Ecological restoration of Hoffselva river outlet

A term paper in ECOL350 Restoration Ecology

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Figure 1: Bestumkilen (1936). Photo: Anders B. Wilse.

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Abstract

The Oslofjord is in a poor ecological condition due to human activities such as pollution and changes in land use. River deltas are vital wetland ecosystems, as the meeting point of a river and a fjord creates a unique environment characterized by rich diversity of species and nature types. They are threatened and degraded both globally and in Norway. None of the rivers that flow into the inner Oslofjord currently possess a functional river delta.

This restoration report explores and reveals the potential that lies in releasing the river outlet of Hoffselva and establishing a better connection with its natural elements. The current outlet is extensively affected, predominantly comprising of vast asphalt surfaces and use as a leisure boat marina. As a result, the river's natural flow is restricted, with its course dictated by rigid surfaces. The restoration efforts will involve intricate work in the transitional zone between freshwater and saltwater, encompassing the tidal zone and its adjacent areas.

The restoration work encompasses a range of objectives to revitalize the ecological condition of Hoffselva's river outlet. These objectives involve removing physical disturbances, such as the marina and invasive species, to restore the natural state of the river outlet. Additionally, the project aims to unlock tidal flushing in the river delta and establish vital habitats, including vegetation buffers, wetlands, and eelgrass meadows. Integration of public access structures is also considered, promoting engagement and appreciation of the restored ecosystem.

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Mission statement

Our mission is to restore the river delta of Hoffselva, reclaiming threatened nature types in the inner Oslofjord, utilizing the principles of restoration ecology. While complete restoration may not be achievable, our project aims to recover crucial ecological processes and functions, offering significant recreational and public benefits. By integrating the new river outlet into Oslo's blue-green infrastructure, we strive to create a harmonious balance between ecological restoration and sustainable urban development. Through restoring the river delta, we unlock natural processes, improve water quality, enhance biodiversity, and demonstrate the power of ecological restoration in revitalizing urban ecosystems. Through community engagement, low-impact recreation, and public access, we create a sustainable and vibrant ecological gem.

Introduction

Nature is rapidly disappearing due to changes in land use, and land degradation and exploitation of natural resources are a threat to ecosystems and habitats all over the world (IPBES, 2018). In Norway, change in land use is the largest threat to 89 percent of the over 2700 threatened red-listed species (Miljødirektoratet, 2023). The United Nations (UN) has designated 2021-2030 to be the Decade on Ecosystem Restoration (UNEP, FAO, 2020). There is a need to restore more degraded nature both on land and in water. In December 2022, the Norwegian government signed the global biodiversity agreement at the UN Biodiversity Conference (COP15) in Montreal, Canada. The agreement pleads for the conservation of at least 30 percent of the world's areas on land and water, and a restoration of 30 percent of degraded areas (Convention on Biological Diversity, 2022).

Importance of wetlands

Roughly 10 percent of Norway's land area consists of wetlands (Miljødirektoratet, 2020). Wetlands are of high national importance due to their high biodiversity, primary production, and their ability to store large amounts of carbon. The high variation in nutrients and water levels creates varied habitats for many plant and animal species. Internationally, 40 percent of all plant and animal species and 30 percent of fish species are dependent on wetlands (Ramsar Convention on Wetlands, 2018).

30 percent of all previously identified river deltas in Norway have disappeared due to climate change, pollution, and human degradation, making it one of the most degraded types of wetlands in Norway (Miljødirektoratet, 2020). Deltas are a land formation that was classified as vulnerable on the Norwegian Biodiversity Information Centre's (nor.: Artsdatabanken) red list for threatened nature types in 2018 (Erikstad, 2018). This classification was based on their total area and the adverse impact of abiotic factors leading to their deterioration. Brackish water deltas are wetland areas where freshwater and saltwater mix to varying degrees, resulting in brackish water.

Deltas are not a singular, independent nature type, but a landscape element including a variety of nature types. Among these, we can find mudflats, salt meadows, and beach swamp woodlands, where the last two are classified as vulnerable (VU) and near threatened (NT) (Artsdatabanken, 2018a). In February 2023, river deltas were proposed to be protected by the Norwegian Environmental Agency (nor.: Miljødirektoratet) (Miljødirektoratet, 2023).

Need for restoration

The Oslofjord is in a serious situation, with a moderate ecological condition and a poor chemical state. Cod (*Gadus morhua*) populations are at all-time low and marine ecosystems are regressing (Klima- og miljødepartementet, 2021). Oslo has ten major rivers, nine of them with outlets into the Oslofjord. None of them has an intact delta (see Figure 2). The ongoing plans for the development of Skøyen district have large parts of the delta planned for high-rise development (Plan- og bygningsetaten, 2023). To mitigate the challenges of the fjord, as well as providing a restorative alternative to the planned development, we wish to propose a restoration plan to improve the ecological conditions and restore the functions of the degraded river delta in Bestumkilen, Oslo.

Figure 2: Map showing existing outlets of rivers in inner Oslofjord. Size of icon is indicating whether the outlets are in channels (big circle) or in pipes (small circle).

Restoration goals

This restoration project cannot expect to restore Bestumkilen to its original state, as decades of urban development, climate change, and pollution have altered the conditions of the river outlet. However, restoration measures can help recover some of the lost processes and functions. Additionally, the restoration will provide significant recreational and public benefits. Bestumkilen is highly suitable for integration into Oslo's blue-green infrastructure. The restoration goals can be divided into ecological and social/cultural goals and are listed below, together with the objectives. The specific objectives are thoroughly detailed under *Implementation of restoration activities*, providing a comprehensive outline of the goals to be achieved.

Ecological goals

- Restore the structures and habitats of a river delta
- Unlock natural processes and functions
- Improve water quality
- Increase biodiversity

Social and cultural goals

- Involve the local community to encourage stewardship
- Integrate access to low-impact recreational and educational opportunities
- Provide Oslo with a new public green space

Objectives

1. Remove physical disturbances, including the marina and invasive species
2. Recreate topography referencing the historic state of the river outlet
3. Unlock tidal flushing of the river delta
4. Establish vegetation as a buffer towards the river and sea (Zone 1)
5. Establish wetland habitats in the intertidal zone (Zone 2)
6. Establish eelgrass and seaweed meadows (Zone 3)
7. Integrate structures for public access

Background

Site description and location

Bestumkilen and Hoffselva river

The restoration site on the western side of Oslo is commonly known as Bestumkilen and serves as the outlet for the river Hoffselva. Stretching 10,1 km in length, Hoffselva consists of several tributaries that run from the hillside between Holmenkollen and Vettakollen. The areas along the river streams are highly urbanized, but a vegetation belt with varying depth and diversity follows most of the riverbank. Hoffselva runs through Skøyen, where it is funneled through a culvert underneath the railroad and E18 (Nie, 2011). The river connects to the fjord in a channeled outlet in the small-boat harbor of Sjølyst Marina.

Surrounding area

Bestumkilen is situated between the Bygdøy peninsula to the south-east and the urban district of Skøyen to the north (see Figure 3). The presence of major infrastructure, such as E18 and the railroad, creates a barrier separating the river outlet from the densely populated urban surroundings. Bygdøy is a partly protected popular recreational area (Forskrift om Bygdøy kulturmiljø, 2012), that also provides diverse habitats for numerous species. On the eastern side of Bestumkilen, an important calcareous forest exists, which benefits from protection within the Prinsesseåsen Nature Reserve (Miljødirektoratet, n.d. a).

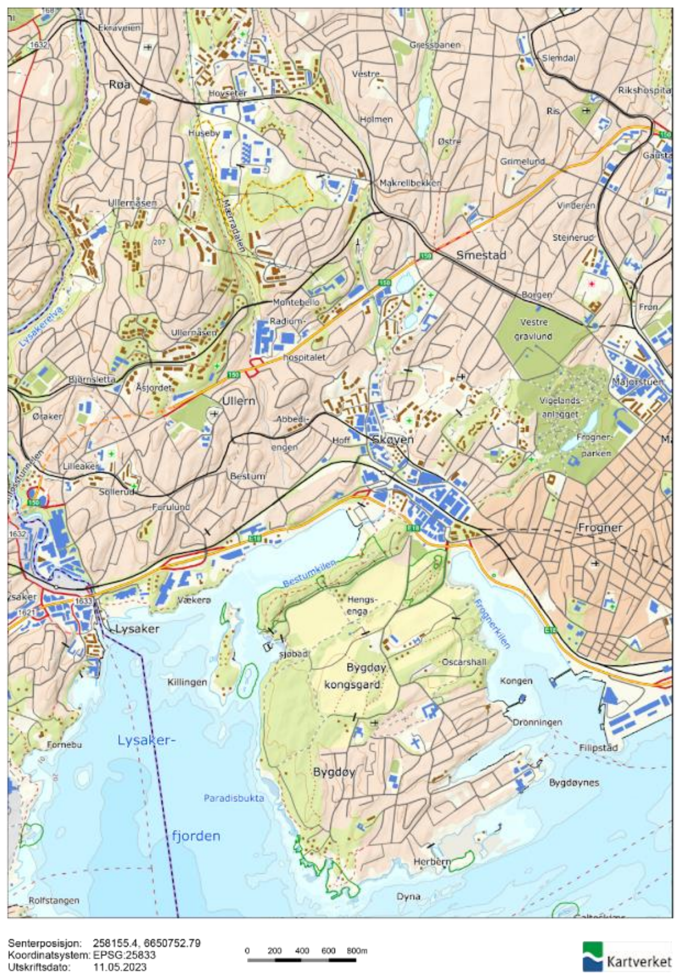

Figure 3: Map illustrating the location of Bestumkilen and the river outlet of Hoffselva, situated between Bygdøy to the southeast and Skøyen to the north.

Historical development

Due to long term urbanization and harbor activity the natural premises of the river landscape have changed drastically. By comparing aerial photos from almost a century back the gradual change of the river delta and wetland is revealed (see Figure 4). In the 1930s, the surroundings of the delta comprised wetlands and agricultural land, with the development of a harbor for small boats underway. Presently, the area has been transformed into a channeled space, filled with asphalted surfaces serving as storage space for leisure boats. This process of land filling has occurred gradually over time, with the most recent filling occurring along the north side of Bygdøy in the early 1980s.

Figure 4: Aerial photos showing where the river Hoffselva is meeting Bestumkilen in 1937 (top left), 1947 (top right), 1980 (bottom left) and 2022 (bottom right). Photo: https://kart.finn.no

Current ecological state

Bestumkilen is an area of brackish water, where the freshwater from Hoffselva meets saltwater from the Oslofjord. From nature mapping done by the Norwegian Environmental Agency, there are areas of interest in Bestumkilen in the brackish waters that were classified as a mudflat in 1994 (Miljødirektoratet, n.d. a). Mudflats are some of the most species-rich habitats of shallow water and beaches. The soil is made of a fine substrate consisting of mud, clay, silt, and fine sand. Mudflats are generally not mapped well, but they are important areas for rare and vulnerable water and beach plants that do not tolerate competition (Direktoratet for naturforvaltning, 2007). Plants living here have a high seed production, which is an important nutritional basis for many animal species. Mudflats also serve as resting localities for migrating wading birds. Bestumkilen is currently under no protection management.

Pollution of the Oslofjord

The ecosystems of the inner Oslofjord are under severe stress, with physical conditions, overfishing, fertilization, environmental toxins, and climate change being identified as the biggest threats (Miljødirektoratet, 2019). The physical conditions consist of the man-made changes applied to the shoreline and fjord, including docks, fillings, dredging, change of fresh water supply, artificial beaches, and more. This changes the marine ecosystem and has had a negative effect on the biota (Miljødirektoratet, 2019). Several of these factors are present at Bestumkilen today and can be mitigated by restoration.

The overall plan for a clean and diverse Oslofjord details proposed measures against the three worst sources of pollution in the fjord: pollution from sewage, agricultural runoff, and reduction of toxic waste such as marine pollution and microplastics (Klima- og miljødepartementet, 2021, p. 12). In Bestumkilen there are sources of pollutants from the highway E18 and from Hoffselva, as well as from the fjord itself. Fish death in lower part Hoffselva has been present as a consequence of chemical spill from factories (Saltveit & Brabrand, 2009), and precipitation leads polluted water from E18 into Bestumkilen (Nie, 2011).

Flora and fauna

Bestumkilen and the surrounding coast is classified as nationally important spawning areas for cod (Havforskningsinstituttet, 2019). A great threat to spawning cod is climate change, as the species migrate further north when the oceans are getting warmer (Sandø, Johansen, Aglen, Stiansen, &

Renner, 2020). Because of this and the current ecological state of the Oslofjord, the cod's spawning habitats are becoming scarcer. Implementing management measures in areas such as Bestumkilen can be crucial to secure a healthy future population.

Bestumkilen is frequently visited by common murre (*Uria aalge*), a sea bird native to Norway (Bergan & Andersen, 2007). Recorded sightings date back to 1996 (Artsobservasjoner, 2019). It usually breeds in large colonies in mountains along the coastline of Northern Norway and uses the Oslofjord as a resting place while migrating back and forth to its breeding habitats. It is classified as critically endangered (CR) as oil spills, pollution, human activity, and climate change severely alter its distribution. Food resources are becoming scarcer in the Northern Sea as the water temperatures rise, and the common murre escapes starvation by migrating. Strong winds draw the birds into the fjords, where they either must find new food resources or they die. Individuals have been found dead in Bestumkilen (Stokke, et al., 2021).

Black-headed gull (*Chroicocephalus ridibundus*) is classified as critically endangered (CR) in Norway and has had a steep decline since the late 1980s (Artsdatabanken, 2021). This species has a low breeding success rate of 20 percent and is frequently disturbed by humans during this period (Artsdatabanken, 2021). They are breeding in the Oslofjord, which makes this habitat important for the future distribution of the species (Bergan & Andersen, 2007).

On the outskirts of Bestumkilen, there are spots of eelgrass (*Zostera spp.*). As a productive population, an eelgrass meadow can have a primary production of 0.5-1.0 kg carbon per square meter and year (Artsdatabanken, n.d. b). As a habitat, they offer shelter for a high diversity of flora and fauna, with high speciation of different epiphytes and animals, mostly fish and birds. The meadows function as hiding spots, spawning areas, and food source for fish fry, and is important food for birds. A high density of eelgrass reduces water movement, binding sediments and substrates, and reduces the danger of erosion (Artsdatabanken, n.d. b). Eelgrass meadows are declining in the fjord (NIVA, 2022a),.

Invasive species found in Bestumkilen and the outlet of Hoffselva include turkish wartycabbage (*Bunias orientalis*), giant hogweed (*Heracleum mantegazzianum)*, and honey clover (*Melilotus albus*). These are all classified to have a high risk of both ecological effect and potential for dispersal (Artsdatabanken, 2018b), which means they can have great significance to our restoration proposal.

On the north side of Bygdøy there is a larger area of temperate deciduous forest and calcareous forest. This is a diverse and important biotope for the area. Kilingen is an island next to Bygdøy, partly protected by Kilingen Naturminne (Oslo Byleksikon, n.d.). It is an island where birds breed and should be managed in relation to a possible restoration of Bestumkilen and its delta. Both the island and a future delta could act as habitat patches and increase the landscape connectivity in the area. Invasive species are frequent inhabitants at the edges around highway E18 (Miljødirektoratet, n.d. a) which could serve as a threat to the species used for revegetation in the restoration project.

Land ownership and key stakeholders

The project site is on public property. The marina is on municipality-owned property, and the south-eastern parts are owned by the Norwegian State (see Figure 5). The boundaries of the project area belong either to the municipality or Statens vegvesen. The river passes through the property of several private landowners.

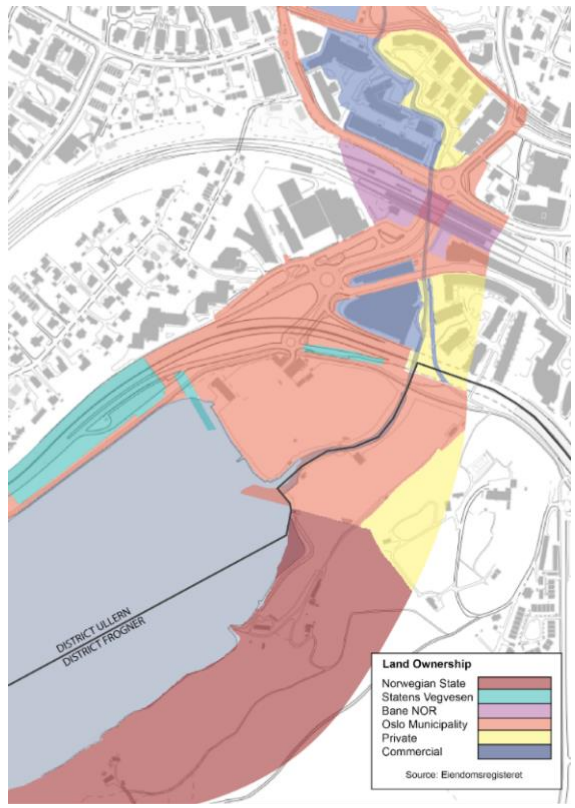

Figure 5: Map showing distribution of land ownership in the area of Hoffelva's outlet in Bestumkilen.

The site has many potential stakeholders, with different interests, influences, and narratives. A visual representation of the potential variation among stakeholders is shown in Figure 6. We hope to reduce potential conflicts, engage the community, and integrate the project goals into local decision-making. The stakeholders represent social, economic, and political factors, and include civil groups, private actors, government bodies, and landowners. Six key stakeholders have been identified.

From the municipality, Plan- og bygningsetaten as well as Bymiljøetaten are crucial to implement the plan and for long-term management. Sjølyst Marina is the main private actor in the project area. As they are already forced to relocate by the municipality due to the development of Skøyen, their conflicts with the restoration are not viewed as significant. The area also has several active civil groups. Hoffvassdragets venner is a driving force in the protection of the river and can be an asset for future restoration. With a social media following of 1800, the citizen park movement Bestumkilen på Skøyen - Oslos nye folkepark (n.d.) is led by District Ullern and involves upwards of 30 local organizations (Bestumkilen på Skøyen - Oslos nye folkepark, n.d.). They should also be included in the planning of the restoration.

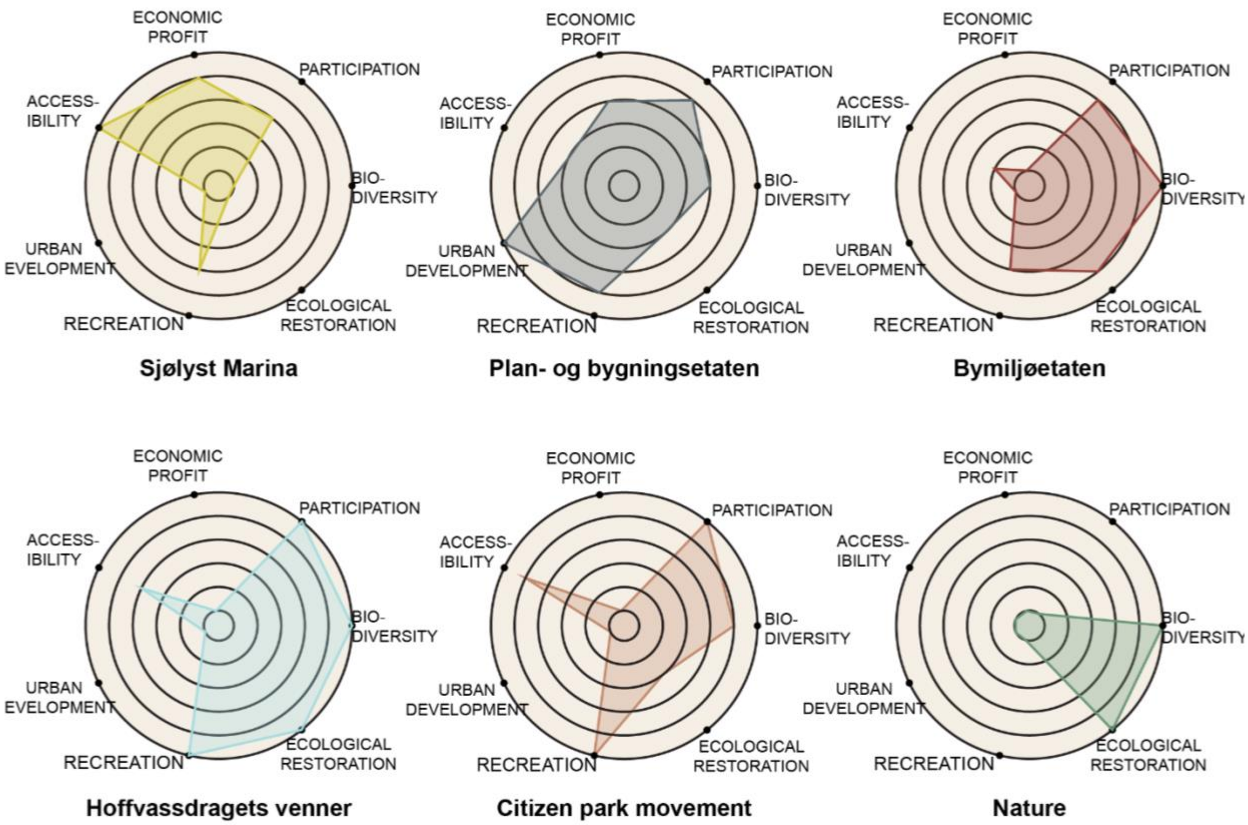

Figure 6: Visual representation illustrating potential variations in interests (recreation, urban development, accessibility, economic profit, participation, biodiversity and ecological restoration) among six key stakeholders.

Reference site: Existing river delta

The inner Oslofjord does not have an intact delta to use as an ecological reference site to compare ecological conditions. As a reference this report uses a mixture of historic photos (see Figure 1), scientific reports and general descriptions of the nature types we are aiming to restore. The Sandviksdelta has some qualities that we aim for, even though the outlet is largely channelized, it has some shallow mudflats by its outlet in the fjord. Further, we will look at the Aulidelta in Tønsberg as a reference.

Figure 7: Aerial photo of Aulidelta in Tønsberg. Source: Miljødirektoratet – Naturbase kart.

Aulielva meets Byfjorden (see Figure 7), and is Ramsar protected under the Ilene and Presterødkilen wetland system and the Ilene nature reserve (Miljødirektoratet, n.d. b). This is an important site with nature types which include brackish water delta, salt meadows, beach swamps, and eelgrass meadows with high biological diversity. In the Ilene nature reserve, it has been created a visiting center for wetlands to educate people with presence of trails and bird-watching tower (Besøkssenter våtmark Ilene, 2023b). Due to the location of the Aulidelta in the outer Oslofjord, it will have differences to an ecosystem in the inner Oslofjord. Although it is highly different from our site, the Aulidelta contains the nature types we want to restore and could be of great inspiration for Bestumkilen and proves that this could have a successful outcome.

Implementation of restoration activities

Objective 1: Removing disturbances

The first step of the restoration process is to remove the physical disturbances at the project site. This means the complete removal of the marina. On land, this includes buildings, asphalt, and equipment. In the fjord, the floating dock disrupts the planned vegetation of the seabed, preventing access to light. Coordination with landowners and the marina is essential. Invasive species must also be eradicated to prevent their dispersal into the restored zones.

The changes in land use from before and after the restoration work, including area estimates, is illustrated in Figure 8.

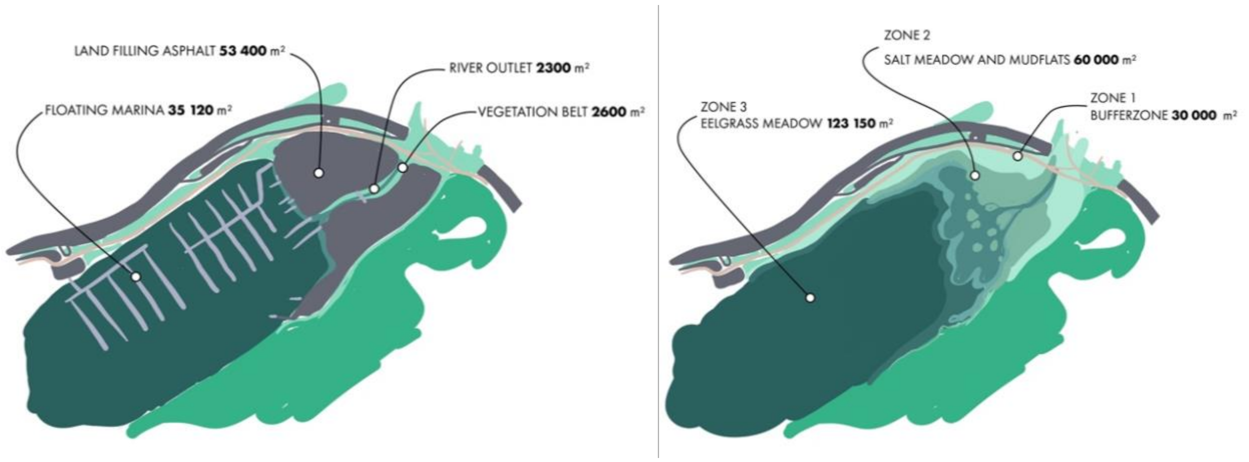

Figure 8: Sketches depicting the change in land use, from the current situation of boat marina and a channelized river outlet (on the left) to a river delta (on the right).

Objective 2: Altering topography and terrain

Large alterations of the terrain are needed before releasing the river from its channeled state. The existing topography is dominated by a landfill that has gradually evolved as the marina has expanded. Shaping of a new topography, water flow, soil, and sediments condition will affect how the river manages to establish itself as a functioning delta area.

The bedrock in the area around Bestumkilen and upstream consists of larger belts of slate and limestone, with top layers of sediments from the ocean and the fjord, and weathering after studying digital maps from the Geological Survey of Norway (NGU, n.d.). Natural geomorphological river processes such as sedimentation will be hard to restore due to dense urbanization. After the removal of non-permeable surfaces, the condition of existing masses must be evaluated. Depending on ground contamination, as much as possible of the existing masses should be reused in the project. Contaminated masses should be considered cleaned, preferably on-site. If a significant portion must be relocated due to high contamination, external resources will be needed. A pilot project in Fredrikstad may be used as a reference, where wetlands close to Glomma are being restored with sediments from dredging (Valvik, 2023).

Underwater, the goal is to make as few disturbances as needed. We know that the seabed has been altered due to the dredging of the harbor. The project *Ren Oslofjord* dredged the bottom of Bestumkilen with the goal of improving the environmental conditions of the fjord (Oslo Kommune, 2007). We hope that by removing the source of direct pollution and disturbance from the harbor it will have a positive effect.

Objective 3: Unlock tidal flushing of the river delta

The catalyzing step of the implementation will be to remove the constructed vertical edge between the sea and land, as it is the structure that prevents tidal flushing. Figure 9 illustrates the current situation and Figure 10 is our vision of the new tidal zone.

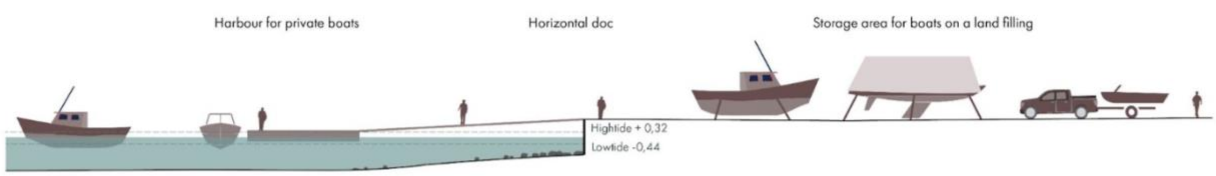

Figure 9: Existing situation showing the land filling disrupting the tidal zone.

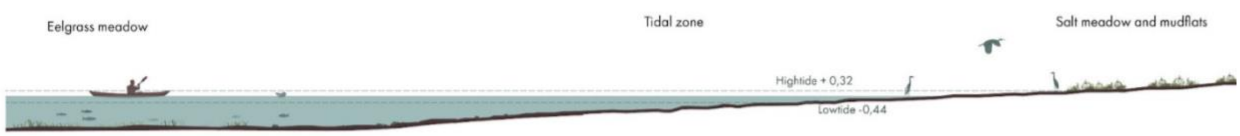

Figure 10: New situation allowing restoration of the tidal zone and river outlet.

Objective 4: Zone 1, Buffer zone - Calcareous forest and beach swamp woodland

The vegetation on land will function as a buffer zone between the urban disturbances and the littoral zone (see Figure 11). The main function is to filter and clean the water from surrounding pollutants, as well as water from Hoffselva. Runoff such as sediments and stormwater will be filtered through nature-based solutions. The vegetation is composed of local species and can withstand both drought and moisture. The composition includes a low vegetative layer, and taller mixes of reeds, bushes, and water-tolerant trees (Artsdatabanken, 2016). A mixture of open and dense areas will create variation in the landscape. The vegetative layers will act as a filter medium for pollutants and saltwater runoff from nearby roads.

On the eastern side of Bestumkilen, the existing calcareous forest will be expanded, and terrain will be used as a barrier and buffer between the road and the coastline. The trees will aid in decreasing noise pollution, improving air quality, reduce flooding and erosion (Sunding, Larsson, Tomter, & Dalen, 2023). Beach swamp woodland is a flood-resistant nature type due to its high abundance of common alder. Their root systems have plinths above the groundwater to increase access to oxygen. These plinths produce a network of tufts that prevent flooding by containing water (Artsdatabanken, 2023b).

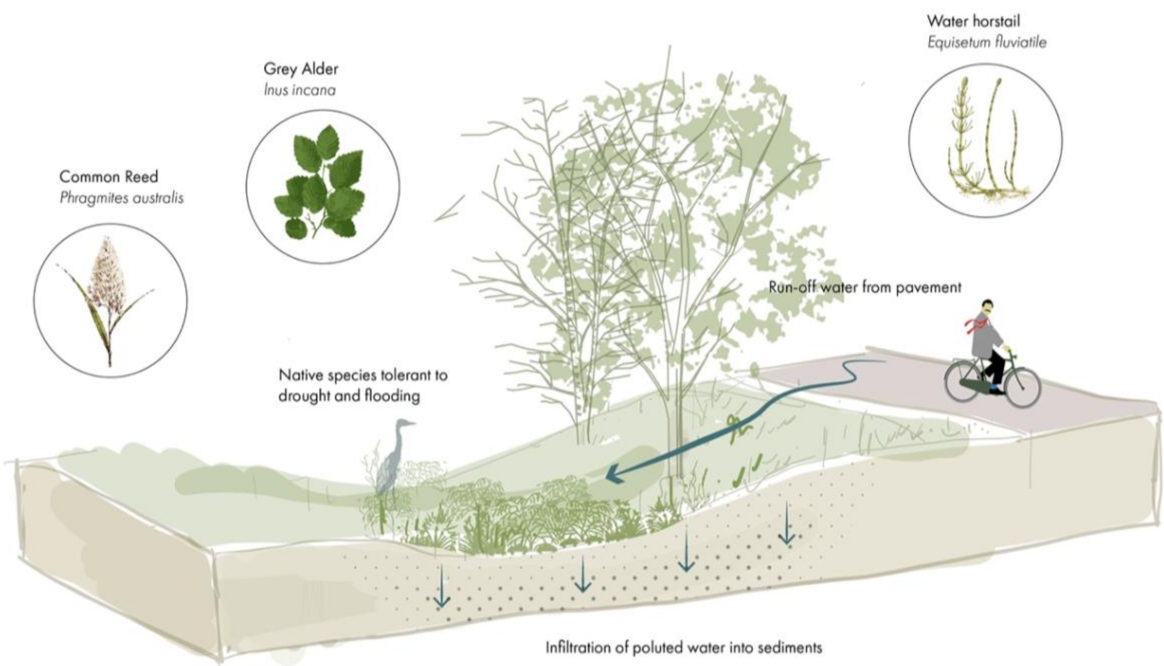

Figure 11: Illustration of main elements in the buffer zone of the river delta (trees and vegetation acting as a filtermedium).

Vegetation type:

Desirable local vegetation in the buffer zone includes tall grass and tolerant reeds that are known to thrive in this area. Recommended tree species are common alder (*Alnus glutinosa*) and grey alder (*Alnus incana*), while meadowsweet (*Filipendula ulmaria*) and common hop (*Humulus lupulus*) are preferred large herb species (Artsdatabanken, 2016). Grass species such as elongated sedge (*Carex elongata*) and weak sedge (*Carex laxa*) are also recommended.

Revegetation method:

The preferred approach is to utilize local seeds and plants whenever possible. Transplanting vegetation from local or similar sites and seeding grass are recommended methods. Planting trees will also be part of the revegetation process.

Soil and sediment type:

The ideal soil and sediment composition should act as effective filter media for runoff water. It should consist of a heterogenous soil composition including sand, turf, gravel, and clay to effectively slow down water flow and absorb pollutants.

Objective 5: Zone 2, Intertidal zone - Salt meadows and mudflats

The edge zone where the river meets the sea can be described as an ecotone, where the transition between two ecosystems creates a new, unique, and diverse ecosystem (Kark, 2013). Brackish waters are found where a river meets the sea, characterized by nutrients and sediments that are brought down the stream by the river (Universitetet i Oslo, 2011). This is the case in Bestumkilen and will contribute to increasing biodiversity in this zone. The difference between the highest astronomical tide (+32 cm) and lowest astronomical tide (-45 cm) is 77 centimeters in Bestumkilen (Kartverket, 2023). As the bay is less affected by strong waves than in exposed coastal areas, a sedimentation process will happen slow and steady, which results in fine and semi-fine particles being left over when the tidal water retreats (Vestergaard, 2000, p. 10).

The goal of zone 2 is to establish a transition zone with salt meadows and mudflats, ensuring high biodiversity and connectivity to its surroundings. The intertidal zone (or foreshore) is the area affected by high tide and low tide and will on a regular basis be flooded with seawater (see Figure 12). Hence, the species found in this zone needs to be specialized, with high salt tolerance and resistance to water flooding (Artsdatabanken, n.d. a). There will be less vegetation on the mudflats as there will be more water present, and it will consist mostly of sedimentation such as fine silt, sand, clay and gravel (similar to the salt meadows).

Both the salt meadows and mudflats should have a high abundance of macrophytes. These are big swamp plants that can create a cover for animals and provide food for many organisms. Macrophytes are primary producers and work as filtrators where they slow down the water stream that is contaminated with pollution and sediments (Brix, 1995). This will unlock a process where contaminated water from Hoffselva or from E18 will be filtrated before reaching Bestumkilen.

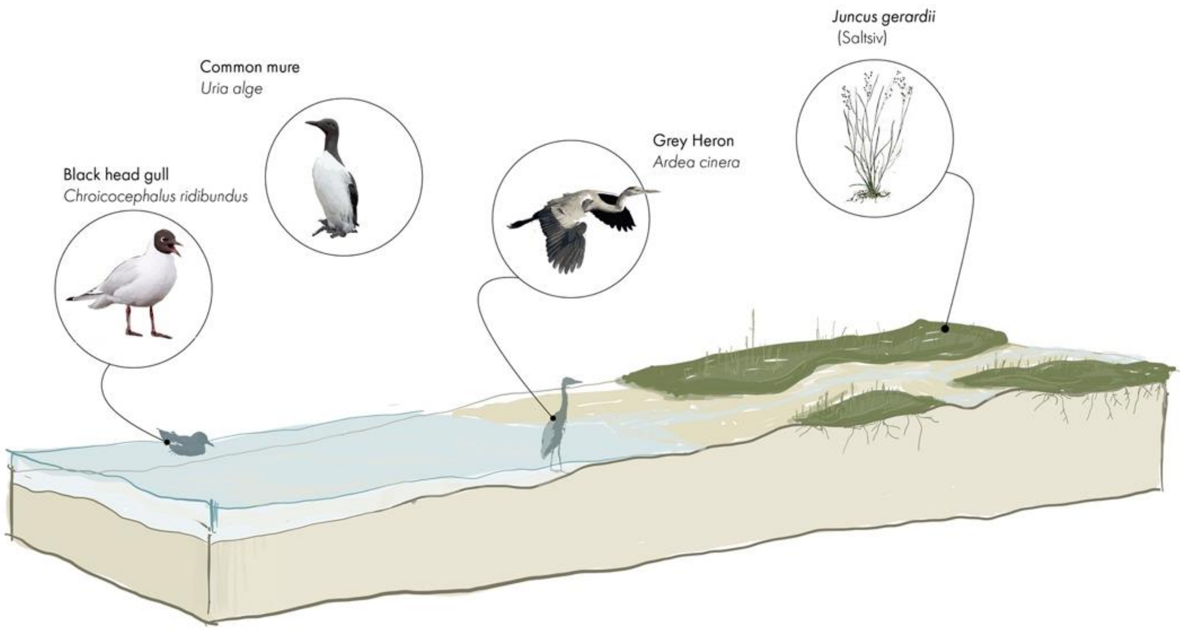

Figure 12: Illustration of main elements in the intertidal zone of the river delta (mudflats, salt meadows, different birds species).

Vegetation type:

The vegetation in salt meadows consists of specialized, salt-tolerant species that are low-growing (Artsdatabanken, n.d. a). These meadows often exhibit a zonation pattern, where the vegetation closest to the water edge is more tolerant to water and salt compared to the vegetation further inland.

Recommended plant species for salt meadows include alkali grass (*Puccinellia maritima*), saltmarsh rush (*Juncus gerardii*), red fescue (*Festuca rubra*), common reed (*Phragmites australis*), fen bedstraw (*Galium uliginosum L.*), woodland angelica (*Angelica sylvestris*), and meadowsweet (*Filipendula ulmaria*) (Artsdatabanken, n.d. a; Artsdatabanken, 2023a).

Revegetation method:

The preferred approach is to relocate species from areas with similar environmental conditions. Seeding can also be effective, particularly in drier sections of the meadow. In some cases, it is beneficial to allow natural processes to take control.

Soil and sediment type:

The ideal soil and sediment composition for salt meadows consists of fine silt, sand, clay, and occasional gravel, promoting a diverse ecosystem. The soil should be tolerant of regular flooding by saltwater while also maintaining good drainage.

Objective 6: Zone 3, Sublittoral zone - Eelgrass meadows

In the sublittoral zone we will be establishing eelgrass meadows and create a habitat for a variety of fish species (see Figure 14). Eelgrass meadows prevent erosion of the seabed, and transport oxygen through the root system to the seabed. In a report by the Norwegian Institute for Water Research (nor.: Norsk institutt for vannforskning, NIVA) from 2022, potential areas for restoring eelgrass meadows in the inner Oslofjord are discussed. It is hard to determine the exact extent of lost eelgrass meadows (NIVA, 2022b, p. 18), but eelgrass thrives in shallow areas and sheltered bays. Such areas have also been popular for establishing marinas (Havforskningsinstituttet, 2022). Figure 13 shows suitable terrain for establishing eelgrass meadows in the Oslofjord.

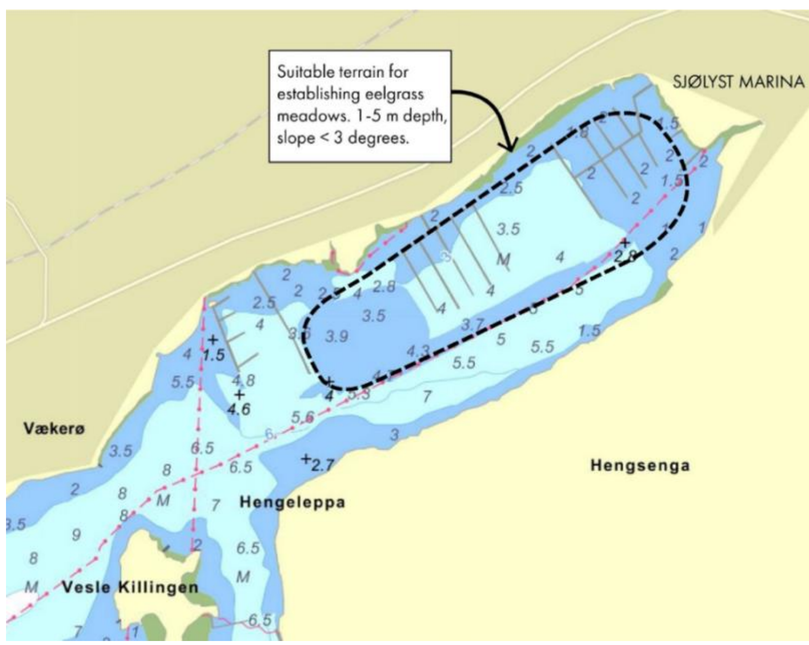

Figure 13: Suitable terrain with the potential of establishing eelgrass meadows. Based on the NIVA-report from 2022 uncovering potential areas in the Oslofjord for eelgrass restoration. Basemap from: https://kart.gulesider.no/?c=60.446382,10.964355&z=7&l=nautical

A second report by NIVA implies that a larger area of Bestumkilen has the right slope and depth conditions for a potential eelgrass meadow (NIVA, 2022a). This must be put in relation to the restoration of the delta and river outlet. We have calculated this area to include over 120 000 m^2 (see Figure 8). This will probably not result in a 120 000 m^2 meadow, but it implies an area where there is potential to be tested.

Removing the boats that block daylight and disrupt photosynthesis and growth for the eelgrass, combined with managing runoff water from the city, can have a positive impact on the restoration results.

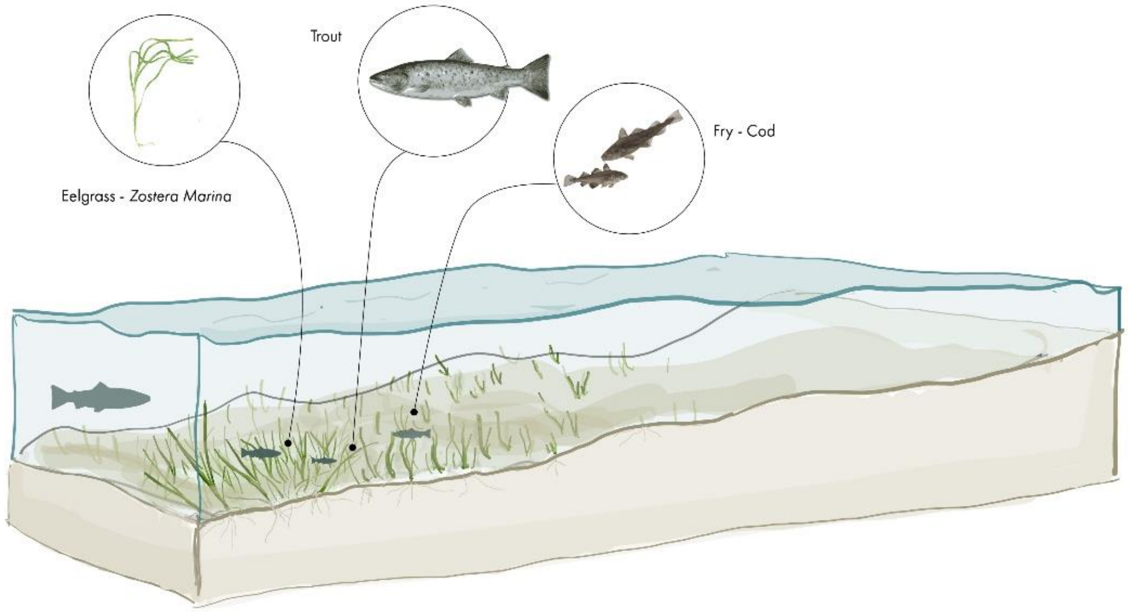

Figure 14: Illustration of main elements in the sublitteral zone of the river delta (eelgrass meadows from about 1 meter's depth functioning as a shelter for small fish).

<u>*Vegetation type:*</u>

In Norway, there are three types of eelgrasses. In Bestumkilen *Zostera marina* will be planted, which also is the most common for this area (Lei en biolog, 2020).

<u>*Revegetation method:*</u>

Relocating plants, including the sediments surrounding the roots, from an existing meadow with a vital population of eelgrass (NIVA, 2019, p. 30). The knowledge and expertise of marine biologists and divers will be used to successfully relocate and establish a new meadow in Bestumkilen. The goal is to provide as much light access as possible to the plant. This is achieved by an ideal depth, and the average depth in the inner Oslofjord measured 3,4 meters in 2020. The maximum observed depth was 5,2 meters below the sea surface (NIVA, 2022b).

Soil and sediment type:

Sediment analysis of the seabed should be conducted before starting the revegetation process. For example, if the ratio of clay exceeds 50 percent, studies in both Sweden and the US has had a low success rate. Eelgrass can be found in situations with a range of different sediments, from gravel and sand to fine sediments with a high amount of organic material and water (NIVA, 2022b). To prevent movements and erosion of fine sediments a mixture of larger rocks can contribute to stabilizing the seabed (NIVA, 2019).

Objective 7: Integrate structures for public access

Information and education

We will provide information signs on site, concerning the restoration process and the natural environment we are trying to create. The signs will include observable species, and how you can use the area without disturbing the ecosystem. Partnerships with local stakeholders can help coordinate events that are both social, educational, and informative.

Accessibility

Public accessibility of the site will rely on boardwalks. Elevated paths are selected as it does not disturb tidal flushing. Universally designed, the boardwalk will be accessible to everyone and create an improved connection between the city and the seafront. In relation to the boardwalk there will be a bird-watching tower. Figure 15 present a landscape plan for how the outlet of Hoffselva river will look like post-restoration, and Figure 16 is a further visualization on how a future situation might look like from a citizen’s point of view.

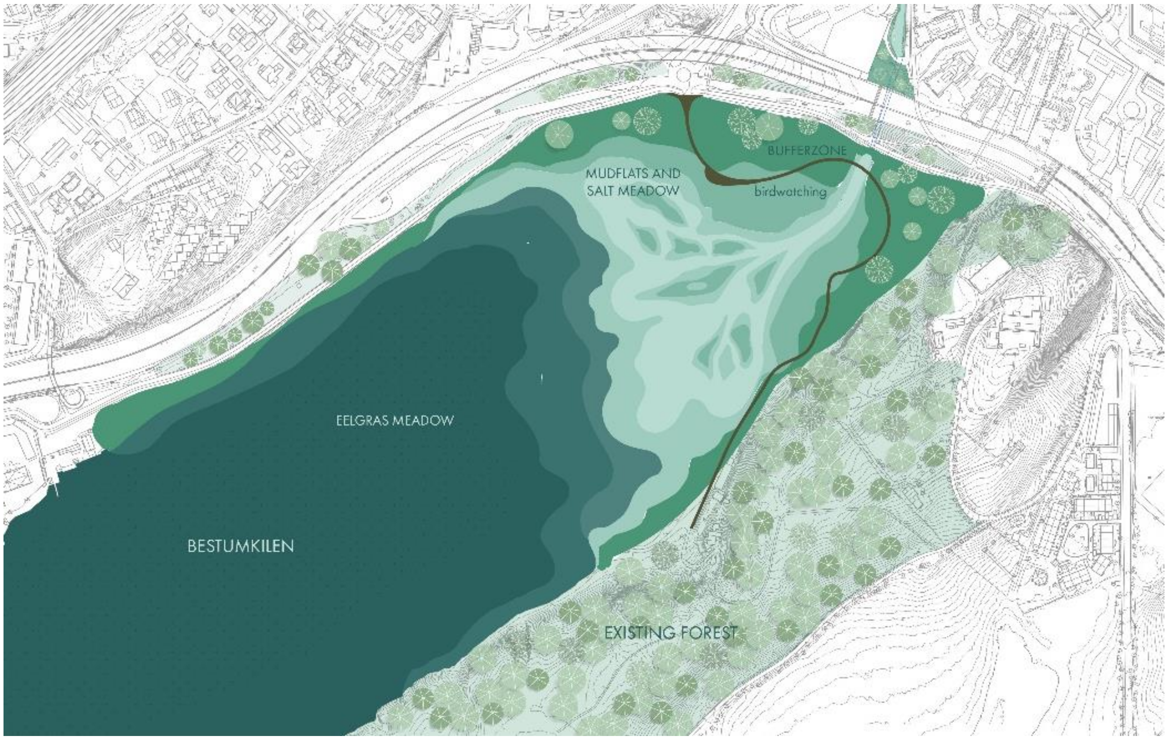

Figure 15: Landscape plan for the restoration project, with the final vision for the area including river delta (consisting of mudflats and salt meadows) and a public boardwalk.

Figure 16: Future vision of the restoration project. Boardwalk for public access on the outskirts of the wetland.

Monitoring and evaluation

The purpose of the project is to improve the ecological conditions of the delta to a state where it independently maintains the functions of a river delta. To assess whether the restoration efforts are successful or not, monitoring is needed before, during and after the implementation. The timing of the monitoring processes is outlined in the timeline in Table 1.

Phase 1: Pre-restoration

The goal of pre-restoration monitoring is to gather data that can be used as a reference for future monitoring as well as to inform the following detailed implementation plans. This includes:

- Inventory of ecosystem degradation (site assessment)
- Estimation of tidal flushing
- Water quality, ground pollution, sediment analysis (data collection and analysis)
- Biodiversity inventory (estimation of species composition and abundance)

Phase 2: Implementation

Continuous monitoring will continue each year of the implementation phase. Responses of the restoration efforts such as the presence of new species may lead to the need for additional monitoring. Indicator species include cod, eelgrass, and marine/wetland birds.

- Estimation of tidal flushing
- Water quality, ground pollution, sediment analysis (data collection and analysis)
- Registering of species abundance of indicator species
- Carbon levels in mudflats
- Species composition and succession rates at the nature types

Phase 3: Post-implementation

An evaluation of the plan is scheduled at the conclusion of the implementation phase. If restoration goals are not achieved as desired, further measures can be implemented. Alternatively, the objectives may be adjusted. Monitoring from phase 2 will continue until the end of the project.

Timeline and budget

The project is currently in need of funding. As steward and majority landowner, Oslo Municipality are asked to fund the restoration efforts. Volunteer labor should be facilitated in all phases to reduce expenses if competence is not a prerequisite and safety is ensured. The project could qualify for the following grants and allocations:

Miljødirektoratet: *Midler til naturrestaurering, Midler til oppryddingstiltak i forurenset grunn og sjøbunn, Tilskudd til vassmiljøtiltak, Tilskudd til tiltak mot fremmede organismer, Tilskudd til trua arter, Tiltak for trua naturtyper.*

Oslo kommune: *Grønne midler i Bydel Frogner*, *Tilskudd til kultur- og idrettsaktiviteter i Bydel Ullern.*

The following timeline (see Table 1) is proposed for executing the restoration plan. Detailed field plans for each activity will be developed in collaboration with contractors closer to implementation. The implementation activities will be guided by appointed members of the restoration team. Given the scale of the project and the degree of ecosystem degradation, the plans need to be able to adapt to the responses of the restoration measures. Adaptive management should be adopted in all phases of the restoration plan. For references on adaptive management and ecological restoration, see Murray and Marmorek (2003) and Littles et al. (2022).

Going into phase 3 (post-implementation), the maintenance of the restored area is transferred to Oslo Municipality represented by Bymiljøetaten. Maintenance includes continuous removal of invasive species, replanting and maintenance of accessibility, including upkeep of the boardwalk and bird-watching tower. The monitoring will continue as outlined in the monitoring section.

Table 1: Budget and activities for the three phases of restoration (pre-restoration, implementation and post-implementation).

Phase 1: Pre-restoration		
Year	Activity	Budget
1	**Project planning** - Appoint restoration team, contact contractors	Low cost
1-2	**Pre-restoration monitoring** - See monitoring section **Source biomaterials** - Soil, substrate, seeds, plants **Assess site condition** - Inventory of ecosystem degradation, hydrology analysis, biodiversity inventory, identify possible eelgrass habitats **Involving stakeholders** - Create limited public access, host informational and educational campaigns, engage and train volunteers, media coverage	Low cost Medium cost Medium cost Low cost
Phase 2: Implementation		
Year	Activity	Budget
3	**Restrict access to project area** - Fencing and marking **Removal efforts** - Removal of floating dock, marina, asphalt, invasive species. If needed: removal of contaminated masses **Terrain manipulation** - Addition of new masses, terrain manipulation, introduction of soil and substrate **Planting of experimental pilot plots** - Test species, substrates, and methods of revegetation **Experimental vegetation phase, zone 3** - Substrate deposition, planting	Low cost High cost Medium cost Low cost Low cost
4	**Release river flow** **Submit applications for approval** - Bird-watching tower, raised board walk **Experimental vegetation phase, zone 1** - Seeding, transplantation of plants **Experimental vegetation phase, zone 2** - Seeding, transplantation of plants **Vegetation phase, zone 3** - Substrate deposition, planting	Medium cost Medium cost Medium cost Medium cost High cost

5	**Vegetation phase, zone 1** - Seeding, transplantation of plants **Vegetation phase, zone 2** - Seeding, transplantion of plants **Preparing for public access** - Build raised boardwalk and bird-watching tower	High cost High cost High cost
Phase 3: Post-implementation		
Year	Activity	Budget
6	**Welcoming the public** - Remove fencing where not needed, opening with media coverage and educational campaigns **Continuous monitoring and maintenance**	Low cost Low cost
7	**Evaluation** - Ecological evaluation, project evaluation and adaptation **Publicize project** **Continuous monitoring and maintenance**	Medium cost Low cost Low cost
8	**Adapting plan according to evaluation**	Low cost
Long-term	**Continuous monitoring and maintenance**	Low cost

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