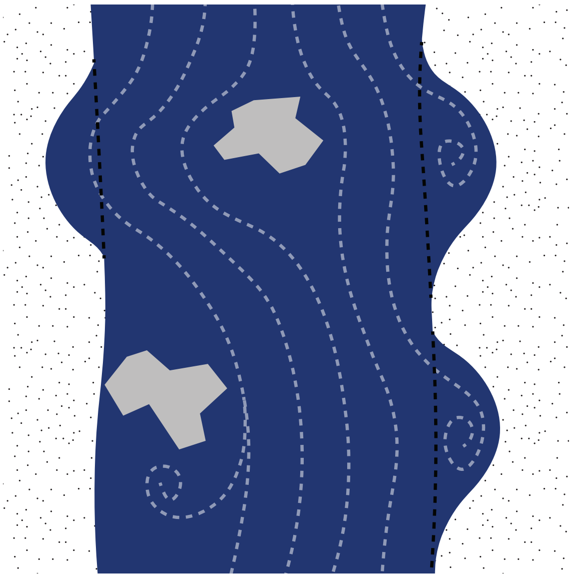


figure 55: Meandering through introduction of biological material (ex. stones and branches)

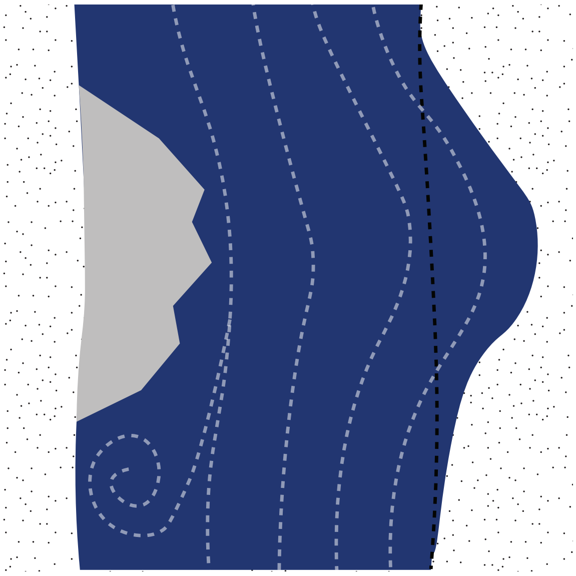


figure 56: Meandering through introduction of groynes (small peninsulas)

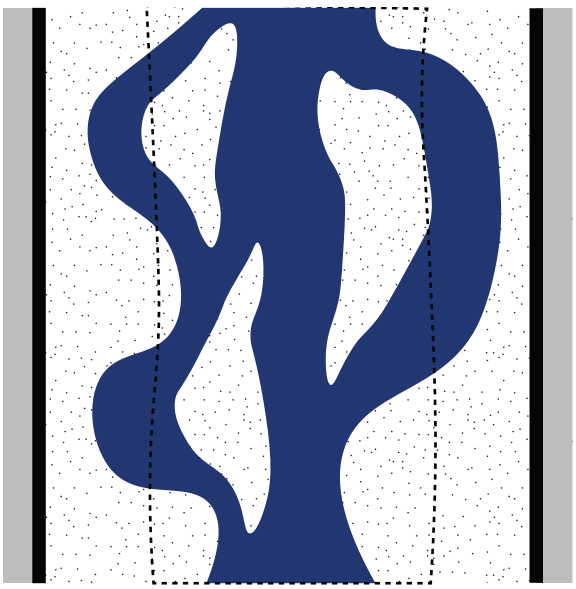


figure 57: Meandering through removing erosion barrier

PHYTOREMEDIATION TO TREAT POLLUTANTS

Phytoremediation can be summarized as the ability of plants to remove, stabilize, transform, or decompose pollutants. It works for both organic (oils, fertilizers and micro plastics etc.) and inorganic (metals etc.) pollutants but inorganic pollutants cannot be decomposed (KSLA et al, 2022). It can be divided into phytoextraction, rhizofiltration, phytodegradation, phytostabilization and phytovolatilization and different strategies and plants need to be used to remove pollutants (Delgado-González et al, 2021).

Phytoextraction

In phytoextraction roots of plants send out root exudate which binds pollutants to the plant and sends them to the sprout. To remove the pollutants this should later be harvested and taken care of. It has been proven that better results are shown when using fast growing plants that take up less pollutants than slow growing plants that take up more pollutants (KSLA et al, 2022).

Rhizofiltration

Rhizofiltration is similar to phytoextraction but here the pollutants are binded to the roots instead of the sprout. Rhizofiltration works especially good in water (KSLA et al, 2022) and for taking up metals (Delgado-González et al, 2021). For efficient rhizofiltration the water has to stand still or move very slow. (Greger, digital interview, 24 April 2025)

Phytodegradation

Phytodegradation is similar to phytoextraction. The difference is that when pollutants have been transported to the sprouts they are decomposed within the cells into less toxic substances. This only works for organic pollutants such as pesticides, oil/petroleum products and plastics but not metals (Delgado-González et al, 2021). Like phytodegradation is rhizodegradation where organic pollutants are decomposed in the root zone by enzymes being sent out from the plant (KSLA et al, 2022).

Phytostabilization

In phytostabilization the plants either bind pollutants harder into the cells of the plant or help particles in the ground or water to bind pollutants to them. This means the ability for pollutants to spread in water, or air is limited. This means the plants does not need to be harvested and transported somewhere else for treatment since the pollutants are stabilized in the specific location (KSLA et al, 2022) (Delgado-González et al, 2021).

Phytovolatilization

Phytovolatilization takes up pollutants in similar ways as the other methods. The difference is that most of the pollutant is not kept within the plant. Instead, the pollutant either evaporate (fluid to gas) or volatilise (solid or fluid to gas) into the atmosphere. This process also makes the pollutant less toxic for the environment. It only work for some metals (Delgado-González et al, 2021). Nitrogen retention presented under the strategy habitat management in water could be seen as one example of this.

Phytoremediation in practice

The most effective way to treat pollutants is through phytoextraction by carefully planting willow bushes (ex. salix viminalis). If the right species is planted in the right way it normally takes around 7 to 10 years to take up pollutants at a depth of 0.5 meters up to 1 meter. Willow is also the only plant used in phytoremediation where pollutants can be separated from the plant in treatment plants. In that way it can be used for bio energy without spreading pollutants. The plant itself is not harmful during the cleaning process but if the ground is heavily contaminated a grass meadow could be planted to limit the ability of people to come in contact with the soil. Trees such as silver birch could be used to stabilize contaminants in the ground through phytostabilization (Greger, digital interview, 24 April 2025)

Even though it is uncertain how well other plants work for treating pollutants outside of laboratory environments and how these should be taken care of if they would work some species have been identified as possible. Silver birch (betula pendula) could also work for phytodegradation of PAH, different kinds of grass for phytoextraction of different metals, Heath dog violet for phytoextraction of metals (Olsson, 2011) and Indian mustard for Phytovolatilization of mercury (Kristani et al, 2023).

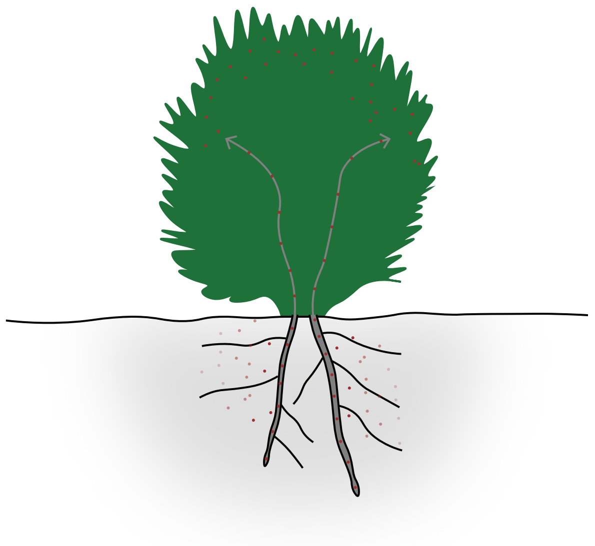


figure 60: Phytoextraction with willow (salix)

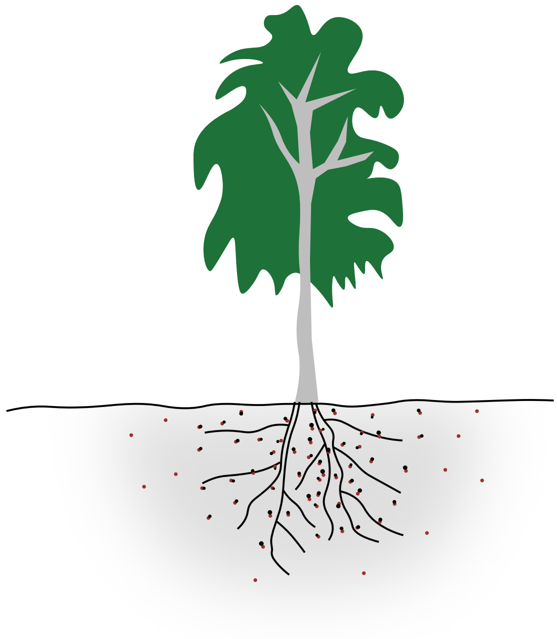


figure 61: Phytostabilization with silver birch

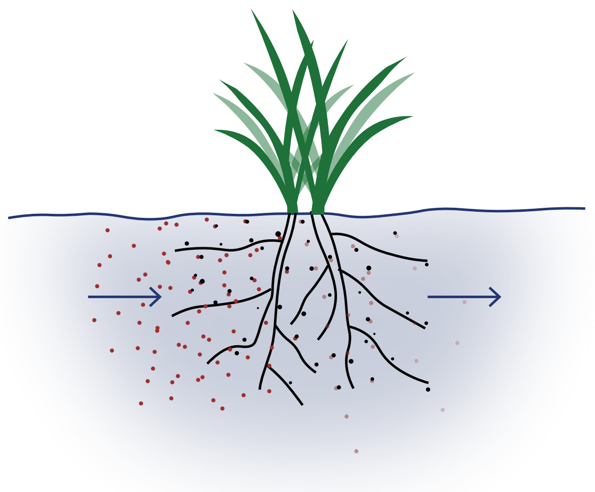


figure 58: Rhizofiltration with wetland plants

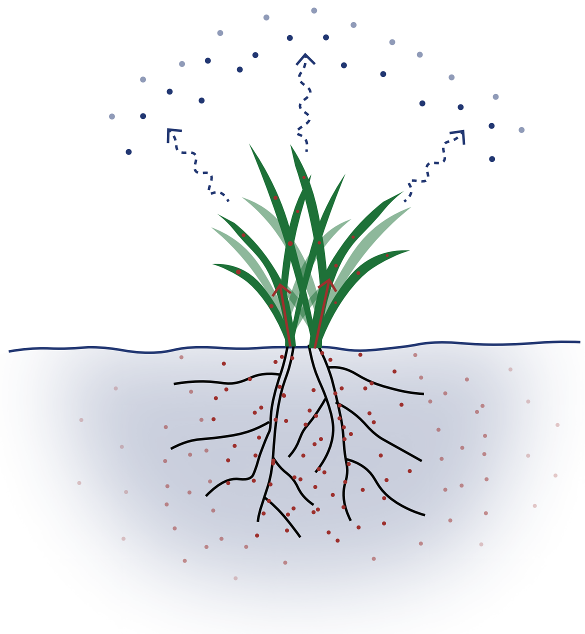


figure 62: Phytovolatilization with wetland plants

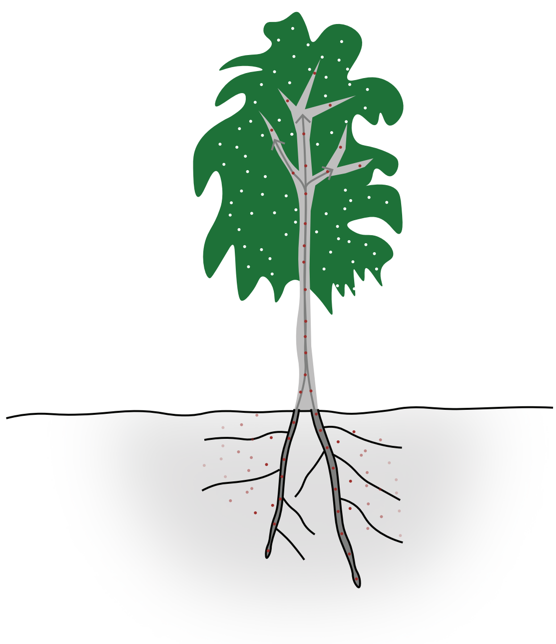


figure 59: Phytodegradation with silver birch

DESIGN

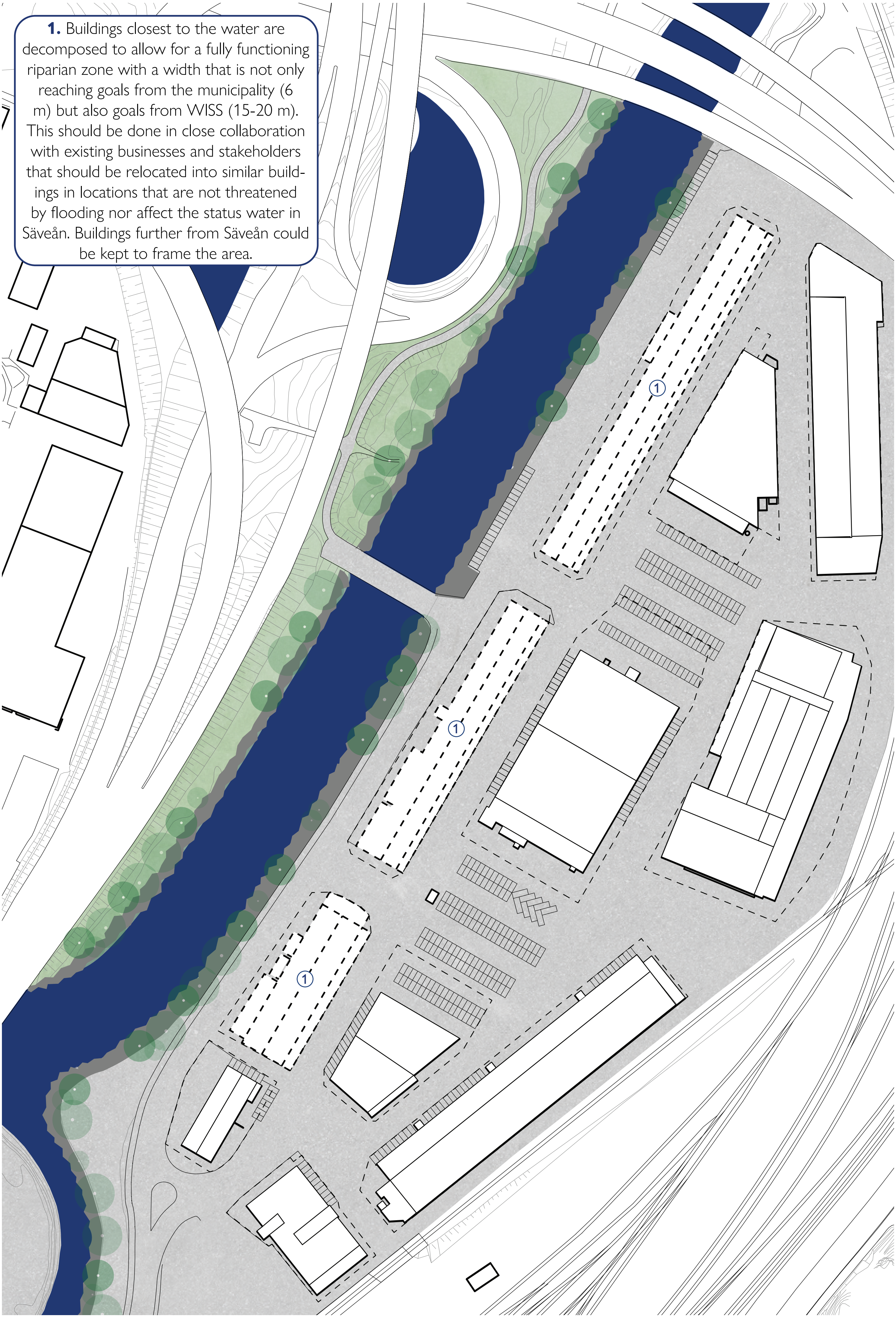


figure 63: Stage 1 of spatial transformation

INTRODUCTION TO DESIGN

The design part of the project should be seen not only as a solution to how urban planning could lead to better status in water bodies but also as a critical reflection on how we have historically built our cities, especially Gothenburg, in relation to water. It is also an exploration of what the city could look like if we would let functioning ecosystems occupy more space in urban environments to support both regulating and cultural ecosystem services. In that way it also relates to social ecological urbanism by examining the intersection between nature, the city, and people.

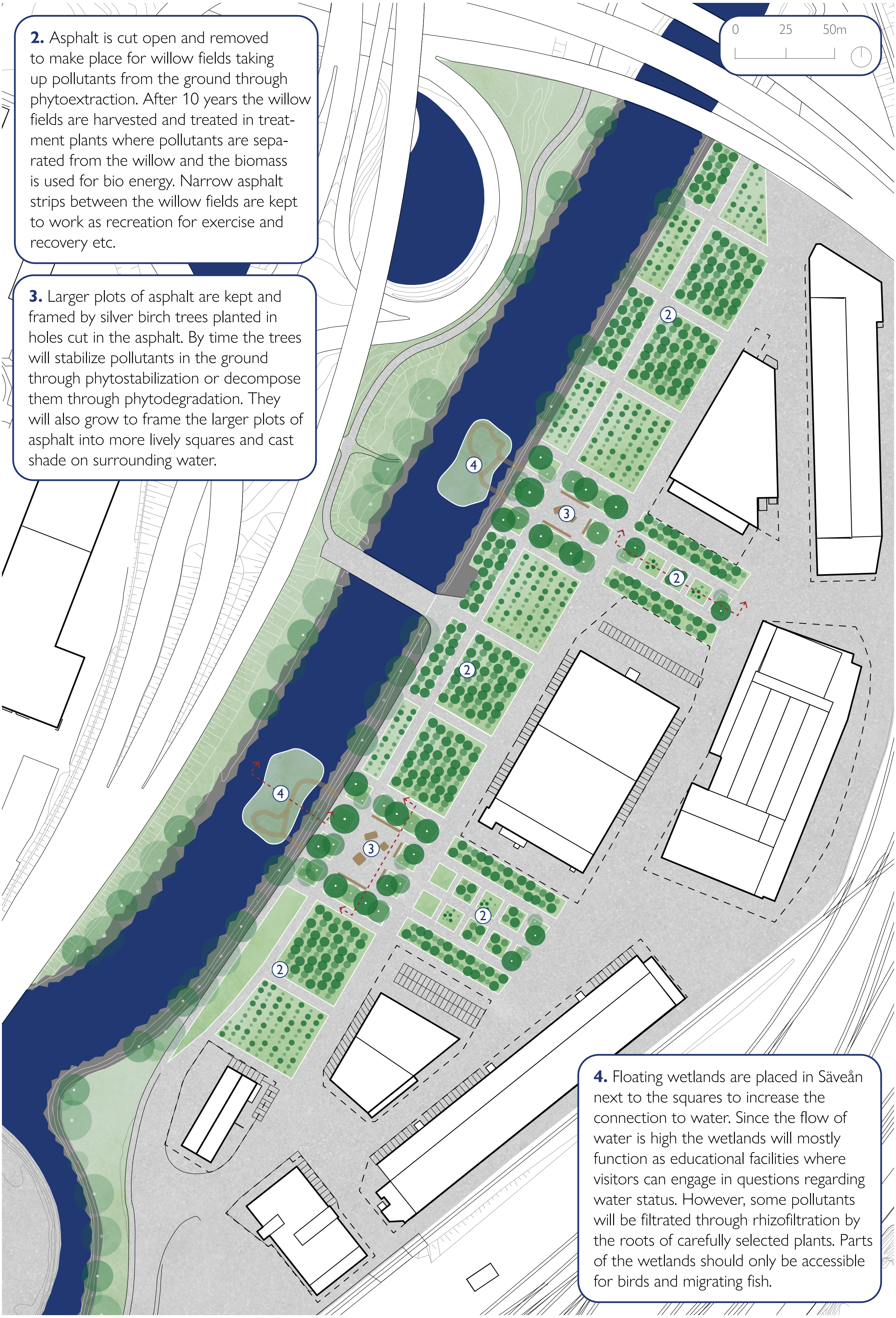
The visualisations that follow on the coming pages showcase one possible scenario of how the selected industrial area can gradually transform in three stages into a natural environment where water is allowed to occupy more space. The intention with a gradual transformation is to investigate how small place-making interventions in the long term can transform the whole area to contribute to better water status on a strategic level. If the project was implemented, this would also increase the possibility for participatory design as decisions and upkeeping of interventions would have to be taken care of at a detailed community based level.

To be able to in a clear way represent the previously developed design principles and the spatial qualities of them only the area around Partihallarna is developed further. Marieholm could be elaborated in the same way since both areas obtain similar qualities based on previous site analysis.

Explanations of ideas for the different stages are based on previous research presented in the thesis, especially in the design strategies.

2. Asphalt is cut open and removed to make place for willow fields taking up pollutants from the ground through phytoextraction. After 10 years the willow fields are harvested and treated in treatment plants where pollutants are separated from the willow and the biomass is used for bio energy. Narrow asphalt strips between the willow fields are kept to work as recreation for exercise and recovery etc.

3. Larger plots of asphalt are kept and framed by silver birch trees planted in holes cut in the asphalt. By time the trees will stabilize pollutants in the ground through phytostabilization or decompose them through phytodegradation. They will also grow to frame the larger plots of asphalt into more lively squares and cast shade on surrounding water.



4. Floating wetlands are placed in Säveån next to the squares to increase the connection to water. Since the flow of water is high the wetlands will mostly function as educational facilities where visitors can engage in questions regarding water status. However, some pollutants will be filtrated through rhizofiltration by the roots of carefully selected plants. Parts of the wetlands should only be accessible for birds and migrating fish.

figure 64: Stage 2 of spatial transformation

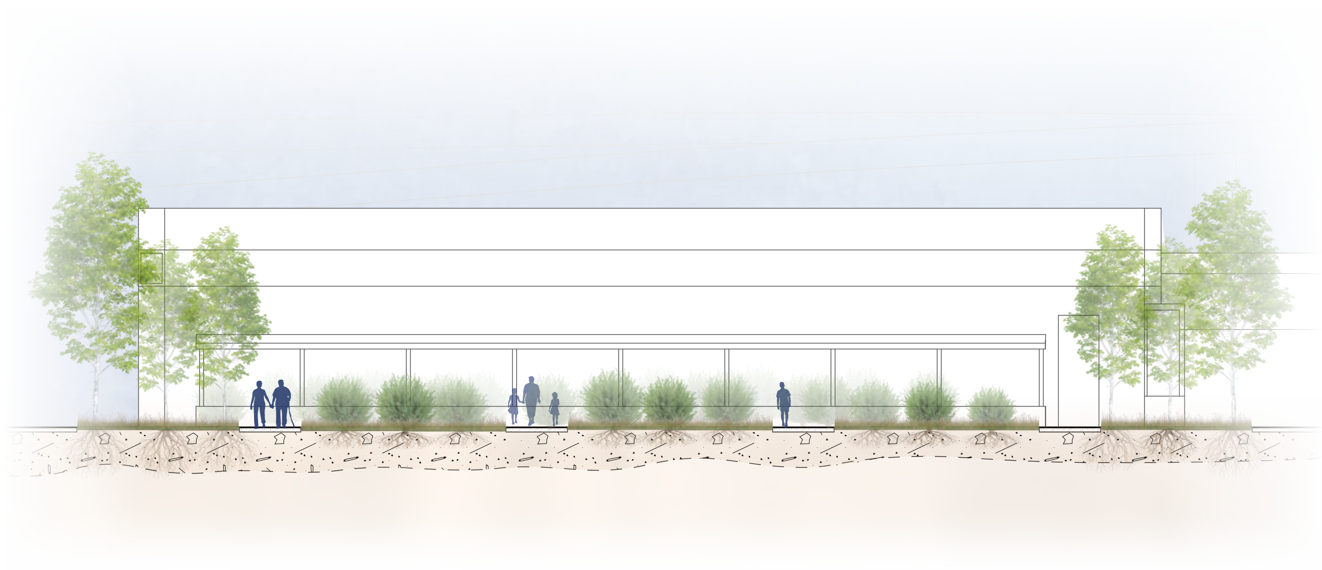


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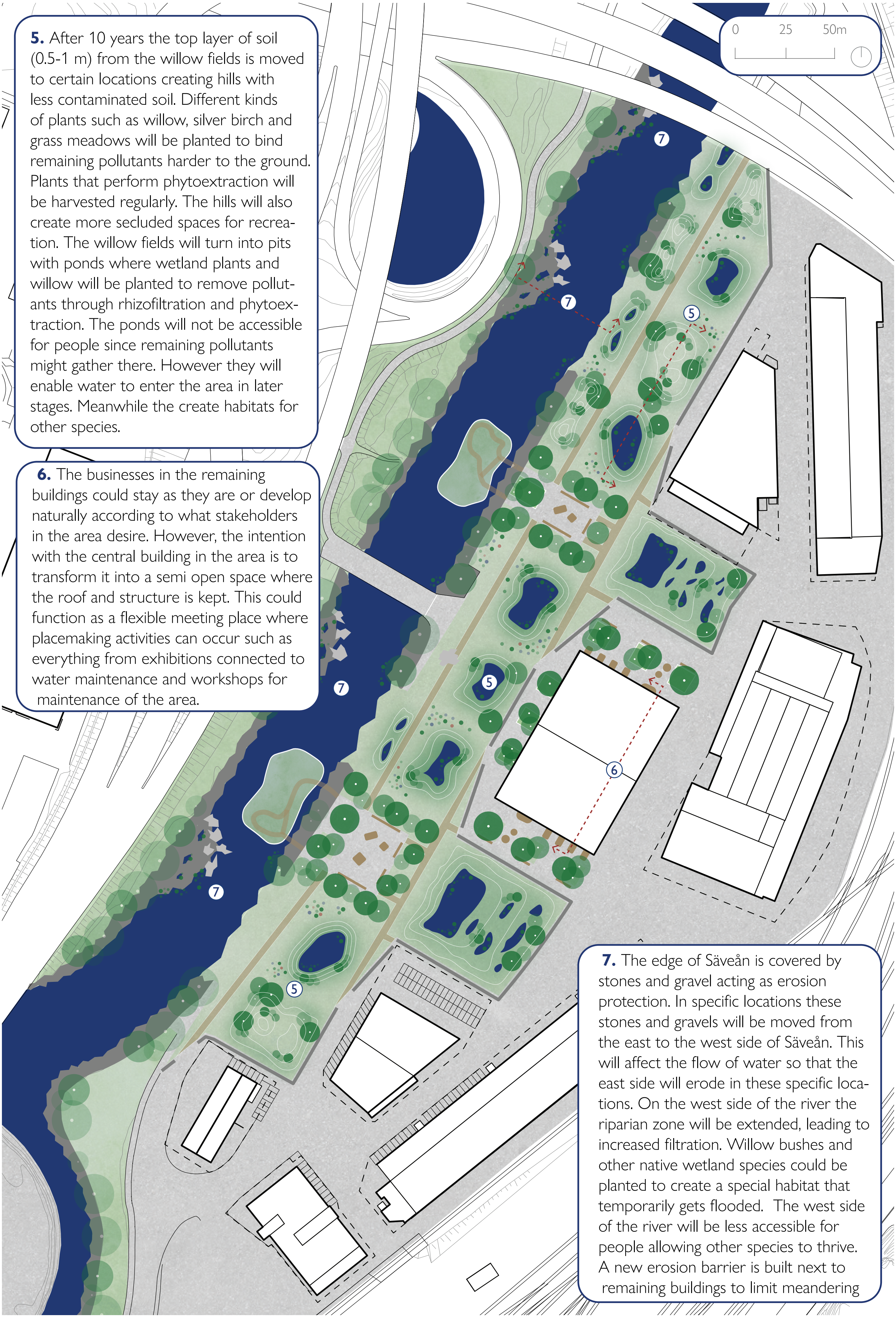
figure 65: Examples of spaces created for synergies between cultural and regulating ecosystem services in stage 2



5. After 10 years the top layer of soil (0.5-1 m) from the willow fields is moved to certain locations creating hills with less contaminated soil. Different kinds of plants such as willow, silver birch and grass meadows will be planted to bind remaining pollutants harder to the ground. Plants that perform phytoextraction will be harvested regularly. The hills will also create more secluded spaces for recreation. The willow fields will turn into pits with ponds where wetland plants and willow will be planted to remove pollutants through rhizofiltration and phytoextraction. The ponds will not be accessible for people since remaining pollutants might gather there. However they will enable water to enter the area in later stages. Meanwhile the create habitats for other species.

6. The businesses in the remaining buildings could stay as they are or develop naturally according to what stakeholders in the area desire. However, the intention with the central building in the area is to transform it into a semi open space where the roof and structure is kept. This could function as a flexible meeting place where placemaking activities can occur such as everything from exhibitions connected to water maintenance and workshops for maintenance of the area.

7. The edge of Säveån is covered by stones and gravel acting as erosion protection. In specific locations these stones and gravels will be moved from the east to the west side of Säveån. This will affect the flow of water so that the east side will erode in these specific locations. On the west side of the river the riparian zone will be extended, leading to increased filtration. Willow bushes and other native wetland species could be planted to create a special habitat that temporarily gets flooded. The west side of the river will be less accessible for people allowing other species to thrive. A new erosion barrier is built next to remaining buildings to limit meandering

figure 66: Stage 3 of spatial transformation

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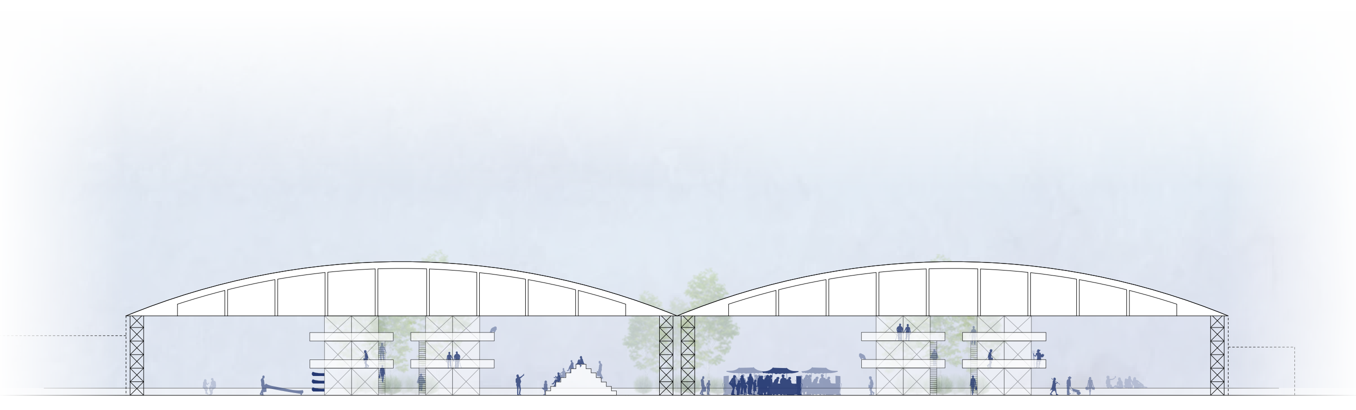

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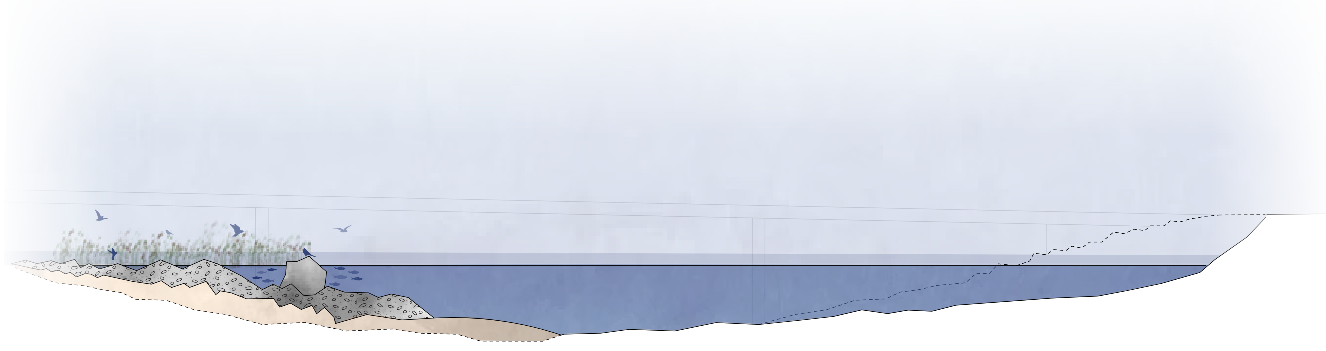

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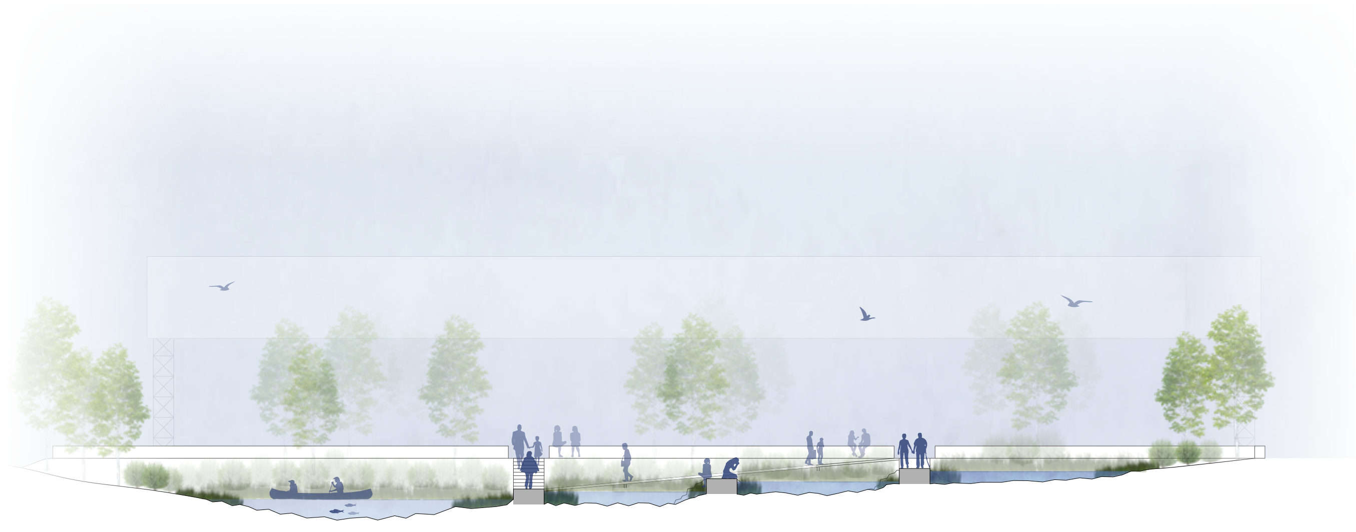
figure 67: Examples of spaces created for synergies between cultural and regulating ecosystem services in stage 3

8. Previously cleaned soil under former parking lots is turned into a two storm water pond system which are placed at low points where water naturally gather. In this system storm water is meandering through there different levels of oblong ponds where pollutants sediment and get filtered by carefully selected wetland plants. Between the ponds sand and gravel banks are placed to increase filtration. In total the ponds would occupy around 2500 m^2 which means they could clean run off water from an area of around 1-2 times the current area of Partihallarna (0.125–0.25km^2). Since big parts of the area will be green filtration of storm water will occur naturally and storm water from neighbouring areas could be led to these ponds instead. The facilities will be equipped with board walks for recreation where people can engage in natural cleaning processes and learn about storm water management.

9. On the east side of Säveån a similar pond and ditch system is implemented. Next to the highway an additional side ditch is excavated. It works as initial sedimentation and filtration of heavily polluted water from traffic leading to a system of more natural looking storm water ponds. Due to gradual expansion of the riparian zone towards the highway the width should be sufficient for a cleaning process. This side of Säveån is left more unkept and less accessible for people to provide other animals with secluded spaces.

10. In the final stage Säveån has started to meander and create secondary channels that can improve possibilities for cultural ecosystem services. Since the project is more strategic and about how the transformation from industry to wetland park could happen it has not been possible to look into exact details of what this should be. However, some examples are that people can swim in still water. Parts of the riparian zone can be developed into beaches. And the side channels can be perfect for canoeing.

figure 68: Stage 4 of spatial transformation



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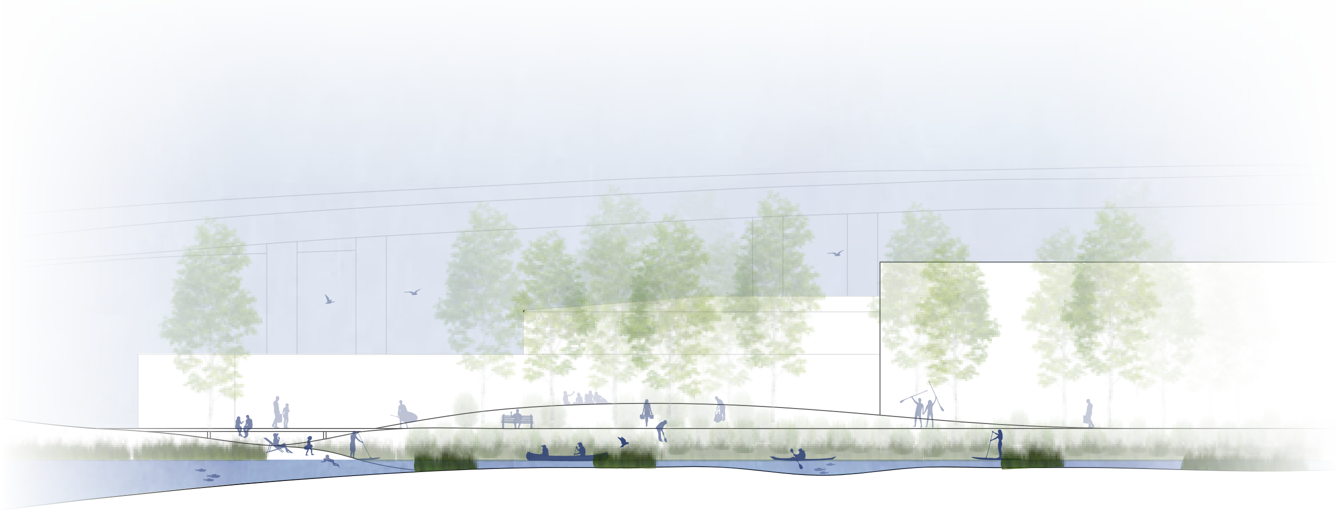

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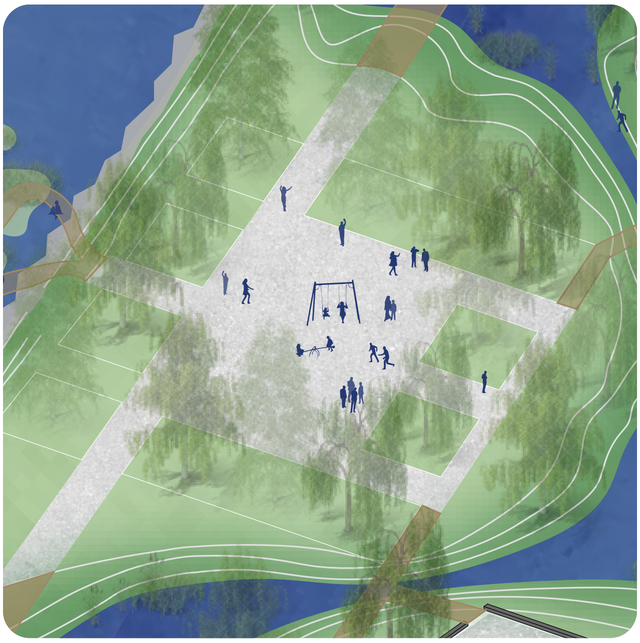
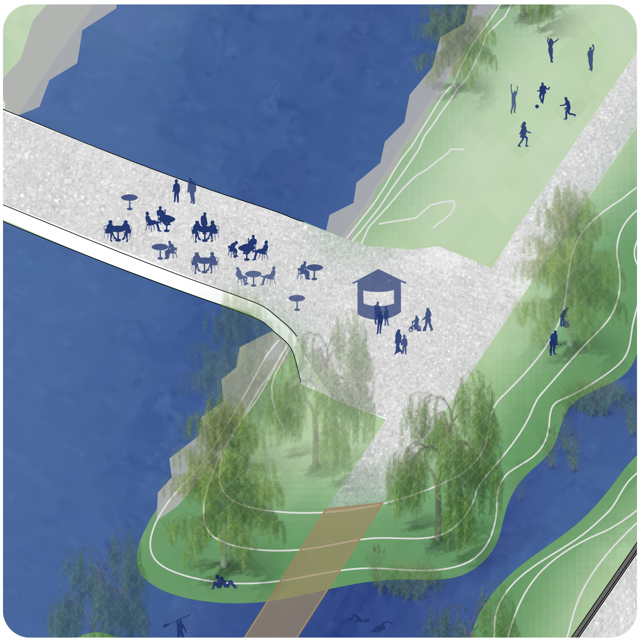
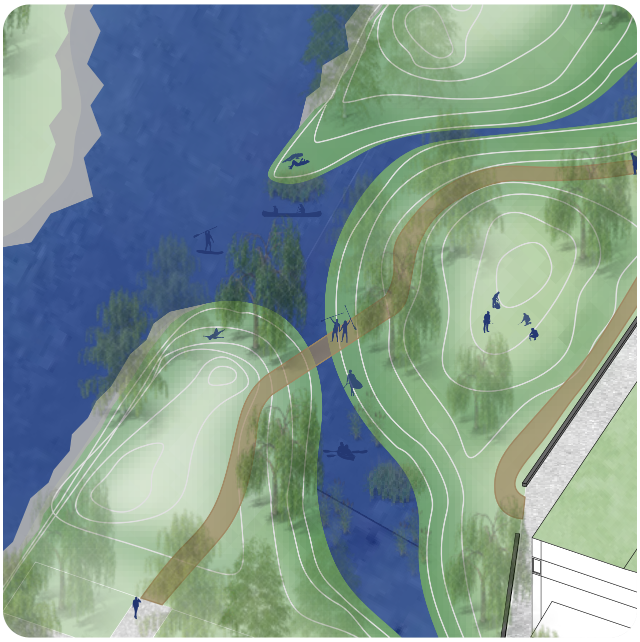
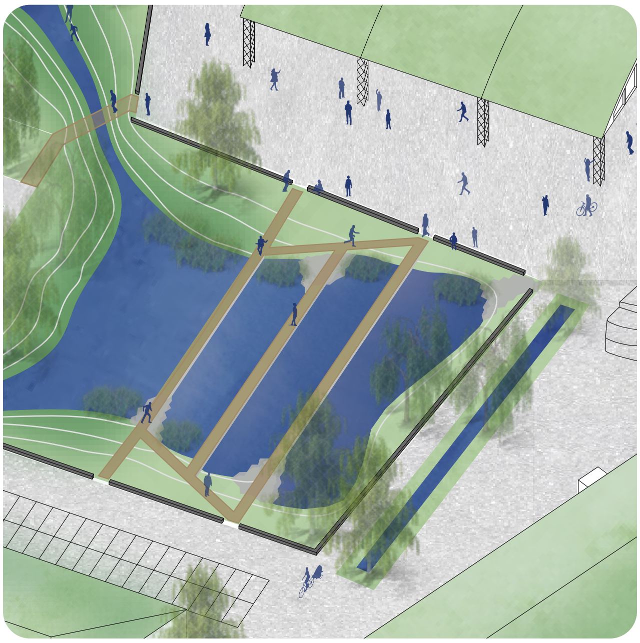
figure 69: Examples of spaces created for synergies between cultural and regulating ecosystem services in stage 4

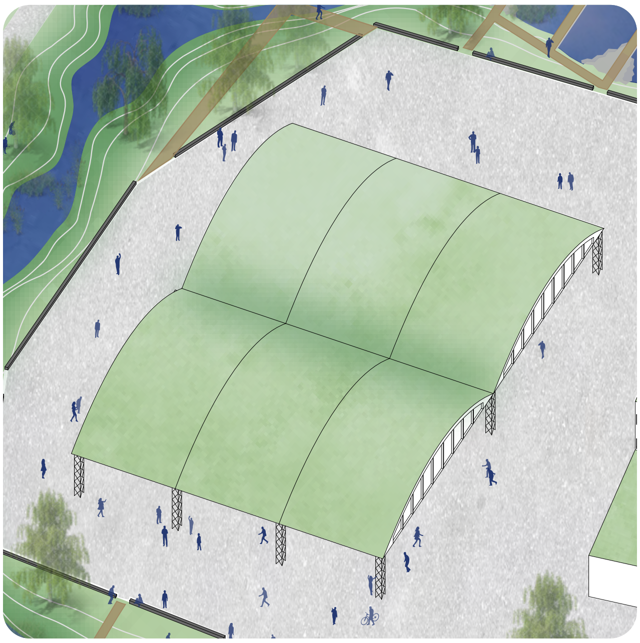
figure 70: Possible future scenario after all stages of spatial transformation





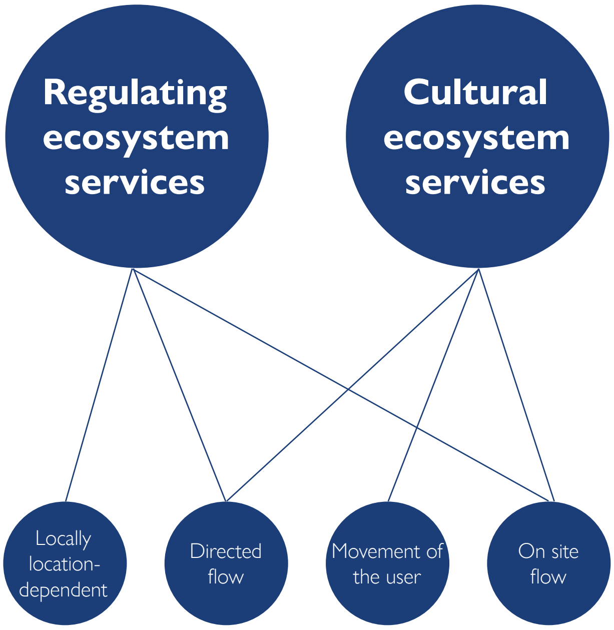






ANALYSIS & DISCUSSION

DISCUSSION ON IMPACT OF ECO-SYSTEM SERVICES



Cultural ecosystem services

To evaluate how cultural ecosystem services and ecosystem service flows, especially connected to movement of the user, could be affected by the project space syntax analysis have been used. As identified in the site analysis the reach from housing units to Säveån is quite good as it is today. The problem is that there is only one formal park along to whole watercourse, leading to a lack of recreational spaces next to water where regulating and cultural ecosystem services can be combined. Because of this access to parks next to water have been analysed.

The first analysis (figure 71) shows current distances while the second one (figure 72) shows access to parks if only the suggested transformation in this project would occur. As seen in the analysis this would have impact on access to parks next to water, especially for housing units to the south in Bagaregården. However, if at the same time as the phases of the project develop new connections to and from the area would be added access would increase drastically (see figure 72). That would increase movement of the user and in that way make the on site flows of cultural ecosystem services more accessible.

This emphasizes the importance of a holistic approach to urban planning to find synergies between different projects.

Lastly, the project is still on a quite strategic level which means that before implementing it specific details would have to be elaborated more. This would showcase further how the design principles that are mostly related to regulating ecosystem services could be made accessible for people in different ways and in that way also turn into cultural ecosystem services.

Regulating ecosystem services

The spatial relations of the regulating ecosystem services in the design could for example be the reduced heat island effect in water and on land because of greenery (locally location dependent), the reduction of pollutants reaching Göta älv and the sea (directed flow) and the pleasant micro climate that is created on site both for people and animals (on site flow). To evaluate the regulating ecosystem services further it is interesting to look at how well the design principles have been implemented in the project.

The capacity of wetlands to clean water are high, however as presented in the site analysis it would need to occupy quite large areas to reduce levels of pollutants enough. Even though some wetland like spaces, both natural and artificial, are created these are quite limited. They would reduce some pollutants but the real potential of the spaces might instead be to work as educational facilities to spread knowledge and influence other stakeholders to implement wetlands elsewhere.

The riparian zone in the area has been extended to have a functional width of over 15 meters (Viss, 2016). This does not necessarily mean that it would reach its full capacity of filtering pollutant and shading the water curse. In a continuation of the project it would be important to evaluate on a detailed level which plants should be placed where and how the difference in terrain level should be bridged to shade, filter pollutants and create zones that are temporarily flooded in the most efficient way.

As presented in stage 3 of the design the storm water ponds in the area would be big enough to clean the storm water form a larger area than the area itself and the entrances to these pond systems are placed at low points. This means the potential cleaning capacity is high if the right plants and filtration banks are added at the same time as how water should be lead there from neighbouring areas is elaborated further.

For habitat management the design mostly focuses on how the flow of water could be changed to allow for natural erosion creating tributaries. Of course, this should be done by adding the right biological material in close collaboration with geotechnical engineers to archive the desired result. In this stage of the project there is also uncertainty of the time perspective and exactly how man-made excavations could help the natural erosion which should also be elaborated further.

Phytoremediation is the most elaborated design strategy in the proposal and the potential of the it to work could be considered high, especially if willow is used extensively. However, the exact number of pollutants in and around the area is uncertain and it should be tested before implementing the project to see in which part of the area what type of phytoremediation should be prioritized. Additionally further research on phytoremediation in practice but also how the plant material (that is not willow) should be taken care of when harvested is needed (Greger, digital interview, 24 April 2025). There is also a risk that if the phytoremediation is not working as planned pollutants that are bound to the ground might spread when water is entering the area. Lastly, according to Swedish law it would be problematic to move polluted soil within the area which might have to be done in order for roots to reach pollutants further down, making the use of phytoremediation in urban development difficult (Karlsson, in-interview, 10 April 2025).

Need for further social ecological processes

To analyse the impact of how the regulating ecosystem services in the project affect water quality in a correct way the interdisciplinary of the project would have to be taken further. As supported but the theoretical framework around social ecological urbanism and actor network theory it would be beneficial for similar projects in the future to start by building up a network of architects/planners, ecologists, limnologists, geotechnical engineers etc. that could work in close collaboration. In that way the potential of ecosystem services can be divided between each discipline based on their expertise. The role of the architect could be to look at the project from a holistic point of view to creatively combine the insights from other expertise and in that way combine cultural and regulating ecosystem services.

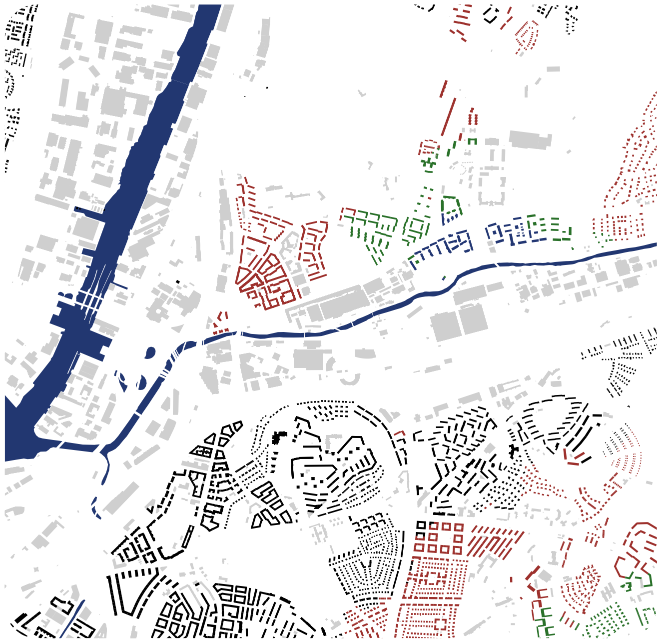


figure 71: Distance from housing to parks next to water before project

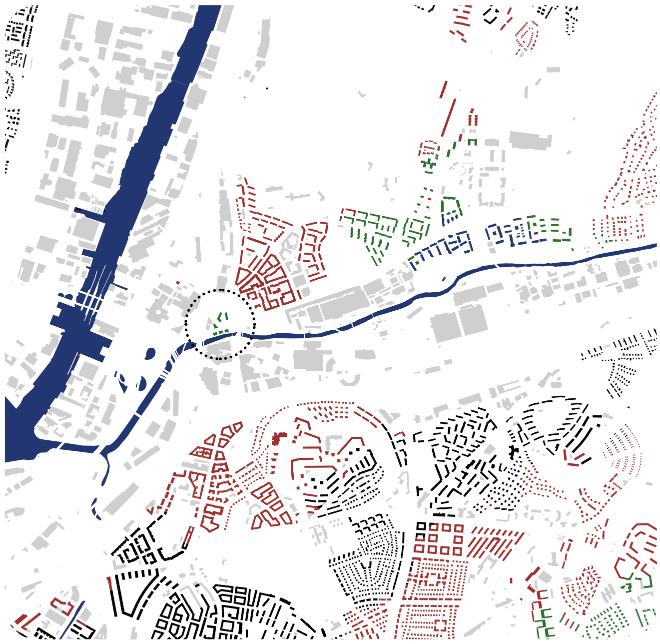


figure 72: Distance from housing to parks next to water after project

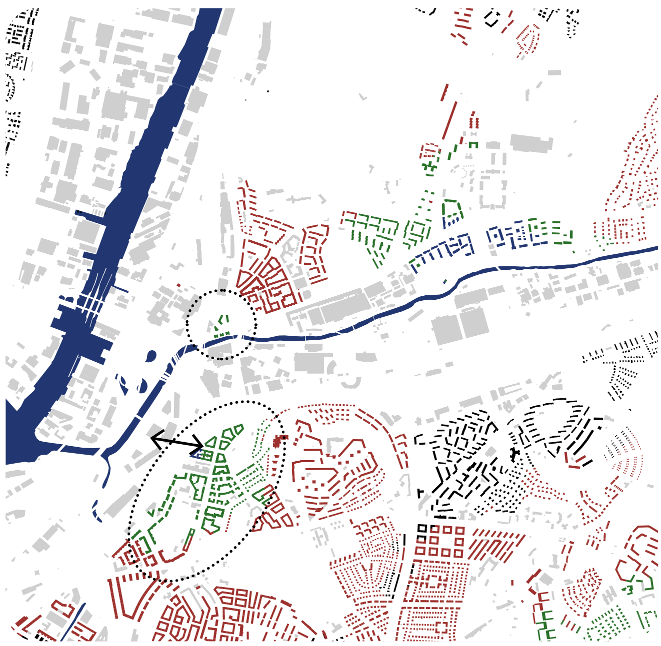


figure 73:Distance from housing to parks next to water after project with new pedestrian connection to the south

Dictance in meters
0-500
500-1000
1000-2000
< 2000

Other buildings
Most impacted areas
New pedestrain connection

FURTHER DISCUSSION

Need for comprehensive waterscape planning

In order to improve the status of our watercourses, more comprehensive efforts are needed beyond isolated measures in urban environments. This becomes evident when reviewing the proposed actions from WISS (Länsstyrelsernas WebbGIS, 2024). Similar financial incentives, such as the Swedish Board of Agriculture's support for farmers to implement protection zones on agricultural land, (Jordbruksverket, 2025) could be a solution to better balance the costs of measures aimed at reducing the impact on watercourses between rural and urban areas. While this has not been thoroughly investigated in this work, it should be explored further to enable the most effective collaboration between urban and rural sectors.

Even at the urban scale watercourses should be addressed at a more strategic level, as exemplified by the City of Gothenburg in the report Göteborgs stads åtgärdsplan för god vattenstatus (Göteborgs stad 2023). In this project, a brief overall study was conducted on how the remaining parts of Säveån within Gothenburg Municipality could be developed to contribute to improved water quality, illustrating how this issue needs to be addressed on a larger scale (figure 74). The study was primarily carried out through site visits, analyses in the software Scalgo Live, and based on the regional mapping and design principles. During the site visits, a general assessment was made of Säveån's accessibility for people and where the riparian zone would need development. The Scalgo analyses were used at an overview level to identify low-lying areas that could be transformed into wetlands, as described in the webinar naturrestaurering (Scalgo, n.d-a), and steeper sections of Säveån where re-meandering might be possible, according to the video River Restoration (Scalgo, n.d.-b). This part of the project should be further developed so that the City of Gothenburg can do as much as possible to improve the water quality in Säveån River and reduce the outflow of pollutants and nutrients into Göta älv and the sea.

Site specific participatory design

As described earlier in the thesis participatory processes would be crucial for the implementation of the project. Both to involve existing business and stakeholders in the area but also to engage citizens in how to develop and maintain the urban environment to improve water status. In the project participatory elements have been left on a more strategic level and the design proposal is developed to allow for placemaking which in turn could help involving different actors. However, if the project would be realized a more thorough mapping of actors connected to the project should be carried out. This will help understanding existing flows and in what phase/phases different actors can contribute and in what way. Making theses detailed and site-specific design choices in close collaboration with the local community will hopefully create a sense of ownership that can enhance the accessibility and quality of cultural but also regulating ecosystem services connected to the project

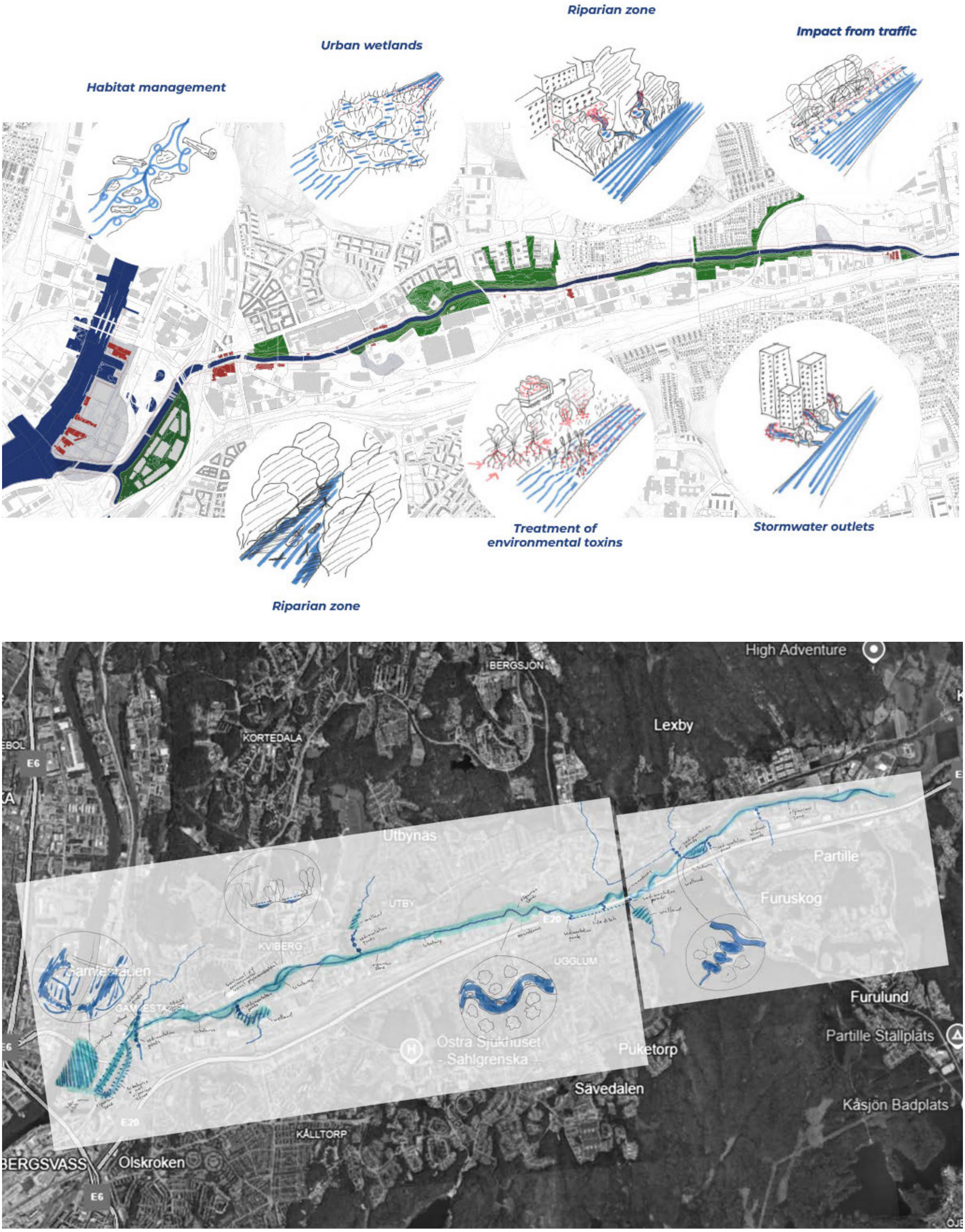


figure 74: Outcome of brief overall study on remaining parts of Säveån

QUESTIONS FOR FURTHER RESEARCH

- How can stakeholders in urban environments work together with stakeholders in rural environments to develop regional waterscapes that improve water status and accessibility to recreational spaces next to water both in urban and rural environments?

- What financial incentives are needed to change the landscape to improve water quality, and how should it be financed?

- How can the design principles in the project be applied on an even broader strategic level to reshape entire water courses in urban environments (ex. Säveån in Gothenburg)

- What laws (ex. around contaminated soil) exists that affect the possibility for the project to be implemented and should they be revised to allow for projects like this to be implemented in the future?

- How much of the reshaping of a watercourse can be done naturally and in what extent is human impact needed?

- What actors exists and how should they be part of a strategic participatory design process to transform urban environments/industrial areas next to water to improve water status?

- What does site specific details that combines regulating and cultural ecosystem services look like looking beyond a strategic level?

CLOSING WORDS

This project is an attempt of looking beyond a traditional architectural project. Even though the approach is very general and strategic it is supposed to inspire and open for further discussions and research on similar social ecological processes.

The main takeaways of the project is firstly that for similar projects to work, especially in reality, it is important to build up a stable network of actors and experts in different fields to continuing the work of developing methods for how this collaboration could work. Secondly it has become clear that when working with ecological processes just as spatial processes it is important to understand how one specific site is part of a complex network and trends in society.

This means one project can't solve it all, however by working on multiple scales and understanding the relation between theses scales it will be easier to generate several solutions that might help us reinventing waterscapes.

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Thank you for reading my thesis!

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UNIVERSITY OF TECHNOLOGY

Reinventing waterscapes
Master’s thesis 2025
Fredrik Olausson