Beneficial use options for dredged sediments: circular economy and climate change-based assessment and classifications

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Introduction: Dredging of sediments is a requirement for waterborne transportation, creating one of the biggest material flows in the world. At the same time, sediments present a valuable mineral resource, the use of which would significantly reduce consumption of primary raw resources. The potential contribution of sediments towards achieving circularity led to the creation of a dedicated SedNet working group in 2018. Beyond minerals reuse, sediments have a broader role in the beneficial use (BU) of materials for a circular economy. Case studies encouraged by INTERREG, PIANC, CEDA and USACE led to the uprise of the Building with Nature (BwN) concept. Key applications of sediments within BwN include climate change adaptation works (flood and shoreline protection), natural habitat restoration (like wetlands), use on agricultural land, river restoration works, and civil works (like dike construction). This contribution provides an overview and analysis of the current global BU projects.

Methods: Structured data sheets of case studies published by CEDA and USACE, were classified along the main applications categories, thereby providing partial but significant statistics on beneficial use options, and recent trends. More projects identified by literature scans were added.

Results: A total 78 projects and pilot projects [1] provided data on the beneficial use of 725 Mm^3 of raw sediments. Climate change impact applications accounted for 80.5% of the total, while 20.6% for agricultural or landscape applications and 2.5% for raw minerals applications. This result is unexpected when referring to circular economy applications as outlined around 2000-2010, in which sediments were mainly proposed as beneficial substitutes for minerals from primary extraction [2]. In the meanwhile, the fast growing needs for sustainable building material [3] of climate change adaptation [4] works acted as a driver for cost-effective beneficial use [5].

Discussion: One of the main issues with sediments as substitutes for raw minerals applications was, and still is, social acceptance and potential liabilities for the end user, either long term performance or contaminants contents. On the opposite, climate change adaptation works are perceived as positive regardless of potential issues, and the material costs implied by their massive size can be reduced by sediments reuse. Besides this, most of these works are implemented along or nearby the water body the sediments were dredged from, hence reducing the environmental suitability constraints and transportation costs. With the growing urgency of such works, they provide a sustainable alternative to the current landfilling or disposal at sea practices. This implies revisiting enablers and barriers for circular economy options, such as regulations, incentives or standards, and opportunities, such as priority works.

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[5] Wijdeveld et al. (2024) *J Soils Sediments* https://doi.org/10.1007/s11368-024-03811-z.

Fig. 1: Sediments beneficial use for dike construction, Germany.

River Works: Soil-Based Programming in the River Area

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Introduction: Many functions converge in the river area: water safety, shipping, nature, water quality, freshwater availability, living, working, and recreation. Yet, the space for the major rivers has steadily decreased over the centuries. Since the dawn of humanity, people have settled close to rivers, which have served as lifelines for societies. For centuries, rivers flowed freely through the landscape, with channels silting up and shifting, and adjacent areas regularly flooding. In the 19th century, large-scale river normalization projects were undertaken in many rivers to benefit navigation and flood safety.

In the Dutch context, floodplains have silted up over the last centuries due to flood events and space narrowing caused by dikes. As a result, floodplain nature restoration in the Netherlands requires excavation. Meanwhile, around 2000 km of dikes in the Netherlands must be reinforced before 2050 to comply with safety requirements. Therefore, linking soil supply (nature restoration) with demand (e.g., dike strengthening) seems logical from a sustainable river management perspective. This approach not only provides sustainable material that can be used locally but also potentially leads to cost savings and reductions in CO2 footprint and environmental nuisance. This method, referred to as soil-based programming, was the focus of the Rivierwerken (River Works) project, which concluded at the end of 2024.

Materials and methods: River Works was organized in three work packages: 1) Sustainable Resource Extraction, 2) Circular material use and 3) Soil-Based programming.

The consortium, led by HAN University, included other 20 partners (public, private, knowledge): two ministries (Infrastructure, and Agriculture and Nature), a nature management agency (Staatsbosbeheer), three waterboards (Limburg, Rijn en Ijssel, and Rivierenland), two provinces (Limburg and Gelderland), two foundations (Smart Rivers and EcoShape), three additional knowledge institutions (Deltares, TU Delft and Van Hall Larestein), a multidisciplinary group of private companies (Fugro, Van Oord, K3 Delta, Netics, Aveco de Bondt, Witteveen+Bos, and Arcadis) covering both consultancy and contractors role.

Results and conclusions: The project's outcomes are summarized in Tab.1. These results provide valuable support to technical managers, designers, risk managers, project managers, and administrators of dikes and floodplains, contributing to a more sustainable approach.

Tab 1. Output per work package

Output WP1
-Tool for estimating soil volume extracted in nature development projects based on river DNA and validated with an expert-based system approach -Opportunities for local sediment replenishments to counter river bed erosion -Designing nature restoration projects that follow the DNA of the river
Output WP2
-Soil treatment techniques review -Improving the mechanical properties by mixing different clay types and analysis of a case of study -Compositional effects and suitability for dikes -Soil-based dike design
Output WP3
-Methodology for an integrated approach to soil -Evaluation of existing tools -Developing of a new improved tool to match soil offer with demand

Fig. 1: Screenshot of the tool developed in WP3

This presentation will explain in a summarized way all the lessons learnt from River Works, which contribute to the mainstreaming of soil-based programming, and explain how these lessons link with ongoing national and international initiatives and policy.

Acknowledgements: This project was conducted with the support of all the partners mentioned, and not solely by HAN University of Applied Sciences. Due to space constraints, only the name of the project leader, main researcher, and presenter is explicitly mentioned as author.

Field labs sustainable use of sediments in the Rhine-Meuse delta

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Introduction:
In the period from 2019 to 2024 we developed three field labs for sustainable use of sediments in the Rhine - Meuse delta ("Proeftuin Sediment Rijnmond"). The target of these field labs is to understand and innovate the approaches for better and circular (re)use of non-contaminated sediments, and to keep these sediment in the estuarine system.

Every year, a huge amount of material is dredged in the Rhine – Meuse delta to guarantee navigability. Most of this sediment is not contaminated, but is relocated offshore to the North Sea. However, the Rhine – Meuse delta also needs sediment for erosion protection, nature development, recreation and water safety. Balancing the supply and the demand of sediment will give great opportunities for circular and sustainable use of dredged sediment, and to better satisfy the needs of sediment in the delta.

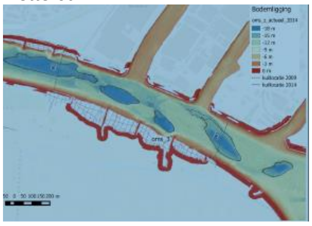
The field labs are a cooperation between suppliers of sediment (RWS, WSHD, PoR), contractors (DEME), Nature conservation organizations (World Wildlife Fund, ARK rewilding) and knowledge institutes (Deltares, WMR).

Methods:
Important issues for the field labs were research, demonstration, sharing of knowledge, working together and learning by doing.

The first step was to quantify and locate the supply (dredging) and demand of sediment in a sediment atlas. The sediment atlas also provides insight into the environmental quality of the sediment. Outcome of the sediment atlas was that there is a huge amount of sediment available for circular and sustainable sediment management but that there is a mismatch between the need (demand) of sediment and the supply of the sediment.

The field labs provided execution of three pilot projects. The first pilot is located in the port area, whereby sediment was used for nature development in a groyne field instead of relocating the sediment to the North Sea. The second pilot is located in the river channel of the Oude Maas, whereby the (sandy) sediment was used for filling up and stabilize deep scour holes and creating a 'sand engine', instead of selling it on the 'sand market'. The third pilot is located in a partially closed estuary (Hollands Diep) where very fine sediment also will be used to improve ecology in bank zones.


Pilot 1: field lab "Groene Poort" at entrance channel of Port of Rotterdam


Pilot 2: Filling of deep scour holes


Pilot 3: Nature development in estuary bank zones

Results:

The results of the field labs were presented last November. The shared vison and ambition connect the partners and they will continue the cooperation.

It results in an approach for the future:
1. Develop locations for circular / sustainable use of sediment, and connect them to sediment sources;
2. Organize the cooperation;
3. Keep opportunities for experiments, research and monitoring

The final target will be the circular /sustainable use of sediment as a daily business

Reuse of dredged sediments from hydropower reservoirs in France: Recent experiments highlighting current enablers and barriers

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Introduction: Fluvial sediments are natural materials that are issued by the process of erosion.
Hydropower is today the first power renewables in the world, and also in France. The creation of a dam associated with hydropower is necessary for electricity generation. By trapping sediments in the reservoir, dams interrupt the continuity of sediment transport through rivers. Sedimentation thus affects the safety of dams and reduces energy production, storage, discharge capacity and flood protection capabilities. These sediments may also increase loads on it and its gates, damages equipment and creates a wide range of environmental impacts.
EDF is operating in France 433 hydropower plants totalling capacity of 20,000 MW with a CO2 electricity generation of around 50 TWh a year. These power plants were associated to 622 dams, including 150 more than 20 meters. The storage capacity of reservoirs created by these dams is 7.5 billion m³ of water, i.e. 75% of the surface water storage reserves in France.
EDF has to dredge sediments for several reasons: i/ Ensure sediment continuity (i.e. priority sediments stay in water); ii/ Ensure the safety of the operation/maintenance; iii/ Limit the loss of energy generated and/or loss of flexibility; and iv/ Maintain navigation. Sediment continuity is preferred as much as possible in France for EDF, according to our integrated sediment management. However sometimes sediments have to be dredged and remove from the water: these dredged sediments become waste by regulation in Europe (cf. Waste Framework Directive 2008/98/EC).

Methods: This paper will present a methodology developed by EDF with several stakeholders, using dredged sediments from several reservoirs for different recovery ways (i.e. mineral and agricultural valorisation paths). First the context and main current issues are presented in France (sediment characteristics and volumes, analyses required, arising issues, …). Then the method to address them, with the different stakeholders and possibles recovery purposes are described issuing dredged sediments as an alternative to raw materials. Then main results of these different experiments are summarised in the context of climate change mitigation and adaptation (an alternative to raw materials for concrete, terracotta, agricultural soils, …). And finally main current enablers and barriers are highlighted assuming the current state, and possible future publication of guides could make sediments a nature-based solutions to contribute for a real circular economy.

Fig. 1: Dredging sediments for reuse.

Fig. 2: Drying sediments is essential for recovery.

Fig. 3: Recovering sediments for agricultural uses.

References: [1] CIS document. (2022) *Integrated sediment management - Guidelines and good practices in the context of the Water Framework*

Please submit your abstract before the 29th of November 2024 to the SedNet secretariat: secretariat@sednet.org.

Description of and criteria for nature-based solutions involving sediments that reduce erosion as well as slope instability

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Introduction: International organizations such as UN, OECD and EU have their own, although quite similar, definitions and descriptions of what a nature-based solution (Nbs) is. A common denominator is that a Nbs should contribute positively to biological diversity and strengthen ecosystems. Since these definitions and descriptions are very generalized, we have aimed to define, describe and list criteria to be used or considered when a solution is designed, implemented and used to be classified as a nature-based solution involving sediments and reducing erosion as well as slope instability. Experiences and comparisons of pilot studies of Nbs solutions that reduce the risk of erosion in rivers based on the descriptions and criteria are also presented.

Methods:
The International Union for Conservation of Nature's (IUCN's) and the Swedish Environmental Protection Agency's descriptions have been the base for the descriptions and list of criteria that have been developed and adapted to Nbs solutions involving sediments and reducing erosion as well as slope instability.
Evaluations, follow-ups and comparisons with the descriptions and lists of criteria for existing Nbs solutions that are reducing erosion in the Göta river, located in southwestern Sweden, are also performed.

Results: These eight criteria should be met or considered when a solution is designed, implemented and used to be classified as a nature-based solution that involves sediments and prevents problems and damage caused by erosion and landslides:

1. the function and strength of the technical solution works.
2. is adapted to the conditions of the area.
3. promotes biological diversity and strengthens the functioning of ecosystem services.
4. is resource efficient, i.e. that the measure, for example, is designed energy-efficiently and that a sustainable use of materials is applied.
5. is designed in cooperation, i.e. that relevant interests, competences and stakeholders are identified, considered and involved in relevant parts of planning
6. balances different interests, clarify different interests and take them into account in as fair and inclusive way as possible, both in time and space.
7. creates value and provides synergies with other sectors, i.e. that different interests are made clear and synergies with other sectors can be identified. A well-designed Nbs can create more values and benefits and do not cause other problems, geographically and in time, as remobilizing and transporting polluted sediments. An Nbs do not increase emissions of pollutants to air, soil and water. An Nbs do not create unhealthy sediments.
8. is followed up, maintained and adapted to new conditions. An Nbs must be able to be adapted to meet new conditions, such as changed environmental and social conditions.

One riverbank protection consisting of core logs, logs and timber built in 2021 and one that consists of logs and cut-down trees built in 2021 are compared and evaluated with regards to the list of criteria and sediments.

Discussion: The Nbs consisting of core logs meets and fulfills criteria 3 and 4. However, criteria 4 is in some respects not fulfilled, since the core logs are imported from Asia. Criteria 1 and 7 are not fulfilled because the core logs were eroded and wiped away. The function was deficient and cause a risk of remobilizing polluted sediments. The Nbs solution consisting of logs and trees fulfills criteria 1, 2, 3 and 4, and in some respects criteria 6, 7 and 8. This Nbs solution also reduces sediment dynamics and the effects of erosion. One main experience for both Nbs is that criteria 5 should be more considered. That is, for example, ecologists and biologists to follow up the biological diversity and ecosystem services, with regards to the sediments, that the Nbs solutions provide.

LIFE NARMENA: Nature based remediation techniques for heavy metals in sediment – results of a constructed wetland in the Winterbeek site

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Conference theme number(s): 3, 1

Introduction: The industrial legacy of western Europe has caused several problems with contamination. One particular issue that will be targeted in the LIFE NARMENA project is contamination with heavy metals in small watercourses that flow through nature reserves. While the source activities are often no longer present, the contamination remains in the sediment and on the banks of the stream. The sediment and banks act as secondary source zones, gradually causing further spreading of the stored contamination, exacerbating the problems caused by this heavy metal contamination. Beside human exposure, ecological exposure is an important issue not only in the streams itself but also in nature reserves through which they flow. Traditional remediation techniques for contaminated sediment typically rely on the removal of contaminated material. While this might be an effective technique in residential or agricultural settings, it is often not desirable in areas with a high nature value as significant ecological damage can be caused by such conventional techniques.
The objective of the LIFE NARMENA project is to demonstrate less intrusive, nature-based remediation techniques to manage heavy metal contamination in flood-prone watercourses.

Methods: The remediation concept will be aligned with the general water and nature management and requires an integrated approach to deal not only with the environmental issues but also the economic and social implications. To facilitate this, the LIFE NARMENA project brings together a diverse consortium of stakeholders: relevant public organizations, nature NGO's and technical partners.

The project consists of three test sites where different nature-based remediation concepts will be demonstrated.
Two of the sites will be used to demonstrate the use of free water surface constructed wetlands. Both sites are primarily contaminated with cadmium, and additionally contain lower traces of other metals (mainly mercury and arsenic). The contamination on both sites was caused by a combination of historical sediment deposition on the banks and significant seasonal flooding. The remediation concept consists of controlled inundation of the sites, hereby altering the geochemical conditions in the top of the soil/sediment, which results in a decrease in bioavailability and overall mobility of the contaminants.

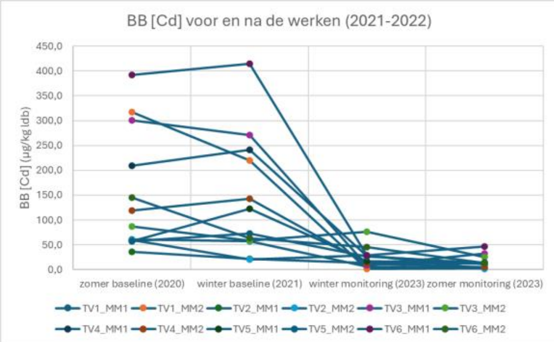

Fig. 1: Bioavailability of Cadmium in sediment before and after inundation.

Results: For one of these two cadmium-contaminated sites, called the "Winterbeek", the works started in the fall of 2022 and the constructed wetland will be finished in 2023.

Discussion: In the first year of monitoring post works, decreases in the bioavailability of Cadmium of more than 90% have been observed in some of the monitored areas, as well as significant declines in toxicity. At the conference, we will be able to share more details about the positive results of the use of constructed wetlands as efficient nature-based remediation technologies.

Soil carbon and nutrient addition from dewatered sediment application to agricultural land –benefits and synergies for dredging and Net Zero

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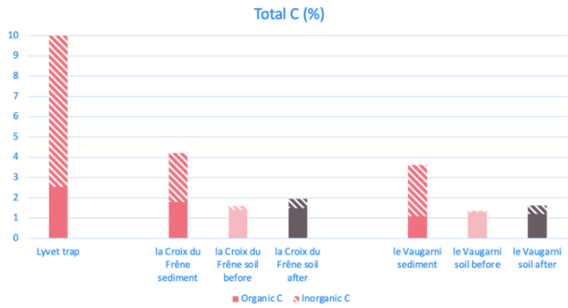
Conference theme number(s): 3 Nature Based Solutions.

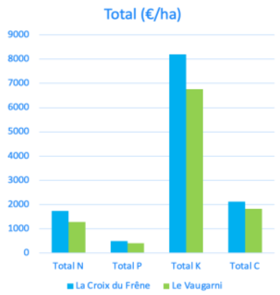
Introduction: Beneficial use of sediment on agricultural land is a common reuse option for uncontaminated, freshwater or desalinated estuarine sediments. Their favourable mixture of particle sizes and decaying organic matter content provide the basis of a loamy soil texture and a slow-release source of major nutrients, including nitrogen, phosphorous, and potassium, together with neutralisation potential from biogenic carbonate. What is less clear is the fate of the organic carbon, its residence time and future storage potential as soil carbon. If the whole system carbon footprint of dredging is to be considered under net zero targets, then this must also be compared to the likely counterfactual, including the offset greenhouse gas emissions from the *in situ* sediment before removal, or any negated contribution to blue carbon stores if the sediment had been left in place.

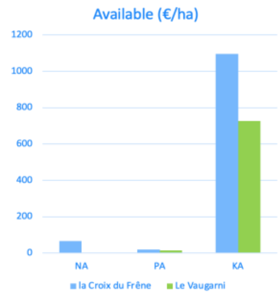
Methods: In September 2022 as part of the Interreg NWE Suricates Project (Sediment Uses as Resources in Circular And Territorial EconomieS) the receiving soils at two agricultural sediment application sites, near la Croix du Frêne and le Vaugarni, were sampled together with the stockpiled dewatered La Rance Estuary sediment delivered to the sites from the La Hisse treatment facility ready for spreading. At both sites the soils were resampled in May 2023 following incorporation of the sediment into soil by the respective farmer and continued rotational or cover crop planting.

Results: Our soil analyses confirm that the placed sediment, which had been stored at La Hisse since January 2020, has broadly similar levels of organic matter (2-3%) and soil organic carbon to that of the receiving soils (2.2-2.4 %), and roughly half that in samples of fresh sediment collect from near to the Lyvet sediment trap. However, the sediments also contain significant inorganic carbon content, presumably from the marine shells observed while sampling. For the 500m^3/ha application rate this corresponds to 18-20 t of total biogenic C addition per hectare (or 68-77t CO_2 equivalent). If this total amount of C could be considered as stored this would represents a value of over €2K/ha (OECD C price 2018-21).



The placed sediments also contain significant total major nutrients in rank order K > N > P. Measured available nutrients were <3 % for N and P, compared to 14 % for K. However, the total equivalent value of mineral fertilizers (UK prices January 2023) for the total nutrient addition present in the sediment would be €6.5-8K/ha..





Discussion: Further work is required to ascertain the long-term C dynamics and nutrient release of organic matter contained in sediment place on land. However, assuming complete decomposition will occur over the 10 year interval between permitted spreading, the loss of temporary soil C storage will be replaced by the much larger value of nutrients released, which together exceed the actual cost of sediment application.

Acknowledgements: The SURICATES Project was funding through the INTERREG NWE programme from the European Regional Development Fund (ERDF).https://vb.nweurope.eu/projects/project-search/suricates-sediment-uses-as-resources-in-circular-and-territorial-economies/

Aquaforest: a Nature-based-Solutions for restoring and developing new mangrove habitats through eco-engineering

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Conference theme number(s): 3.

Introduction: Human activities, rising sea levels, and more frequent severe storms have drastically reduced mangrove habitats, putting over half of the world's mangrove ecosystems at risk of collapse, according to the IUCN Red List of Ecosystems. This loss is catastrophic for nature and people, as mangroves provide vital services such as coastal protection, carbon storage[1], and fisheries support.

Meanwhile, vast volumes of dredged sediments are discarded annually during waterway maintenance, though these sediments could support mangrove growth in tropical and subtropical regions. Addressing this opportunity, the Aquaforest project explores and demonstrates the reuse of dredged material to create new mangrove habitats. Initiated by the Jan De Nul Group, the project is managed by a consortium of eight partners (Haedes, Mantis, SouthPole, ESPOL, VUB, UAntwerp, and Calisur), with financial backing from G-STIC and IUCN. Located in Ecuador's Guayas Delta, the project leverages sediment from the maintenance of the Access Channel to the Port of Guayaquil, managed by Jan De Nul since 2018.

Methods: Aquaforest is an innovative project that repurposes dredged sediments sustainably to create mangrove habitats in the Guayas Delta. After extensive investigations and eco-engineering studies, a 50-hectare landmass was designed on an intertidal flat near the Access Channel, enclosed by a J-shaped sand bund and semi-permeable structure filled with silty sediments. Hydrodynamic modeling confirmed the habitat's stability, and sediment analysis validated its suitability for mangrove growth.

The project combines eco-engineering with community involvement through capacity building and sustainable management. By fostering assisted natural regeneration, it enhances biodiversity and ecosystem resilience. Aquaforest integrates key stakeholders at every stage, ensuring the long-term ecological and socio-economic sustainability of the newly created mangrove habitat.

Results: Haedes utilized its NESEV tool (Ecosystem Services network model) to evaluate ecosystem services for the AquaForest project. NESEV provides a holistic valuation framework, identifying a wide range of ecosystem services and actors (nodes), allowing to create a matrix and visualize the values in the network. It enables multi-currency valuation based on client needs (€ per area) and highlights the benefits nature provides to human society, bridging ecosystems and human well-being[2].

Key ecosystem actors identified in this study include fisheries, mangroves, local businesses, local population, and tourism. NESEV was applied to analyze different scenarios: baseline, one year post-plantation (Scenario 1), 10 years post-plantation (Scenario 2), and 20–25 years post-plantation (Scenario 3). The results show that the new island will significantly enhance the ecosystem after 25 years, when the mangrove forest matures.

NESEV predicts an increase in biodiversity, with new species populating the island. The mangroves will also improve water and air quality, contributing to a higher standard of living for the local population. Overall, the analysis indicates that the mangrove-covered island will generate an added ecosystem value.

Some Sustainable development goals (SDGs) were evaluated in NESEV for the baseline situation and the scenarios of island creation. The process was assessed to see the SDGs achieved by the project due to the newly created mangrove ecosystem.

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First morphological response of a large nearshore nourishment project using fine sand, Knokke, Belgium

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Introduction: Sandy nourishments are a common and successful engineering solution to mitigate coastal erosion. They make the coast more resilient as the supplied sand creates a larger beach to accommodate the natural dynamics, storminess associated to climate change and rising sea level [1]. Nearshore nourishments have usually a lower cost, while providing an improved protection from waves. The largest nearshore nourishment with fine sand (150 µm) project ever in Belgium was completed between 10/2023 and 02/2024. A volume of 1.2 million m^3 was placed in Knokke below the low water line and extending 650 m from the coastline. The aim of this study is to assess the efficiency of a nearshore nourishment with fine material as well as its incipient morphological evolution.

Methods: Knokke is located on the east coast of Belgium. It is characterized by a moderate wave energy and a macro-tidal regime. The coastline is oriented WSW-ENE and consists of a gentle sloping sandy beach up to 400 m wide back by a seawall. The coast suffers from long-term erosion due to the offshore presence of the Appelzak tidal channel at -8 m TAW (Belgian Ordnance Datum corresponding to low spring tide) [2]. High-resolution nearshore bathymetry surveys were conducted with multibeam.

Results:
An accretion up to 2.5 m was observed surrounding the groynes between the low waterline and the depth contour of -4.5m (Fig 1).

Fig. 1: *DEM of difference between pre (10/2023)-post (03/2024) nearshore nourishment surveys.*

The channel floor just off the shoreface was subject to a vertical gain by on average 0.4 m. A few concentrated spots that accreted by up to 1.7 m were direct remnants of nourishment ship dumps. In contrast, negative morphological changes ranging from -0.05 to -0.7 m characterized the beach especially in the west part of the resort. This was likely due to the spreading of the beach nourishment carried out in 02-04/2023.

Discussion:
Knokke coast is liable to erosion by fast hydrodynamic processes causing alongshore and cross-shore sand transfers. The 'efficiency' of the nearshore nourishment characterized by fine sand ranges from 61% to 72%. At the end of the nearshore nourishment, the immediate environment inside of the Appelzak channel also showed a significant sedimentation. It is hypothesized that the nearshore nourishment might have induced a reduction in tidal currents by blocking of the part of the tidal channel just in front of the shoreface and diverting flows more offshore inside the channel. This would have engendered deposition in the alongshore relatively sheltered parts of the channel bed. Thus, most of the supplied sediment would still be present at the immediate environment of the nourishment area. The evolution of the nearshore nourishment and its effect on the beach-shoreface morphology will further be monitored in 2025.

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[1] Brand, E. et al. (2022) Dutch experience with sand nourishments for dynamic coastline conservation, an operational overview, *Ocean and Coastal Management*, **217**; [2] Houthuys, R. et al. (2022) Morfologische evolutie van de Vlaamse kust tot 2019: Evolutie van de Vlaamse kust tot 2019. Versie 2.0. WL Rapporten, 18_142_1. Waterbouwkundig Laboratorium: Antwerpen.

Dewatering of Dredged Sediment by Natural Solutions

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Introduction: Dewatering of dredged sediment often relies on chemicals and heavy machinery, which increase fossil fuel use and emissions [1]. Traditional sediment dewatering methods only worsen the financial and environmental burdens associated with sediment management. When the slurry eventually dries at dewatering fields, it is perceived that the biological quality of the resulting sediment does not meet the standards of healthy soil, meaning it is rarely reused. It is also important to note that none of the existing commercial dewatering methods improve the environmental quality of the final product; they only address its physical properties.

Fig. 1: One of the dewatering ponds after having been filled with dredged sediment.

Over the past decade, more nature friendly innovative methods have been developed [2]. These methods use only endemic fauna and flora to significantly accelerate the dewatering process for various types of slurry. Additionally, the treated final product resembles closely biological properties of soil. Soil is a valuable resource, which would otherwise need to source it from the commercial soil market, a process that is both expensive and environmentally harmful due to operations-related emissions.

Methods: The goal of this research is to demonstrate that dewatering can be sped up without increasing the financial and environmental costs of sediment management, while also improving the quality of the dried product so it can be reused after the treatment. This can be achieved through the application of natural technologies. To achieve these objectives, the City of Rotterdam and Medeina conducted a pilot project. In this pilot, natural dewatering technologies were implemented after filling in dewatering ponds with dredged sediment (see Fig 1). Three dewatering ponds, each approximately 15m x 15m, with a total capacity of around 250 m³ were filled with slurry. One pond (Vak4A) was treated with worms and plants, one pond was only dewatered with worms (Vak4b) and one pond was used as a reference (no treatment). During the pilot, an intensive monitoring was conducted to capture the changes in solid content and strength of soil for a period over 4 months. This pilot marks a pioneering effort of using natural solutions for sediment circularity and reuse.

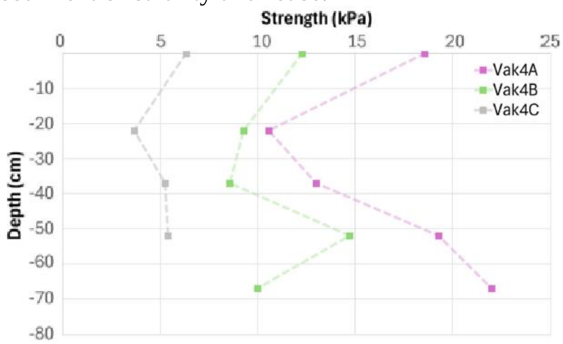

Fig. 2: In-situ soil strength measured 3.5 months after filling dewatering fields. Vak4A was treated by worms and plants, Vak4B was dewatered by worms and VAK4C was used as a reference (no treatment).

Results: The solid content of the slurry was increases by 15% over three months by suing natural solutions, while the reference depot showed virtually no average increase in solid content. Looking at the soil strength (see Fig 2), natural solutions exhibited strengths ranging between 10 and 20 kPa after 3.5 months, with the reference remaining around 5 kPa. This explains why the two depots that were treated with Medeina were accessible up to 80% of their surface, whereas only a quarter of the reference depot could be walked.

References: [1] Tarleton (1992) *Filtr. Sep.* **29**:246-252; [2] de Lucas Pardo et al. (2020) *Terra et Aqua* **161**:6-19; [3] de Lucas Pardo and Kirichek (2020) *Land/Water* **8/9.**

Adaptive Management for environmental aspects of dredging and reclamation projects: Reactive and Pro-Active

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Introduction: A number of publications, among which the CEDA information paper on Adaptive Management (AM), published in 2015 [1], contains a high-level description of the different aspects of AM. The descriptions are often generic and do not include details of AM of specific parameters yet. In this fast-evolving topic, a number of information gaps and subjects that require revision have appeared the past years. For instance, a topic which has undergone a considerable evolution in recent years is pro-active adaptive management of turbidity.

The CEDA Environment Commission (CEC) has therefore decided to establish a Working Group to prepare a CEDA information paper on (Pro-active) Adaptive Management in dredging and land reclamation projects [2]. The paper provides an overview of existing tools and platforms to implement AM and recommended best practises. Also, a questionnaire on the awareness and experience with AM was launched in the industry and a significant number of responses was received from all different types of stakeholders in dredging and reclamation projects. It was found that significant awareness of the concept of Adaptive Management exists in the industry, but that the benefits of Pro-Active AM for environmental management are less known. Therefore, this aspect was covered in more detail in the paper. Finally, case studies demonstrate that (Pro-active) AM can help to guarantee environmental compliance.

References: [1] CEDA (2015): Integrating adaptive environmental management into dredging projects. CEDA Position Paper; [2] CEDA (2024) : ADAPTIVE MANAGEMENT FOR ENVIRONMENTAL ASPECTS OF DREDGING AND RECLAMATION PROJECTS: REACTIVE AND
PRO-ACTIVE.

Dredging project and environmental monitoring programme in the O Burgo Estuary (A Coruña, Spain)

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Introduction: The O Burgo estuary has been the recipient of numerous discharges for years that deteriorated the quality of its waters and created a layer of polluted sediments from industrial and urban discharges. The removal of contaminated materials from the estuary and their partial restitution by new zero polluted sediments will improve the quality of the waters and the bottom of the estuary, thus promoting the recovery, productivity and quality of the shellfish banks located there, as well as the recreational uses of the area.

This project includes a dredging of 583,337.04 m^3 in the estuary and a total investment of approximately €40 million. The complexity of this dredging is conditioned by three factors: 1) it is an environmental dredging, not designed to get sand or increase draft. To do this, it is necessary to remove only the upper layer of polluted sediments (which constitute a thin layer 50 cm width) and replace them with clean sediment; 2) the Ria de O Burgo is a closed estuary with a very shallow draft, subject to large tides with tidal range up to 4.5 m, with suspended mud that lacks bearing capacity and can disperse pollution while dredging. In addition, there are large areas very shallow even with high tides; 3) it has great environmental consequences, being an estuary of high environmental value, with a great wealth of wintering birdlife, seagrass meadows and where shellfishing is an important socio-economic activity.

Methods: The dredging of material with the highest contamination levels, involves a treatment that allows the retention of the materials to later be confined close to the project location, generating green spaces and giving continuity to paths and walkways. The material with the lowest contamination was initially thought to be dumped to the sea.

The discharge of the lixiviated water was carried out in the Fonteculler lagoon ensuring, by means of sensors, measurement systems and periodic analytical controls, rigorous environmental control. Following the environmental monitoring programme, special attention was paid to the control of water and environmental quality and the use of continuous measurement sensors for the different parameters. Once the dredging was completed by mid 2024, clean aggregates were provided for the recovery of the intertidal zone, restoration of channels, improvement of shellfish banks, regeneration of the bottom of the Culleredo lagoon and Santa Cristina beach. After the end of the project 70,000 m^2 of public spaces will be recovered.

Fig. 1: Areal view of the confined dredging facility in Culleredo.

Results and discussion: The Culleredo marshes, of more than 227,000 m^2, have been excluded from the intervention in order to preserve the seagrass meadows and the main habitats of wintering birds. Other activities carried out in the field of environmental conservation have been the periodic analytical control and collection of the affected shellfish species before the start of the work and their subsequent replanting with seeds from hatcheries and the transplantation of the protected marine phanerogam *Zostera noltii* and the elimination of invasive exotic species such as the pampas reed "*Cortadeia Selloana*". mainly present under the bridge of the A9 motorway located close to the dregding site. In all these works, we have had the expert collaboration of the shellfishmen of the estuary, great connoisseurs of the terrain and the special circumstances of their work for the improvement of the environmental quality of the O Burgo estuary.

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