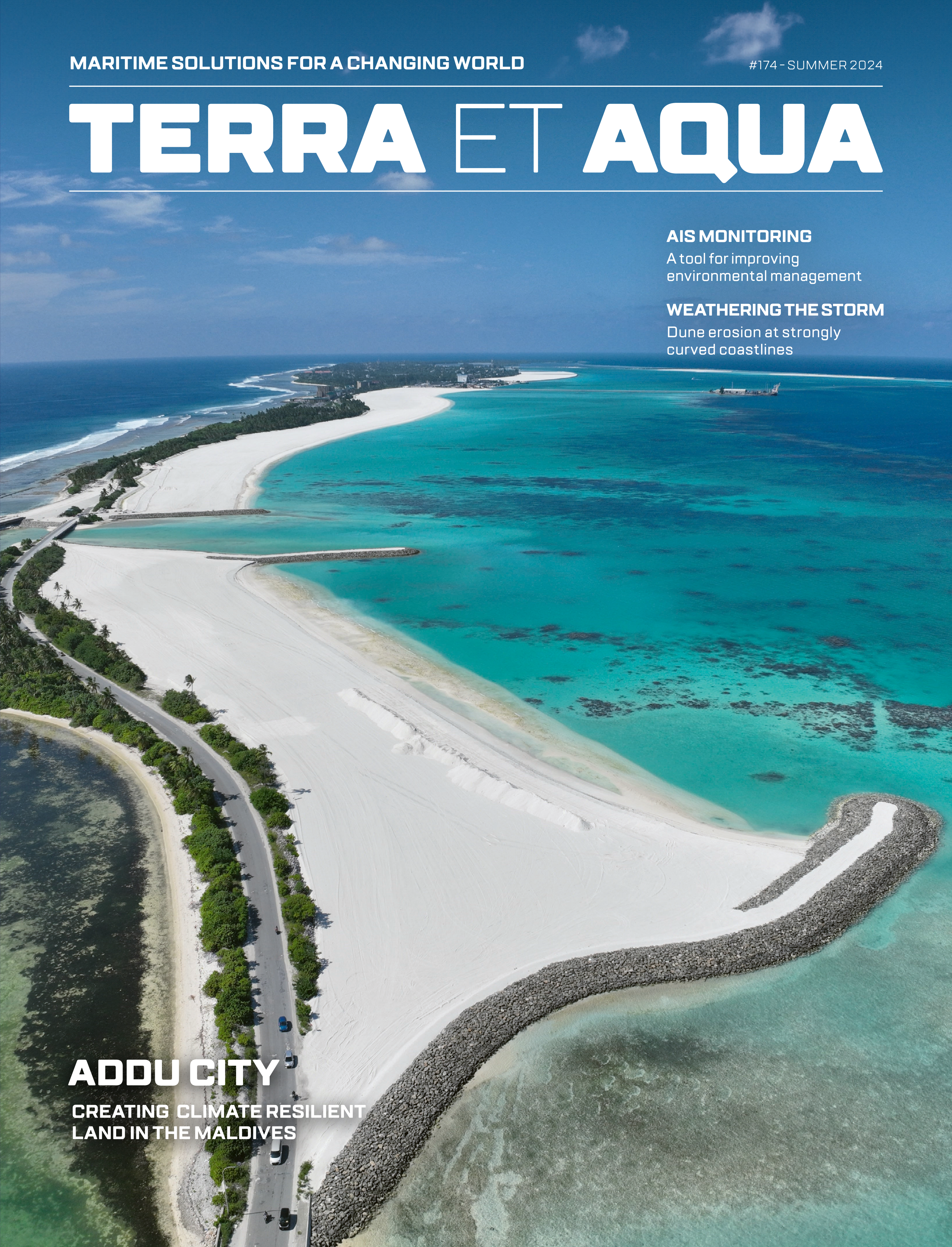
MARITIME SOLUTIONS FOR A CHANGING WORLD

#174 - SUMMER 2024

TERRA ET AQUA



AIS MONITORING

A tool for improving environmental management

WEATHERING THE STORM

Dune erosion at strongly curved coastlines

ADDU CITY

CREATING CLIMATE RESILIENT LAND IN THE MALDIVES

PROTECTING THE ENVIRONMENT

The case of Addu City dredging and reclamation project provides a number of important findings regarding novel construction methodologies, environmental challenges, stakeholder engagement and lessons learnt. Read the full article on page 30.

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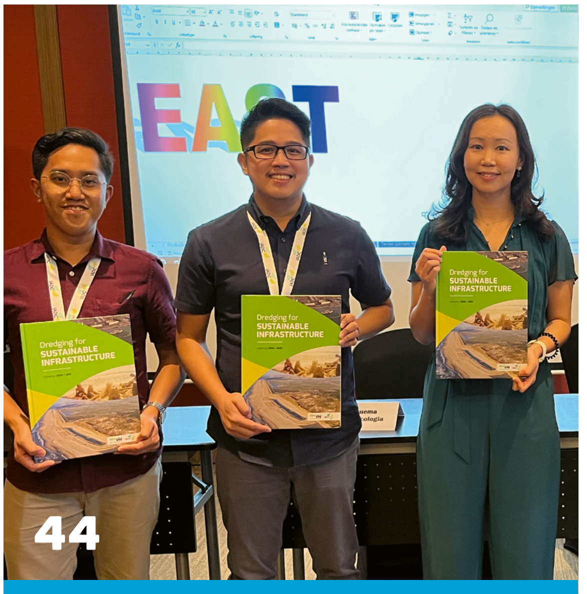

COLLABORATION NOT COMPETITION

For three days at the end of May, dredging professionals from around the globe gathered in Rotterdam for the CEDA Dredging Days 2024. The conference's theme, "Dredging in a changing world", saw the topics of sustainability, energy transition and decarbonisation at the forefront of many sessions, along with how technology such as AI will play a role in our industry. What also stood out was the call for collaboration not competition.

Towards the end of the proceedings, after a myriad of expert panels, debates and opinions, it was the turn of the younger generation as six young professionals took to the stage for IADC's Young Author – Pitch Talk Award. The concept, to turn their submitted papers into a seven-minute presentation much like a TED Talk. Lara Gehrmann, a project manager with Hülskens Sediments in Germany, was the first ever recipient of the award for her presentation on sustainable reservoir sediment management using fully automated dredges.

> **IADC is collaborating with PIANC to work on a global network of universities and colleges.**

The runner up, Sterre Bult, a mechanical engineering student at Delft University of Technology, was given a special mention for her presentation looking at how dredging related knowledge could be utilised in the minimal environmental impact of flatfish trawling. The jury were particularly impressed and enthused to see how technology used in our industry was being applied to solve a problem in the fishing industry.

With this goal in mind, IADC is collaborating with PIANC to work on a global network of universities and colleges. Not only to facilitate and champion the exchange of knowledge around the world, but to excite and engage the next generation of engineers and young professionals for a career in dredging.

Getting students enthusiastic about dredging is a must for the future of our sector.

On the topic of sustainability, on page 30, we hear from the team who worked on the Addu City dredging and reclamation project in the Maldives. A project with many externalities and one which required great attention to sustainable practices given the environmental challenges that it faced. It's interesting how including such externalities in the project assessment could take sustainability to the next level and what impact that would have.

Also in the issue, Juan Cruz Andrini, the recipient of this year's IADC Young Author Award shares his research on how AIS can be used an efficient and cost-effective monitoring tool for improving environmental management in dredging projects. We also take a look at how the winter storms of 2022 offered a unique opportunity to analyse dune erosion patterns along the curved coastline at Maasvlakte 2, an extension of the Port of Rotterdam.

Frank Verhoeven
President, IADC

Construction of the crane platforms with the post-storm dune profile at the back (22 April 2022). Photo courtesy of Joosten Group, who provided the geotubes that guaranteed the platform's stability.

2D EFFECTS ON DUNE EROSION AT MAASVLAKTE 2

Dune erosion due to storm surges and severe wave attack is the primary failure mechanism of sandy sea defences. At a curved coastline, dune erosion is greater than at a straight coastline. However, how much higher is often difficult to predict. This article presents a comparison of field observations and model results of the response of the Maasvlakte 2 curved sandy sea defence to storm attack.

The coastline response of the curved coastline of Maasvlakte 2 after the 2022 winter storms is reproduced using a 2D XBeach model. This model was initially set up to support a feasibility study into construction of a wind park at the perimeter of Maasvlakte 2, which is an extension of the Port of Rotterdam, in the Netherlands. At that stage it proved challenging to properly validate the model. Svašek continued to work on the model and was presented with an opportunity: in the period leading up to the construction of the wind park, the Dutch coast endured a heavy storm season in the winter of 2021-2022. Storm Corrie, Dudley, Eunice, and Franklin made landfall just after a regular maintenance survey and before a post-nourishment survey leading to well-observed dune erosion at Maasvlakte 2.

Simultaneously, a new release of XBeach with recommended model settings for 1D dune erosion was prepared to become the mandated tool for evaluating dune safety in the Netherlands (part of the BOI programme 2020-2023). This presented both opportunity and motive to validate the 2D XBeach Maasvlakte 2 model under extreme conditions to: 1) showcase the abilities of this new XBeach release in combination with the 1D BOI model settings at a curved coast; and 2) emphasise the importance of a 2D approach when dealing with strongly curved coasts such as the Maasvlakte 2.

Dune erosion mechanism at a curved coastline

A strongly curved coast behaves fundamentally different than a straight coast when it comes to storm erosion of dunes. On a straight coast, sand eroded from the dunes is deposited on the foreshore, limiting further wave attack and thus, dune erosion. The angle between the incoming waves and the coast varies alongshore on a curved coast. The angle is an important factor in the magnitude of the alongshore transport. Therefore, a gradient in the alongshore transport exists along curved coastlines.

Eroded sediment from the dunes is not deposited locally but transported alongshore in the direction of the waves (Figure 2). As a result, the curved sea defence is exposed to undiminished wave attacks during the entire storm and erosion volumes can be twice as high as on a straight coast (Den Heijer, 2013). In theory, the location attacked by waves arriving perpendicular to the coastline will not generate longshore transport. In practice, as at the Maasvlakte 2, the effect of increased dune erosion is expected to occur over the entire curved part of the coastline, as the wave angles vary over the course of a storm.

At Maasvlakte 2, not only the curve in the coastline adds complexity to storm erosion processes. A transition between a hard and sandy sea defence about 1.5 km north of the curved coastline further complicates the matter. For waves incoming from the north, strong southward longshore currents with a high transport capacity (but no sediment to move) arrive over the foreshore of the soft sea defence, leading to high pick up of sediment and consequent erosion at the sandy side of the transition. For waves incoming from the south, sediment eroded from the dunes moves further north, leading to a reduced build-up of the foreshore and additional erosion.

Triplet-storm attack of the Maasvlakte 2 sea defence

At the end of January 2022, storm Corrie swept over the Netherlands. Shortly thereafter

WIND PARK MAASVLAKTE 2

Rijkswaterstaat, responsible for the design, construction, management and maintenance of the Netherlands' primary infrastructure facilities, challenged itself to become climate-neutral before 2030. Wind Park Maasvlakte 2 played an important role in reaching this goal. The park includes wind turbines on the soft (sandy: 3.2-10 km, Figure 1) and the hard (rock and pebbles 0-3.2 km, Figure 1) sea defence of the Maasvlakte. These defences protect the 2 hectares of land reclamation against the North Sea. Rijkswaterstaat asked Svašek Hydraulics to conduct a study into the morphological feasibility of Wind Park Maasvlakte 2, especially concerning the sandy sea defence. In these studies, we investigated the influence of wind turbines on beach and foreshore morphology, and aeolian sediment transport to the dunes.

FIGURE 1

Overview of Maasvlakte 2 including the alongshore referencing.

in February, the dunes were tested by a series of powerful and consecutive storms, named Dudley, Eunice and Franklin. This impressive and unique trio of storms resulted in an unprecedented phenomenon: six consecutive days of stormy weather along the coast, setting a record for the Netherlands.

Eunice was the heaviest storm of the three, with peaks up to Beaufort wind scale 11. All Dutch meteorological stations (except Maastricht) observed wind gusts exceeding 100 km/h and coastal areas registered gusts over 160 km/h. The extent and duration of the storm front was exceptional and it was the heaviest storm to hit the Netherlands since 1990. Public life came to a stop and five people lost their lives.

Large waves generated by the storms hit the coast from the north-west (Dudley), south-west (Eunice) and south-west to north-west (Franklin). Coastal defences did their job. Dykes endured the storm and dunes eroded to an extent, as designed, but held. Afterwards, impressive sights of steep cliffs could be observed at many coastal spots as a result of the battering waves.

The Maasvlakte sea defence has been in place since 2012 and the storms of January/February 2022 were among the heaviest in its existence. Waves in these storms reached significant wave heights of up to 6 metres (m), wave periods of over 15 seconds and water levels of up to 2.8 m+NAP. NAP stands for Normaal Amsterdams Peil or the normal water level in Amsterdam, which is slightly lower than sea level, and is used as a base to measure water levels in the Netherlands.

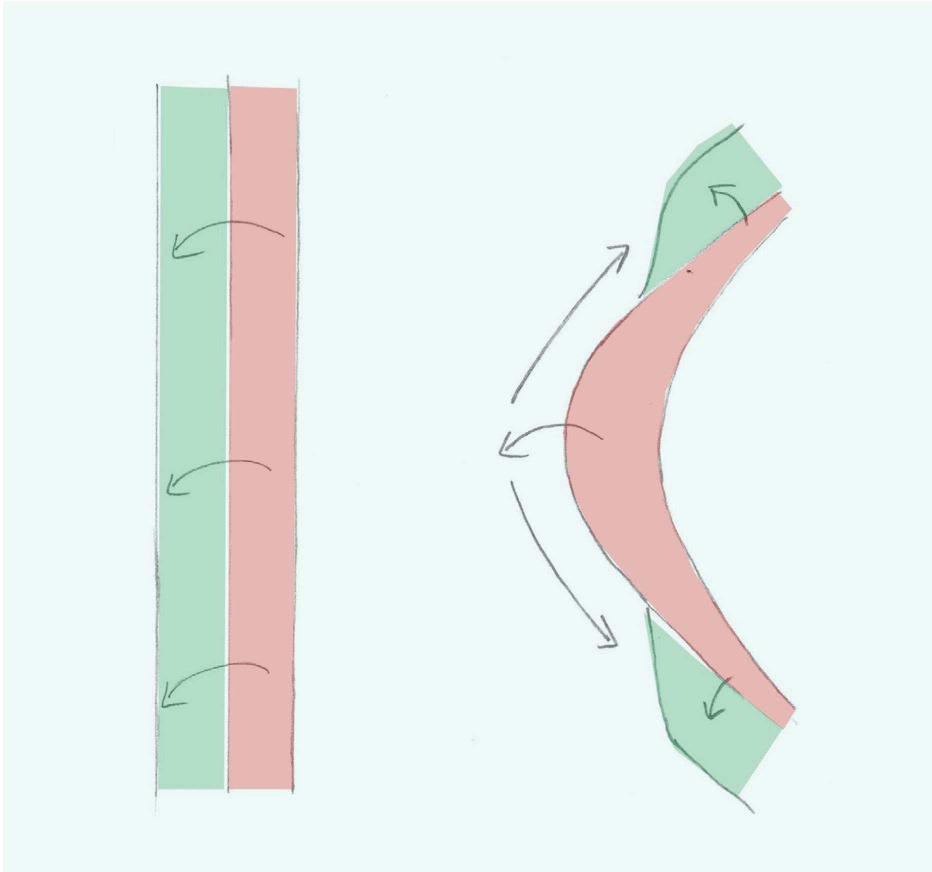

FIGURE 2

Schematised difference in dune erosion and foreshore deposition between straight (left) and curved (right) coasts under directionally varying wave attack.

Measurements before and after the storm

PUMA, the project organisation for the extension Maasvlakte 2, was contracted by the Rotterdam Port Authority for designing, constructing and maintaining the Maasvlakte 2 between 2012 and 2022, which included yearly measurements through a combination of multibeam (below water) and laser altimetry (above water). The measurements took place every second quarter of the year to monitor the coastal defence and to direct nourishments where most needed. Before construction of the wind park, the maintenance responsibility of the Maasvlakte 2 sea defence was transferred from the Port Authorities to Rijkswaterstaat. It was the latter who commissioned an additional measurement in Q4 2021 in anticipation of the construction of the wind park by PUMA. This gives a good baseline of the sea defence before the storms.

Together with the survey of Q2 2022 after the completion of the nourishment, the impact of the heavy storm season on the dunes of the Maasvlakte 2 was quantifiable. Unfortunately, the storm-induced bed changes below 3 m+NAP could not be distinguished from the bed changes associated to construction of the platforms and the nourishment. Nonetheless, we processed the Q4 2021 and Q2 2022 measurements to investigate the change in bed level. A transect of this analysis is presented in Figure 4. In this figure, a heightened beach can be observed (see red patch), which is in part due to dune erosion and in part due to the nourishment. In addition, a clear erosion zone is visible at the dune front, which is the result of the storm season (blue patch in Figure 4).

The dune erosion along the complete Maasvlakte 2 is subsequently determined by analysing the volume in the erosion zone (blue patch) for the complete stretch of coastline. This is shown in the top panel of Figure 5. In this figure, we observe two areas with increased dune erosion: 1) at the bend where the material is not deposited on the foreshore and waves hit the dunes unobstructed

> **The storms of January/February 2022 were among the heaviest in the existence of Maasvlakte 2.**

NOURISHMENTS MAASVLAKTE 2 IN 2022

The Maasvlakte 2 sea defence is an eroding system by design, which needs regular maintenance. This maintenance has been performed every two years via beach and foreshore nourishments. Rijkswaterstaat had scheduled maintenance for 2022 in the summer. However, due to anticipation of the wind park construction, Rijkswaterstaat advanced the nourishment to March. This made it possible to reinforce the storm-eroded volume and simultaneously place sand for constructing the crane platforms. After completion of the nourishment but before platform construction, laser altermetry measurements were performed.
The platforms were necessary for the cranes to lift the eleven turbines of the wind park in place. The platforms were made to be resistant to flooding and erosion. To this end, they were constructed to a height of around 3 m+NAP and were lined with geotextile bunds.

FIGURE 3

Wind Park Maasvlakte 2, as seen from the south. Photo© Svašek Hydraulics/Bernard Eikema.

(4.5–6 km); and 2) at the hard to soft transition (around 3.5 km) where the strong longshore transport without supply leads to large pick up and erosion of sediment, in turn leading to a low foreshore and heavy wave attack, and related dune erosion.

Further south (around 6 km), the dune erosion is reduced, even though this is still in the curved section of the Maasvlakte. This is likely related to the fact that a significant part of the incoming waves arrive perpendicular to the coast at this location (bottom panel in Figure 5) generating less longshore transport, resulting in accumulation of sand on the foreshore, and thus leading to less dune erosion. In addition, the sediment from the highly erosive sections of the coast settles in adjacent sections, causing the heightened foreshore to reduce wave attack and limit dune erosion. This contrasts with a straight and regular coast where dune erosion would be much more uniform. What is remarkable however, is the reduction of dune erosion right in the middle of the bend (at 5.1 km), but we can only speculate on the cause of this local reduction. It may be related to post-storm recovery (by aeolian processes) or dune reconstruction and nourishment, but we have not been able to verify this.

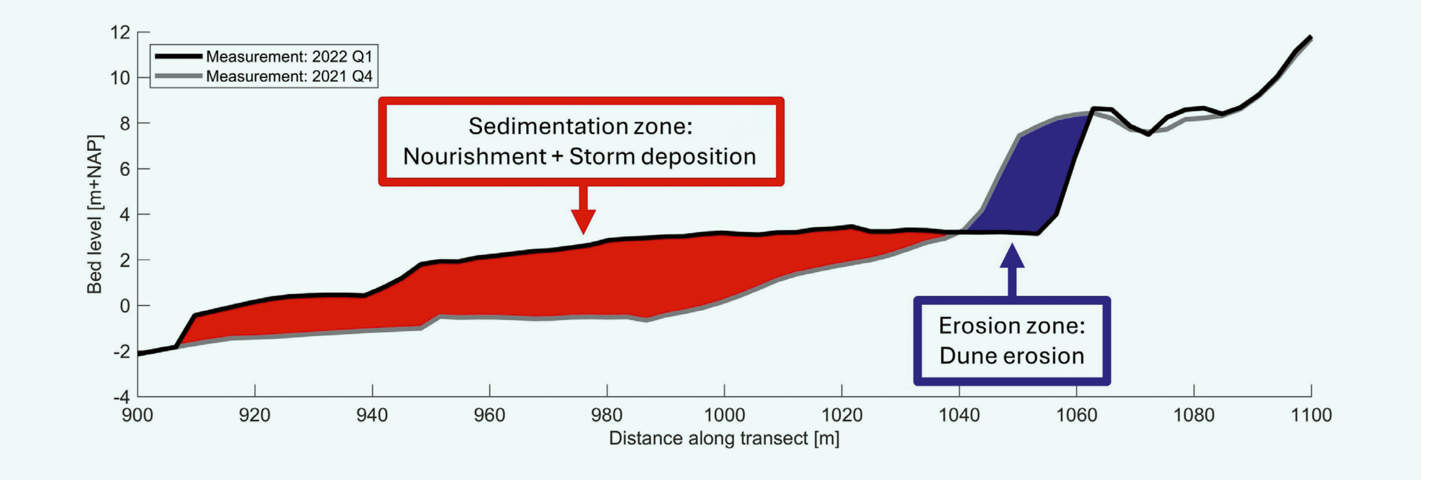

FIGURE 4

Overview of a representative transect at Maasvlakte 2 indicating the dune erosion and the sedimentation.

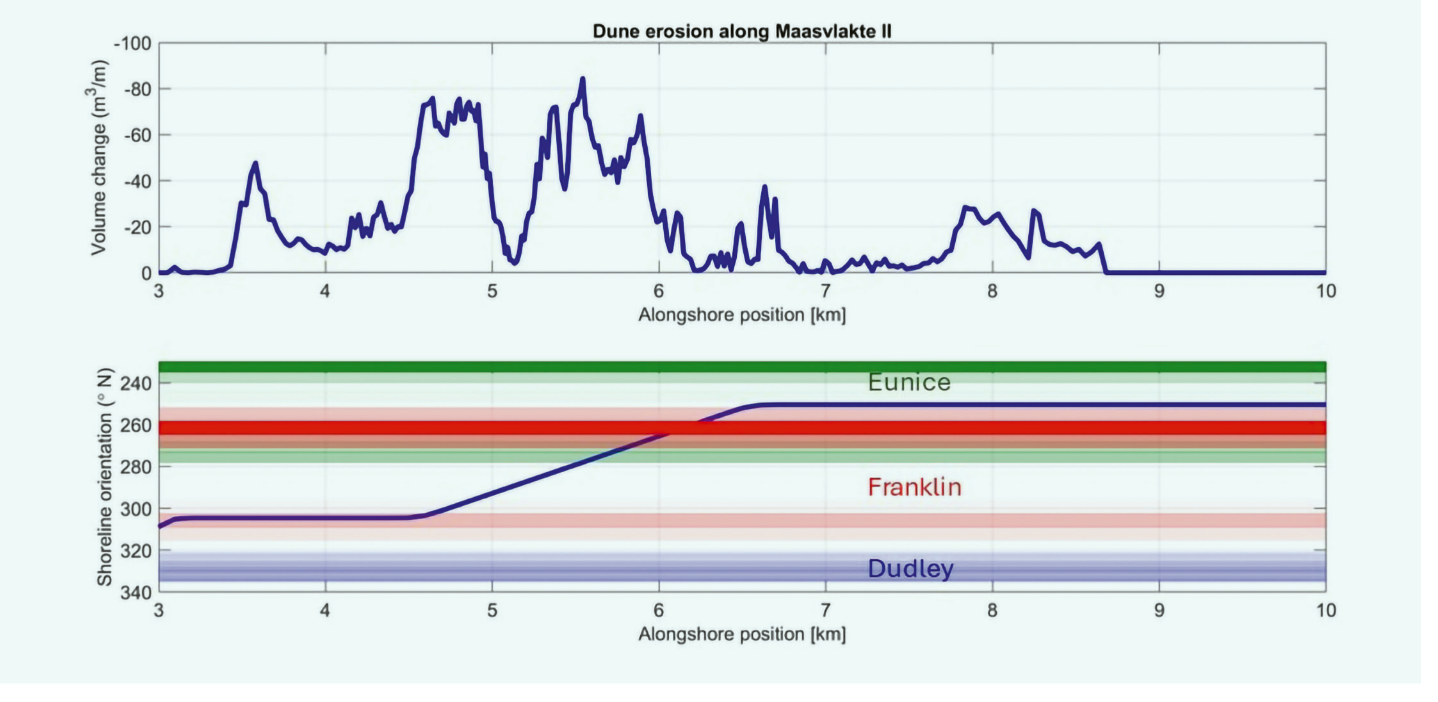

FIGURE 5

Top panel: Dune erosion volume along Maasvlakte 2. Bottom panel: Shoreline orientation of Maasvlakte 2 (blue line) in relation to the incoming wave angles (blue: Dudley, green: Eunice, red: Franklin).

The modelling software

To model the coastal response to storm conditions (i.e. dune erosion) and the complexity at play around the curved coastline of Maasvlakte 2, we chose to apply the two-dimensional XBeach modelling software, as it has been developed especially for modelling dune erosion. The XBeach software is applied in surfbeat mode to simulate the important hydrodynamic and morphodynamic processes in the swash zone that impact sandy coasts. The surfbeat mode resolves the short-wave variations on the wave group scale and the long waves associated with them in combination with a detailed approach to wave-driven sediment transport (Roelvink, 2009). This is the recommended mode since we focus on swash zone processes where long waves are the main driver of dune erosion.

Another reason to apply the XBeach software is that within the national programme BOI (Assessment and Design Instrument for flood defenses), the new instrument for dune safety assessments is also based on the XBeach modelling software. This development includes a BOI XBeach release (Rijkswaterstaat, 2023) with thoroughly validated model settings for 1D dune erosion applications, tuned especially to the Dutch coastal system (Deltares and Arcadis, 2022). Therefore, the XBeach software is considered very suitable for this case study.

Svašek continued to develop the 2D XBeach model of Maasvlakte 2. When the winter storms in 2022 hit, and pre and poststorm surveys became available, we saw an opportunity to validate the model properly. As the BOI settings had only be validated on 1D cases up to this point.

Modelling approach

We used a curvilinear 2D XBeach computational grid. Applying a curvilinear grid for a curved stretch of coast is very efficient because gridlines are parallel to the depth contours and grid refinement can be applied from the point of wave breaking until the dune region. This resulted in a grid with a resolution of 2.5 m in the cross-shore direction and a resolution of 25 m in alongshore direction (see Figure 6). These elongated grid cells are justified as the variation in hydrodynamic conditions is gradual in the alongshore direction, while in the cross-shore direction, the hydrodynamic conditions change rapidly. In the end, the computational grid consisted of 70,000 elements.

A crucial next step in the modelling approach is applying adequate wave-forcing conditions on the model boundary since the morphological development of the dunes at the Maasvlakte is primarily governed by wave forcing. The influence of the tidal flow and the river outflow from the Nieuwe Waterweg (new waterway) are found to be of minor importance, as the dune erosion mainly occurs in the upper part of the profile where wave action dominates.

We impose temporarily and spatially varying wave-forcing conditions on the model boundary. The spatial variability in wave-forcing conditions is found to be necessary, as the height and direction of the incoming waves along the model boundary can vary significantly due to the curvature of the coastline. Therefore, spatially and temporarily varying wave-forcing conditions are prescribed at five locations along the model boundary. These wave-forcing conditions are derived with a wave transformation matrix, which was set up during the construction of the Maasvlakte 2 to translate the measured wave conditions at the Europlatform to the -20 m+NAP depth contour along the perimeter of the Maasvlakte.

These wave-forcing conditions have been derived for the complete validation period which is the period between the two bathymetrical surveys. This is a period of 126 days, starting at the end of October 2021 and ending at the beginning of March 2022. However, running this 2D XBeach model for 126 days (or 170 million modelling timesteps) is rather computationally expensive, even though the model is run with parallel computing on our in-house advanced computer cluster.

Therefore, two acceleration techniques have been applied. The first is the application of a morphological acceleration factor

DEVELOPMENT OF THE MAASVLAKTE 2 XBEACH MODEL

The development of the 2D XBeach model for Maasvlakte 2 started as part of the wind park's feasibility study. The model's aim was to support decision-making by assessing the wind turbines effects on the beach and dune morphology. To this end, the XBeach model was set up to investigate the morphological response under design storm events and under regular long-term conditions. The model was set up in consultation with a group of Rijkswaterstaat and dune experts. During the study, the successful application of the model made it possible to quantify the expected coastal response to the wind park. The wind park was eventually realised in 2022. A forthcoming paper will discuss the challenges and eventual success of that project (in which Svašek played only a small part) in cooperation with RHDHV and Deltares. Here, we will discuss the 2D XBeach model that resulted from the exploratory phase.

Svašek continued to develop the 2D XBeach model of Maasvlakte 2. When the winter storms in 2022 hit, and pre and poststorm surveys became available, we saw an opportunity to validate the model properly. As the BOI settings had only be validated on 1D cases up to this point.

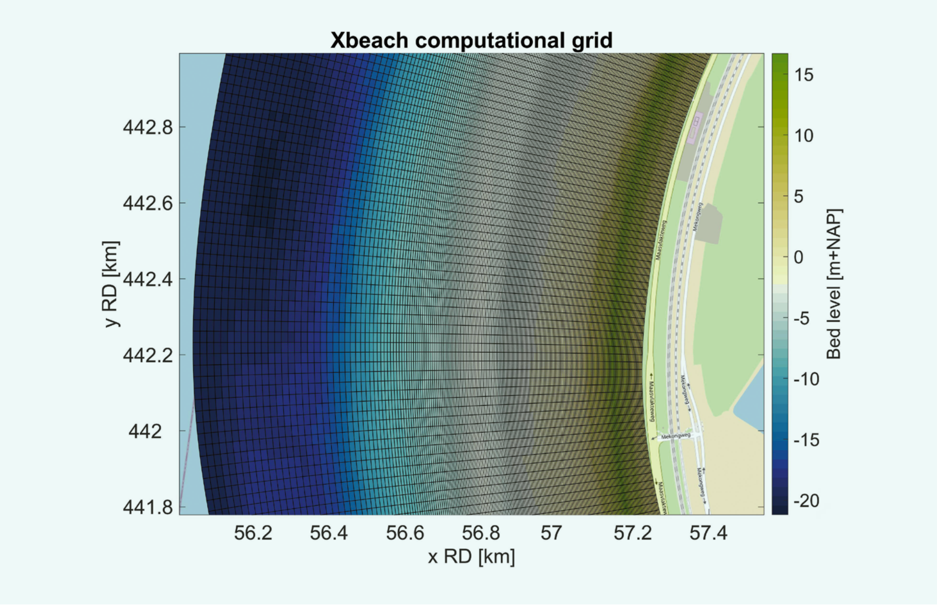

FIGURE 6

Illustration of the applied curvilinear 2D XBeach model grid for Maasvlakte 2.

(or MORFAC, Ranasinghe, 2011) and the second is a model forcing reduction technique (Luijendijk, 2019). The MORFAC technique allows for morphodynamic upscaling and enables the simulation of long-term morphological evolution. The concept is that the MORFAC speeds up the morphological time scale relative to the hydrodynamic timescale. In our modelling approach, a MORFAC of 12 is used. This implies that a simulation for a period of 2 hours with a MORFAC of 12 results in morphological evolution of one day. The assumption behind this concept is that the changes in hydrodynamics are magnitudes bigger than the changes in morphology.

In addition, the model forcing reduction technique allows for a significant decrease in required simulation time by reducing the number of input wave conditions applied and simulated in the XBeach model. This is achievable because this case study focuses solely on dune erosion, necessitating only the forcing conditions leading to such erosion. Since these are only the energetic wave conditions (wave height above 2 m) that attack the dunes during high water conditions (water level above -0.5 m+MSL), a reduction of the applied wave (and water level) time series of 88% is achieved.
The combination of these two acceleration techniques allows for very efficient morphological modelling of the dune erosion at Maasvlakte 2, resulting in a simulation time of only 14 hours to model a period of 126 days.

To investigate the importance of using a two-dimensional approach to predict dune erosion at a curved coastline, we compared the results of the 2D model with a series of 1D computations. To obtain the erosion volumes for the 1D XBeach simulations, a total of 117 simulations were conducted for 100 m spaced perpendicular transects along Maasvlakte 2. The model settings and boundary conditions for the 1D approach are similar to that of the 2D model. For a fair comparison between the 1D and 2D approach, a surcharge is applied to the 1D results to compensate for the absence of 2D effects. This surcharge depends on the offshore wave height, the erosion volume, the grain size and the coastal curvature.

Modelling results

The validation of the XBeach model involved applying the model to replicate the observed dune erosion at Maasvlakte 2 during the winter storms. To assess the performance of this XBeach model in combination with the 1D BOI model settings and to explore the necessity of employing a 2D modelling approach, we compared the measured dune erosion volumes with the results obtained from both 1D and 2D XBeach simulations. The resulting dune erosion volumes for these simulations are presented in Figure 9.

This figure indicates that the 2D XBeach model is most capable of reproducing the

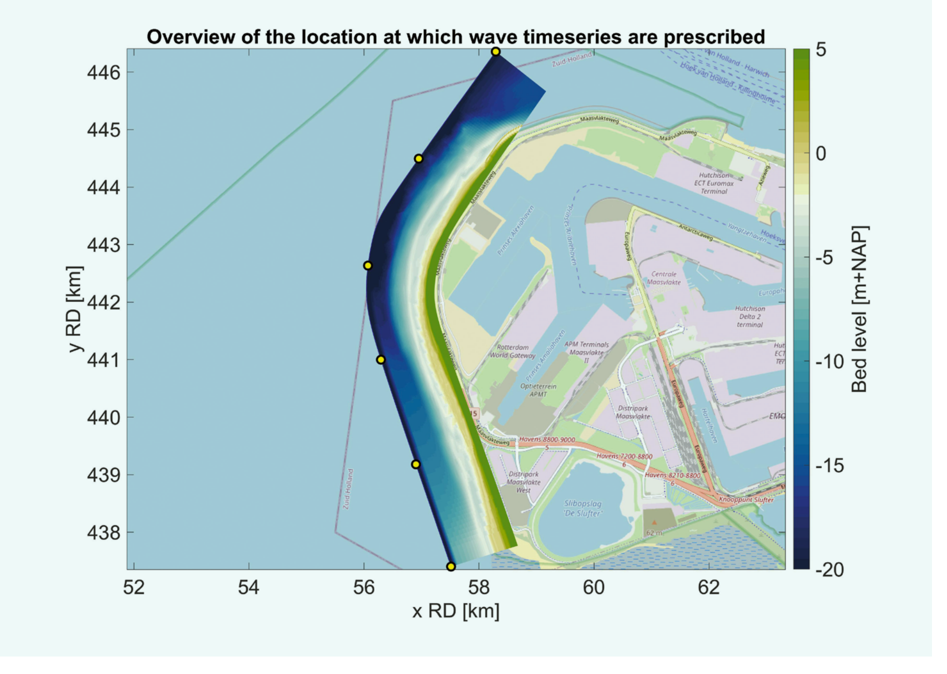

FIGURE 7

Overview of the model bathymetry and the location at which the spatially varying wave-forcing boundary conditions are applied to the XBeach model.

dune erosion volumes accurately, while significant differences in the amount of dune erosion are observable between the 1D and 2D model results. This is especially noticeable in the strongly curved coastal section of Maasvlakte 2 between km 4.5-6.5, where the 1D modelling approach underestimates the amount of dune erosion. The results at straight coastal sections (km 3.5-4.5 and km 7.0-10.0) are more similar between the 1D and 2D approaches. Although the applied surcharge for curved coastlines does increase the predicted dune erosion, it is insufficient to compensate for the high differences between the 1D and 2D predicted erosion at the curved part of the coastline (km 4.5-6.5).

The validation results also show that the 2D XBeach model accurately captures the transition between the highly erosive curved coastal sections and the less erosive sections (km 4.0-4.5 and km 5.5-6.0), indicating that the gradients in the alongshore transport due to variations in incident wave angles are accurately reproduced. The most significant deviation between the measurements and the model results is seen at the remarkable reduction in dune erosion right in the middle of the bend (at km 5.1). However, this reduction is likely to be related to post-storm reconstruction, placement of the nourishment, aeolian dune recovery or displacement of the nourishment.

The difference in performance for the 1D and the 2D model on straight and curved sections is confirmed even more strongly by looking at several relevant transects along the perimeter of the Maasvlakte 2 (Figure 10). The dune erosion predicted by the 1D and 2D model is similar for the transects a) and b) at the straight coastal section. However, the 1D model significantly underestimates the dune erosion at the curved section of Maasvlakte 2 (transect c). When looking at the bed level below 3 m+NAP, significant differences between predicted and modelled bed levels can be observed due to the placement of the nourishment. The accuracy of the model in predicting sedimentation volumes can thus not be assessed directly with these results.

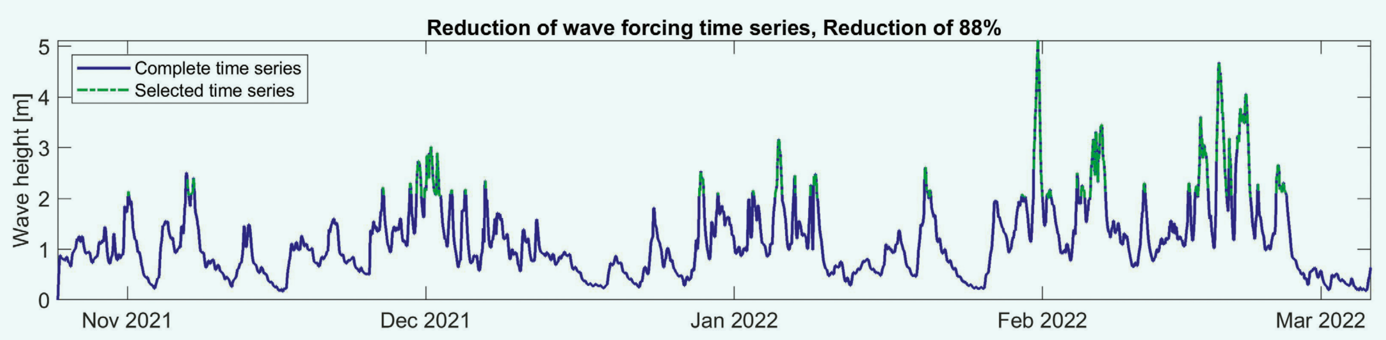

FIGURE 8

Overview of wave time series between the end of November 2021 and the beginning of March 2022 (blue line), together with the reduced wave time series applied in the model (green line).

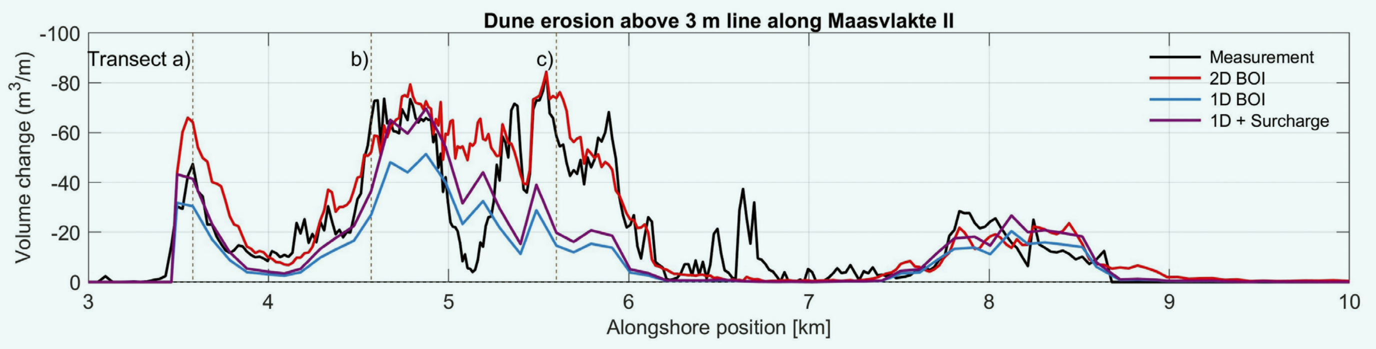

FIGURE 9

Overview of the XBeach model validation showing the measured and modelled dune erosion volumes above the 3 m line.

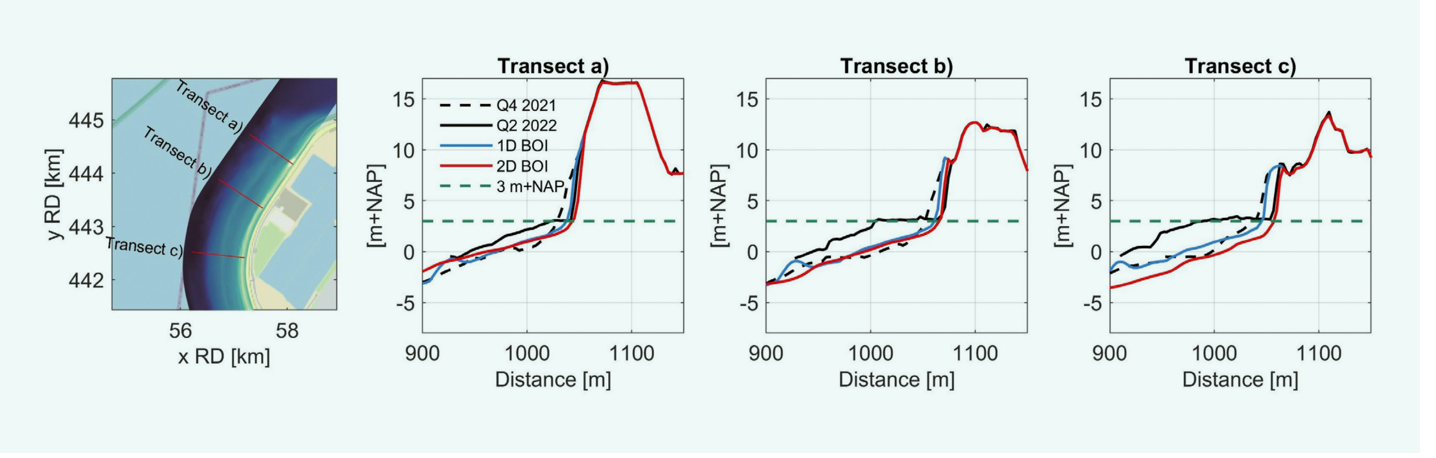

FIGURE 10

Overview of the XBeach model validation showing dune erosion for various transects along Maasvlakte 2. Note that the bed level below 3 m+NAP is heightened by both storm deposition and construction works).

Nonetheless, dune erosion volumes would not be predicted accurately when the pattern of sediment deposition and alongshore transport is not accurate. Moreover, for safety assessments, accurate prediction of erosion volumes is of primary interest.

Based on these validation results, it is concluded that 2D XBeach modelling is required to accurately capture dune erosion at strongly curved coastlines. Furthermore, the validation shows that the 1D BOI settings can accurately model dune erosion at Maasvlakte 2 when applied in a 2D XBeach model.

Discussion

The validation of a two-dimensional XBeach model (BOI2023 version) with 1D BOI model settings to model a curved coastline is a successful first step. However, there are still sufficient challenges before XBeach 2D can be considered a valid model for generic curved coastlines. The profile shape of the Maasvlakte is rather simple, with a steep foreshore and a single dune row. This profile resembles those at the Dutch coast and is close to many cases used to calibrate the model settings. The effects of the tidal current are limited to the deeper foreshore and there are no shoals that induce additional gradients in alongshore transport, as would be the case at the curved coastlines at the heads of the Wadden Islands, which are sheltered by an ebb delta.

Regarding future safety assessment with 2D XBeach models, our results imply that it will be important to model storms with a non-stationary wave direction and multiple storms with varying peak direction, since a stationary wave angle would significantly underestimate the dune erosion at the point of perpendicular wave incidence.

Conclusion

The dune erosion measurements following the 2022 winter storms at Maasvlakte 2 have been used to validate a 2D XBeach model. This validation event, which is the first proper validation possibility for a dune erosion event at the curved Maasvlakte 2, is successfully utilised to gain insight into the performance of the 1D BOI model settings and the necessity of a 2D modelling approach at a curved coastline.

The XBeach simulations, which have been carried out following both a 1D and 2D modelling approach, revealed that the 2D model with 1D BOI model settings was most capable of reproducing the dune erosion volumes accurately, while a significant underestimation of dune erosion is observable in the 1D model. This underestimation in the 1D model occurred at the strongly curved coastal section of Maasvlakte 2 and could not be compensated for by the prescribed surcharge for 1D modelling approaches at curved coastlines. The underestimation in the 1D modelling approach is likely related to the absence or underestimation of alongshore sediment distribution processes at strongly curved coastlines. This process prevents localised build-up of eroded sediment on the foreshore as it is redistributed alongshore, leaving the dune vulnerable to undiminished wave attacks throughout the entire storm duration. Therefore, a 2D modelling approach appears to be required for strong curved coasts such as Maasvlakte 2 and is highly advised in similar situations (in the Netherlands).

Results from this study highlight the importance of applying a 2D process-based model such as XBeach on strongly curved coastlines to assess the safety of the dunes under storm conditions. Moreover, the study results suggest that it is important to include non-stationary wave direction when modelling the normative storm conditions to prevent underestimation of the dune erosion. This prompts us to reconsider the schematisation of the normative storm for strongly curved coastal systems, encouraging further research and discussion.

A 2D modelling approach appears to be required for strong curved coasts such as Maasvlakte 2.

Summary

Dune erosion caused by storm surges and severe wave attack is the primary failure mechanism of sandy sea defences. At a strongly curved coast, such as that of Maasvakte 2 (Port of Rotterdam, the Netherlands), dune erosion can be twice as high as at a straight coast.

Following the winter storms of 2022, measurements of dune erosion at Maasvlakte 2 offered a unique opportunity to analyse erosion patterns along this curved coastline. Moreover, it allowed for the validation of dune erosion predictions with a 2D XBeach model, and an investigation into the importance of using a two-dimensional modelling approach to predict dune erosion.

To this end, XBeach simulations have been conducted with both a 1D and 2D modelling approach. Both models use the same model settings, derived for safety assessment at the straight Dutch coast with the 1D model (BOI settings). The study demonstrates that the 2D model was most capable of reproducing the dune erosion volumes accurately, while a significant underestimation of dune erosion is observed in the 1D model. The underestimation of the 1D modelling approach is likely related to the absence of alongshore sediment distribution processes at strongly curved coastlines. This process prevents localised build-up of eroded sediment on the foreshore as it is redistributed alongshore, leaving the dune vulnerable to undiminished wave attack throughout the entire storm duration.

The findings of this study highlight the necessity of utilising a 2D process-based model like XBeach 2D for evaluating dune erosion during storms on highly curved coastlines such as Maasvlakte 2. These results indicate that the 1D BOI settings are also applicable for 2D applications of curved coastlines. Therefore, this approach is strongly recommended for similar scenarios (in the Netherlands) to ensure an accurate assessment of dune safety.

Ype Attema

Ype is the lead expert in morphodynamics at Svašek Hydraulics. He graduated from the Technical University of Delft and started working at Svašek Hydraulics in 2015. Since then, he has been involved in various consultancy and research projects related to morphology. His primary focus within these projects is the modelling of hydrodynamics (flow, waves), morphology and the interplay between these phenomena. Typical projects include channel siltation studies, design and morphological impact studies in the coastal zone, and nature restoration studies in the Eastern and Western Scheldt. In addition, Ype is co-developer of FINEL, a software package developed within Svašek Hydraulics to model hydrodynamic flow and sediment transport.

Anna Kroon

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AN EFFICIENT TOOL FOR ENVIRONMENTAL CONTROL IN DREDGING OPERATIONS

Environmental management and monitoring programmes are essential for identifying and mitigating adverse impacts that dredging activities may have on the environment. However, it is not always feasible, especially for the client, to have the necessary tools to conduct these tasks adequately, whether due to cost constraints or limited information availability. The use of the Automatic Identification System (AIS), as an efficient and cost-effective monitoring method in dredging projects, can lead to significant improvements in project environmental management. In cases involving trailing suction hopper dredgers (TSHD), this tool allows for equipment tracking, verifying the proper use of contract-approved areas and additionally estimating daily production values through a simplified method.

In a worldwide context of globalisation, population growth and constant technological advancement, water transportation emerges as a fundamental pillar for international trade. Projects related to this mode of transportation, especially those aimed at developing navigation infrastructure, are crucial to sustaining economies at the local, regional and/or national levels.

Dredging works aimed at increasing and maintaining depths in waterways and ports play a key role in the described scenario. In this type of project, continuous monitoring of tasks is of utmost importance for both the contractor and the client. Especially for the latter, it will allow verifying the proper fulfilment of the contract conditions.

Among the most relevant contractual aspects that must be monitored in a dredging project, those related to the use of discharge zones are crucial.

These sites are selected and approved by the client after an analysis involving technical, economic and environmental criteria. As a result, conflicts of interest between parties may arise, necessitating the implementation of specific and efficient controls during operations, especially regarding compliance with environmental requirements.

Trailing suction hopper dredgers (TSHD) are currently one of the most relevant and widely used equipment in the industry. These dredgers operate as highly specialised vessels, conducting dredging operations while moving similarly to that of a regular ship. This is where the possibility of implementing the Automatic Identification System (AIS) arises for straightforward, cost-effective and efficient monitoring of operations.

The use of AIS for tracking TSHD equipment proves to be a tool of great potential for environmental control of contract-approved discharge operations. On the one hand, it enables verification of compliance in the use of designated disposal sites, and on the other, it allows for a preliminary estimate of the volumes discharged. Both aspects are elaborated upon in this article.

Dredging and environment

One of the themes that has gained increasing relevance in the field of dredging in recent years is the consideration of aspects related to environmental preservation. All activities encompassed in such a project inherently have an impact on the environment, making addressing environmental concerns one of the major challenges in a project.

The mentioned challenge finds its best solution through the implementation of a comprehensive process in project management, involving all parties and disciplines from the project's inception and considering the concept of environmental sustainability. The latter has become one of the relevant criteria in decision-making, complementing the classic technical and financial analysis of the works.

One of the primary alternatives available to address this theme is the so-called environmental control or monitoring of the project. This tool encompasses a series of preventive actions, operational controls, samplings and monitoring, among others, which often stem from an analysis presented in the Environmental Impact Assessment (EIA) of the project.

Environmental monitoring in a dredging project can and should be beneficial for all stakeholders involved. Cost-effective monitoring throughout the entire project development will inevitably result in the limitation of impacts, both short and long term, making it a valuable investment.

Environmental control and discharge operations

Among the tasks for which environmental control is possible in a dredging project, the management of discharged material stands out as the main focus of this work. When referring to the management of

FIGURE 1

A trailing suction hopper dredger (TSHD) in operation.

discharge in dredging tasks, the following three aspects should be considered:

1. Type of material to be dredged and discharged.
2. The volume of dredged and discharged material.
3. Discharge site for the dredged material.

The definitions of the above points are usually included in the scope of the EIA, which aims to ensure that dredging activities are carried out in an environmentally acceptable manner. In all cases, monitoring the mentioned aspects will involve a series of measurements and continuous monitoring to verify compliance as established in both the contract and the EIA.

Monitoring everything related to the type of material to be dredged/discharged will be primarily covered through strict processes of periodic sediment sampling and subsequent laboratory analysis. Regarding points related to the use of the discharge area, the range of possibilities for environmental control is broad and will depend on each project. This topic is addressed in the following section.

Monitoring the use of discharge areas

The defined and approved zones for the discharge of dredged material, as determined by the client, are critical elements when evaluating a project, especially for the contractor. The location and capacity of each site will have a direct influence on the production values of dredging equipment, determined by the distances to be covered and the number of zones to be used. Consequently, these variables will impact the overall costs of the project.

Considering the effect that the location of discharge zones has on costs, it is understandable that contractors seek to "save" on distances covered during their operations. Therefore, the control and supervision of dredging discharge by the client are fundamental for the proper development of the project and, above all, for compliance with environmental preservation aspects.

As mentioned, environmental monitoring of dredging activities has assumed a significant role and can be beneficial for all stakeholders. However, this does not mean that a cost-benefit analysis should not be considered, even when evaluating monitoring procedures to implement. Environmental monitoring can be a lengthy and expensive process. For larger projects, it may last for many years and require specific and high-value equipment. Therefore, not all monitoring methods apply to smaller projects.

A clear example of the above, with potential application in environmental monitoring, is the U.S. National Dredging Quality Management Program (DQM). This initiative by the US Army Corps of Engineers (USACE) aims to provide a standardised and automated system for remote monitoring, analysis and documentation of dredging projects using both government and contractor dredgers.

The DQM collects information from sensors installed on the vessel, calculates dredging activities and presents the information through standardised reports and graphical representations. The information obtained includes three elements: dredging cycle data; hopper load; and real-time dredger positioning.

While this system offers numerous benefits related to dredging operations and monitoring, especially in controlling the use of client-approved discharge zones, its implementation involves the need to acquire, install and maintain specific instrumentation, which can be costly. Additionally, its application outside the realm of USACE work could pose an additional complication, restricting its use.

However, for some dredging projects, depending on contractual obligations, daily production information from dredging contractors may not be available for environmental management purposes (Bell et al., 2022). This could prove to be another obstacle when defining monitoring tools by the client.

Having an efficient, simple and low-cost material discharge monitoring system would be highly beneficial for small projects, projects where specific control methods are not envisaged or situations in which not all information is readily available. From this premise arises the motivation for the present work and the idea of implementing the AIS system as a tool for environmental monitoring, leveraging the use of publicly available information.

Trailing suction hopper dredgers

This type of equipment falls within the category of "mechanical/hydraulic dredgers." Essentially, they are self-propelled vessels equipped with hoppers where dredged material is deposited and later expelled in the vicinity of the working area or transported horizontally to the discharge site. Dredging takes place while the dredger navigates at low speeds using suction pipes located on the sides of the vessel, which are lowered to make contact with the seabed. Material suction, a mixture of water and sediments, is achieved through centrifugal pumps. Figure 1 shows a trailing suction hopper dredger in operation.

These kind of dredgers are characterised by their great versatility due to the range of materials they can extract, the various discharge modalities and their ability to work in both protected and unprotected waters. These aspects give TSHDs the flexibility to be employed in various projects, including channel opening and maintenance dredging, beach nourishment and trench excavation, among others.

The most common operation of a TSHD can be understood as a series of simple dredging cycles, consisting of the following stages:

1. Loading the hopper – dredging stage.
2. Navigation to the discharge site (loaded).
3. Discharging the hopper at the discharge site.
4. Navigation to the dredging site (unloaded).

The dredger's productivity will depend on the type of material to be extracted, hopper capacity and the total duration of the dredging cycle. The distance to the discharge areas is a crucial factor in calculating efficiency, as it directly affects navigation times.

Automatic Identification System

The AIS is a data transmission system installed on ships and land-based stations, operating in the VHF marine band. The primary objective of this system is to enable the identification of vessels, meaning that ships communicate their position and other relevant information so that other vessels or land-based stations can be aware of it. This helps prevent collisions and assists the ship during its navigation. This tool contributes not only to navigation safety but also to traffic management efficiency.

The AIS was approved by the International Maritime Organization (IMO) in 2002 and has been mandatory since December 2004 for ships subject to the SOLAS Convention that meet the following characteristics:

- Ships with a gross tonnage exceeding 500 GT.
- Ships on international voyages with a gross tonnage exceeding 300 GT.
- All passenger ships, regardless of size.

The AIS unit consists of a VHF radio transceiver capable of sending information about the station's identification, position, heading, speed and ship and cargo-related data, among others, to other vessels and land-based receivers. Once the unit is installed onboard and configured correctly, it transmits information continuously and automatically without the need for intervention by the ship's crew. Figure 2 provides a schematic representation of the AIS system.

The data generated by the AIS system can be stored for subsequent management and processing using software that allows a graphical representation of this information. This enables the performance of (offline) analyses, both static and dynamic, on the voyages of vessels equipped with an AIS unit onboard.

AIS for monitoring TSHD

Considering the operational methodology of TSHD dredgers, it is evident that the use of AIS-generated data allows for tracking the equipment during dredging tasks. This facilitates a detailed analysis of the operation and enables several verifications for the project. AIS also allows the monitoring of dredgers in each of the work cycle phases.

By obtaining a spatial and temporal detail of the operation, it will be possible to verify the use of the areas defined and approved by the contract, especially for the discharge of material. Additionally, and through a simplified methodology that will be explained in a later section, an estimate of the volumes dredged in each work cycle could be obtained.

A simplified method to estimate volumes with AIS

If AIS data generated by a TSHD is analysed during a dredging campaign, a quick and simple estimation of the extracted volumes can be performed as follows.

The starting point is the hopper capacity (m^3) of the dredger used. This value is known as the nominal volume of the hopper (Vh) and is easy to know since it is a characteristic of each dredge, and is also the value used to classify TSHD equipment.

The next step will be to determine the capacity or effective volume of the hopper. This variable will be identified with the acronym Vhe (m^3). This value represents the effective volume of material contained in the hopper in its fully loaded condition.

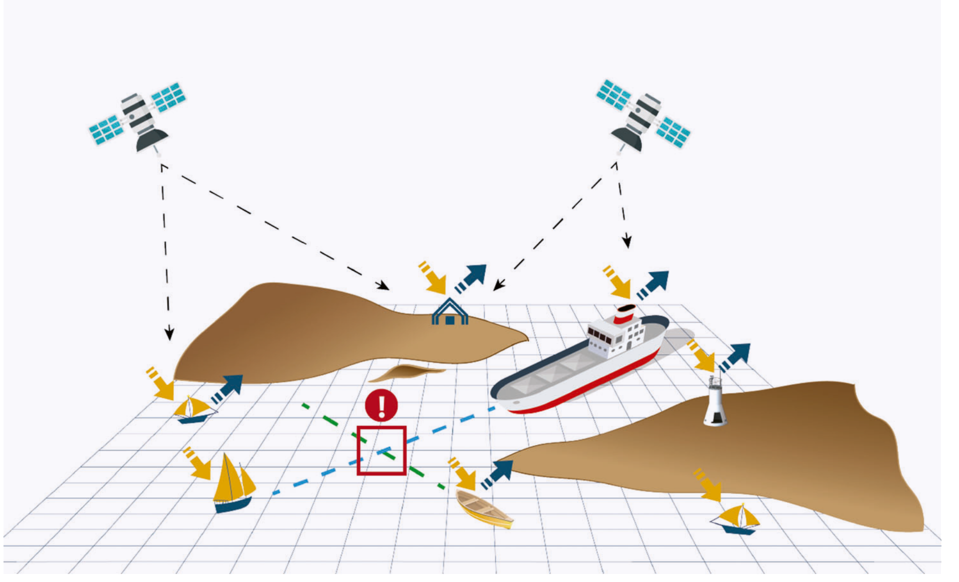


FIGURE 2

General scheme of the AIS system.

To obtain the Vhe, it is necessary to affect the value of the nominal capacity of the hopper (Vh) by a correction factor. This factor will be represented by the letter "F" and is called the utilisation factor. This value, which in the case study developed below has been adopted as 0.70, depends among other aspects on the:

- characteristics of the type of soil to be dredged; and
- work methodology used. Especially the overflow discharge time.

The hopper utilisation factor (F) is specific for each dredging campaign carried out and remains reasonably constant as long as the working conditions are not modified. These conditions include the type of soil, the dredging equipment used, the pumping power and the dredging methodology used (overflow time).

About the above, it should be noted that before the start of each campaign at a specific site, a planning and programming stage of dredging activities is carried out in the technical office. In this stage, the different factors that condition the operation during the tasks are evaluated, such as the type of soil, work and unloading areas, and characteristics of the equipment to be used, among others. This prior procedure seeks to guarantee the correct execution of a work routine, in which operations are carried out efficiently and systematically throughout the entire campaign. This concept of systematisation strengthens the premise of maintaining working conditions throughout the same dredging campaign.

When defining the utilisation factor, at least two methodologies are identified. On the one hand, it is possible to adopt a value based on work experiences and previous studies. That is, evaluate productions obtained by the equipment in previous campaigns at the work site or sites where the extracted materials and dredging conditions are similar. Previous studies and research can also be used as a reference. On the other hand, it is possible to define a value based on the results obtained and reported by the contractor for the first dredging cycles executed during the campaign to be studied.

Finally, the number of work cycles carried out during the period studied (Cd) must be determined, that is, the total number of trips made by the dredger with a full hopper between the extraction area and the unloading area. This data is one of the main results of the analysis of operations through AIS.

With the mentioned data, it will be possible to implement this simplified method that will yield estimated values of the volumes dredged during the campaign. To summarise:

- Nominal hopper capacity = Vh [m^3]
- Hopper utilisation factor = F [%]
- Effective hopper capacity = Vhe = Vh x F [m^3]

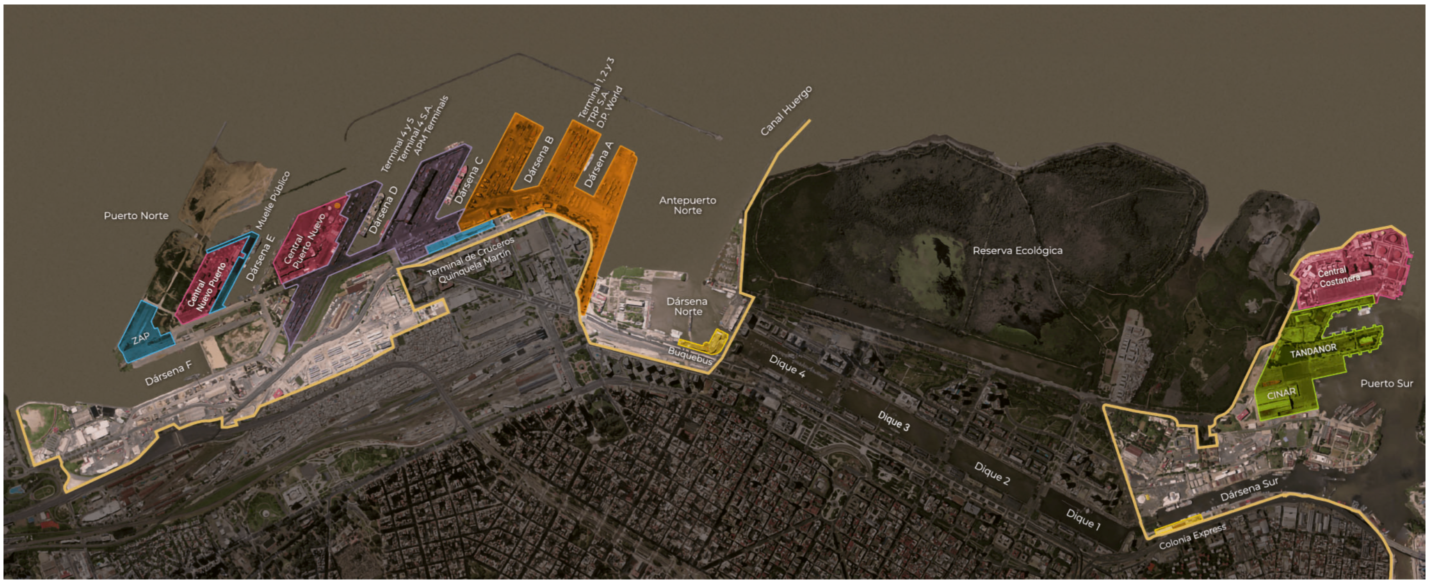


FIGURE 3

Aerial photography of the port of Buenos Aires.

- Number of work cycles = Cd [–]
- Dredged volume = Vd = Vhe × Cd [m³]

It is important to mention that the calculated value corresponds to the volume of material extracted in the hopper, and due to soil characteristics, it is greater than the in-situ volume or the effective volume, which is generally calculated as the difference between two bathymetric surveys, one before and one after dredging.

Application case

To verify the validity of the described method, an analysis will be conducted using AIS data from dredging operations of a TSHD during a campaign carried out as part of the project for the maintenance of the access channels to the Port of Buenos Aires in Argentina.

The Port of Buenos Aires, located in the homonymous province on the shores of the Río de La Plata, is the main container port in Argentina and one of the most important in the Latin American region. Managed by the Administración General de Puertos SE (AGPSE), it has a capacity of 1.5 million twenty-foot equivalent unit (TEUs) annually for total cargo and receives approximately 1,200 ships per year. This port accounts for over 60% of the country's container movement.

It is a multimodal port divided into two main sectors known as Puerto Norte (left in Figure 3) and Puerto Sur (right in Figure 3). This case study will focus on the access channels to the North sector.

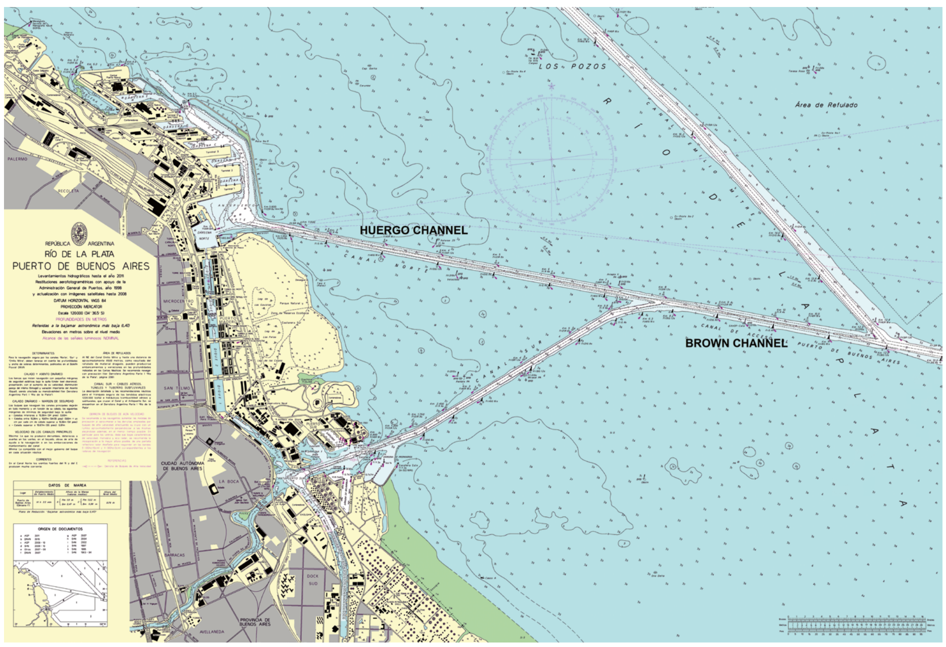


FIGURE 4

Nautical chart of the Port of Buenos Aires.

Puerto Norte comprises 6 docks used for port operations and the service of deep-sea and cabotage vessels. This port sector accommodates five general cargo terminals with 23 berths and a quayside depth of 10.05 metres (m).

Access to the mentioned zone is achieved through two channels named Brown Channel, with a length of 4.7 kilometres (km) and Huergo Channel, with a length of 7.3 km. In total, there is an entrance of 12 km in length, 10.36 m (34 feet) in depth and a bottom width of 100 m. This access route connects with the Vía Navegable Troncal, which is a logistical corridor linking the main river terminals in Argentina. Figure 4 shows the mentioned channels.

The maintenance dredging of the access channels is one of the main projects tendered at the Port of Buenos Aires approximately every 3 or 4 years.

As of May 2024, the most recent dredging operations at the port were conducted by the company Compañía Sudamericana de Dragados, a member of the Jan De Nul Group. This company was responsible for the work in the channels after winning a public tender in 2019 for the opening dredging and 3 years of maintenance of the access waterways.

The activities covered in the contract from the aforementioned tender were primarily executed with TSHD, including the dredger Afonso de Albuquerque. This equipment will be used to study its operation and implement the proposed environmental monitoring methodology.

The dredger Afonso de Albuquerque, built in 2018, is a small-sized TSHD with a hopper capacity of 3,500 m³. It has been operational in Argentina since 2019, specifically in the Vía Navegable Troncal (the most important waterway in Argentina) and the channels of the Port of Buenos Aires.

The Albuquerque dredger specifications are:

- Length: 89.30 metres.
- Beam: 22.00 metres.
- Draught (loaded condition): 5.70 metres.
- Suction tube diameter: 800 mm.
- Maximum dredging depth: 27.60 metres.
- Discharge mechanism: bottom doors.

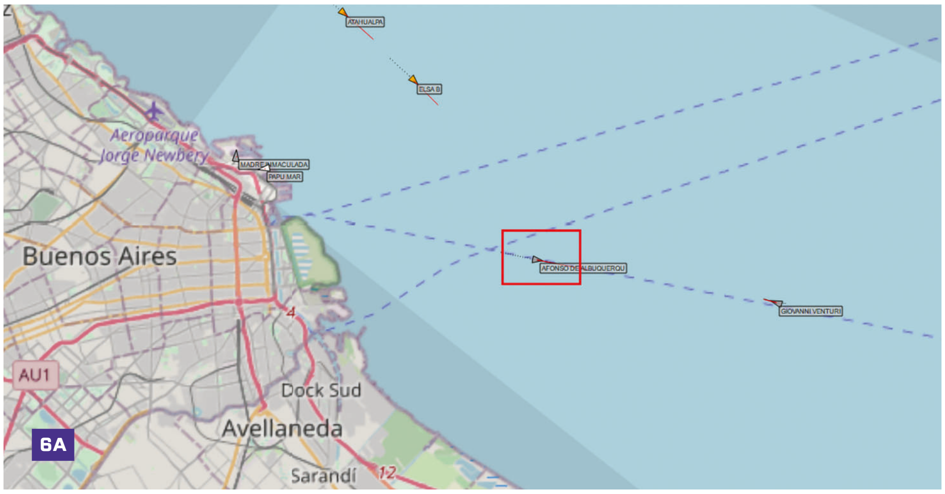
AIS data analysis

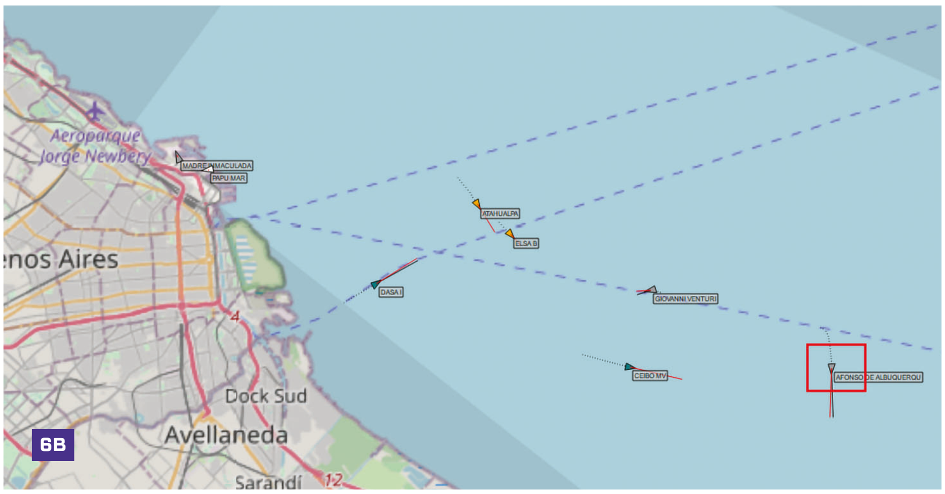
To analyse the operations of the TSHD Afonso de Albuquerque, verify the use of approved discharge areas and estimate the volumes extracted, AIS data generated by the dredger was collected during a 13-day campaign in September 2022 within the framework of the maintenance dredging in the Huergo and Brown channels. To present the results in this case, the analysis time was limited to five consecutive days between 8-12 September.

To visualise the available data, an AIS data processing subroutine of the software called IWRAP Mk2 (IALA Waterway Risk Assessment Programme) was used. This programme was developed by IALA, the International Association of Marine Aids to Navigation and Lighthouse Authorities, to conduct risk analyses. In this instance, the programme was solely used as a graphical viewer for AIS data.

FIGURE 5

Afonso de Albuquerque dredger.





FIGURES 6A AND 6B

IALA IWRAP Mk2 screenshots.

FIGURE 7

Afonso de Albuquerque traffic density (8-12 May 2022).

Figures 6A and 6B display screenshots of the software during the playback of AIS data for the mentioned dates and the analysed sector of the channels. The dredge Afonso Albuquerque, highlighted in red, can be observed actively working.

Figure 7 displays a traffic density graph of all the dredger navigations during the five analysed days. This will be important when evaluating the use of the dumpsites.

Verification of the use of discharge zones

Tracking the movements of the dredger during its operation is a quick and straightforward way to verify compliance with the use of approved zones in the project. In the case of dredging the access channels to the Port of Buenos Aires, the discharge of material must be carried out within the zones defined for this purpose by the National Directorate of Waterways.

Figure 8 shows the areas approved for the discharge of material in green and the areas subject to discharge restrictions in red. The green areas are used for the discharge of material from different dredging works in the area. The sector where each dredge discharges will depend on the available depths and the draft of the ship. In the case of maintenance work on the access channels to the port of Buenos Aires, the areas in orange are usually used.

It is possible to see that the distance to be navigated by the equipment between the work sector and the dumpsite is significant, reaching an average value of 20 km.

Once the AIS analysis was completed, the verification of the use of the unloading areas was carried out. This was done by crossing the map of approved zones and the traffic density map of the dredger. The result is presented in Figure 9 where it is possible to see that the use was correct and therefore the Afonso de Albuquerque dredger respected what was established by the regulatory authority regarding the dredged materials placement.

While in this instance, the verification was done using a traffic density chart generated by AIS processing software based on data from the five analysed days, it is indeed possible to carry out this operation in real time. This allows for the immediate verification of compliance with approved zones during ongoing operations.

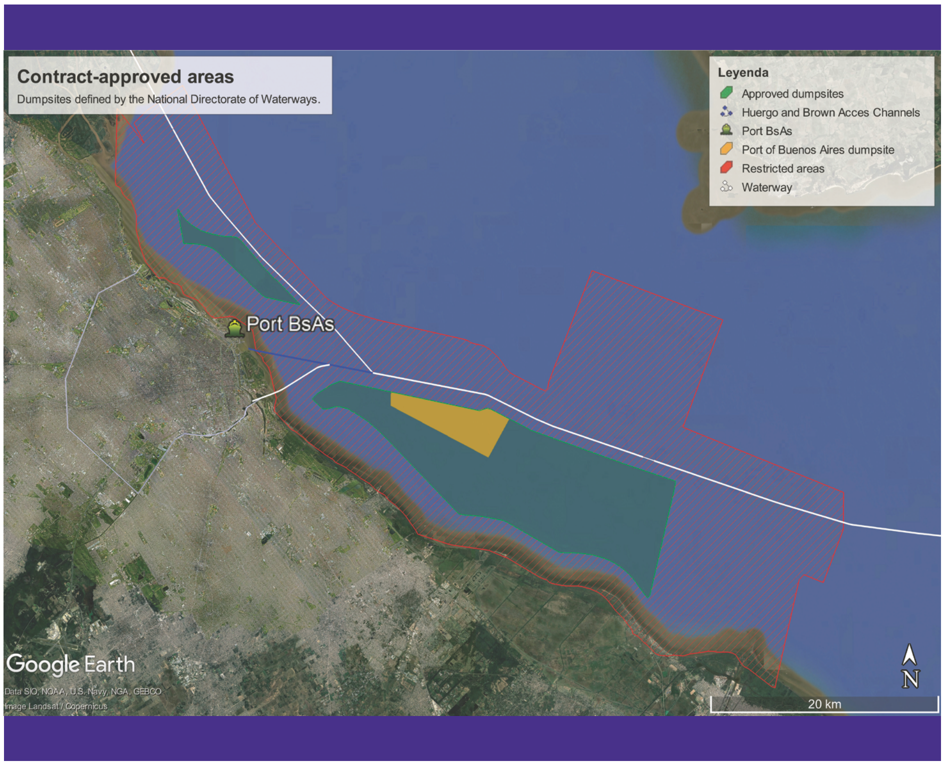


FIGURE 8

Contract-approved areas.

FIGURE 9

Verification of the use of the discharge area.

Estimation of dredging volumes

Regarding the operations of the dredger between 8-12 September 2022, a total of 44 work cycles were recorded, resulting in between 8 and 9 cycles per day. In detail, the analysis revealed the following averages:

- Dredging time: 43 minutes.
- Loaded travel time: 56 minutes.
- Discharge time: 11 minutes.
- Empty travel time: 53 minutes.

It is noticeable that the distance to the discharge zone in this project is significant and strongly influences the number of work cycles that can be performed daily.

With the results obtained from the processing, especially the number of cycles performed, it is possible to apply the simplified methodology to estimate the volumes of dredged material (Vd) as indicated in a previous section.

The step before computing is to define a value for the hopper utilisation factor (F). For this, the following was taken into consideration:

- Soil type. According to AGPSE data, the material dredged in the Huergo and Brown channels corresponds to a mixture of silt, fine sand, and clay of a lean consistency, generally good for dredging.
- Characteristics of dredging cycles. The operation times resulting from the analysis of AIS data were evaluated, especially those intended for the dredging task itself.
- Information provided by the contractor to the AGPSE on the operations carried out during the analysed campaign. Although the analysis of five consecutive days is presented in this work, information on the operation is available for the entire 13-day campaign.
- Information on previous dredging work on the site and other works in areas near the Port of Buenos Aires.

In this case, a utilisation factor of 0,7 was adopted, and therefore, the effective capacity used in the calculation for the dredger Afonso de Albuquerque will be 2,450 m^3 per cycle. The results obtained for the estimated dredged volumes are summarised in Box 1.

Next, to validate the method, Box 2 presents the comparison with the volumes extracted by the dredger during the analysed campaign. These data were obtained after being requested from AGPSE, which provided the corresponding daily operation reports. In these documents, the complete activity of the dredger is reported, including material extraction and discharge zones, dredging time and delays, the number of trips made and equipment production values.

It is possible to see in Box 2 that the results obtained are satisfactory. The volume estimation carried out using the proposed simplified method yields values whose order of magnitude is significantly representative in comparison with the values reported by the contractor to the AGPSE through the daily work reports. The differences found do not exceed 5%, except for one day which was around 9%, which is more than appropriate considering the simplicity of the method and the assumptions made to define the hopper utilisation factor.

Conclusions

Considering the content presented throughout this article, a series of final comments can be made as conclusions. Firstly, it is important to emphasise the significance of monitoring during dredging operations. While these tasks are usually the responsibility of the contractor and are contractually established, it is good practice for the client to have its control tools or methods.

When referring to environmental control in discharge zones, it essentially addresses three variables dealt with by the Environmental Impact Assessment (EIA) of each project: the type of material to be dredged and its behaviour; the location of the discharge sites; and the physical capacity to receive these.

This work has focused on the control of the last two mentioned variables. As mentioned, the definition and approval of these zones are based not only on operational or project profitability issues but also on environmental aspects and conflicts of interest can arise in this regard. Considering the influence that one single kilometre difference in the location of discharge zones can have on construction costs, it is understandable that contractors try to save on distances travelled. Therefore, control and supervision of dredging operations are fundamental in this aspect. The Automatic Identification System (AIS) emerges as a tool with great potential for monitoring dredging operations, especially those carried out by TSHD equipment due to the typical characteristics of their operation. Given the mandatory nature of this automatic identification system, established in 2004, obtaining AIS data from vessels to monitor should not be a problem.

Tracking the movements of dredgers via AIS in real time as well as after operations allows for simple and quick verification of compliance with approved work zones. Respecting approved discharge zones is crucial for the proper development of the project. On the other hand, the possibility of estimating dredged volumes with TSHD equipment through AIS data processing adds value to the use of this tool. Preliminary monitoring of the amount of material discharged in the areas approved for this purpose is another environmental aspect that can be covered with the proposed control methodology. The volume values estimated using this simplified method and their relationship with those measured by the contractor demonstrate the potential of the procedure, as long as the working conditions are maintained throughout the entire dredging campaign. Although this is an estimate, finding differences between what was calculated and what was reported by the dredger in charge could be an initial indicator to later request more precise controls, such as bathymetric surveys or direct measurements in the equipment hoppers.

Based on the above, it is correct to state that the use of AIS as an environmental control tool in dredging projects, especially when using TSHD equipment, has great potential. It is a simple, efficient and, above all, economical method since it does not involve the use of specific equipment as other control methods do such as the DQM. This last aspect should be emphasised since, as mentioned in this article, environmental monitoring can be beneficial for all stakeholders in a project, but this does not mean that a cost-benefit analysis should not be considered when analysing the monitoring procedures to be implemented.

The case study demonstrates that with the minimum necessary information, AIS can be an important environmental management alternative in a project, especially in smaller-scale projects or cases where daily operation information is not available.

Day	Cd (-)	F (-)	Vhe (m³)	Vd (m³)
08/09/2022	9	0,7	2.450	22.050
09/09/2022	8	0,7	2.450	19.600
10/09/2022	9	0,7	2.450	22.050
11/09/2022	9	0,7	2.450	22.050
12/09/2022	9	0,7	2.450	22.050

BOX 1

Estimation of dredged volumes by AIS data.

Day	Cd (-)	vd AIS (m³)	Vd AGPSE (m³)	Difference (%)
08/09/2022	9	22.050	22.184	-0,6%
09/09/2022	8	19.600	21.493	-8,8%
10/09/2022	9	22.050	23.047	-4,3%
11/09/2022	9	22.050	22.490	-2,0%
12/09/2022	9	22.050	21.511	2,5%

BOX 2

Comparison of estimated and contractor-provided volumes.

Summary

All aspects related to material discharge in dredging work are fundamental for project development. The definition and subsequent approval of sites designated for such operations are complex tasks that involve technical, economic and environmental factors. In particular, the geographical location and material reception capacity of discharge areas are two aspects that significantly impact construction costs, demanding a certain level of control by the client over the contractor's work to verify its proper use. In projects involving trailing suction hopper dredgers (TSHD), the implementation of the Automatic Identification System (AIS) as a monitoring tool for operations represents an efficient and cost-effective alternative for conducting environmental and contractual controls. Through this method, it is possible not only to track dredging equipment and verify the use of contract-approved zones but also to estimate dredging volumes. A practical case study at the Port of Buenos Aires in Argentina demonstrates the tool's potential and presents some relevant conclusions.

Juan Cruz Andrini

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René Kolman, Secretary General of IADC, presents the Young Author Award 2024 to Juan Cruz Andrini. The award is presented at industry-leading conferences, with this year's winning author selected from the proceedings of the PIANC World Congress held in Cape Town, South Africa, 29 April – 3 May 2024.

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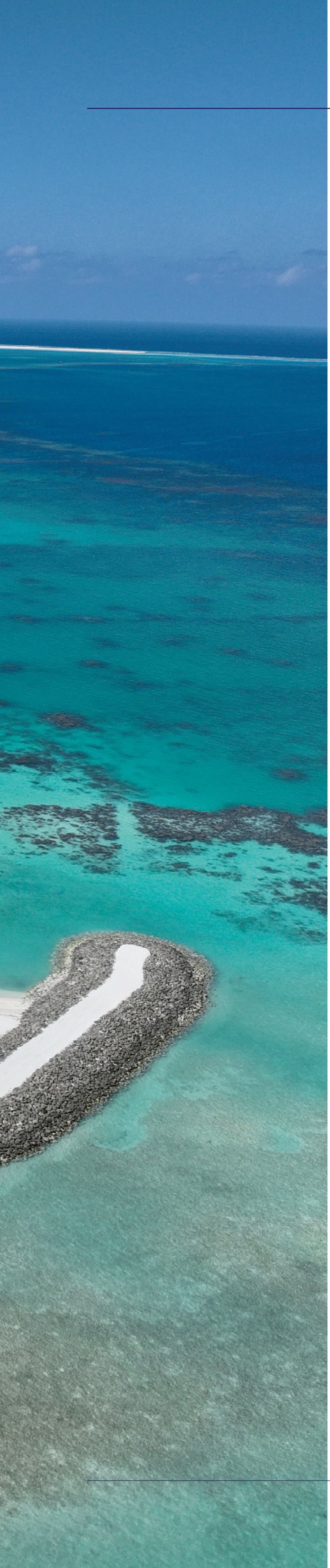

ENVIRONMENTAL MANAGEMENT AND MITIGATION MEASURES: ADDU CITY PROJECT

Dredging and reclamation projects can significantly impact local ecosystems. Negative impacts can be minimised by adopting proper environmental management and mitigation, from preparation to completion phase. Addu City project sets an example of implementing novel construction methodologies and successfully addressing environmental challenges. The project has created over 200 hectares (ha) of climate resilient land for housing and touristic development. Enclosure of footprints, relocation of corals and seagrass (at pilot level) before reclamation process, and monitoring sediment impact in the nearby marine protected areas during dredging and reclamation are exemplary of the management approach applied to ensure minimisation of potential negative environmental impacts.

Since the 19th century, dredging and reclamation projects have taken place around the world (Borel, 1867). Its processes have undeniable impacts on the footprint of the newly created areas and the ecosystems adjacent to those areas. The potentially negative impacts to the environment can be minimised when proper mitigation measures are adopted prior and during the execution of works and when proper environmental management is present throughout the course of the project. Mitigation measures refer to all measures aiming at minimising or eliminating factors that can potentially negative influence physical, biotic and socioeconomic environments within and surrounding the works.

The case of Addu City dredging and reclamation project provides a number of important findings regarding novel construction methodologies, environmental challenges, stakeholder engagement and lessons learnt for engineers. The project's main scope has been the creation of over 200 ha of climate resilient land to support housing of local population and touristic development. Project management and mitigation measures aimed at conducting the reclamation works in this sensitive area with minimal negative environmental impact included: proper enclosure of the footprints and relocation of corals prior to reclamation process; thorough monitoring of sediment impact in the nearby marine protected areas during dredging and reclamation; and execution of a pilot project for seagrass relocation. The effectiveness of such actions can be directly visible in the reef health of Addu atoll after the completion of the works.

In this article, the sequence of events along with the results of environmental actions and initiatives will be shared. The importance of a detailed and high-quality Environmental Social Impact Assessment (ESIA) will be highlighted to identify environmental challenges as early as possible in preparation. The Addu City dredging and reclamation project deployed one of the highest set of standards for management practices in a very effective manner. This approach can be adopted for projects of similar magnitude and sensitivity within and outside the region.

The project location

The Addu City dredging and reclamation project (referred hereafter as the project) took place in the Addu or Seenu Atoll (Figure 1). This southernmost atoll of the Republic of Maldives. Addu City consists of the inhabited islands of Gan, Feydhoo, Maradhoo, Hithadhoo and Hulhumeedhoo (Hulhudhoo-Meedhoo).

The project description

The Ministry of National Planning, Housing and Infrastructure of the Maldives awarded the reclamation by dredging and shore protection works for land in Addu City to Van Oord. The project is part of the Addu City development project to help transform Addu City into a fully functional city, a thriving economic hub and an attractive tourist destination. To help obtain this goal, five key preconditions need to be met: stimulating the economy, tackling high unemployment, enhancing connectivity, addressing climate change and environmental protection, and promoting decentralisation. The scope of work consists of the design and construction of:

1. Dredging and reclamation of 76 ha and shore protection works in Maradhoo;
2. Reclamation of 90 ha and shore protection works in zone 1 and zone 2 of Hithadhoo;
3. Reclamation of 25 ha for three island resorts;
4. Reclamation of 4.7 ha and shore protection works in Hankede;
5. Reclamation of 1.4 ha and shore protection works for the new four lane link road connecting Maradhoo and Hithadhoo islands;
6. Storm water drainage; and
7. Relocation of existing utilities.

This article will focus on the strategy and execution of points 1-4, with a specific focus on the dredging and reclamation sequence, and the impact on the environment. The reclamations can be seen in Figure 2 and Figure 3. The potential impacts of the project are described in the Environmental and Social Impact Assessment (ESIA) of the project (Water Solutions, 2022).

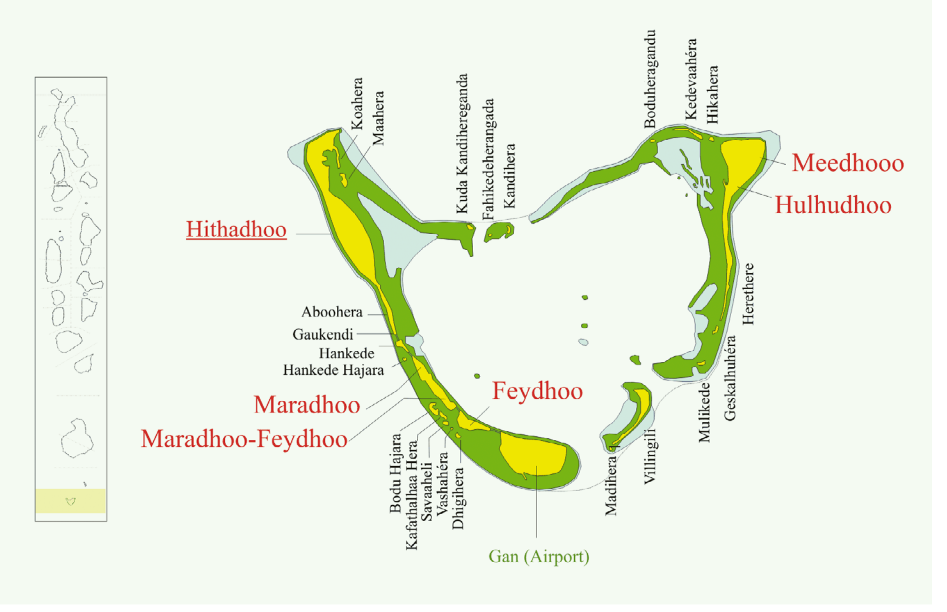

FIGURE 1

Location of the Addu Atoll in the Maldives and its islands (Ahmed, 2008).

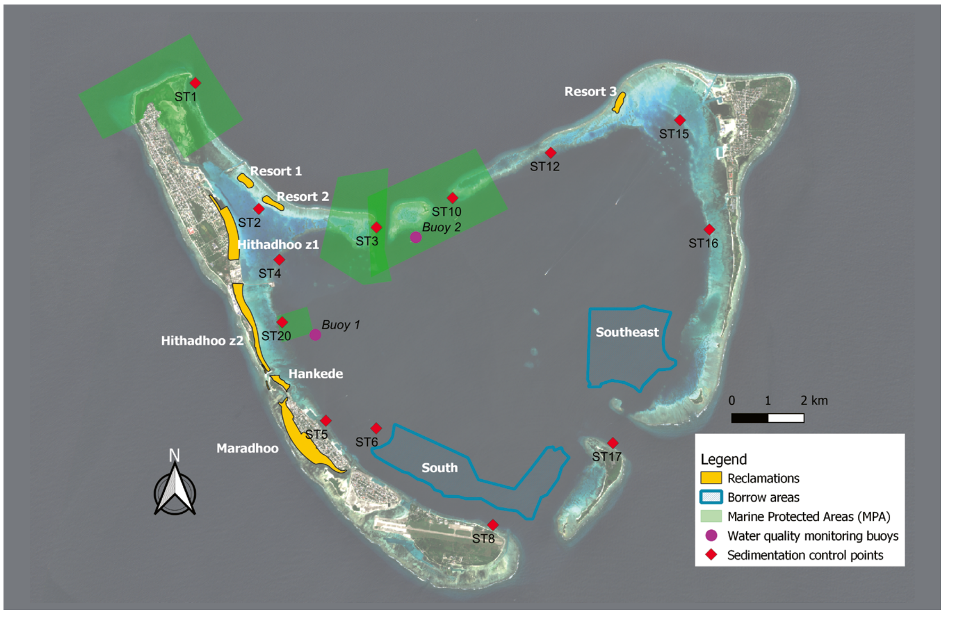

FIGURE 2

General outline of the reclamation project in Addu City.

Dredging equipment

The dredging and reclamation was executed by the trailing suction hopper dredger (TSHD) HAM 318 with hopper capacity of 39,467 m³, two suction pipes of 1,200 mm and maximum dredging depth of 135 metres (Van Oord, 2016).

The vessel is capable of under-keel overflow and is equipped with an environmental or green valve (PIANC, 2010). The environmental valve is a butterfly valve in the overflow system of the TSHD aimed at reducing the formation of air bubbles in the overflow mixture. This results in more stability of the near-field overflow plume, which increases the settling of the generated plume on the seabed. This way the spatial extent of the plume is

FIGURE 3

Focus on the area of the Hankede island indicating the abutments for the new four lane link road.

FIGURE 4

The trailing suction hopper dredger HAM 318 in Addu City, Maldives during reclamation of Hithadhoo zone 2.

The Addu City project deployed one of the highest set of standards for management practices.

significantly reduced keeping it close to the dredging area.

Sequence of execution of works

Preparatory works

Preparatory works include every activity preceding the main volume of the construction process, namely the dredging and reclamation works. Those works include mobilisation of personnel and equipment on the construction site. They also include the bathymetric survey of the existing condition of the project area prior to any construction process.

Furthermore, with regards to the environmental aspects of the project, the preparatory works include all the required surveys assessing the marine life and existing environmental conditions in the project area. In further detail, those surveys include:

- Marine ecology surveys assessing benthic life and marine species on the reclamation footprint and adjacent areas.
- Environmental monitoring surveys assessing the prior-to-dredging conditions on water quality, temperature, sedimentation, air and noise quality.
- Preparatory works for coral relocation. A selection of corals from the reclamation footprints needs to be transferred to suitable recipient sites. Van Oord, with the support of a local sub-contractor has performed coral relocation pre-survey in July 2022 to assess quantitatively and qualitatively existing coral reefs within reclamation footprints (see Figure 5) and immediate vicinity. Moreover, an assessment of potential recipient sites within Addu Atoll was made. Those sites should have the same or similar environmental conditions to ensure that corals will survive and grow in the new environment. The results of the pre-survey were used to identify number, species and type of donor corals and the most suitable recipient site for each category of donor corals.

Construction works prior to dredging and reclamation

Construction of enclosures of the reclamation footprints

This part of the works includes the proper enclosure of the reclamation footprints. This requirement stems from the environmental impact assessment mitigation measures to contain the high turbidity levels expected during reclamation. For that purpose, depending on the design strategy for each footprint, the enclosure consists of:

- Sand bunds, in case the final reclamation is expected to have a form of a beach. Such footprints include the Hithadhoo zone 2 and Hankede (Figure 6) reclamations.
- Sand and rock bunds up to the reclamation

FIGURE 5

Corals collected within the reclamation footprint of island resort 3 during coral relocation works.

FIGURE 6

Sand bund for the enclosure of Hankede reclamation footprint (28/07/2023).

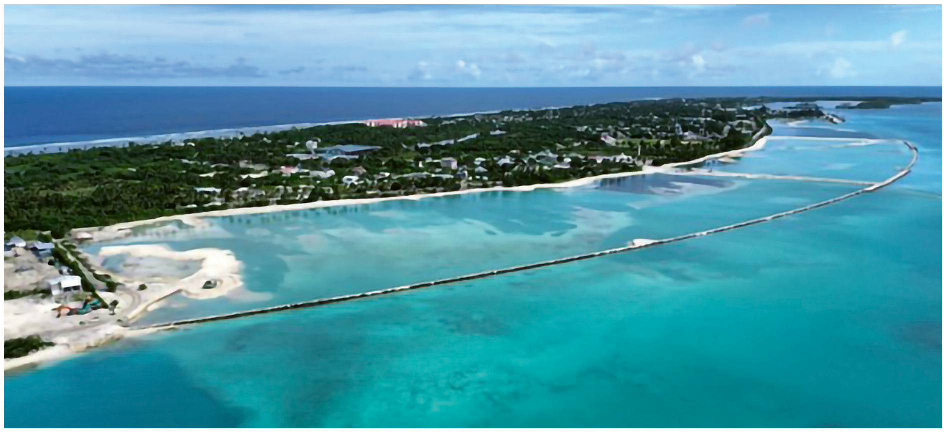

FIGURE 7

Rock bunds for the enclosure of Hithadhoo zone 1 reclamation footprint (24/06/2023).

level, in case that coastal protection works have been foreseen. Such footprints include Maradhoo and Hithadhoo zone 1 (Figure 7) reclamations.

- Sand-filled geotextile tubes for creating the outline and the coastal protection of the resort islands 1, 2 (Figure 8) and 3 (Pilarczyk, 2008). The coastal protection consists of two layers of geotextile tubes and the enclosure of the footprint has been implemented by installing the first layer of the geotextile tubes.

Implementation of coral relocation works

Another mitigation measure arising from the ESIA has been the relocation of a selection of corals from the reclamation footprints to suitable recipient sites. Therefore, after the completion of the marine ecology and environmental monitoring surveys, and the preparatory works for the coral relocation, an elaborate plan for relocation of corals from the reclamation footprints was implemented. These corals were transported to safe recipient sites within Addu Atoll. The recipient sites were chosen based on ecological, recreational, educational and cultural criteria.

Van Oord appointed three local dive groups with marine biologists to execute this task of relocating more than 73,000 coral colonies within the provided timeline of the project. The relocation works lasted a total of three months. The sub-contractors removed coral colonies from the reclamation footprints using hand tools, such as a hammer and chisel. The detached corals were then safely transported by boats to nearby selected recipient sites. Detached corals were categorised based on their growth forms: fragile coral colonies were placed on frames (Figure 9) whereas massive and sub-massive coral colonies were placed freely on the seabed (Figure 10) or fixed using a cement mixture.

Implementation of seagrass pilot

Even though the ESIA indicated that the project will have an impact on the seagrass meadows, no mitigation measures were imposed. However, Van Oord implemented a seagrass pilot programme relocating a total of 640 seagrass sods of 0.125 m² from the reclamation footprint of Maradhoo, to three specifically chosen locations nearby Feydhoo. Van Oord has worked closely with local stakeholders to replant those sods in different patterns (see indicatively Figure 11) to examine the survivability of the pilot programme and to scale it up in future endeavours.

FIGURE 8

First layer of geotextile tubes for the enclosure of resort island 2 reclamation footprint (01/06/2023).

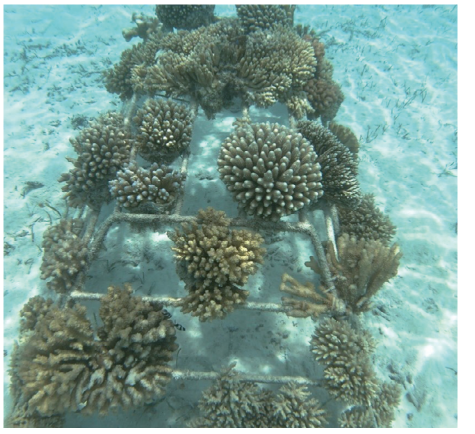

FIGURE 9

Fragile corals placed on frames at recipient sites.

Monitoring scope and additional mitigation measures during dredging and reclamation

Silt curtains

Silt curtains are arrangements designed to control suspended solids and turbidity generated in the water column as a result of environmental dredging operations and navigation. The Ecocoast Ecobarier Silt Curtains ESC-300 type III were chosen for the project. This type of silt curtains is suitable for nearshore application, for moderate to strong tidal flows (<1.5 m/s), for moderate exposure waves (<1.5 m) and medium to long project duration. Those technical specifications are consistent with the tidal and wave conditions within Addu Atoll and with the project duration. Installation, (re-) handling and anchoring has been implemented according to the specifications of the supplier (Ecocoast, 2020).

Figure 12 shows the installed silt screen at Hankede reclamation. The outfalls consist of 8 pipes of 1 m diameter. The silt screen is placed around those pipes to further contain dispersion of sediments further away from the immediate vicinity of the reclamation outfalls. This limits the negative impact of sediment induced turbidity clouds originating from the reclamation works onto the coral reefs within the atoll. It is anticipated that the amount of suspended fine sediments that the silt screen would need to prevent from spreading increases as the reclamation filling progresses. As an indication, the turbidity just outside of the silt screen in Hankede was measured with a water quality EXO3 probe on 3 August 2023, one day prior to the completion of Hankede reclamation.
The exact location of measurement was the water column in front of the groyne located in the south of Hithadhoo zone 2 reclamation (Figure 12), 85 m from the silt curtain.
Spot measurements on this location indicated turbidity of 37.53 ± 0.02 NTU, whereas the turbidity in the buoy in the British Loyalty Shipwreck did not exceed 3 NTU within the following days. It is safe to consider that the sediment that managed to pass the silt screen was deposited relatively fast, due to the low current speeds in this particular location.

Adaptive sediment management plan

An adaptive sediment management plan is a set of actions taken during the active phase of dredging to ensure that no exceedances of turbidity limitations occur or if they do, that they remain under control. There is a set of measures that can be adopted, which are divided in two categories: proactive management including the measures that are taken when level 1 triggers are exceeded; and responsive management including the measures taken when level 2 triggers are exceeded.

The strategy followed for this plan is based on the approach used within the Building with Nature research group on adaptive management strategies. Adaptive management was also selected as a management practice applicable to the project during the PIANC 100 Workshop.

Among the measures applied to the project, the proactive management actions include:

- Continuous collection of data from both reactive and informative monitoring programmes to generate useful datasets.
- Recording all relevant environmental

FIGURE 10

Corals placed on seabed in recipient sites.

FIGURE 11

Replanted seagrass in wave active sites has been protected with hessian bags filled with rock.

management actions carried out.
- Analysing all data and reporting to look for optimisation possibilities.
- Adapting work methods to optimise environmental and dredging performance.

Moreover, responsive management actions include:
- Reviewing the origin of trigger level exceedance and select most appropriate management practices.
- Investigating the expected effect of selected management practices.
- Preparing implementation plan and procedures.
- Confirmation that implementation of management practices is still required.
- Implementing management practices.
- Prioritising reactive (water quality) monitoring to measure the effects of implemented management practices.
- Informing stakeholders of exceedance and responsive actions taken.

Monitoring scope

A series of monitoring campaigns were implemented prior, during and after the execution of the dredging and reclamation works. It was important to minimise the impact of the dredging works in the local marine environment. In addition, temperature, pH, turbidity and sedimentation are parameters that needed to be monitored to ensure that no exceedances beyond the regulated limitations occurred. Furthermore, the local marine environment should be frequently inspected to investigate whether the dredging and reclamation works have no impact to the marine life, namely coral health, fish abundance, protected species, etc. Those requirements are indicated within the ESIA of the project (Water Solutions, 2022).

The means of monitoring turbidity throughout the project include floating buoys. The buoys were installed in the project area (as shown in Figure 2) at locations in the marine protected areas that were expected to be affected by the project's works.

The buoys are equipped with an EXO3 Multiparameter sonde (referred to as sensor). The sensor is placed under the water surface and the measured data is collected in the buoy and transmitted to the office by means of a GPRS connection. Secondly, the data is stored in the buoy datalogger and can be downloaded to a computer using a serial USB link. The major components of the water quality monitoring buoy are indicated in Figure 13. The datalogger is equipped with a GPS receiver for timing and tracking of the buoy. Additionally, the monitoring buoys are equipped with a strobe light and a radar reflector for detection. The sensor is connected with the controller (data processor) in the instrument barrel with an individual sensor cable. The controller uses the GPS for timing and position. The turbidity sensor measures turbidity levels every minute and logs the observations in the controller. Accordingly collected data is transmitted every 15 minutes to the office. The buoys are capable of measuring turbidity, pH and water temperature continuously.

The total suspended solids can be indirectly calculated based on the turbidity measurements using a conversion coefficient. The conversion coefficient depends on the composition of the sediment. Consequently, sediment samples were taken from several locations within the Addu Atoll. The correlation coefficient between turbidity [NTU] and total suspended solids (TSS) [mg/l] was calculated at 1.512.

The Environmental Protection Agency of Maldives indicated that the maximum values of turbidity are 3-5 NTU in the MPA and for sedimentation rate 15 mg/cm²/day in specifically chosen locations within the inner atoll. It has to be highlighted however, that as indicated by PIANC (2010) in report number 108, "Dredging and Port Construction around coral reefs", exposure to turbidity and sedimentation rate of levels higher than the indicated limits needs to last weeks to cause stress to corals. Consequently, short- term exposure to slightly higher values of turbidity and sedimentation rate is not expected to affect the coral health.

Based on the measurements acquired from the monitoring buoys, there have been no significant modifications in the background values of pH and water temperature throughout the dredging and reclamation period. Moreover, the combination of enclosing the reclamation area and installing silt curtains around the

FIGURE 12

Installed silt screen for the Hankede reclamation and the south groyne of Hithadhoo zone 2 reclamation.

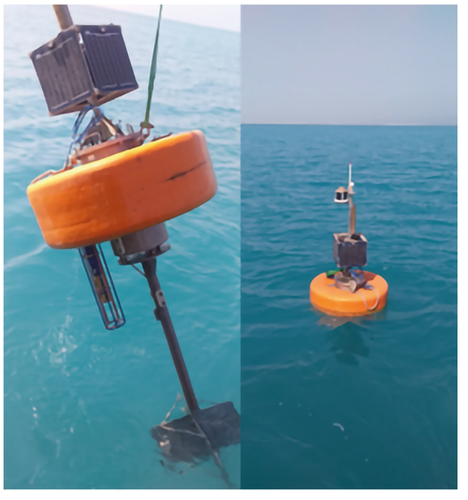

FIGURE 13

Left: water quality monitoring buoy showing the solar panels, the underwater connectors, the floater (orange), the water quality EXO3 sensor, the buoy tail and resistance cross. Right: deployed monitoring buoy showing (above the solar panels) the radar reflector, the solar panel charged light and the antenna.

reclamation outfalls to contain turbidity levels further from reclamations, has resulted in maintaining daily average values of turbidity below 5 NTU or 7.56 mg/l, if the correlation coefficient is applied. Exceedance was only recorded within the last two days of dredging and reclamation at 6-8 NTU. This is attributed to a swell event entering from the east side of Gan island and resulted in transporting the dredge-induced plume towards the buoy at the British Loyalty Shipwreck. Nevertheless, the duration of the exceedance was too short to have significant impact on the coral health and marine life.

Measurement of sedimentation rate has been achieved by means of installation of sediment traps in specific locations within Addu Atoll indicated by the ESIA (see Figure 2). The location was chosen in order to monitor the sedimentation rate along the reefs within Addu Atoll and have a more extensive overview of the sediment transport throughout the active phase of dredging.

Sediment traps have been constructed by 5 cm internal diameter PVC pipe, 11.5 cm long and sealed at the bottom end, with baffles at the top of the pipe to prevent entry of fish. Each set of traps consisted of three traps tied together to an iron stake driven to the seabed, approximately 20 cm from reef bottom (see Figure 14). At each site, three sets of traps were deployed between 5 and 10 metres, for a duration of 14 days. Retrieved sediments are washed in freshwater multiple times to remove salt and then oven dried at 60° C and weighted to 100th of a gram. Sedimentation rate is calculated as mg of sediment per cm² per day, as the ratio of the sediment weight (total dry weight of the sediment samples from each site) divided by the product of the number of days of deployment and the area of sediment deposition.

Construction works during dredging and reclamation

Dredging and reclamation sequence

As indicated in Figure 2, the TSHD HAM 318 can remove sediment from two borrow areas, namely the south and the southeast borrow

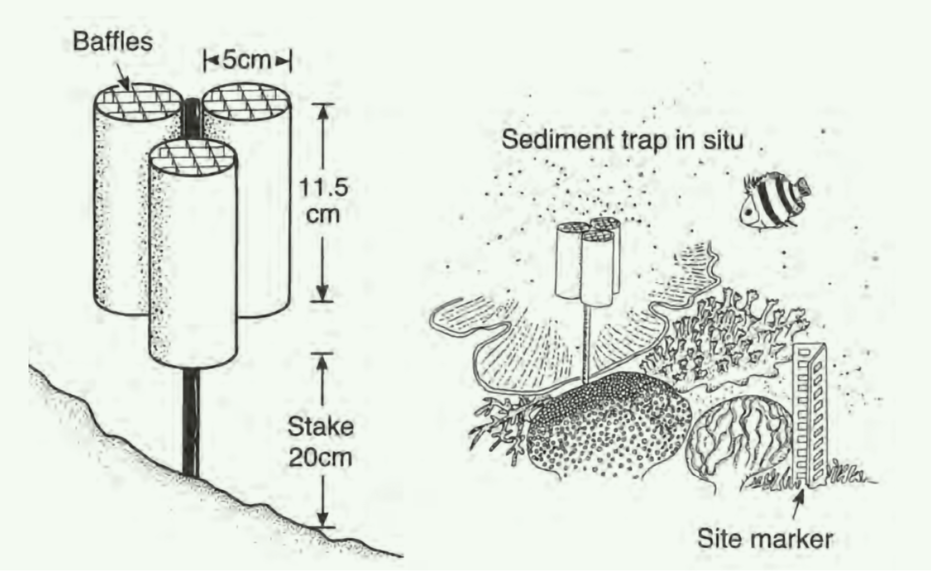

FIGURE 14

Example of sediment trap (English et al., 1997).

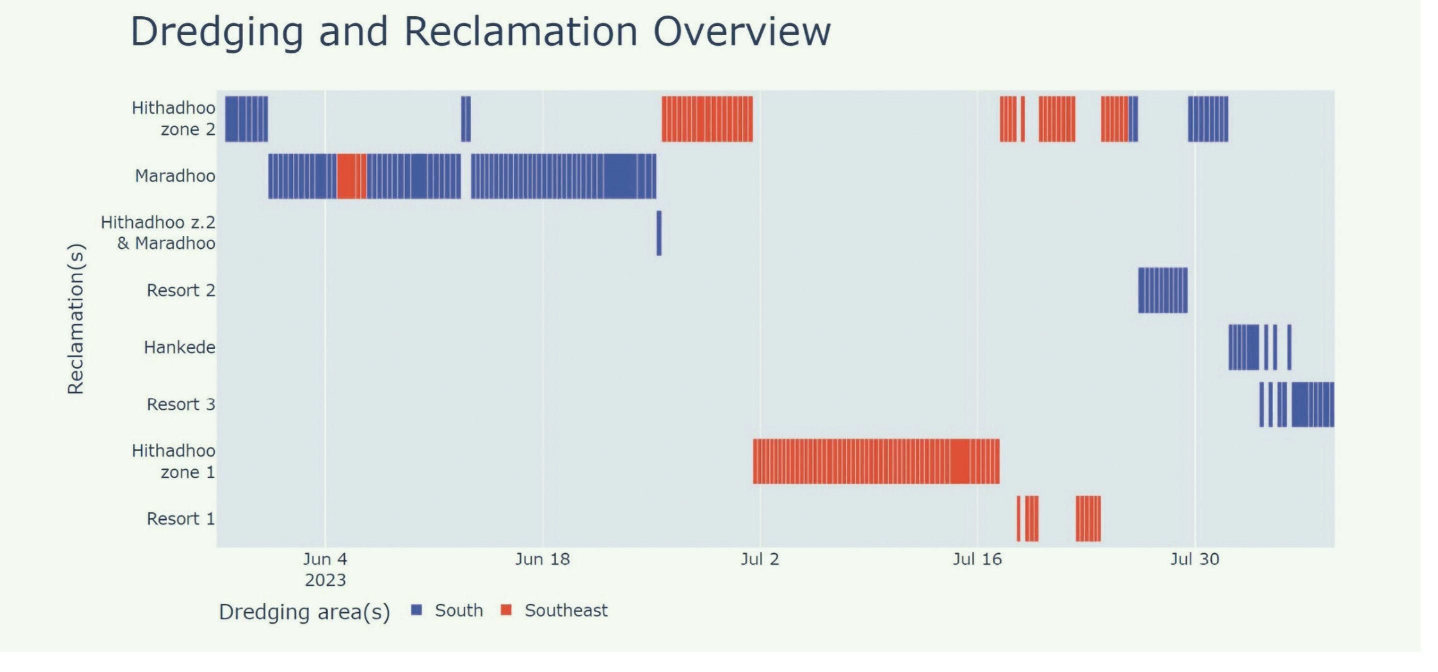

FIGURE 15

Gantt chart for the sequence of dredging and reclamation of the project.

areas. A dredging cycle of the TSHD consists of dredging from one of the borrow areas up to accumulating the maximum volume of hopper capacity. Then, the sediment is deposited in the reclamation footprints by means of a floating pipeline.

Each of the trips of HAM 318 are shown in Figure 15 throughout the course of the dredging and reclamation phase of the project.

The reclamation in Hithadhoo zone 2 took place in several stages as indicated in Figure 16 due to its elongated shape, to accommodate the unobstructed execution of reclamation works and to accommodate the function of the Hithadhoo commercial port. Thus, Hithadhoo zone 2 reclamation started on 28 May 2023 and was completed on 1 August 2023.
The floating pipelines were installed on the southmost and the northmost locations of the footprint, whereas the reclamation outfalls were placed in the middle of the length of the reclamation, close to the marine protected area of the British Loyalty Shipwreck. The choice of the outfalls aimed at accommodating the efficiency of the reclamation execution. Even though the distance from the MPA is substantially small, the use of silt screens combined with the placement of an environmental buoy in the MPA (Figure 2) resulted in a thorough monitoring of the reclamation process and ensured that no turbidity exceedances were recorded within the British Loyalty Shipwreck area.

Maradhoo reclamation was implemented between 31 May and 25 June 2023 (see Figure 18). The floating pipelines were placed from the inner atoll, crossing over the main street and discharging sediment mixture from the north (see Figure 17) and the south side of the reclamation, whereas the reclamation outfalls were placed midway in the enclosure sand and rock bund. The floating pipelines were protected with road humps made of sand, so that the reclamation could proceed according to plan and the traffic through Maradhoo-Feydhoo, Maradhoo and Hithadhoo islands remain unobstructed. As shown in Figure 17, an intermediate bund was constructed across the reclamation area to further assist in fine sediment containment from the offshore side of the atoll. Since the outfalls are placed in the offshore side of the reclamation, there was no possibility of using silt curtains for sediment containment in the last stage of the reclamation. However, the strong currents ensured that no sediment plume could possibly form.

FIGURE 16

Reclamation at Hithadhoo zone 2 on 14 August 2023, with groyne constructed in the south of the reclamation and the natural beach started forming in the inner side of the atoll.

FIGURE 17

Maradhoo reclamation footprint progress on 12 June 2023 (floating pipeline discharging sediment mixture from the north).

FIGURE 18

Maradhoo reclamation footprint on 14 August 2023 (drone photo taken from the north edge of the reclamation). The location on the north side where the floating pipeline cross the main street is indicated with red box.

FIGURE 19

Hithadhoo zone 1 reclamation on 13 August 2023 (drone photo taken from the north side of the reclamation).

Hithadhoo zone 1 reclamation was executed between 1-17 July 2023. The floating pipeline was installed from the south side of the reclamation. It must be highlighted that this was the first reclamation completed with sediment taken entirely from the southeast borrow area, whereas Maradhoo and Hithadhoo zone 2 were filled by sediment coming both from south and southeast borrow areas. This is part of the general strategy to periodically switch borrow areas to control the sediment dispersion and the plumes generated locally due to the dredging operations. The reclamation outfall was placed in the midway of the rock bund enclosure and silt screens used to ensure containment of sediment dispersion further from the reclamation area.

Resort islands 1 and 2 reclamations took place 18-23 July 2023 and 26-29 July 2023, respectively. Resort island 1 was filled with sediment from southeast borrow area, whereas resort island 2 was filled with sediment from south borrow area, once again to maintain low turbidity generated by the dredging operations. As previously indicated, the enclosure of the reclamation footprint was accomplished by sand-filled geotextile tubes. The final design of the islands included two layers geotextile tubes, one placed on top of the other. The enclosure was made by installing the first layer of the lower tubes. However, in the circumference of the enclosure, one geotextile tube in the west/southwest of the islands was not placed to serve as the reclamation exit, which was covered by silt screens. The resort islands 1 and 2 after the completion of the reclamation procedure can be seen in Figure 20 and Figure 21, respectively.

Final stage of the reclamation sequence has been the execution of the resort island 3 (Figure 22) and the Hankede (Figure 23) reclamations. The enclosure of the resort island 3 consists of geotextile tubes whereas Hankede consists of sand bunds. Those reclamations collectively were executed between 1-7 August 2023. The major reason for this choice was that for resort island 3, even after creating the enclosure, it was not constantly above water. Thus, the only possibility of executing a closed reclamation, where the sediment mixture would stay within the area of the island would be if the reclamation took place during low tide. The rest of the time, sediment mixture was placed in Hankede reclamation. Silt curtains were used here as well to contain sediment dispersion.

FIGURE 20

Resort island 1 reclamation on 13 August 2023 (drone photo taken from the south of the island). In the southwest of the island the opening used as the reclamation exit can be seen.

FIGURE 21

Resort island 2 reclamation on 13 August 2023 (drone photo taken from the south of the island). The opening used as reclamation exit is visible in the west of the island.

FIGURE 22

Resort island 3 reclamation footprint on 14 August 2023 (drone photo taken from the west of the island). In the lower left of the photo you can see the second layer of geotextile tubes being installed.

Discussion and lessons learnt

The information contained in the above clearly supports the argument that environmental management was present throughout the entire course of the project. The environmental manager is always responsible for performing inspections of processes and equipment to avoid any accidental situations (oil spills, damage to coral reefs etc.). It is also within the responsibilities of the environmental manager to inform local community (city councils, NGOs, etc.) about progress updates and record concerns and feedback that need to be addressed in every phase of execution.

Prior to the reclamation, the initial phase of construction is strongly dependent on the site conditions. In addition, there is a need to minimise the impact of construction equipment so that minimal social obstruction occurs, i.e. no obstruction of transportation of goods and people or fishing activities. Moreover, it is essential to ensure minimal impact on marine life due to the execution of works. Construction with minimal noise and turbidity effects will contribute minimal impact to the marine life. Prior to enclosure of the reclamation footprints, the removal of marine life is highly important and requires timely use of resources (workers, equipment, local community) to work together. Another responsibility of the environmental manager to coordinate.

During execution of dredging and reclamation, rapid response to potential exceedances of monitoring parameters (turbidity, sedimentation, air and noise quality, etc.) is of high importance. If action is taken as soon as possible, then the reversing of the impact on the environment will also be fast. Thus, the environmental manager is always in direct contact with the managers of all other project departments including operations and health and safety.

A direct result of proper environmental management was visible after the completion of the dredging and reclamation works. Not only has marine life not been affected within the marine protected areas, but also in Addu Atoll in total. A significant highlight has been the observation of manta ray sightings during the project. Sighting incidents of manta rays (as shown in Figure 22) were recorded based on information provided by local dive masters, indicating that this magnificent marine life species kept returning every day at the Maa Kandu Manta Point (marine protected area indicated in green polygon around buoy 2 at Figure 2).

Finally, the importance of a detailed ESIA has to be highlighted as it plays an important role in protection of the environment, identification of potential impacts and the proposal of proper mitigation measures. These key points ensure that a project is designed and implemented considering all environmental concerns. These concerns will be integrated in the developments ensuring the sustainability of the project. If an ESIA follows the international standards, set namely by the Organization for Economic Cooperation and Development (OECD) and the International Finance Corporation (IFC), it is feasible to deliver a sustainable project. If this is not the case, a gap analysis is deemed necessary to be carried out by the environmental manager to take into account any shortcomings and to make the list of mitigation measures more complete. All in all, a proper and detailed ESIA can contribute to more accurate environmental management throughout the project execution. In the present case, gaps have been identified between the executed ESIA and the OECD guidelines. The contractor took steps and covered the additional requirements to achieve compliance with the OECD standards.

FIGURE 23

Hankede reclamation completed on 14 August 2023.

FIGURE 24

Manta ray sightings at Maa Kandu Manta Point on 18 August 2023.

Conclusions

In this article, the importance of environmental management is discussed through the case of Addu City dredging and reclamation project. The implementations of sustainable actions to minimise the impact of the project to the environment in a manner that is fast and efficient plays an important role and sets an example for execution of similar projects. In addition, a detailed and thorough ESIA document provides the best starting point for successful environmental management of any project.

Summary

Dredging and reclamation projects have the potential to pose significant impacts on the ecosystems in the footprint of the newly created areas and the ecosystems adjacent to them. Potential negative effects of these impacts can be minimised when proper environmental management through mitigation measures is adopted throughout the course of the project, from preparation to completion. Addu City dredging and reclamation project is a great example of a project where novel construction methodologies were implemented and environmental challenges were successfully addressed. The project's main scope has been the creation of over 200 hectares of climate resilient land to support housing of local population and touristic development. Proper enclosure of the footprints, relocation of corals and seagrass (at pilot level) prior to the reclamation process, and thorough monitoring of sediment impact in the nearby marine protected areas during dredging and reclamation are exemplary of the management approach applied. All aimed at conducting the reclamation works in this sensitive area with minimal environmental impact. The effectiveness of such actions is directly visible in the reef health of Addu Atoll after the completion of the works.

Efstratios Fonias

Efstratios is a civil engineer with experience in the fields of environmental flows and continuum mechanics. He has worked on modelling of wave propagation, sediment transport, fluid-structure interaction, design of coastal protection works. Efstratios received a PhD from the Department of Mechanical and Manufacturing Engineering at the University of Cyprus. He works as an environmental engineer for Van Oord and served as environmental manager for the Addu City dredging and reclamation project focusing on topics including turbidity management of dredging works and implementation of ecological activities, etc.

Erik van Eekelen

Erik graduated in 2007 with an MSc in environmental fluid mechanics on near-field behaviour of overflow plumes from Delft University of Technology in the Netherlands. Since then, he has worked for Van Oord as an environmental engineer on topics, such as Building with Nature, stakeholder engagement, protection of marine fauna and turbidity monitoring and management. Erik was an MT member of EcoShape's Building with Nature 2 (BwN2) programme and since January 2023 is director of the new BwN3 programme. Erik is also course lead for the IADC/CEDA Dredging for Sustainable Infrastructure course.

Afifa K. Shanavas

Afifa is a dedicated environmental engineer and holds a master's degree in environmental engineering and a bachelors in civil engineering. Her professional journey spans over 6 years, prominently with Van Oord in dredging and reclamation, and oil and gas projects. Afifa's passion lies in successfully incorporating environmental sustainability on the projects that she is involved in and completing projects with minimal environmental and social impact.

Marlies van Miltenburg

Marlies holds an MSc in environmental fluid mechanics from Delft University of Technology (2017) and joined Van Oord's environmental engineering team afterwards. Notably, she led sediment spill management for the Fehmarnbelt tunnel dredging project in Denmark, implementing a state-of-the-art spill control and monitoring programme. Her expertise includes ESG due diligence, ESIA guidance and turbidity monitoring and management. Marlies currently coordinates environmental dredging related requests within Van Oord.

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UPCOMING COURSES AND CONFERENCES

Dredging and Reclamation Seminar

1-5 July 2024
IHE Delft Institute for Water Education
Delft, The Netherlands

18-22 November 2024
Venue to be confirmed
Abu Dhabi, United Arab Emirates

About the seminar
Since 1993, the IADC has regularly held a week-long seminar developed especially for professionals in dredging-related industries. These intensive courses have been successfully presented in the Netherlands, Singapore, Dubai, Argentina, Abu Dhabi, Bahrain and Brazil. With these seminars, IADC reflects its commitment to education, encouraging young people to enter the field of dredging and improving knowledge about dredging throughout the world.

For whom
The seminar has been developed for both technical and non-technical professionals in dredging-related industries. From students and newcomers in the field of dredging to higher-lever consultants, advisors at port and harbour authorities, offshore companies and other organisations that carry out dredging projects. Attendees will gain a wealth of knowledge and a better understanding of the fascinating and vital dredging industry.

In the classroom
There is no other dredging seminar that includes a workshop covering a complete tendering process from start to finish. The in-depth lectures are presented by experienced dredging professionals from IADC member companies. Their practical knowledge and professional expertise are invaluable for in the classroom-based lessons. Among the subjects covered are:

- the development of new ports and maintenance of existing ports;
- project development: from preparation to realisation;
- descriptions of types of dredging equipment;
- costing of projects;
- types of dredging projects; and
- environmental aspects of dredging.

Site visit
Practical experience is priceless and it sets aside this seminar from all others. There will be a site visit to a dredging yard or project of an IADC member to allow participants to

Submissions for IADC Safety Award 2024

Conceived to encourage the development of safety skills on the job as well as heighten safety awareness, the award recognises the exceptional safety performance of a particular project, product, vessel, team or employee.

Two safety awards will be presented in 2024: one to a dredging organisation and a second to a supply chain organisation active in the dredging or offshore industry. This concerns subcontractors and suppliers of goods and services.

There is no limit to the number of submissions that can be entered and the awards are open to both IADC members and all other dredging contractors.

Send in your submissions by visiting https://bit.ly/SafetyAward2024.

view and experience dredging equipment first-hand to gain better insights into the multi-faceted field of dredging operations.

Networking

Networking is invaluable. A mid-week dinner where participants, lecturers and other dredging employees can interact, network, and discuss the real, handson world of dredging provides another dimension to this stimulating week.

Certificate of achievement

Each participant will receive a set of comprehensive proceedings and at the end of the week, a certificate of achievement in recognition of the completion of the coursework. Full attendance is required to attain the certificate.

Costs

The fee for the week-long seminar is EUR 3,100 (out of scope EU VAT). The fee includes all tuition, proceedings, workshops and a special participants' dinner, but excludes travel costs and accommodations. We can assist you in finding a hotel or accommodation. For more information and how to register visit https://bit.ly/SemDelft2024.

Dredging for Sustainable Infrastructure Course

24-26 September 2024
DHI A/S
Copenhagen, Denmark

How to achieve dredging projects that fulfil primary functional requirements, while adding value to the natural and socio-economic systems. This is just one of the questions addressed during the 2.5-day course (organised with the support of NMDC) that is based on the philosophy of the book, Dredging for Sustainable Infrastructure.

Experienced lecturers will describe the latest thinking and approaches, explain methodologies and techniques, and demonstrate through engaging workshops and case studies, how to implement the information in practice.

Based on their availability, the lecturers come from a group of experts that include:

Erik van Eekelen (Van Oord),
Pieter de Boer (Rijkswaterstaat/CEDA)
Marc Huygens (DEME Group),
Mark Lee (HR Wallingford)
Frederik Roose (Flemish Government)
Sina Saremi (DHI Denmark)
Thomas Vijverberg (Boskalis)

During the course, participants will learn how to implement the sustainability principles into dredging project practice, through answers to the following questions:

- What is the role of dredging in the global drive towards more sustainable development?
- How can water infrastructure be designed and implemented in a more sustainable and resilient way?
- How can the potential positive effects of infrastructure development be assessed and stimulated as well as compared with potential negative effects?
- What equipment and which sediment management options are available today?
- A brief introduction to the question, "What knowledge and tools are available to make sound choices and control a project?"

For more information and how to register visit https://bit.ly/IADC-events.

IADC and PIANC 1-day conference
Integrating Dredging in Sustainable Development

18 October 2024
Sheraton Saigon Hotel & Towers
Ho Chi Minh City, Vietnam

For those working in the fast changing world of dredging, waterborne transport infrastructure and related industries, IADC and PIANC's 1-day conference is dedicated to advancing industry knowledge in the arena of sustainable dredging and related topics.

Whether an individual or company aiming to deliver dredging projects with longevity that also maximise the benefits to society, nature and economy, this event will be of particular relevance. The 1-day conference "Integrating Dredging in Sustainable Development" will bring essential knowledge for planners, designers, decision makers, regulators, contractors, project owners and environmental advocates.

Joining this event also provides the unique opportunity to network with more than 60 CEOs and senior management of IADC member companies. And all participants are welcome to join the special pre-conference networking drinks and dinner on Thursday 17 October 2024. For more information and how to register visit https://bit.ly/VietnamConf24.

INTEGRATING DREDGING IN SUSTAINABLE DEVELOPMENT

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