
Interreg
North Sea Region
IMMERSE
European Regional Development Fund
EUROPEAN UNION
IMMERSE
IMplementing MEasuRes for Sustainable Estuaries
Summary Report

North Sea Region estuaries
are dynamic environments subject to persistent and increasing pressures which impact estuary functioning and services.

Foreword

The Interreg North Sea Region project **IMMERSE** (IMplementing MEasuRes for Sustainable Estuaries) aims to improve the design, testing and implementation of estuary management measures by using transnational knowledge and integrating stakeholders.

The **IMMERSE** project has **11 partners** from 6 countries and estuaries. The partners are estuary managers or knowledge institutes advising estuary managers who work on estuary management challenges by developing solutions and implementing measures.

Estuaries are complex and dynamic environments with multiple ecosystem services. These valuable areas for nature, industry, recreation and agriculture are however put under pressure both from natural processes and through human interventions. Within **IMMERSE** these inherent pressures became more visible and tangible. The project increased the understanding for a group of pressures and advanced the development of solutions mitigating the effects.

The development of solutions mitigating the effects of common estuarine pressures is not straightforward, it often takes a long time to develop and brings forth significant costs.

Within **IMMERSE** the objective was to advance the development of several solutions that have the capability of **improving the state of estuaries around the North Sea.** The development of these solutions are positioned into one or more phases of the development process: exploration, assessment and preparation for implementation.

'The summary report reflects the project's approach towards the development of solutions. The methodology used in the project showcases how the process can be streamlined, using interim milestones to emphasise achievements.'

Frederik Roose
IMMERSE project lead

Estuary Management and Strategies

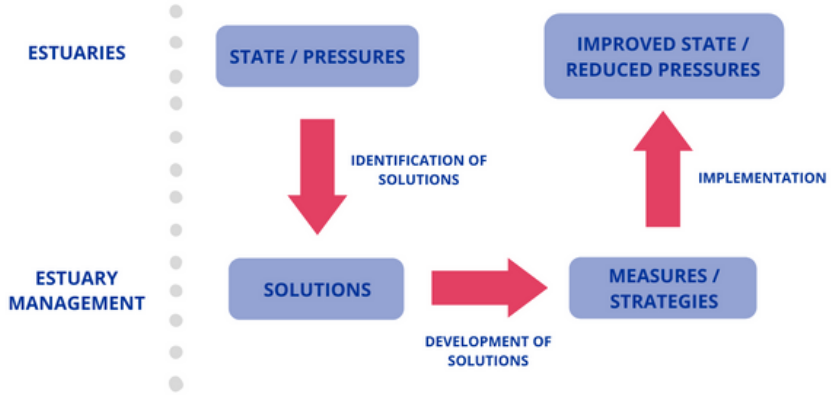
Estuary management aims to **improve the state of estuaries** by reducing the effects of pressures. The state of an estuary needs to be evaluated regularly, based on multidisciplinary monitoring schemes and a thorough understanding of the functioning of estuaries as an ecosystem.

An evaluation framework allows for the identification of deficits in the state of an estuary and excess pressures that are considered problematic.

Finding appropriate and effective solutions for estuary management may be challenging. Often solutions need to be developed or customised before they can be applied as measures or be adopted as part of management plans or strategies.

Therefore estuary managers seek to protect the good ecological functioning of the ecosystem while simultaneously ensuring the delivery of the ecosystem services, which provide socio-economic benefits and safeguard economic activities in the estuary area.

Management plans and strategies are important tools to safeguard the **sustainable development** of solutions. Existing management plans and strategies have been developed in response to activities, pressures or relevant legal directives (e.g. Water Framework Directive, Natura 2000 Directives, Floods Directive).



Improving design, testing and implementation of estuary management measures

using transnational knowledge and integrating stakeholders

Within **IMMERSE** project partners worked together to address challenges in estuaries by advancing management measures through the different phases of development. Through a multi-phase approach, **IMMERSE** became therefore an **enabling factor** and supported management processes, keeping in mind the respective specificities.

A wide range of ideas to address a certain problem are explored
The exploration phase includes the characterisation of the pressure being addressed and the divergent process of collecting possible solutions. The ideas found in the first phase pave the way for further development of measures.

Solutions are assessed and their feasibility tested
The assessment process of the feasibility / test phase can be supported by laboratory experiments, numerical model investigations and field pilots.

Solutions are prepared for implementation
Based on the assessment in the previous phase, some alternative designs can still be evaluated, but the general idea of a measure is fixed. The preparation phase includes the convergent process of making a final decision.

The development of measures, from the exploration phase towards implementation can take many years and some solutions might never complete the whole process.

The implementation of management measures to address pressures require large investments, long planning periods and stakeholder commitment. Moreover, measure development is challenging for estuary managers due to the demand for innovative, cost-efficient approaches which also deliver multiple benefits.

Within the **IMMERSE** project, solutions were developed for 6 estuaries;

- Scheldt (BE/NL);
- Elbe (DE);
- Humber (UK);
- Tees (UK);
- Isefjord, Holbækfjord, Roskildefjord (DK);
- Göta Älv (SE).

The solutions all deal with certain common estuarine pressures and their related (often) site specific effects.

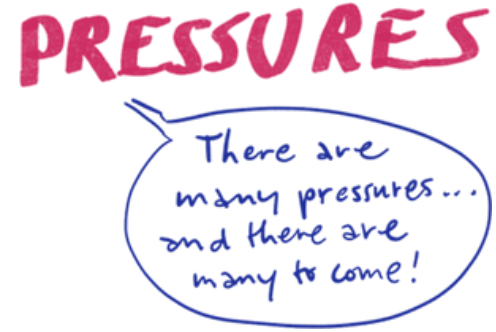
Most estuaries do not just deal with one specific pressure, but a range of them.
Within the frame of **IMMERSE** only a selection of pressures are addressed;

- Flooding;
- Pollution;
- Hydro- and morphological changes.

Flooding

Flooding is a pressure that has always threatened estuaries because they are, by their very nature, at the interface between river and coastal systems. There are generally two types of estuarine flooding: **fluvial (or river) flooding** that occurs as a result of elevated river discharges caused by excess rainfall in source catchments; and **tidal flooding** that can occur at high spring tides, with or without an additional storm surge component caused by intense low pressure systems. It is also possible for both types of flooding to occur simultaneously, resulting in tide locking and exceptionally high water levels.

Since more extreme weather conditions are likely to happen in the future, these phenomena will potentially become more frequent. If the extreme weather conditions are combined with a mean sea-level rise they pose a serious threat.



Pollution

Pollutants are abundantly available in estuaries affecting the water and sediment quality. **Organic and inorganic pollutants** such as TBT and toxic trace metals often have an historic origin from old industries, while **microplastics** are of more recent origin. Both these historic and recent pollutants affect the ecosystem negatively.

Hydro- and morphological changes

Land use changes and river engineering works lead to changes in the geometry and bathymetry of the estuary and, in extension, to changes in **tidal propagation**. Increasing high water levels will influence flood risk, while decreasing low water levels may affect the stability of dikes and shore infrastructure. Changes in the tidal dynamics will also influence the transport of sediments, eventually resulting in higher suspended sediment concentrations related to tidal pumping or in changes of geometry and bathymetry affecting the navigation.

As natural habitats occur within a range of environmental conditions, hydro- and morphological changes may also result in **decreased habitat quality or even habitat loss.**

IMMERSE solutions accomplished different steps as part of measure development, aiming to achieve a milestone. Further development steps can/are foreseen outside the project.

Different terms are used to address a new solution, depending on the stage of development.

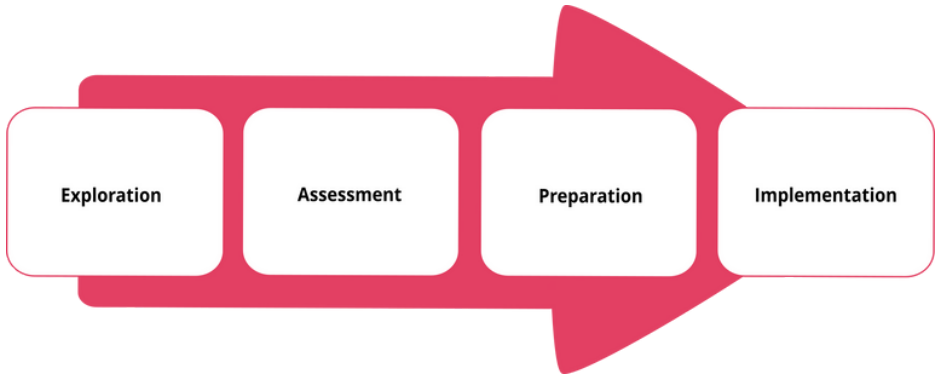
*An **idea** refers to a new solution that has just been initiated,*

showing it is a potential solution to the problem or the challenge (= pressure) that has to be dealt with ("exploration phase"). Ideally, multiple ideas can be formulated in parallel. Brainstorming or similar facilitation techniques may be helpful to find more ideas.

As ideas become more tangible, it might be desirable to **test or assess** the performance or effectiveness of some alternative solutions ("assessment phase").

This can be done in an assessment study, a physical scale study or a field study (or pilot), resulting in an evaluation of the alternatives. In this phase, the number of solutions does not change, but information is collected on capacity of the solutions to address the problem.

With the information from the assessment, the solutions are **evaluated** against some (pre-defined) appropriate criteria, resulting in a selection and/or a ranking of the considered solutions. The most preferred solution can be developed into a measure that is ready for **implementation** ("preparation phase"). During this last phase, the number of solutions is reduced, and a preferred solution is selected.



Solutions for Flooding

Humber

System-scale approach for evaluating flood defence and storage measures contributing to a flood protection strategy

The Humber estuary with its low-lying nature of floodplains is at severe risk of flooding during storm surge events. This risk is expected to increase even more due to sea level rise caused by climate change.

Flood defence and storage measures are needed to protect the estuary in the future. Numerical modelling allows for a system-based approach for evaluating measures, accounting for the different services (ecological, economic and social) of the system when studying the impact of sea level rise and storm events.

A long-list of possible (combinations of) measures and expected effects helps decision makers to develop a flood protection strategy for the Humber.

Danish Fjords

Improve understanding of contributing role of local waterways to develop a holistic flood protection plan

Local municipalities in the Danish Holbæk fjord have been impacted by severe flood events in the past, urging the need to develop a holistic approach to prevent future damages.

A first step in the setup of a holistic flood protection plan is to increase the existing knowledge on the contributing role of local waterways to the system. Understanding which areas are more prone to flooding enables the development of a flood risk map.

A holistic flood protection plan helps the municipality to develop and advise on more specific and local measures to protect the community against the threat of floods.

Danish Fjords

Regional and local approach to develop a flood protection measures catalogue to provide input for future strategies and plans

The Roskilde and Isefjord areas in Denmark experienced severe flooding events during the last years, impacting local communities and urging for more efficient flood protection.

Numerical modelling of flood events and measures helps identify solutions for flood protection and enables to estimate effects on a local scale, creating a catalogue of effective measures.

Analysis and design of flood protection measures using numerical modelling is a pathway to initiate more in-depth studies which can lead to holistic strategies and plans to implement specific measures, protecting the area from future flood events.

Solutions for Flooding

Scheldt

Sediment nourishment to adapt to the effects of climate change and sea level rise

The mouth of the Scheldt is a zone of natural transition from estuary to open sea and has important functions for nature and safety. It can play an important part in the future with climate change and rising sea levels which endanger important ecosystems and impacts the safety against flooding in the estuary.

Monitoring the effects of sediment management measures such as nourishments on morphology and ecology at different locations in the mouth of the estuary can fill knowledge gaps about the role and functioning of the system.

Nourishments in the mouth of the estuary can be a smart strategical long-term solution to let the system grow with sea level rise and can help develop strategies to future-proof the estuary.

Solutions for hydromorphological changes

Scheldt

Use of sediment management actions to reduce tidal propagation while maintaining port accessibility and enhancing nature value

Sediment extraction from the Scheldt estuary caused hydro- and morphological changes which negatively impact safety against flooding, navigability and endangers valuable nature.

Further sediment loss can be prevented by depositing sediment within the estuary at suitable locations, having a positive impact on local hydro- and morphological conditions. A modelling train (multiple models which feed into each other) studies the effects of these sediment management actions on ecology and water and sediment dynamics.

Keeping sediment within the estuary by relocating it to selected locations shows potential to reduce the tidal propagation and increase the ecological value of the system locally while still ensuring navigability.

Elbe

Reconnection of a cut-off anabranch to increase tidal volume, reduce upstream sediment transport and create valuable intertidal habitats

Tidal pumping in the Elbe causes increased sedimentation of fine sediments in the upper estuary and increases the dredging needs to secure safe navigation, negatively impacting economy and ecology.

Reconnecting the Elbe with the Dove-Elbe (a cut-off anabranch) by creating a tidal inlet with a sluice is a measure which can increase the tidal volume. Study results of hydro-morphological, ecological and socioeconomic effects decide on the measure effectiveness.

The reconnection of a cut-off anabranch to the tidal Elbe shows local effects of increased tidal volume in the estuary, reduced upstream sediment transport while also creating valuable intertidal habitat.

Scheldt

Cross-border relocation of dredged sand to limit the need for sediment extraction

Currently sediment is being extracted out of the Sea Scheldt (BE) because of limited capacity of the relocation sites for maintenance dredging. Removing sediment out of the estuary causes hydro- and morphological changes, increasing the tidal range and causing tidal amplification.

Relocating sediment just across the border, in the fairway of the Western Scheldt (NL) reduces the need for sediment to be extracted out of the system.

Limiting the need of sediment extraction keeps the balance in the system and can stop further increase of the tidal amplification.

Solutions for hydromorphological changes

Tees

Soft engineering designs to create intertidal habitat

Land reclamation and habitat loss created coastal squeeze within the Tees estuary, putting pressure on the various species that rely on the intertidal zone.

Creating intertidal habitat along hard estuary edges counteracts part of the habitat that was lost. The habitat is created using soft and eco-friendly materials, which are an alternative to hard engineering options. The created intertidal habitat site now acts as a shop window for projects elsewhere.

Soft engineering designs transform hard estuary edges to intertidal habitats, increasing the area available to each level of habitat.

Scheldt

Creating a secondary channel to reduce tidal intrusion and increase nature value

The tidal range in the Scheldt estuary increased significantly during the last decades with the tidal wave able to propagate more upstream in the system. Tidal amplification affects the hydro-morphology of the estuary and negatively impacts its naturalness, safety and accessibility.

Widening an upstream part of the river by excavating a secondary channel increases the cross-section of the river. It creates more room for the water, with the secondary channel especially of use during high tide. The running water prevents midge infestation while providing valuable intertidal habitat area.

The excavation of a side channel reduces the incoming tidal wave energy locally by dispersing it over a larger cross-section with a higher resistance while at the same time creating valuable nature area. As part of a holistic approach, a wide implementation of this type of measure in the Scheldt can help protect the estuary against tidal amplification.

Solutions for Pollution

Tees

Co-location of mariculture in an inshore windfarm to improve water quality and create economic stimulus

Industrialisation of the Tees estuary caused the environment to be heavily modified with both organic and inorganic pollutants, such as TBT and heavy metals. These pollutants still have a significant impact on the water quality and in extension to the health of living organism in the estuary.

Bivalve shellfish and macroalgae are able to remove pollutants from the water and store them, lowering concentrations in the water and thus improving the quality. Both surface-suspended and seafloor-based mariculture installations are suitable within a wind farm.

The co-location of mariculture inside an inshore wind farm can increase the water quality of the estuary and support commercial fish populations, sequester additional carbon and protect against coastal erosion.

Göta älv

Innovative raingardens to filter and degrade microplastics from road run-off water

The wear and tear of plastic materials such as car tires produce large amounts of microplastic particles, which are transported into rivers and estuaries by run-off water from roads, presenting a serious threat for the water quality in the Göta estuary.

Different filter materials, a selection of plants and possibly fungi have the potential to retain, degrade or recover microplastics, metals, nutrients and organic pollutants from runoff water. This water can pass through rain gardens installed alongside roads and pavements, filtering pollutants, before flowing to the estuary.

Building rain gardens along the run-off routes from roads reduces the transport of microplastics (and other pollutants) to rivers and estuaries and improves the water quality.

Humber

Use of biological agents to filter microplastics from the water column

Microplastics are abundantly found in the water column and sediments of the Humber estuary. Plants and animals are influenced by, and influence, microplastic storage and transport within estuaries.

Benthic biofilms protect sediments against erosion, trap and bind fine particles and provide food to benthic infauna (invertebrates). With these characteristics they play an important role for capturing and resuspending microplastics. Also filter feeders draw microplastics from the water column and retain them.

Understanding the mechanisms and conditions in which these processes occur can help remove microplastics from the estuary. This knowledge can be used to inform habitat creation and management solutions to control this persistent pollutant within estuaries.

Solutions for Pollution

Göta älv

Stabilisation/solidification of dredged material and recovery of metals to manage contaminated sediment

Marine sediments in Gothenburg harbour are heavily polluted due to various harbour activities, long-term use of antifouling paints and inflow from urban runoff. This pollution results in high concentrations of organotin compounds (OTs), metals, organic pollutants, particles and nutrients in the water and sediment.

Alternative management options to handle contaminated sediment have been explored by laboratory testing of different techniques for removal of TBT and by using an integrated assessment method. The management of the sediment by using methods to stabilise and solidify the material by degrading the organotin compounds and recovering metals with monetary value helps reuse of materials and prevents leaching of pollutants.

Integrated assessments show the best options for managing sediment taking into account social, economic and environmental conditions. Treating and reusing contaminated dredged sediment improves the quality of the sediments and water as toxicity is reduced. Moreover, extraction of valuable metals makes the treatment more economically attractive.

Elbe

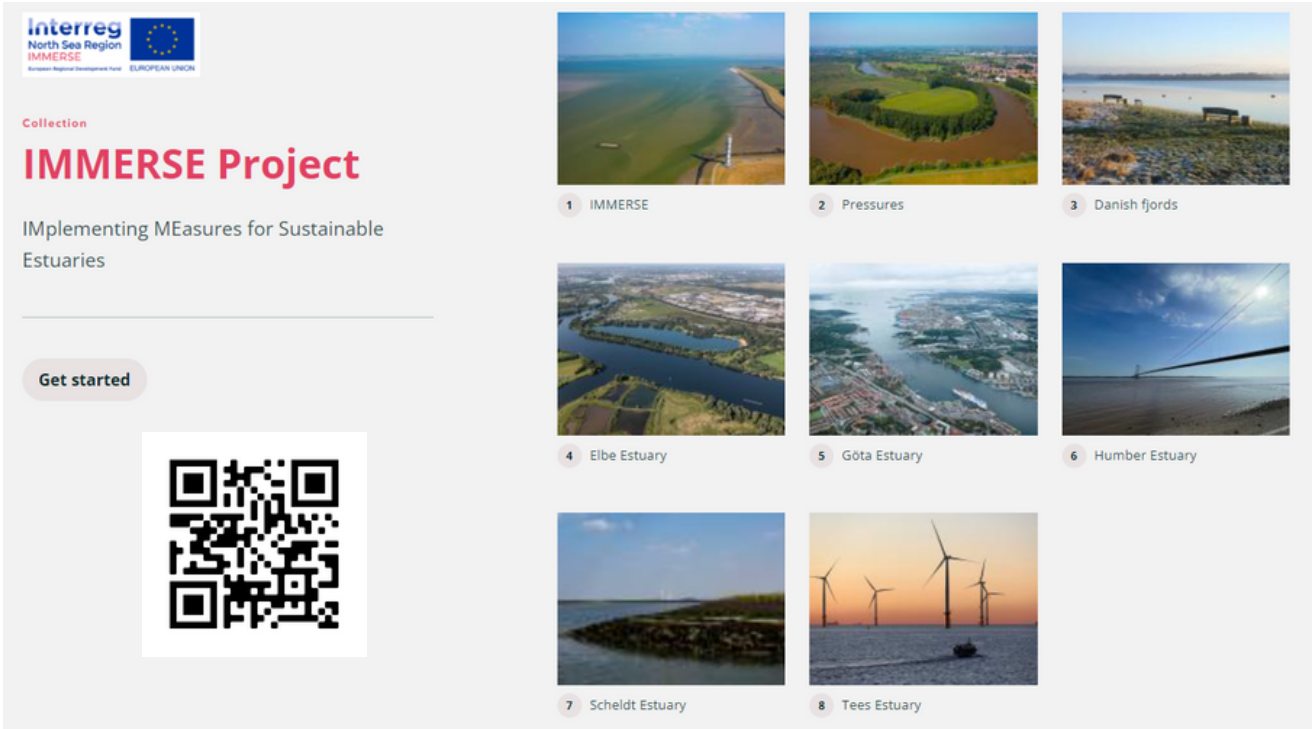
Mapping the spread of sediment-bound pollutants to aid in sediment management decisions

The riverine sediments in the Elbe estuary are partially contaminated by organic and inorganic pollutants which are bound to the sediment. This historic pollution restricts estuary management and development of strategies for the reuse and relocation of sediments.

Understanding the mechanisms and pathways of sediment-bound pollutants is crucial to estimate effects of remediation measures and climate change on future management measures. Suitable modelling techniques help compute the spread and distribution of sediment-bound pollutants in the water-sediment compartment at the Elbe estuary.

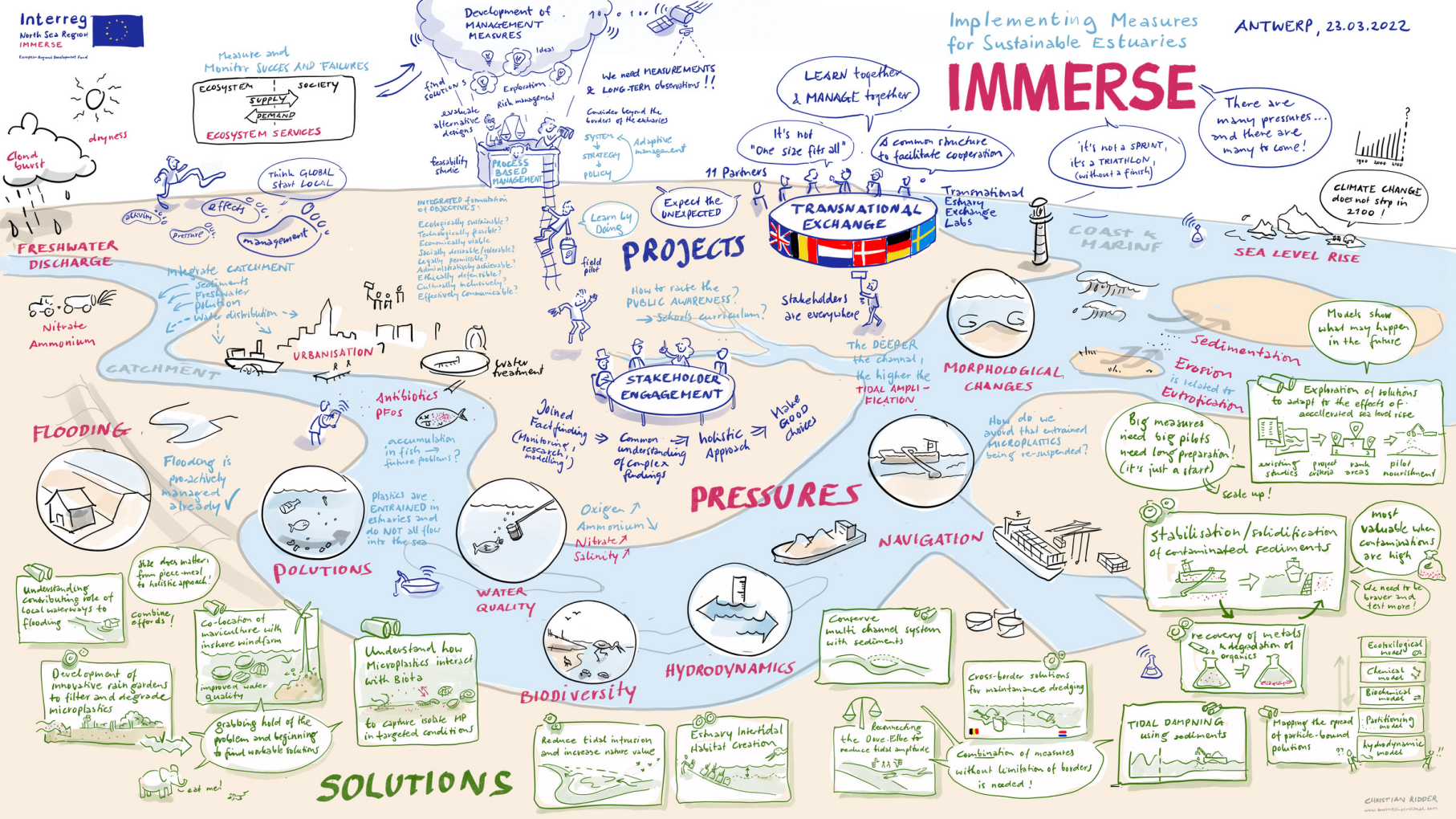
A better understanding of the spread and pathways of sediment-bound pollutants paves the way for the development of improved management measures and strategies by allowing risk assessment. Taking into account the mechanisms and behaviour of these pollutants will improve the water quality in the estuary.

For more information about the solutions developed within **IMMERSE**, the pressures we tackled and some general project information, you can visit our **StoryMaps collection**.



'On our interactive platform you can discover the IMMERSE work and results in more detail. Scroll through the stories, move interactive features and immerse yourself in our storytelling platform.'

Eline Van Malderen
Flemish Department of Mobility and Public Works



Transnational exchange was one of the cross-cutting themes of **IMMERSE**, focussing on the improvement of the quality of estuary management measures by drawing from transnational knowledge and experiences. **IMMERSE** facilitated the transfer of knowledge and experiences by organising **Transnational Estuary Exchange Labs** (TEELs) with different geographic and content-related topics.

'The real value lies in validating new approaches and communicating successes to a wider audience, considering it a process of experimentation and communication.'

Successful Stakeholder Engagement
has to be carried out as a continuous process during the development and implementation of measures with different working phases and related tasks that build up on each other like different stages of a project.

Stakeholders (e.g. administrations, NGOs, etc) are an inherent part of the measure development process. It is important to timely involve all parties avoiding information gaps and misunderstandings at later phases. Moreover, though not always achievable, the ultimate goal should be a win-win situation, a satisfactory result for all.

IMMERSE embraced a stakeholder-sensitive approach to operate as a cross-cutting theme across all measure development steps. The project sought to engage stakeholders to **collaboratively develop** the measures and set management targets that go beyond the requirements of the European and national legal frameworks. At the same time, the project provided recommendations and tools to enhance stakeholder engagement.

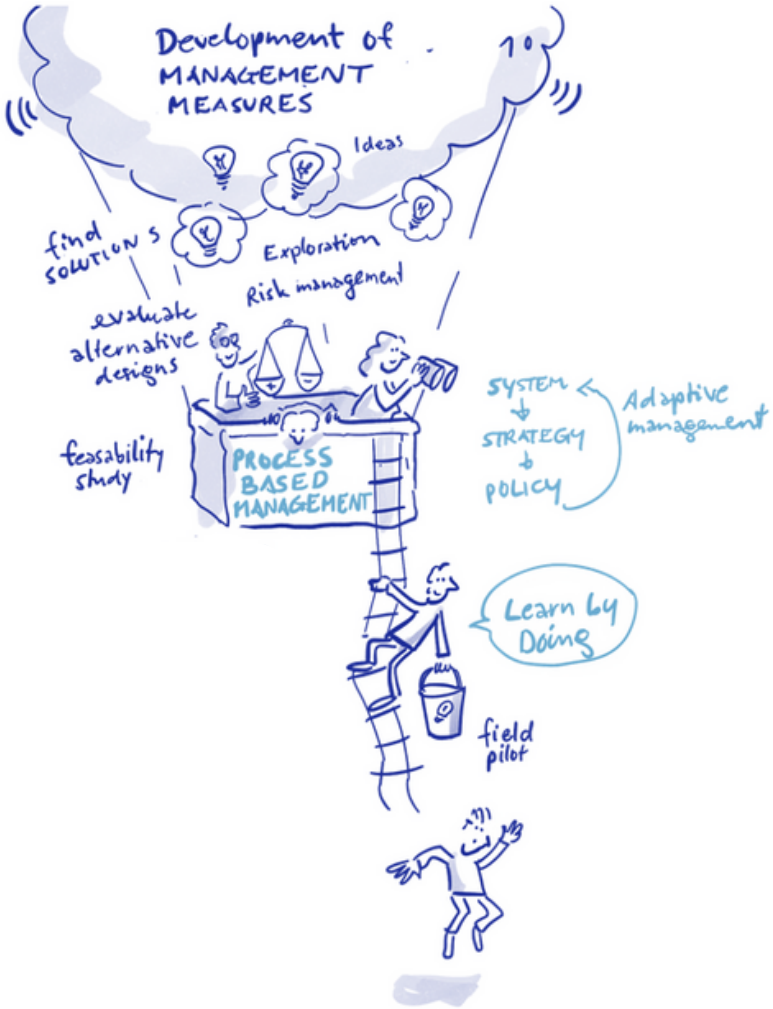
Identifying and informing stakeholders
Understanding all relevant stakeholder groups and involving them from early on in the process with good communication, is important during the development and implementation of measures. It ensures that expectations are clear and can be taken into account during the process.

Developing solutions and engaging stakeholders
During the development phase, stakeholder engagement is of utmost importance to build mutual trust.

There is a need for joint fact-finding with an emphasis on "what is possible instead of what is not possible"– commonalities instead differences.

Scientific findings can provide a factual basis for discussion in case of conflicting positions.

Reflection and obtaining feedback
Feedback and reflection from both sides on the acceptance of the management measures as well as on the complete process of solution development and stakeholder engagement is important at the end of a project. This is the only way that a potential change in degree of stakeholder support and acceptance from a baseline level can be measured and serve as a basis for future progress.



IMMERSE showed that estuary managers can and should **learn together to manage together**, by exchanging knowledge and experiences to develop solutions and adaptive management strategies.

'Transnational exchange organised by IMMERSE did not only help accelerate and improve the development of solutions but could also inspire others exploring solutions'

Frederik Roose
IMMERSE project lead

The involvement of stakeholders in early phases proved to be crucial to the development of effective and supported solutions. Creating ownership, building a bridge between science, estuary management and local stakeholders and joint fact finding while putting emphasis on commonalities instead of differences are some of the tools which are helpful during measure development.

Credits

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More information on our website: www.northsearegion.eu/immerse
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