MARITIME SOLUTIONS FOR A CHANGING WORLD
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TERRA ET AQUA

EARLY CONTRACTOR INVOLVEMENT

Identifying the hallmarks of successful ECI process in maritime projects

INNOVATIVE STRUCTURES

Alternative quay wall structures for inland ports

DREDGE PLUME MODELLING

THE IMPORTANCE OF INCLUDING FLOCCULATION IN NUMERICAL MODELLING

THE IMPORTANCE OF FLOCCULATION IN DREDGE PLUME MODELLING

Numerical models are often used to predict the magnitude and behaviour of dredge plumes to help assess and manage any environmental risks. Previous investigations have shown that in the marine environment, fine-grained sediment suspended by natural processes and dredge-related activities are typically present as aggregated particles known as flocs. Read the full article on page 18 that considers the importance of including the process of flocculation in dredge plume models.

CONTENTS

BREAKING THE DEADLOCK IN FINANCING SUSTAINABLE PROJECTS

On 9 Febrary 2023, IADC hosted a 1-day conference in Dubai on "Financing Sustainable Marine and Freshwater Infrastructure". Designed for professionals in the fast changing world of finance, dredging and related sectors, 80 delegates came together to address what is needed to break the deadlock in the funding of sustainable projects. And most importantly, who needs to do what.

While sustainable projects generally make use of nature-based solutions (NbS), one of the main bottlenecks identified in the financing process of such projects is obtaining the certainty of a project's cash flow. Projects are often relatively small and as a result, the start-up costs are high. A possible solution to interest investors is the bundling of projects. At the same time, a case-by-case approach is necessary since risks, which are a relevant factor for investors, differ per project. NbS projects are generally more risky than traditional projects as the effectivity of the solution is sometimes uncertain.

> **Another problem identified is the difficulty of translating social benefits into financial benefits.**

Can investors be tempted to have a greater risk appetite while accepting a lower ROI as is often the case with NbS projects?

The lack of a proper legal framework with a clear definition of project and governance also remains a challenge.

An ROI can be achieved from, for example, carbon credits. Projects with an NbS design often have a lower ROI and are therefore less preferred by investors. More and more pension funds however are willing to participate in NbS projects, prepared to settle for lower returns in favour of sustainability. In addition, insurers can reduce claim costs with NbS coastal protection projects. By investing, thereby reducing flood risk, they in turn can reduce their costs.

It is paramount that projects are viewed in an integrated way and that all the costs and benefits, including externalities, are assessed. Another problem identified is the difficulty of translating social benefits into financial benefits. While there are methods for this, they involve many assumptions and discussions about the value of parameters.

Delegates suggested ideas for ways to move forward that included organising regional symposia to showcase examples of successful nature-based solutions. Consultants and contractors to highlight existing NbS projects at infrastructure finance conferences. Developers and authorities to integrate NbS in large commercial infrastructure developments. Authorities to facilitate the implementation framework of sustainability by bringing all stakeholders to the table at the early stages of a project. Along with governments to create laws to include sustainable solutions as part of a project's evaluation for approval.

Overall, the conference provided a much-needed springboard to move the topic of funding sustainable projects forward. In keeping with the topic, check out the sustainability article on page 30 that shares research on finding more cost effective and sustainable quay wall structures for the future. Also in this issue are articles addressing the importance of flocculation in dredge plume modelling and early contractor involvement in maritime projects.

Frank Verhoeven
President, IADC

APPLYING EARLY CONTRACTOR INVOLVEMENT IN MARINE INFRASTRUCTURE PROCUREMENT

Complex construction projects that use traditional procurement practices are often impacted by significant cost overruns and delays. Early contractor involvement (ECI) is a concept that strives to involve the contractor collaboratively at an early stage of a project's development to mitigate or otherwise eliminate those risks. In August 2022, PIANC published the report "A framework for early contractor involvement in infrastructure projects" to help industry practitioners in choosing and best implementing ECI. This article is intended to develop on key aspects of the PIANC report and look at the factors that can lead to a successful maritime ECI project.

A framework for early contractor involvement in infrastructure projects
The PIANC report "A framework for early contractor involvement in infrastructure projects" and is available as a free download for PIANC members (and 215 EUR for non-members) on the PIANC website. At some 183 pages, it provides a detailed introduction into the understanding and the application of early contractor involvement (ECI) in waterborne transport infrastructure projects. It is the only comprehensive guidance document available on the subject of ECI in the construction industry. It offers a practical approach to all industry practitioners to assist in the application of ECI in the waterborne transport infrastructure sector.

The report also identifies the hallmarks of successful ECI process, which have been established over many years, such as dealing with good faith, transparency, equal treatment of all parties, fairness, clarity through clear rules of engagement, confidentiality and protection of intellectual property. The stated aim of the report is to further promote and support the use of ECI in the global construction sector. It provides guidance to industry practitioners so clients, consultants and contractors in how to successfully implement ECI for the betterment of the industry as a whole.

The PIANC report states that the definition of early contractor involvement is a strategy initiated by infrastructure owners (clients) towards main contractors and optionally expanded to consultants, stakeholders and subcontractors. The purpose being to optimise values in project delivery and objectives, through their participation and knowledge sharing in stages of project planning and design prior to project execution.

When drafting the report, the authors noted that there was no single dominant concept or approach to ECI. Diverse regions and countries appear to deal with ECI differently. The common denominator identified was that ECI is a strategy initiated by infrastructure owners (clients) towards main contractors and optionally expanded to consultants, stakeholders and subcontractors. The purpose being to optimise values in project delivery and objectives, through their participation and knowledge sharing in stages of project planning and design prior to project execution.

It is important to note that while the principles of early contractorinvolvement may be universal, the specific practices and methods for implementing ECI can vary greatly depending on the region and industry. To ensure success, clients and contractors should take into account the best practices and lessons learned from previous ECI projects in their specific region and apply them to their current project, while also considering the unique local conditions and challenges. This can include factors, such as cultural differences, regulatory requirements and market conditions such as the availability of resources. By taking a localised approach to ECI, clients and contractors can tailor their project to the specific needs and constraints of their region, leading to a more efficient and successful outcome.

A shift to more collaborative contracting

The "business as usual" model of procurement is usually driven on a pure transactional basis by the client seeking the lowest price from tenderers for their project – using either a completed design or for tenderers to price the client's requirements on a design and construct basis. With design and construct, using a traditional tender process there was little scope for innovation and cost savings as usually the client's requirements were fixed. Contractors would be reluctant to propose valuable innovative alternatives as there is always a threat that the tender could be cancelled and re-tendered on the basis of their own alternative, now exposed to the competition.

As Jon Davies, CEO Australian Constructors Association stated in a social media post (LinkedIn, January 2023): "There is significant wastage of skilled resources through inefficient tender processes, but the bigger problem is the myopic focus on selecting the lowest price at the tender box to the detriment of all else. The practice of accepting the lowest bid at the tender box is a completely false economy and is the direct cause of the adversarial contracting environment in which we now find ourselves."

The traditional procurement approach invariably leads to cost and time overruns during project execution. The causes of these overruns have been studied extensively (Arcadis, 2022 Global Construction Disputes Report, Bent Flyvbjergand Gardner, 2023).

A detailed study by Flyvbjerg and Gardner of some 16,000 major projects from large buildings to bridges, dams, power stations, rockets, railroads, information technology systems and even the Olympic Games, revealed a massive project management problem. Only 0.5% were completed on time and on budget, and produced the expected benefits. In other words, 99.5% of large projects failed to deliver as promised.

The highlighted events and challenges mentioned in Figure 1 are being felt post-pandemic and construction industry parties are looking to alternatives to the business as usual approach for potential projects.

Current events and challenges affecting the construction market

Social and economic factors
- Russian invasion of Ukraine
- COVID-19 pandemic
- Climate change
- Inequality
- Population growth
- Natural resource demands

Impacts to the construction industry
- Supply chain impacts
- Material cost increases
- Delays
- Labour shortages
- Impact to bottom line
- Increase in claims activity

Mitigation techniques
- Proactive risk management
- Alternative project delivery
- Contingency planning
- Pre-purchasing materials
- Constructability review
- Willingness to compromise

FIGURE 1

Current events and challenges. Arcadis, 2022 Global Construction Disputes Report.

Present | Causes of cost overruns

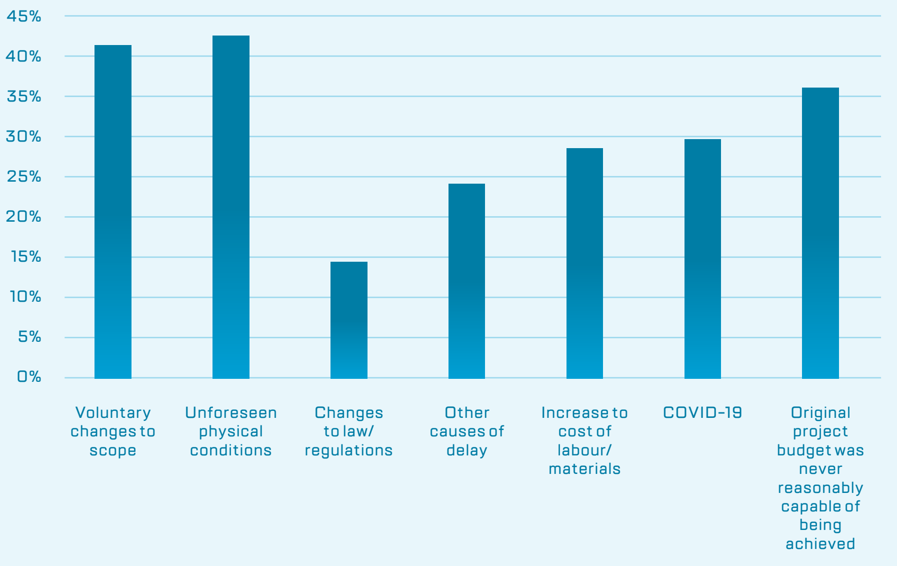

FIGURE 2

Causes of cost overuns. Study carried out in Australia, 2022.

Alternative project delivery using methods such as ECI is increasingly being seen as a valid alternative to ensuring a project is delivered within budget and completed on time. The diagram in Figure 2 gives a typical spread of cost overrun events and causes (Kelly and Judd, 2022).

Of note in Figure 2 is the high incidence of unforeseen physical conditions as a major cause of cost overruns. A proper assessment of physical conditions is vital for any marine infrastructure project. This is where the application of ECI can have a direct and positive impact.

ECI contract models

One established ECI model is the Bouwteam approach in the Netherlands, which is a non-competitive model in which the client has an active, central role. It particularly aims at finding the right solution for the project. This non-competitive model combines the strengths of established contract models such as DG2020 with effective organisational methods outlined in the manual "Handreiking Bouwteams" (Construction Handbook), resulting in a robust framework. It has been successful in the Netherlands and its principles, contractual framework and/or organisational aspects could be used quite easily outside a Dutch context.

Another established model is the Competitive Dialogue in the EU, a competitive model structured as a procurement framework. It particularly aims at finding the right party to deliver the project when the client does not have a single, predetermined solution in mind. This approach has been successful applied on numerous demanding infrastructure projects in the EU. It could be adapted to other regions with similar regulatory environments and project scopes.

Additionally, the NEC4 contract with clause X22 (early contractor involvement) is a well-established model for ECI projects. It is widely used in the UK, Hong Kong and increasingly in other countries, and specifically caters for projects where the contractor is involved at an early stage. The NEC4 contract allows for a collaborative relationship between the client and contractor, with a focus on achieving project objectives and delivering value for money. The contract is flexible and adaptable to different types of projects and procurement methods, and its focus on collaboration and risk management makes it a suitable option for clients and contractors looking to implement ECI in their projects.

Bouwteam and Competitive Dialogue are distinct ECI models each with their own defining characteristics and processes. On the other hand, the NEC4 contract model offers greater flexibility and customisation, enabling the client and contractor to adapt the approach to the specific needs of their project. The contract provides clear guidelines and scope for the ECI phase, effectively placing the contractor in the centre.

By studying and applying the best practices and lessons learned from previous ECI projects in a specific region, clients and contractors can improve the chances of success for their current project, while also considering the unique local conditions and challenges. Models such as NEC4 contract, Bouwteam and Competitive Dialogue each have their own specific characteristics and processes, providing clients and contractors with different approaches to tailor their ECI framework to their specific project needs.

ECI during site investigation

The CEDA information paper "Site Investigation" (Focus group on soil investigation, 2021), identified that inappropriate or insufficient soil investigation is widely acknowledged as one of the most important factors leading to cost increase, time overruns, claims and ultimately disputes between the client and contractor. Surprisingly, project site investigation is a phase where contractors have little to no involvement whatsoever.

For the contractor, having reliable and relevant soil information in time is essential to be able to provide a well-prepared tender. The better the quality, and appropriateness of the results, the more accurately the contractor can determine the most efficient dredging methodology, and corresponding price, to the benefit of the project and the client. "The earlier the consultants and contractor are involved, in the preparation and execution of the soil investigation, the more guarantees the owner has that later disputes and delays can be avoided" (CEDA information paper, Site Investigation, 2021).

Having tendering contractors involved at an early stage as part of an ECI process and influencing the extent of any site investigation and formulating a targeted geophysical and

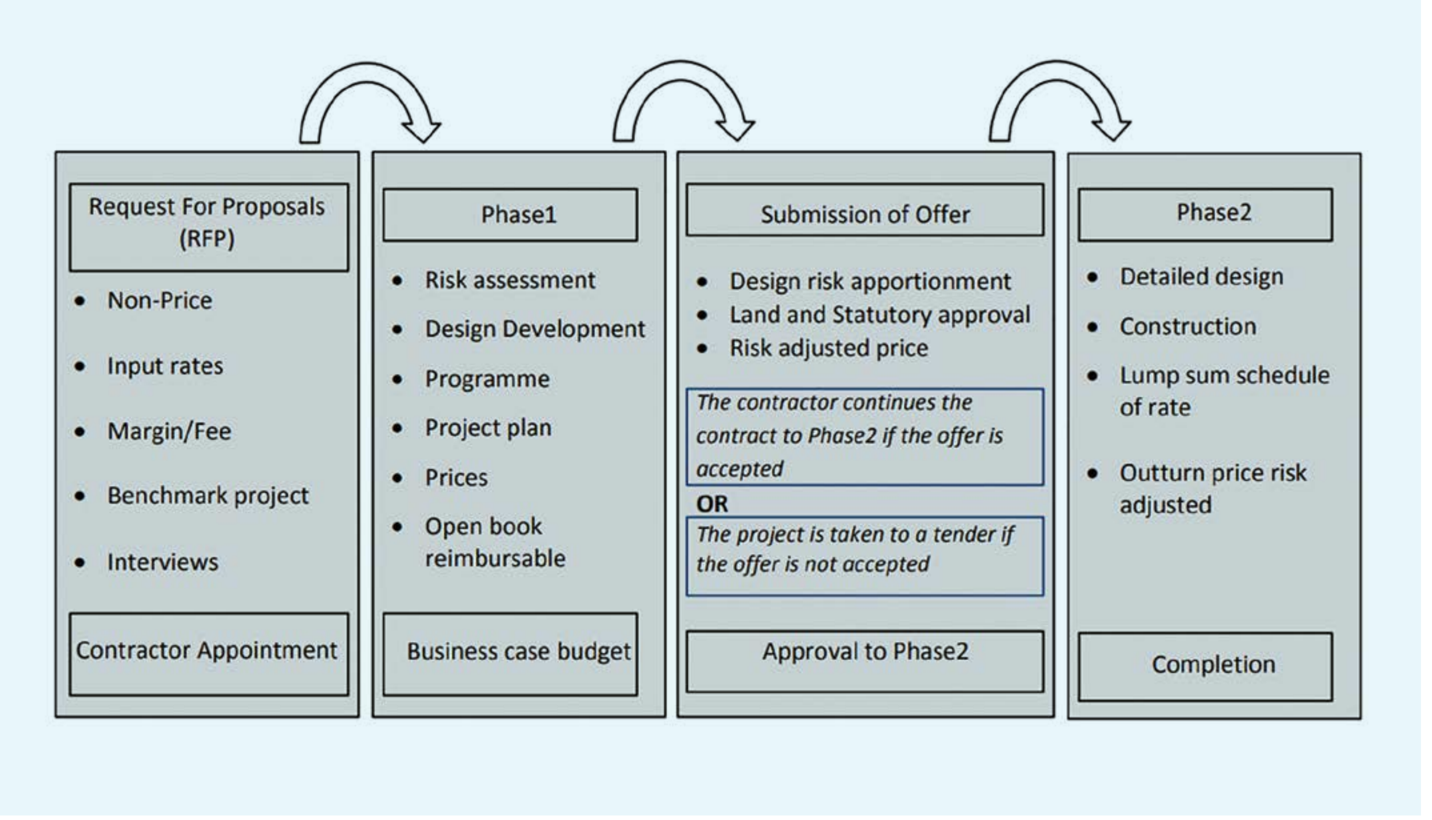

FIGURE 3

Details of the two phases of an ECI Contract adopted from Swainston (2006).

geotechnical assessment can reap dividends and a balanced risk sharing approach can ultimately lead to lower project cost.

An ECI during preliminary soil investigations, i.e. preparation of scope, witnessing and assessment of scope of tests (in situ and in laboratory) can be very useful. The contractor needs to assure itself that the data collection has been prepared by a competent soil investigation contractor, in accordance with accepted international standards. In this regard, as part of the ECI approach, the client should consider inviting potential tenderers to provide input to and witness the execution of the soil investigation.

Budgeting and open book pricing

Also another key aspect is the way that ECI can ensure that the client's original budget can be "reality checked" by potential contractors without the time and expense of going to tender with a complete design. It is a misconception to think that ECI is solely a one-on-one process with a single bidding contractor. Having a competitive ECI process is still achievable and the PIANC report provides helpful guidance on how best to do this. The usual approach is for a Phase 1 and Phase 2 offer. The phases are shown in Figure 3.

The Queensland Department of Main Roads' "Standard contract provisions roads, Volume 6 Early contractor involvement (ECI) Contract" identified a number of mechanisms used in the ECI process to encourage and demonstrate appropriate attention to ensure value for money for the client these being:

- Open book arrangements in Phase 1;
- Selection of competent contractors and designers who have a proven successful track record;
- The use of an independent estimator to analyse and review target costs to validate the Phase 1 outputs;
- Rates based on benchmark projects provided by the contractor;
- A working environment that encourages innovative thinking;
- Integrated teams working together to achieve best value whole-of-life solutions;
- Competitive pricing of supplier and sub-contract components;
- A full understanding and allocation of project risks; and
- Provision for the client to terminate the contract if agreement is not reached on the Phase 2 offer.

When considering a marine infrastructure project, the client would be advised to employ an independent dredging consultant and production estimator to analyse and review the input rates and target costs to validate the ECI contractor's Phase 1 prices.

With respect to the actual costs of marine equipment as these are capital intensive the discussion of how the ECI contractor has arrived at the rates and prices often turns on the valuation of the "cost" of the vessel itself. This is where in an ECI process of an "open-book" evaluation comes into the picture. Tenderers generally are not obliged to provide a detailed disclosure as to how their rates and prices are derived.

With open book pricing, the contractor will share all information and documentation of the financial costs of the work under the contract on a transparent and full disclosure basis. In addition, revealing details of how it has determined how it will recoup the cost of the vessel over its operational life. Such information should be treated as confidential by the client.

The dredging industry has for many years used cost standards for various types of dredging vessels to calculate the allowance for Depreciation and Interest (D&I), and Maintenance and Repair (M&R) costs, using a publication from CIRIA. CIRIA is the United Kingdom's construction industry research and information association. CIRIA published its "Cost standards for dredging equipment" in 2005 with an updated issue in 2009. Each year, the International Association of Dredging Companies (IADC) publishes a time-cost factor index for various groupings for updating these costs.

CIRIA offers a benchmark for estimating a contractors pricing but it is only part of the picture as there are many other pricing variables to consider. Costs specifically excluded in CIRIA are the costs of the contractors technical services department (overhead), crew cost, staff cost, lubricants, fuels and water, laying up and idle time, additional wear to dredging components, spare parts, insurance, mobilisation and demobilisation, general overhead and profit among others. Therefore, this is where a dredging consultant can assist to benchmark the details disclosed by the ECI contractor.

The testing of the ECI contractors rates and prices, and the basis of the valuation is on the premise of a reasonable "price" as would be derived under a competitive tender situation. The rationale is that the rates and prices identified by the ECI contractor will form the basis, either directly or indirectly, for the value of the works to be carried out so should be as market competitive as possible.

The intention of a two-phase ECI approach will normally be to maintain the competitive element in the preparation of the rates and prices, and that open book pricing forms the basis of the assessment. In this respect, the use of CIRIA may seem to be subjective as it is not the contractor's "cost" but rather it is an assessment of the partial allowable and commercial price. It assists greatly however, in a reality check of the ECI contractors "core" pricing.

While CIRIA deals with the dredging equipment pricing, it needs to be realised that marine infrastructure projects have become more complex and multiple disciplinary over the last decades. That complexity has led to other activities becoming just as important in the total pricing of a project. Marine infrastructure projects require more design and engineering, procurement, environmental and sustainable solutions. Those activities can benefit from the use of a specialised dredging consultant who can reality check pricing, review estimates, prepare tailor-made cost models and can also be involved in the execution stage of the project.

Claims from contractors can arise when there is uncertainty. A dedicated dredging consultant who is involved from the early stages of a project can seek to de-risk a project, avoid claims and mitigate risks through implementing ECI techniques such as open book pricing. In the event of a claim situation arising, full history and involvement in the early stages of a project can prove to be invaluable for good project management and dispute resolution.

Regulatory and permitting process

Clients are continually facing increasing technical complexities, increasing regulatory and environmental restrictions coupled with tremendous internal and external pressures to deliver projects on time, within budget and with unchanged scopes. With marine infrastructure,

FIGURE 4

Pricing of marine equipment using CIRIA tables provides benchmark rates.

NEW ZEALAND
GOVERNMENT PROCUREMENT

INFORMATION SHEET

At a glance - Early Contractor Involvement

Guidelines for use

An ECI model is attractive to contractors, due to the embedded relationship principles and overall collaborative approach. ECI is suited to large scale, complex or medium to high-risk projects, because it allows an integrated team time to gain an early understanding of requirements, which facilitates innovation and value for money. Clients should also consider this model in circumstances where:

- the project risks are difficult to quantify fully, and innovative approaches are needed to manage this
- project delivery timeframes are constrained
- they are interested in moving away from a transactional model towards a collaborative model, where there is insufficient capability or capacity to fully resource a relationship based model such as an alliance
- there's identified value in participating in a collaborative arrangement to drive innovative outcomes and knowledge transfer
- there's a need to obtain cost certainty while demonstrating transparency
- there are uncertain or complex design or construction interfaces, and flexibility in scheduling and delivery is required.

FIGURE 5

New Zealand Government information sheet on early contractor involvement.

the permitting process is recognised as being a complex and time consuming constraint to get a project to market.

The permitting process can take many months or even years from the start of the application process. Decisions at an early stage as to how the project is to be constructed and the choice of equipment and the manner in which material is dealt with and any environmental impact, can have significant time and cost impacts. This is where the involvement of an ECI contractor can have direct and tangible results.

So, for instance, will the dredged material be disposed offshore or brought onto land and will it have a beneficial reuse or not? The choice of one execution method over another can have significant impact on the cost of construction and the ECI contractor can advise the client of these so informed decisions can be made at an early stage. Environmental impact is also a key part of the permitting process with issues, such as turbidity, noise and marine mammal impacts being a key concern of both regulators and stakeholders.

One author has been involved with a project where a client undertook an extensive regulatory and permitting process involving addressing government bodies and key stakeholders concerns to allow drilling and blasting as the client considered the material to be removed was too strong to dredge. The contractor who was awarded the project elected to dredge the material using a powerful mega backacter negating any need to drill and blast. The operation of the backacter was ultimately successful and any need to drill and blast the material was avoided as the backacter worked under existing dredging permit approvals. In retrospect, the involvement of an ECI contractor in the early stage of the permitting application process would likely have revealed this and so avoided a lengthy and expensive permitting and approval process based on drill and blasting.

Constructability reviews

Constructability is where construction knowledge is applied during the early stage of a project where errors and omissions in the permitting and contract specifications can been minimised to enable the contractor to construct a high-quality project that is biddable, buildable and executed using best industry practices. As with the regulatory process, this is where the input of an ECI contractor can have direct and tangible results.

A constructability review process carried out by an ECI contractor is designed to help improve the level of constructability of a project. The most important benefits

Early contractor involvement is especially important in offshore wind energy projects due to the complex and challenging nature of construction.

expected from the review process are the achievement of an efficient project development process and the realisation of a cost-effective project.

The author's recent experience is that of a dredging project where the client insisted that onshore disposal of the dredged material was the only and preferred method. This would involve a cutter suction dredger pumping material ashore using many booster stations and kilometres of floating and submerged pipeline. The logistics of such an operation were significant and expensive due to the projects remote location. The most obvious and cost-effective method was using a backhoe dredger loading into barges with offshore rather than land disposal.

A constructability review by an ECI contractor could have helped in the decision-making involved at an early stage in the clients' permitting process rather than going to market and the tenderers pointing this out. While constructability reviews are effective over a broad range of project types and provide the benefit of allowing multiple functions to view the overall project as it develops, it should be realised that the ECI contractor will have gone into some effort and cost of conducting reviews, albeit for both permitting and/or constructability and documenting their results. This should be compensated. Therefore, the decision regarding the number of reviews and the period of involvement of an ECI contractor is a trade-off between the expected benefits and the expected cost of these reviews.

Construction risk assessment

There is no shortage of risk present on a marine infrastructure project. A construction risk assessment at an early stage of a project helps determine at-risk parties, create awareness around the risks present onsite, assess current loss prevention measures in situ, ensure contract requirements are upheld and decide if additional controls need to be applied. Contractors are generally aware of most financial risks, environmental risks, safety risks, productivity risks, as well as contract risks, however, this information is generally not fully exchanged as part of the normal procurement process. A construction risk assessment by an ECI contractor can help the client think "out of the box" and become aware of such potential risks and the possible mitigation actions or measures that can be applied.

Of the international forms of contracts available, only the NEC4 form of contract implements an Early Warning Register. This includes a description of the matter and the way in which the effects of the matter are to be avoided or reduced.

The NEC4 Early Warning Register is not for division of risk allocation but is a document to help promote risk management, after award of contract. As it only comes into existence at the award of contract it is helpful if an ECI contractor can contribute to preparation of a pre-contract Early Warning Register to highlight to the client what potential risk matters the contractor perceives.

An Early Warning Register's clear procedures also support effective risk management after contract award. Early warning identification at the ECI stage and the Early Warning Register are simple but effective risk management tools. Both encourage and require the ongoing assessment and management of risk throughout the period of the contract.

New frontiers: offshore wind

The past decade has seen exponential growth in the amount of offshore wind energy projects globally and with it came the creation of a new supply industry and specialised installation vessels to serve it.

The expansion of the number of projects will continue as four North Sea countries (excluding the UK) envisage a 20-fold increase in capacity. The EU member states of Denmark, Germany, Belgium and the Netherlands will create offshore energy hubs and islands, and build 300 GW of offshore wind energy by 2050 (the Esbjerg Offshore Wind Declaration, May 2022). A tremendous increase from the present 15 GW of capacity. Offshore wind farms are multi-billion euro projects and such investments require extensive and careful planning throughout the entire supply chain. Fairly early on in the development of this new market, offshore wind energy developers realised that they had to work hand in hand with the installation contractor to get to final investment decision (FID) and the realisation of a commercially viable project.

The sector continues to develop bigger wind turbines, with 15 MW turbines forecast to enter the market in the next decade. These larger and heavier wind turbines require stronger installation vessels and cranes. The existing installation vessels are unable to install the designed 15 MW turbines and are either being upgraded or bigger installation vessels are being built and commissioned. Innovative concepts and designs are needed to develop next generation vessels able to lift over 1,500 tonnes.

The offshore environment poses unique technical and logistical challenges that require specialised knowledge and expertise. By involving contractors early, developers can leverage their expertise to mitigate these challenges and drive the balance of plant costs down.

The balance of plant (BOP) cost consists of offshore foundations, cabling and transformer platforms and is the one of the most challenging of problems in the offshore wind industry at the moment. In addition, it is linked to the development of support ports and fit for purpose installation and cabling vessels. Balance of plant can account for as much as 50% of the offshore wind farm cost and is one of the most complex and ripe areas for the contractor and its supply chain to produce cost savings.

Another advantage of early contractor involvement is that it allows for more innovation and creativity in the design and construction process. Contractors can bring new ideas and technologies to the table, which can lead to a more efficient offshore wind farm that is able to generate cheaper electricity without the need for government subsidies.

FIGURE 5

Installation of offshore wind turbines in the North Sea.

Early contractor involvement in offshore wind energy construction does not just generate cost savings but it leads to better communication and collaboration, innovation and creativity, and positive relationships between all parties. It is a practice that is becoming increasingly popular and is seen as a key way to improve the supply chain risk as well as the construction process and mitigate the unique challenges that the offshore wind energy industry faces.

All these matters fit well with the application of alternative procurement techniques in the entire supply chain and indeed in the past ECI was instigated in various forms. Now with a predicted "hot" market with wind turbine manufacturers ramping up output exponentially for the years ahead there is limited availability of installation vessels. There is likely to be a worldwide installation vessel shortage, which is a risk to planned project execution and some project developments may have insufficient or in a worst case scenario no installation asset at their disposal (H-Blix, 2022). Early contractor involvement and vessel scheduling is therefore seen as vital.

Vessels are being booked many years in advance. Coupled with reducing the BOP as much as possible, this means that offshore wind clients are increasingly turning to work with preferred contractors and using ECI to a far greater extent as well as seeking to develop more long-term relational and collaborative contracts.

Indeed the FIDIC (The International Federation of Consulting Engineers) contracts committee are in the process of drafting a specialised contract drafted specifically to serve the offshore wind energy market. It is unclear at this stage to what extent the FIDIC contract drafters will address the clear need for a collaborative ECI process.

Establishing trust and rapport with your ECI contractor

In 1848, Johan Thorbecke (a Dutch politician) said, "Trust comes on foot, but leaves on horseback." It is interesting to consider his words and how it succinctly describes the essence of trust and its vulnerability. Trust in business is not just important, it is essential.

To build trust takes time and it can be gone quickly, and perhaps forever if it is violated. Trust is essential for any kind of business relationship and the need for it in a construction project is no different. Perhaps it applies to a lesser extent for a one-off relationship than for a more collaborative relationship that ECI tends to offer.

> **The sector continues to develop bigger wind turbines, with 15 MW turbines forecast to enter the market in the next decade.**

In collaborative ECI relationships, you need to be able to rely on what your chosen partner is saying and your partner must be able to rely on you. Trust in a collaborative relationship is always two ways: it is impossible for you to trust your partner while your partner does not trust you. Without this mutual vulnerability, trust is impossible to build on and can thwart a successful collaborative partnership.

Building trust takes time and requires constant positive reinforcement. Earlier in this article, open book pricing was touched upon that reinforces a willingness from the contractor to be open for critical inspection. However, from the client side it also involves accepting that the contractor should have the ability to make a reasonable margin on the project and having a balanced project risk profile. ECI contractors have valid concerns about confidentiality of such critical inspection and can feel vulnerable with complete exposure of sensitive commercial pricing information.

The commercial challenge with a client taking an ECI contractor on board on a one-to-one basis is obvious; how to ensure competitive pricing? Although nothing will completely mitigate that challenge, building openness and freedom of communication between the partners at an early stage is vital. Generally the core means to reduce that risk/concern is using competitive dialogue with more contractors in the Phase 1 stage. This will lead to selecting the contractor with whom the client feels most comfortable.

Unlock ECI success: an ECI advisor matters

Clients who regularly undertake construction projects on a repetitive basis are likely to have built up relationships with consultants, constructors and suppliers and will often turn to them first when embarking on a new project. These relationships may be loose or formalised in specific ECI arrangements or framework agreements.

However, the majority of clients who are new to ECI and are considering applying it, can benefit from the expertise of a consultant knowledgeable in ECI practices. What is essential is that the ECI selection process is systematic.

The role of the ECI adviser can broadly cover the following:

- Evaluate the potential for enhancing the project's value through ECI;
- Guide in the selection and setup of the most effective ECI framework, such as the contract model, regulatory compliance, selection process, ECI organisation, scope and schedule;
- Assist in coaching, training, team building and running workshops with parties, intended to facilitate communication and collaboration;
- Record and document the project team relationships, the commitments made by each party and their expectations in a multi-party ECI contract; and
- To provide a first port of call in the event of misunderstandings or disagreements between project team members.

The precise selection process chosen by an ECI advisor may vary according to circumstances, such as the level of experience and knowledge of the client, the nature of the project and the specialisation of the ECI contractors being sought. The strongest recommendation and takeaway is to have an ECI advisor that has in depth experience and can build the best project partnering team for the client. It is unwise to skimp on costs when building the ECI team. These costs represent a small part of the overall project expenditure and will directly influence how the rest of the money is spent over the whole life of the project.

It should be noted that lawyers and law firms may offer ECI consulting services, but a legal background alone may not be the most appropriate for ECI and collaborative contracting as legal training is largely based on an adversarial approach and contract enforcement. A real change in mindset is needed.

The key to making the ECI and collaborative contracting process work lies in the ECI advisor building and maintaining strong teams. A good team produces far more than the sum of the efforts of its individual members; poor teams more often than not produce less. Right from the outset, it is essential that team building and maintenance are in the minds of the ECI advisor who is charged with bringing the team together. Getting the team right will be at the forefront from the first steps in the ECI process.

Conclusions

Early contractor involvement comes in many shapes and sizes, and when applied properly and with joint commitment it has consistently shown to result in a more positive and productive relationship between the client or developer and contractor and their supply chain. By working together from the start, parties can develop a better understanding and trust for each other, which can lead to a more collaborative and ultimately successful project.

The PIANC report "A framework for early contractor involvement in infrastructure projects" is an invaluable tool to assist industry practitioners and provide hands on advice as to how to apply early contractor involvement to the benefit of any potential project.

In summary, early contractor involvement in construction projects, whether onshore or offshore, brings many direct benefits, such as cost savings, better communication and collaboration, innovation and creativity, and positive relationships between all parties with a decreased risk of disputes and claims. It is becoming increasingly popular as an alternative procurement method and is seen as a key way to improve the construction process, de-risk potential issues and mitigate the unique challenges of any project.

Summary

The PIANC report "A framework for early contractor involvement in infrastructure projects" provides a detailed introduction into the understanding and the application of early contractor involvement (ECI) in waterborne transport infrastructure projects. It is at present the only comprehensive guidance document available on the subject of ECI in the construction industry.

Early contractor involvement in construction projects, whether onshore or offshore, brings many direct benefits such as cost savings, better communication and collaboration, innovation and creativity, and positive relationships between all parties with a decreased risk of disputes and claims.

In marine infrastructure projects, ECI can achieve direct benefits during the site investigation stage and when developing project budgets using open book pricing as well as when preparing constructability reviews and construction risk assessments. It has also been used effectively during the regulatory and permitting stage of a project.

Parties need to be open and mutual trust needs to be built in a collaborative relationship. With it comes vulnerability. Without acceptance of this trust is impossible to build on and lack of trust can thwart a successful collaborative partnership. ECI is becoming increasingly popular as an alternative procurement method and is seen as a key way to improve the construction process and mitigate the unique challenges of any project.

David Kinlan

David is a contract and procurement specialist based in Queensland, Australia, with 35 years' experience in marine infrastructure projects on a global basis. He has in depth knowledge of procurement practices, commercial management, contract and risk assessment, dispute avoidance, adjudication and arbitration. Together with co-author Kenneth Willems, David set up a consultancy, InfraMara to implement ECI and collaborative contracting in the infrastructure market. David has published a book dealing with adverse physical conditions and has previously published articles in *Terra et Aqua* on a range of subjects.

Kenneth Willems

Kenneth is managing director at the consultancy firm Vuentica, acted as chairman of the PIANC working group on ECI and co-founded online collaboration start-up V-Rooms. Before Vuentica, he spent most of his career at DEME Group in various management roles across Europe, the Middle East and in Latin America before leading its risk management department in Antwerp, Belgium. Kenneth is an experienced infrastructure and enterprise risk management professional based in Belgium. He has a wide range of experience in early contractor involvement, project management, risk management and contract management.

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THE IMPORTANCE OF FLOCCULATION IN DREDGE PLUME MODELLING

Numerical models are often used to predict the magnitude and behaviour of dredge plumes to help assess and manage any environmental risks. To provide a realistic prediction of plumes resulting from dredging, numerical models require information on the rate at which sediment is suspended by the dredging, along with the characteristics of the suspended sediment. Previous investigations have shown that in the marine environment, fine-grained sediment suspended by natural processes and dredge-related activities are typically present as aggregated particles known as flocs. This article considers the importance of including the process of flocculation in dredge plume models.

Field measurements have shown that in the marine environment, fine-grained sediment that is naturally in suspension and fine-grained sediment suspended by dredging are typically present as aggregated particles known as flocs (Manning, 2004; Smith and Friedrichs, 2011; Beecroft et al., 2019). The process of flocculation in marine environments is most likely to occur due to particle collisions from turbulent motions meaning that increased flocculation occurs when suspended sediment concentrations (SSCs) are higher and moderate turbulence is present (Winterwerp and van Kesteren, 2004). Therefore, the localised elevated SSC and increased turbulence that can occur during dredging has the potential to result in flocculation. However, aspects of dredging that result in very high turbulence such as pumping sediment through pipelines, have the potential to break up existing flocs either down to smaller flocs or individual particles.

Measured data collected in the Port of Gladstone have shown that flocs were present in a plume generated by a trailing suction hopper dredger (TSHD) dredging silt and clay-sized sediment but that they were smaller than the flocs naturally in suspension (Symonds et al., 2022). This indicates that the turbulence caused by the TSHD did not break up all the flocs present in the dredge sediment, but it did reduce the size of the flocs resulting in the larger flocs >100 microns (μm) being broken up. However, the size of the flocs in the dredge plume were found to increase over time after the plume was generated, demonstrating that ongoing flocculation occurred within the dredge plume. The ongoing flocculation is likely to have been due to flocculation with both sediment suspended by the dredging as well as sediment that is naturally in suspension. These findings indicate that flocculation is an important process that influences how dredge plumes behave, while interactions between dredged and natural suspended sediment could also influence both the behaviour of dredge plumes and of natural suspended sediment.

Port of Gladstone

The Port of Gladstone (the Port) is located within Port Curtis on the east coast of Queensland in Australia (Figure 1). Port Curtis is a macro-tidal embayment with a mean spring tidal range of 3.2 metres. It is a naturally turbid environment and the sediment transport processes are influenced by strong tidal flows, local wind waves and local river discharges. The Port waters cover Port Curtis and the areas offshore extending to the port limits as shown in Figure 1.

The Port is made up of approximately 50 kilometres (km) of shipping channels, which utilise the natural deeper channels in Port Curtis and offshore wherever possible. Despite this, ongoing natural sedimentation occurs within sections of the shipping channels and annual maintenance dredging is required to maintain depths in these sections. The annual maintenance dredging is undertaken by a TSHD, which dredges sediment from the channels and places it at an approved offshore placement site (East Banks Sea Disposal Site (EBSDS)). The highest sedimentation rates occur at the north-western end of the Port, including Jacobs Channel, with the deposited sediment predominantly made up of fine-grained silt and clay (Figure 1). The average natural SSC in the Jacobs Channel region is 14 milligrams per litre (mg/l), with the 99th percentile reaching 64 mg/l.

Approach

A suite of coupled hydrodynamic, spectral wave and sediment transport numerical models were applied to ensure all key processes that influence the transport of natural sediment and sediment suspended by dredging and placement were represented. The modelling was undertaken using MIKE software, which has been developed by the Danish Hydraulics Institute (DHI) and is one of a number of internationally recognised state of the art software packages.

The sediment transport modelling was undertaken using the Mud Transport (MT) module, which is able to describe the erosion, transport and deposition of mud (silt and clay-sized particles) or sand and mud mixtures due to currents and waves. The module can be adopted for sediment transport studies in estuaries and coastal areas, dredging investigations and sedimentation studies, and can represent the process of flocculation.

The spatial discretisation of MIKE's flexible mesh enabled the model mesh resolution to be varied within the model domain, with higher resolution in areas of interest, such as within the Port waters and channels and lower resolution in offshore areas. This approach assists with optimising the model simulation times without compromising on representing important physical processes within areas of interest. The model extent covered an area of approximately 180 km by 80 km and the resolution of the triangular elements varied from around 2 km in the offshore area

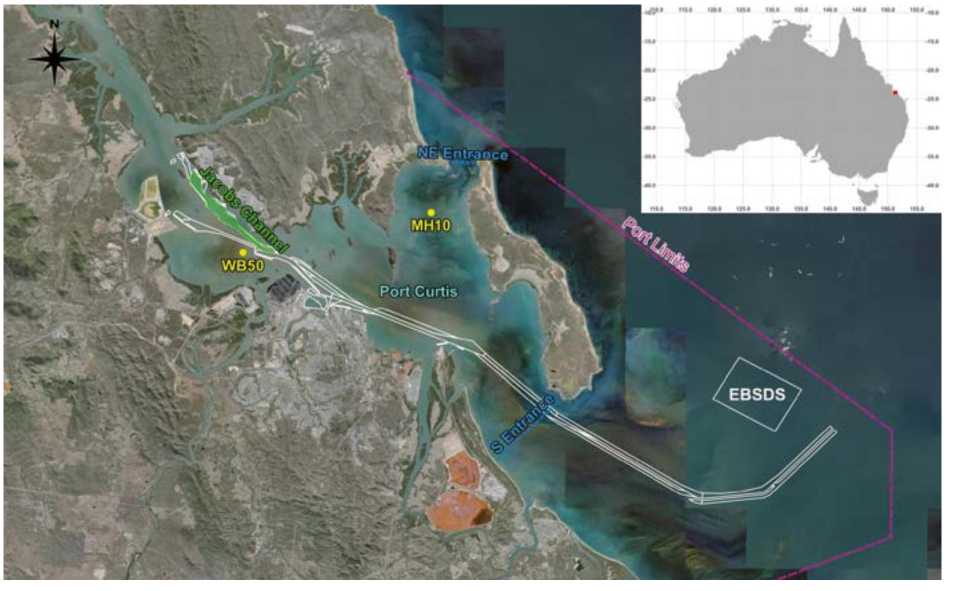

FIGURE 1.

Location map showing the Port of Gladstone and its location relative to Australia (inset).

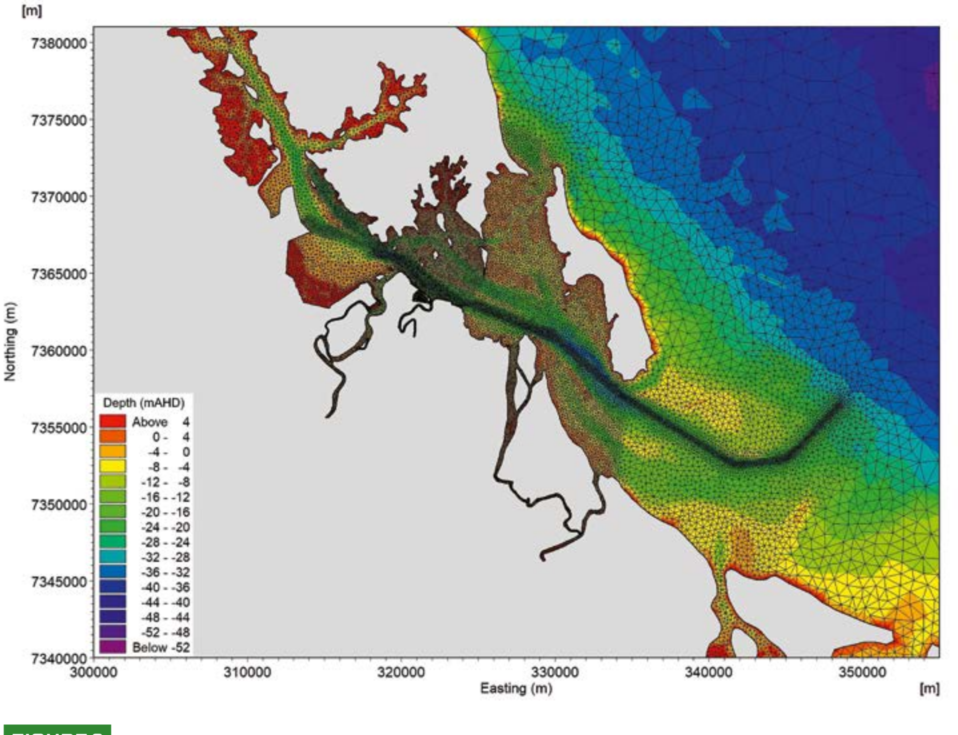

FIGURE 2

Model mesh and bathymetry around Port Curtis.

to less than 100 metres in the Port channels (Figure 2).

Outputs from the hydrodynamic, spectral wave and sediment transport models were compared to in-situ measured data as part of the model calibration and validation process. The calibration and validation demonstrated that the models were able to provide a good representation of the natural hydrodynamic, wave and sediment transport conditions in the region. Example plots comparing the measured and modelled SSC at sites close to Jacobs Channel and the northern entrance to Port Curtis are shown in Figure 3.

The different model setups adopted to represent the natural sediment transport, the dredging related sediment transport and the combined natural and dredging sediment transport were as follows:

- Natural sediment transport: the model was set up with a spatially varying thickness of natural sediment on the seabed at the start of the simulation (defined as part of the model calibration process), with no sediment in suspension at the start of the simulation and with no suspended sediment input at the boundaries;
- Dredging sediment transport: the model was set up to represent the sediment transport of the excess sediment suspended by maintenance dredging using a TSHD in Jacobs Channel and the subsequent placement of dredged sediment at EBSDS. The source terms for the mass of suspended sediment released by the dredging activity and placement were determined based on comparison with measured data in combination with information from the literature (Becker et al., 2015). The model did not include any natural sediment on the seabed or in suspension, with the only sediment present in the model being the excess sediment suspended by the dredging. It was assumed that the dredger was dredging in Jacobs Channel and placing within EBSDS non-stop over the model simulation period. In the model, the dredge vessel was assumed to spend the majority of the time sailing to and from EBSDS where the dredged sediment was placed, with the vessel assumed to spend less than 30% of the time dredging at Jacobs Channel. Typically, the 1-2 weeks of dredging in Jacobs Channel required as part of an annual maintenance dredging campaign would be split over the entire dredging campaign (1 month), so continuous dredging in Jacobs Channel is considered unlikely to actually occur and therefore, a worst case scenario for potential plume intensity; and
- Natural including dredging sediment transport: the model was set up to include both the natural sediment and the sediment suspended by dredging in a single simulation to help understand the relative importance of interactions between the natural and dredged sediment. The model was set up to include both the natural sediment and dredged sediment as detailed in the previous two points. In addition, the model included a second bed layer above the natural sediment layer. This surface bed layer had no sediment in it at the start of the simulation, but any sediment deposited during the simulation (natural or dredged) would be placed in this layer and resuspension of sediment in this layer would occur before the resuspension of the layer of natural sediment below.

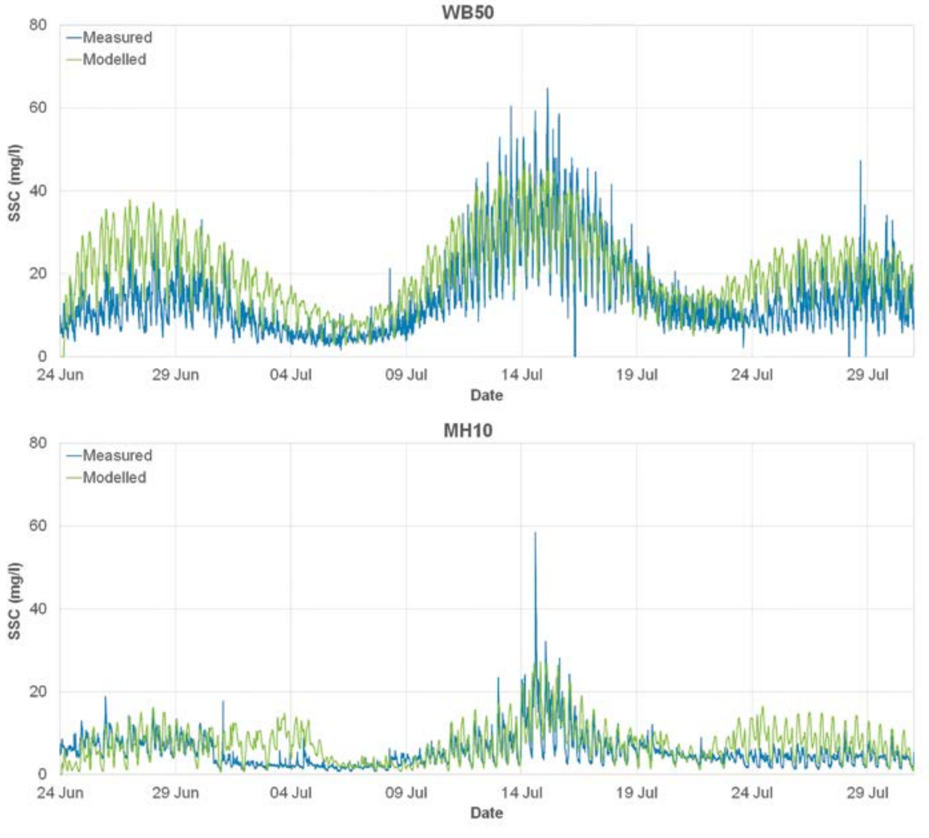

FIGURE 3

Modelled and measured SSC at WB50 and MH10 (see Figure 1 for locations).

Three different particle sizes were used to represent the natural sediment transported in suspension, clay, fine to medium silt and medium to coarse silt. Model simulations were set up with and without flocculation of the fine-grained sediment included. When flocculation was excluded, a constant settling velocity representative of the individual particle sizes was adopted for each and when flocculation was included, the settling velocity varied depending on the SSC, with the minimum settling velocity being representative of the individual particles. For all the simulations that included flocculation, the process of flocculation was assumed to occur when the SSC was above 10 mg/l. For the dredge plume simulations, a single particle size of fine silt was adopted as this was representative of the modal peak in the particle size distribution (PSD) for sediment suspended by the dredging based on measured data. For the dredge plume simulations, the fine silt settling velocity without flocculation included was representative of the individual fine silt particles and the with flocculation simulations were representative of the minimum size of the measured in-situ flocs (30 μm, with the peak in measured flocs in the plume being between 30 and 200 μm).

The minimum settling velocity for the dredge plume when modelled with flocculation included was set to represent a small floc rather than the individual particle size. This is because the spatial resolution of the model mesh results in an instantaneous dilution of the plume from the dredger, which will limit flocculation. As the measured data have shown that the majority of the sediment in suspension in the dredge plume close to the dredger is present as flocs, this approach was considered to provide the most accurate conceptualisation of the sediment in the dredge plume.

Results

Influence of flocculation

The modelled natural SSC in Port waters was processed to calculate the SSC percentiles over the 5-week model simulation period. The percentiles are duration-based and show the value by which the SSC was below for a given percentage of time over the entire model simulation period. The 50th percentile modelled natural SSC with and without flocculation included in the model are shown in Figure 4. Comparison between the with and without flocculation plots shows that the most significant differences were within Port waters and in the nearshore areas where higher SSC occurs. With flocculation included, the 50th percentile SSC within Port Curtis was predominantly less than 40 mg/l, while without flocculation included all of Port Curtis had an SSC of more than 40 mg/l. The spatial extent of the SSC, with higher concentrations within Port Curtis and lower concentrations offshore, highlights how Port Curtis is a semi-enclosed bay, which acts as a natural sink of sediment. The measured SSC data shown in Figure 3 shows that the SSC at WB50 (within Port Curtis) remains below 40 mg/l for the majority of the time, indicating that the model results with flocculation included provide a better representation of the actual conditions.

Spatial plots of the SSC due to the maintenance dredging by a TSHD are only shown for the 95th percentile as the 50th percentile shows limited elevated SSC. The 95th percentile SSC resulting from the maintenance dredging at Jacobs Channel and placement at EBSDS by the TSHD is shown with and without flocculation in Figure 5. The results with flocculation included show that the SSC of more than 5 mg/l extends from Jacobs Channel to the southern entrance to Port Curtis. It also shows that a higher concentration plume of more than 15 mg/l occurs within Jacobs Channel, but remains confined within the channel. The results predict a localised low concentration plume at and adjacent to EBSDS, with a peak in SSC of just over 10 mg/l but concentrations of generally less than 5 mg/l.

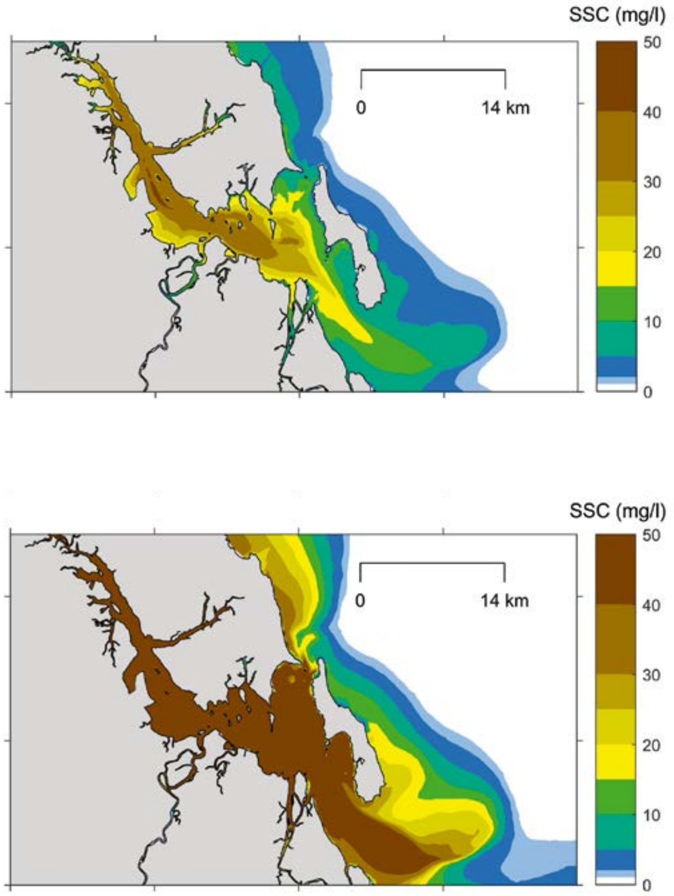

FIGURE 4

Modelled 50th percentile natural SSC in the Port region with flocculation (top) and without flocculation (bottom).

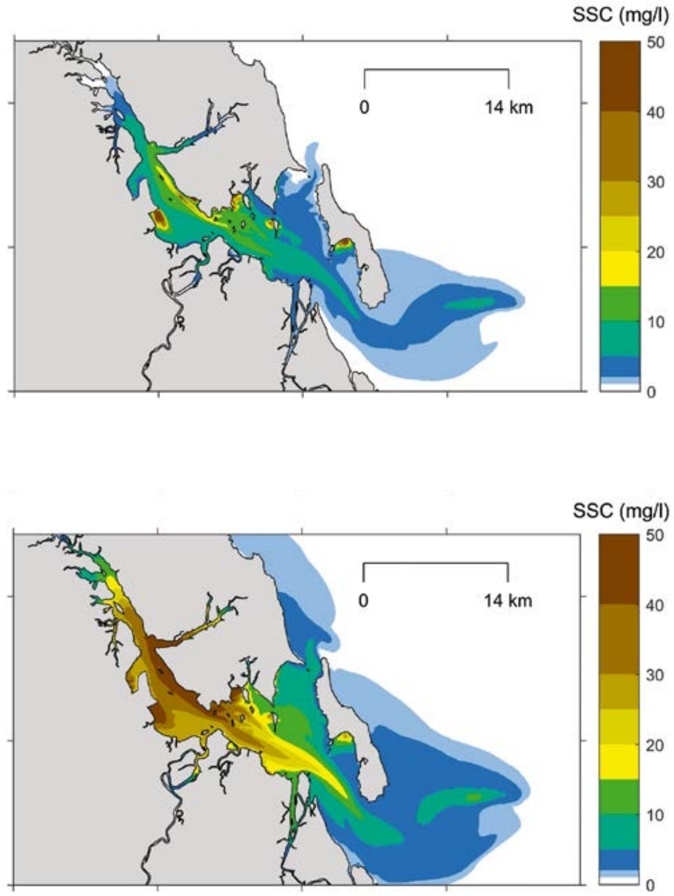

FIGURE 5

Modelled 95th percentile excess SSC resulting from maintenance dredging by a TSHD in the Jacobs Channel and placement at EBSDS with flocculation (top) and without flocculation (bottom).

The results without flocculation included show a significantly larger area with higher concentrations of above 15 mg/l, extending from the north of Jacobs Channel to the southern entrance of Port Curtis. The results also show an SSC of up to 10 mg/l being exported through the north-eastern entrance to Port Curtis. The plume around EBSDS is also larger without flocculation than it was with flocculation, with an SSC of up to 5 mg/l extending from EBSDS to the eastern shoreline of the adjacent Facing Island.

Time series plots of the water level and natural SSC with and without flocculation included at the water quality monitoring site WB50 (see Figure 1 for location) are shown in Figure 6. The results show that the natural SSC is controlled by the tidal range, with higher SSC during spring tides and lower SSC during neap tides. The modelled natural SSC is predicted to be five to ten times higher at WB50 when flocculation is excluded compared to when it is included.

Time series results at WB50 for the excess SSC from maintenance dredging using a TSHD in Jacobs Channel with and without flocculation included are shown in Figure 6. WB50 is the closest long-term monitoring site to the dredging at Jacobs Channel. The results show that the predicted SSC in the plume from the maintenance dredging is up to five times higher without flocculation compared to with flocculation.

To help understand the fate of sediment released by the dredging and how flocculation influences it, the spatial distribution of sediment thickness at the end of the model simulations is shown for both with and without flocculation in Figure 7. Both the with and without flocculation results generally show a similar spatial pattern, but sedimentation depths are generally higher when flocculation was included. Without flocculation, the results show the potential for increased sedimentation in the most quiescent locations, such as the sheltered creeks and intertidal areas upstream of Jacobs Channel. With flocculation included the sedimentation depths at EBSDS are predicted to be up to 10 mm, while without flocculation they remain below 0.5 mm. This is more than an order of magnitude difference and suggests that flocculation could be a very important process for the settling of sediment to the seabed and subsequent retention of deposited sediment from the placement activity at EBSDS.

Influence of natural sediment

Natural SSC is sometimes modelled as well as excess SSC from dredging to allow any potential impacts from the dredging to be related to the natural conditions. However, they are often modelled in separate

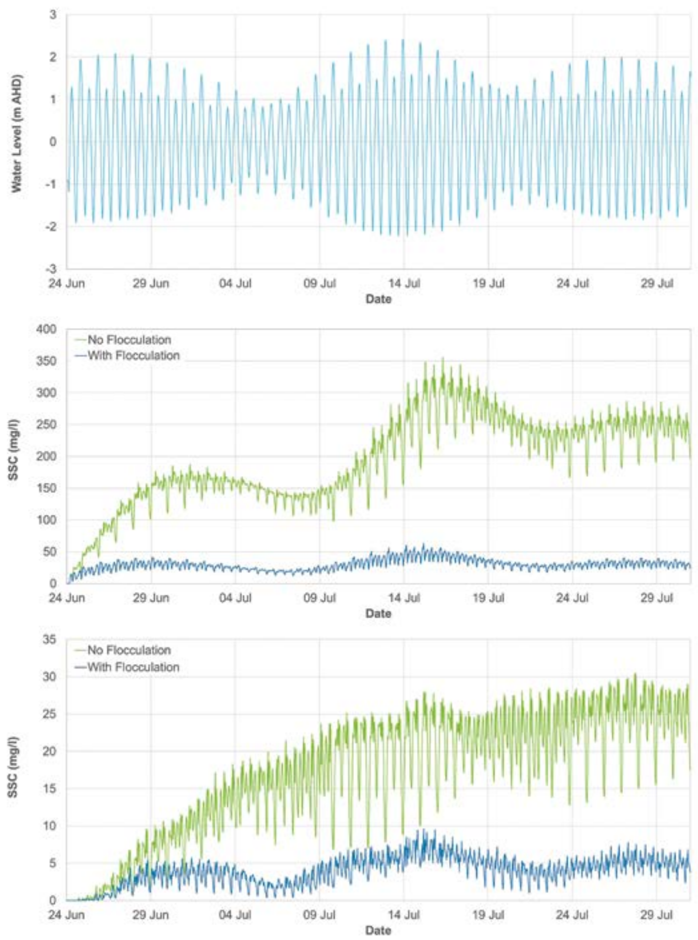

FIGURE 6

Modelled water level (top), natural SSC at WB50 with and without flocculation (middle) and excess SSC at WB50 resulting from maintenance dredging by a TSHD at Jacobs Channel with and without flocculation (bottom).

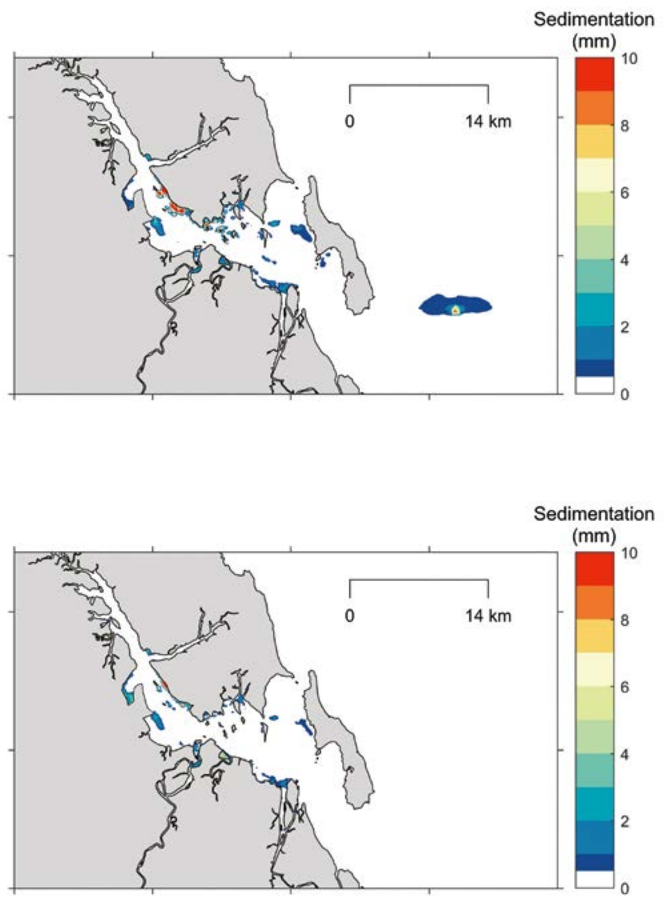

FIGURE 7

Modelled sedimentation depth after 5 weeks of maintenance dredging at Jacobs Channel by a TSHD with flocculation (top) and without flocculation (bottom).

simulations or with limited interaction between the different sediments for efficiency and to ensure the results from the different sediment sources remain separate. However, in a semi-enclosed bay environment such as Port Curtis where naturally high resuspension occurs due to the astronomical tide and local wind waves, only including the excess sediment released by dredging in the model simulation has the potential to overestimate the ongoing transport and ultimate fate of the sediment. There are two reasons for this:

- the SSC controls the flocculation that can occur, with floc size increasing as the SSC increases. Therefore, when the natural SSC is included in the model as well as the excess SSC from dredging, it will allow the sediment released by the dredging to mix with the natural sediment as well. This increases the total SSC and allows larger flocs to form that will have a higher settling velocity; and
- when the sediment suspended by dredging is deposited, it is likely that natural sediment will also be deposited and the two sediments will mix in the surface layer on the seabed with the potential for some particles to be buried under other natural or dredged sediment. When the deposited sediment is subsequently resuspended, some of the resuspended sediment will be the recently deposited natural sediment and some will be the recently deposited dredged sediment. As a result, the total mass of dredged sediment resuspended will be lower compared to when natural sediment was not included in the model. Similarly, the total mass of natural sediment resuspended in areas where dredged sediment was deposited will be slightly lower compared to when the excess dredged sediment was not included in the model.

To assess the relative influence of the natural sediment on the SSC and fate of sediment suspended by maintenance dredging in Port waters, the numerical model was set up to simulate both natural sediment transport and the transport of sediment suspended by dredging together in the same simulation along with flocculation. The modelled 95th percentile excess SSC from the TSHD undertaking maintenance dredging in Jacobs Channel and placement at EBSDS without flocculation, with flocculation and with flocculation and natural sediment transport included are shown in Figure 8.

Comparison between the results with flocculation and the results with flocculation and natural sediment transport shows that including natural sediment transport in the model results in a significant reduction in the plume extent and SSC within Port waters, but does not result in such a significant change around EBSDS (where Figure 4 shows the natural SSC is much lower than within Port waters). The extent of the higher concentration area of plume above 15 mg/l in Jacobs Channel is reduced by around 30% when natural sediment transport is also included. In addition, the extent where the SSC is between 1 and 15 mg/l for the 95th percentile is significantly reduced when natural sediment transport is also included in the model.

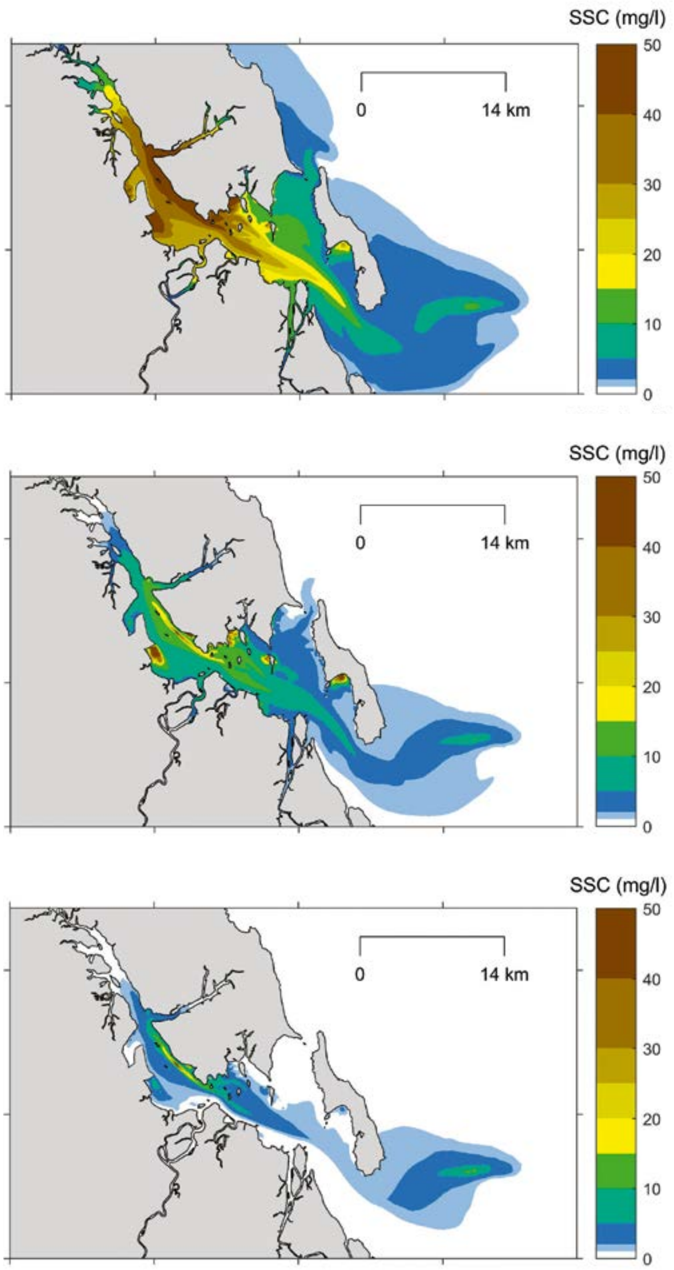

FIGURE 8

Modelled 95th percentile excess SSC resulting from maintenance dredging by a TSHD in the Jacobs Channel and placement at EBSDS when flocculation is not included (top), when it is included (middle) and when flocculation and natural sediment transport are included (bottom).

The reduction in SSC from the maintenance dredging by a TSHD in Jacobs Channel at

WB50 due to the inclusion of natural sediment transport in the model is shown in Figure 9. The plot shows that the SSC is reduced by between two and five times depending on the tidal range due to the inclusion of natural sediment transport (up to five times during spring tides and around two times during small neap tides).

Percentile results show that for the 50th percentile and below the natural SSC when flocculation is included and when flocculation and the maintenance dredging at Jacobs Channel are included are almost identical. Plots showing the 80th percentile natural SSC when flocculation is included and when flocculation and the maintenance dredging at Jacobs Channel are included are shown in Figure 10. The plot shows that the natural SSC is similar between the two simulations, except that the extent of the 40 to 50 mg/l contour is reduced within Jacobs Channel and in the adjacent Clinton Channel when maintenance dredging is included.

The relative influence of including the SSC released by the maintenance dredging at Jacobs Channel by a TSHD on the natural SSC at WB50 is shown in Figure 11. The plot shows that there is predicted to be a reduction in the natural SSC at WB50 of up to 2 mg/l when the maintenance

The SSC is reduced by between two and five times due to the inclusion of natural sediment transport.

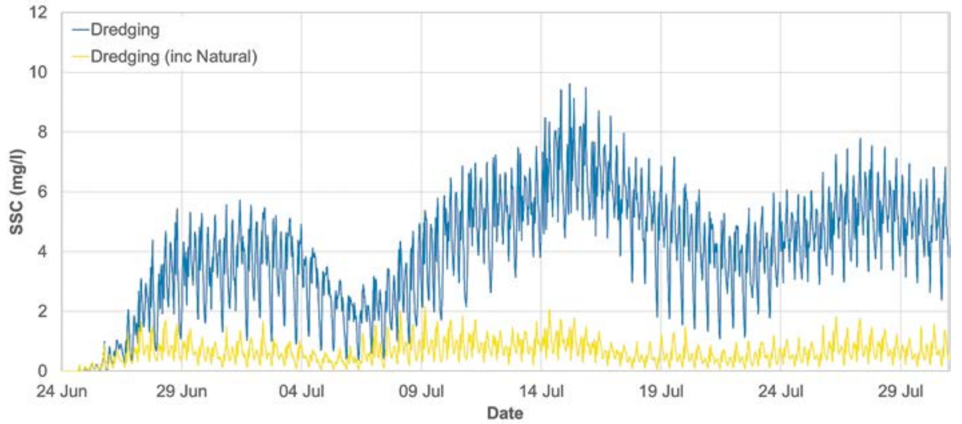

FIGURE 9

Modelled excess SSC at WB50 resulting from maintenance dredging by a TSHD at Jacobs Channel with flocculation (blue) and with flocculation and natural sediment transport (yellow).

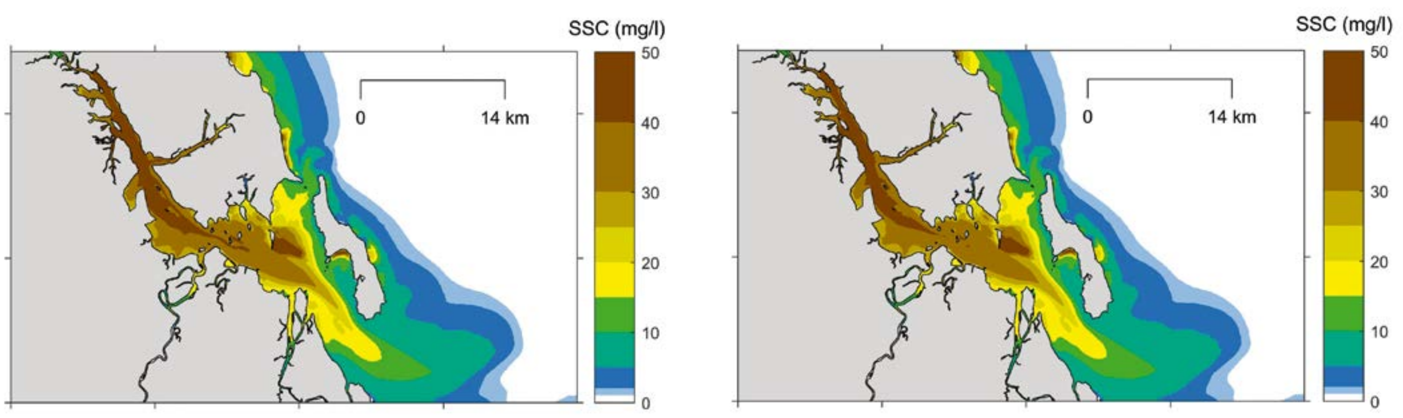

FIGURE 10

Modelled 80th percentile natural SSC in the Port region over a 5-week period with flocculation (left) and with flocculation and TSHD dredging (right).

dredging is included in the model simulation compared to when the model is simulating just natural sediment transport. For the simulation with both natural and dredged sediment when the excess SSC due to maintenance dredging is added to the natural SSC, the resultant total SSC at WB50 is almost identical to the natural SSC when the model excludes maintenance dredging.

The rate of erosion of sediment from the seabed is controlled by the sediment properties and bed shear stresses from local currents and waves. In Port waters, erosion generally only occurs over a limited period, typically the 2-3 hours when peak flood and ebb currents occur. This means that a limited mass of sediment can be resuspended during each flood and ebb stage of the tide. As a result, the mass of recently deposited natural and dredged sediment that can be resuspended could be reduced for each of the two sediment types compared to when the bed sediment was just a single type. This could occur when the mass of recently deposited natural and dredged sediment on the seabed exceeds the total mass that can be resuspended during a single flood or ebb stage of the tide. This will be more significant in a natural sediment sink such as the Port waters where widespread natural deposition occurs. In addition, as the SSC close to the dredger will be higher when the SSC released by dredging is included compared to just the natural SSC, there will be increased flocculation of both the natural and dredged sediment, which can result in larger flocs forming. These larger flocs will result in a slight increase in sedimentation of both the natural and dredged sediment, and therefore a slight reduction in SSC for both.

The potential long-term fate of both naturally suspended fine-grained sediment and sediment suspended by dredging is important to understand. The results from the numerical modelling have been processed to predict the cumulative mass of sediment exported through the two entrances of Port Curtis (southern and north-eastern) over the duration of the simulations. Over the model period, the north-eastern entrance was found to be where the majority of both the natural and dredged sediment was exported. Time series plots showing the cumulative export of sediment through this entrance for natural and dredged sediment are therefore shown in Figure 12. The results predict that the mass of both naturally and dredged suspended sediment exported from Port Curtis would be approximately three times larger if no flocculation occurred. When flocculation was included in the model, approximately 3% of the sediment suspended by dredging was predicted to be exported from Port Curtis, but if flocculation was not included this value increased to 11%.

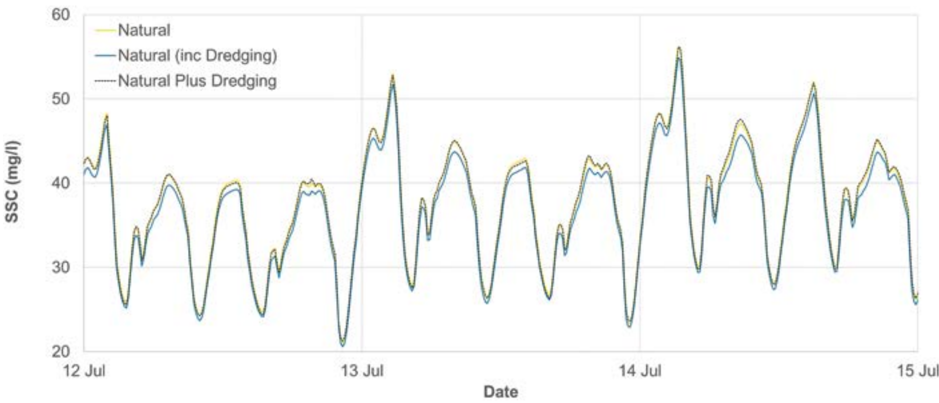

FIGURE 11

Comparison between SSC at WB50 for simulations of just natural SSC and natural plus maintenance dredging SSC.

When both flocculation and natural sediment transport were included in the model, the mass of sediment suspended by the TSHD predicted to be exported from Port Curtis was almost an order of magnitude lower than just with flocculation (see Figure 13), with 0.3% of the sediment released within Port Curtis by the maintenance dredging predicted to be exported from Port Curtis. The results therefore indicate that the fate of the majority of the sediment suspended by the maintenance dredging activity (> 99%) is to be deposited within Port Curtis, with very little sediment predicted to be exported from the embayment.

As previously noted, the inclusion of dredged sediment along with natural sediment also had the potential to result in increased flocculation (and therefore deposition) as well as a small reduction in the resuspension of natural sediment. Figure 13 shows that these two processes have resulted in a small reduction in the mass of natural sediment exported from Port Curtis. Including the sediment suspended by the annual maintenance dredging resulted in a small reduction of natural sediment being exported from Port Curtis. The predicted reduction in mass of natural sediment being exported was slightly higher than the mass of sediment released by the maintenance dredging predicted to be exported. Therefore, for the scenario considered to be most representative of actual conditions (flocculation included and dredged and natural sediment modelled together), the modelling predicted that the total combined mass of natural and dredged sediment exported from Port Curtis was similar, but slightly lower than the mass of natural sediment predicted to be exported when just natural sediment transport was modelled on its own.

Conclusions

Numerical modelling has been undertaken to determine how important the process of flocculation is in Port waters for both natural and dredging-related sediment transport. The modelling predicted that the natural SSC

> **The mass of both naturally and dredged suspended sediment exported from Port Curtis would be approximately three times larger if no flocculation occurred.**

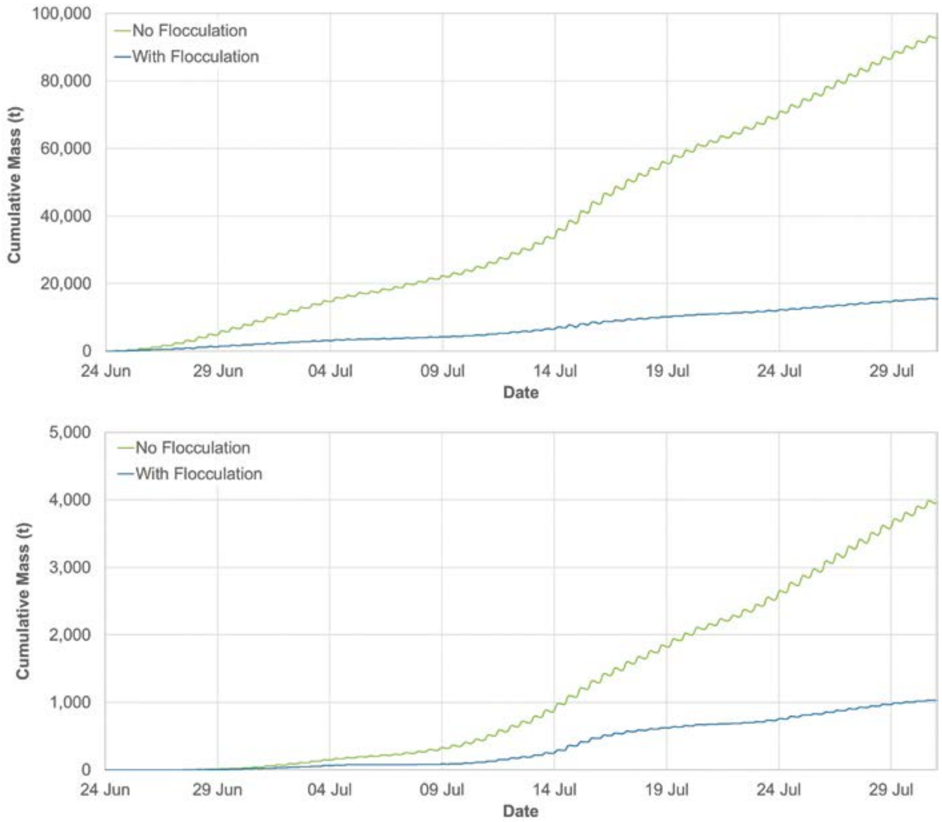

FIGURE 12

Cumulative mass of naturally suspended sediment (top) and sediment suspended by a TSHD undertaking maintenance dredging in Jacobs Channel (bottom) exported through the north entrance to Port Curtis with and without flocculation.

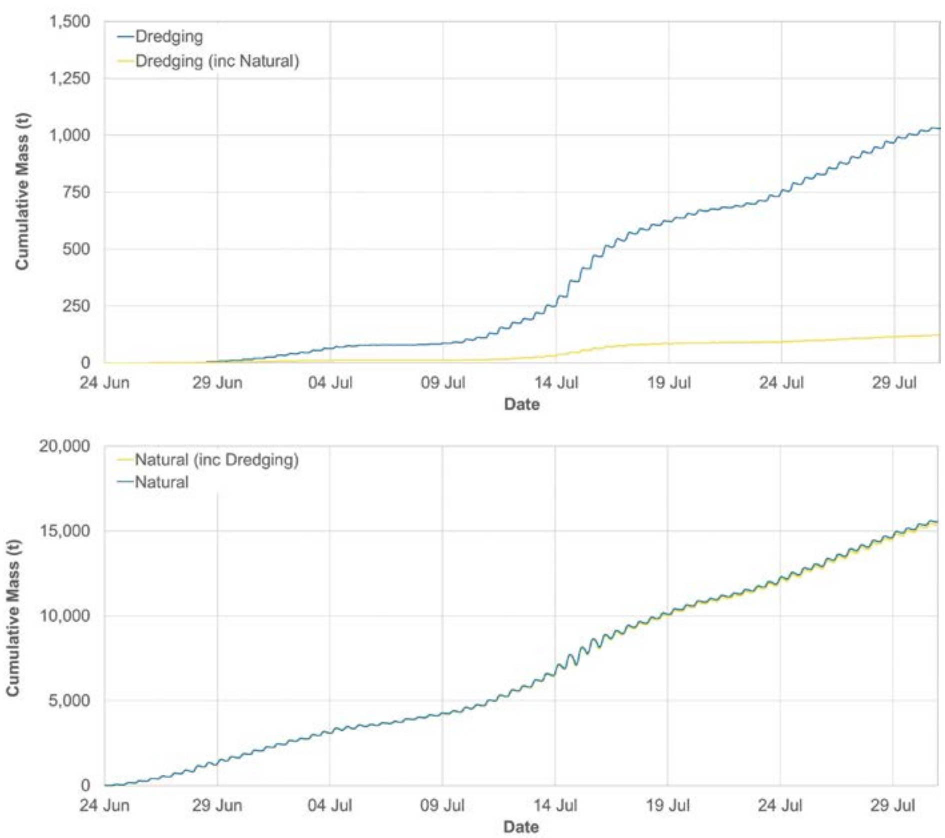

FIGURE 13

Cumulative mass of sediment suspended by a TSHD undertaking maintenance dredging in Jacobs Channel (top) and naturally suspended sediment (bottom) exported through the north entrance to Port Curtis when the model is run with just natural or just dredged sediment and natural sediment plus sediment released by TSHD dredging in Jacobs Channel.

would be five to ten times higher if flocculation did not occur, while the SSC of plumes resulting from annual maintenance dredging could also be increased by up to five times if flocculation did not occur. In addition, the modelling results predicted that the process of flocculation reduces the mass of fine-grained sediment suspended by maintenance dredging that is exported from Port Curtis by a factor of four.

The modelling showed that when natural sediment transport is included in the same simulation as excess SSC from dredging, there is a further reduction in both the predicted SSC due to dredging and the mass of dredged sediment exported from Port Curtis. This is because of an increase in flocculation due to the higher combined SSC resulting from including both natural and dredged sediment, and because the sediment deposited on the seabed is a combination of both natural and dredged sediment. Therefore, when natural sediment transport is included as well as dredged sediment, the eroded sediment will be a combination of natural and dredged sediment, while when natural sediment transport is excluded the sediment will be entirely composed of dredged sediment. As a result, in areas where both natural and dredged sediment are deposited the amount of dredged sediment resuspended will be lower when natural sediment transport is also included.

The modelling results also predicted that due to increased flocculation of natural sediment close to the dredger and some dredged sediment being resuspended rather than natural sediment, there was a small reduction in the natural SSC in some areas when dredged sediment was also included in the model at the same time. This reduction in natural SSC meant that the mass of natural sediment exported from Port Curtis was also reduced. As a result, the total combined mass of natural and dredged sediment exported from Port Curtis was predicted to be similar (slightly lower) to the mass of natural sediment predicted to be exported when just natural sediment transport was modelled on its own. As the natural and dredged suspended sediment have a similar PSD, it is likely that the suspended sediment from dredging will be deposited in locations where similar composition natural sediment has been deposited. It can therefore be inferred that once the sediment suspended by the maintenance dredging is deposited, it is unlikely to result in any additional impacts in terms of SSC or deposition compared to what would naturally occur (assuming that the dredged sediment is not contaminated).

Results from this study highlight how important it is for any numerical modelling related to dredging fine-grained sediment in a marine environment to include flocculation. The study has also shown that in areas with high natural SSC modelling just excess SSC from dredging can result in a significant overestimation of the SSC and ongoing resuspension of the sediment, which could influence potential impacts as well as the ultimate fate of dredged sediment.

Summary

Sediment can be suspended into the water column during dredging and placement activities. This suspended sediment has the potential to be transported away from the dredge and placement locations by currents and therefore could result in environmental impacts. Previous investigations have shown that in the marine environment, fine-grained sediment suspended naturally and by dredging are typically present as aggregated particles known as flocs. To reliably represent the behaviour of dredged sediment in a numerical model and predict potential environmental impacts it may be necessary to include the process of flocculation in the model.

This article presents results from numerical modelling of maintenance dredging in the Port of Gladstone, on the east coast of Queensland in Australia, to assess the importance of flocculation. The model was set up to simulate sediment transport both with and without flocculation for natural sediment and sediment suspended by maintenance dredging. The importance of interactions between the dredged suspended sediment and natural suspended sediment on flocculation was also investigated.

The results from the study highlight the importance of including flocculation in numerical modelling related to dredging fine-grained sediment in a marine environment. Without the inclusion of flocculation, the modelling has shown that the SSC in the dredge plume can be overestimated up to five-fold compared to observations. The results also showed that modelling the sediment suspended by dredging without including natural suspended sediment can result in a significant overestimation of ongoing resuspension of the dredged sediment and therefore an overestimate of the transport rates, as well as the distance the dredged sediment is transported.

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Andrew is a founding director at Port and Coastal Solutions having set up the company in 2017. He completed a PhD at the National Oceanography Centre, Southampton, in the UK, focusing on the hydrodynamics and sediment dynamics associated with managed realignment. With over 20 years of experience in port and coastal projects, he specialises in numerical modelling and marine data analysis, and has extensive experience in sediment transport and dredging projects.

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REINFORCED SOIL - THE QUAY WALL STRUCTURE FOR THE FUTURE?

Steel and concrete are the most common materials used in quay wall structures. The application of these materials contributes to a high emission of greenhouse gasses such as CO_2 and the materials make up a large part of the construction costs. This graduate research examines whether alternative quay wall structures have the potential to be more cost effective and more sustainable compared to conventional structures for inland ports. An innovative quay wall of reinforced soil was designed and quay elements implemented to make a quay wall structure. A comparison was then made based on the criteria costs and sustainability between the innovative quay design and two conventional quays.

For their thesis, the authors conducted research on more sustainable and cost-effective quay wall structures for inland ports in the Netherlands. There is still a demand for new inland ports that can fulfil a function as a connecting link in the Dutch inland waterway network. Moreover, most of the current quay walls were constructed shortly after the Second World War. These outdated quays may have reached both the technical life span and safety limits due to increased loads over the years, and a large replacement programme must be executed in the next decades.

Expectations for the future must be considered prior to the design. By anticipating increasing loads, rising water levels and long-term trends will create a future-proof quay that is able to retain its functionality over a longer period. Due to the growing demand of today's consumer society, a trend is happening in the transshipment of containers. The rising number of transported containers results in a need for extra transshipment ports that require heavier port equipment and bigger storage loads.

As previously mentioned the most common materials applied in current quay walls are steel and concrete. The use of these materials results in both high emissions and high investment costs. However, the ongoing climate changes and rising material prices create a growing necessity for sustainable and more cost-effective quay wall structures. After promising results and having been successfully applied in different civil engineering disciplines, it is interesting to investigate the possibilities of reinforced soil structures within hydraulic engineering.

Quay elements

A reinforced soil structure is a well-known construction method with which height differences can be reached. Using a reinforced soil structure as a quay requires adjustments and implementations to withstand a combination of variable unfavourable loads caused by heavy port equipment, ships and water level fluctuations.

Conventional quay wall structures allow bollards to be anchored in a concrete substructure. Since there is no option for the bollard to be anchored in the structure itself, alternatives must be considered to be able to integrate a bollard into the body of the structure. Designing an L-shaped capping beam makes it possible to spread and transfer mooring forces in the reinforced soil structure with the least amount of concrete and the most favourable load transfer. A vessel classified in CEMT-Va/Vb has a line pull force of 250 kN, multiplied by a safety factor 1.5 gives a line pull force of 375 kN. The capping beam is able to spread this load over the track distance of the bollards, which is 15 metres. This results in a spread tensile load of 25 kN/m. Tensile forces due to mooring lines occur in either horizontal or vertical direction. The vertical load and moment are carried by the self-weight and the favour ground pressure on the feet of the beam. The horizontal tensile force is carried by a horizontal anchorage of geogrids consisting of a 5.6m long strip fixed in the concrete capping beam. When designing mooring facilities it is important that the bollard anchorage be a factor 1.5 stronger than the occurring line pull force. This results in a geogrid with a tensile strength of at least 37.5 kN/m.

Removable concrete panels as a facing of the structure improves the quays appearance and are a solution for the robustness of the structure. The concentrated load caused by a ship collision, which may occur, will be spread by the panel and prevents damage on the geotextile. Besides collision, the soil structure is protected against friction between a moored ship and the retaining wall, the polymer geogrids are protected against UV radiation and from the mounting of fendering systems on the retaining wall.

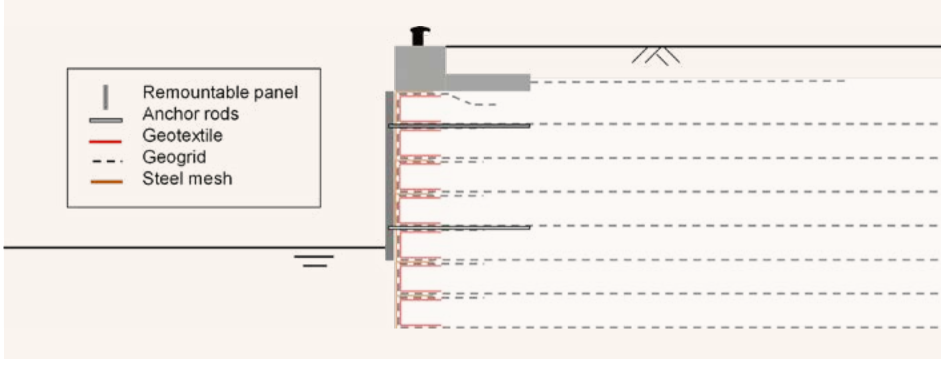

FIGURE 1

Quay wall elements reinforced soil structure.

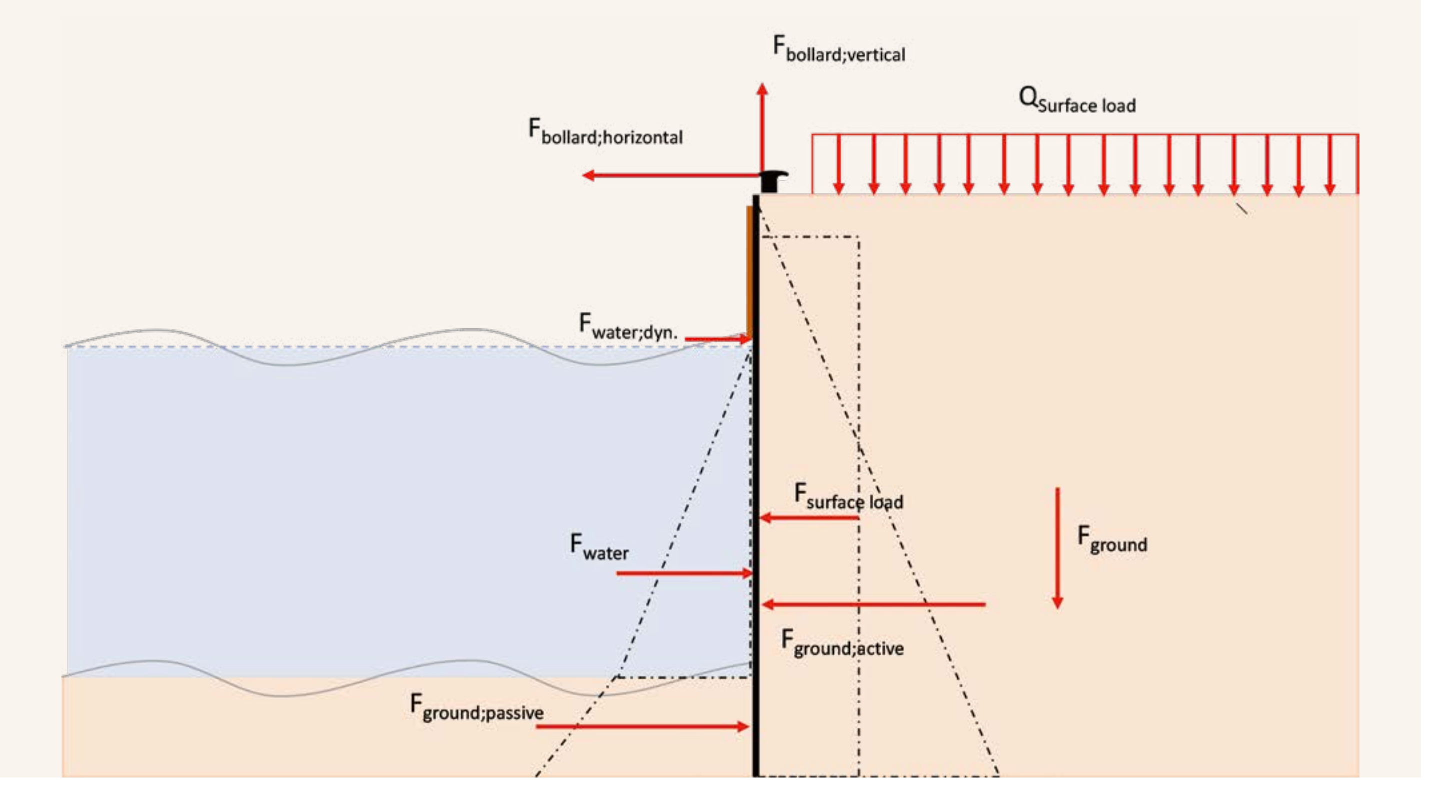

FIGURE 2

Loads on a quay wall structure.

Designs

For equal circumstances, all three quay wall structures are computed in the situation of the Flevokust haven, located near Lelystad, in the Netherlands. The main reason for choosing the Flevokust haven as case location is due to its representative characteristics for inland ports with deltaic soils. The soil consists of non-loadbearing soil types, there are limited water level fluctuations and this inland port is accessible to a representative number of vessels. In addition, this port is used as a container terminal that causes large surface loads, which is also representative for other inland ports due to a trend in the transshipment of containers.

The three different quay wall structures are designed with a total retaining height of 9.25 metres. In case of any settlement, an extra height can be added to maintain the total retaining height. The topside of the constructions must be on a level of 2.45 metres + N.A.P. With the current water level of 0.5 metres - N.A.P. there is 2.95 metres above the water surface. The remaining 6.3 metres of the total retaining height is below the water surface. This water depth provides the accessibility to vessels classified to CEMT-Va/Vb. The transshipment of containers requires heavy port equipment and storage of the containers resulting in high surface loads that effect the quay wall. Figure 2 includes all horizontal and vertical forces in the situation of the Flevokust haven.

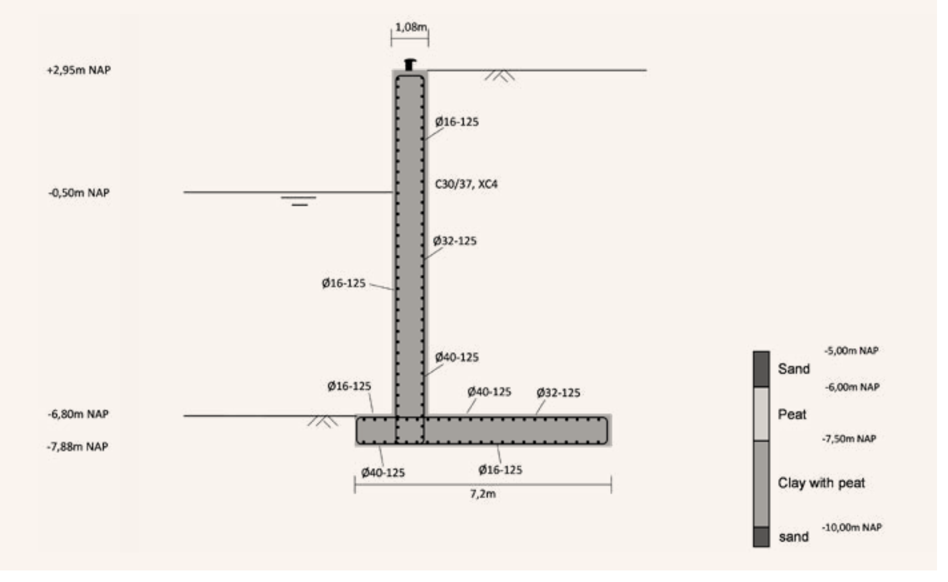

FIGURE 3

Cross-section concrete cantilever wall.

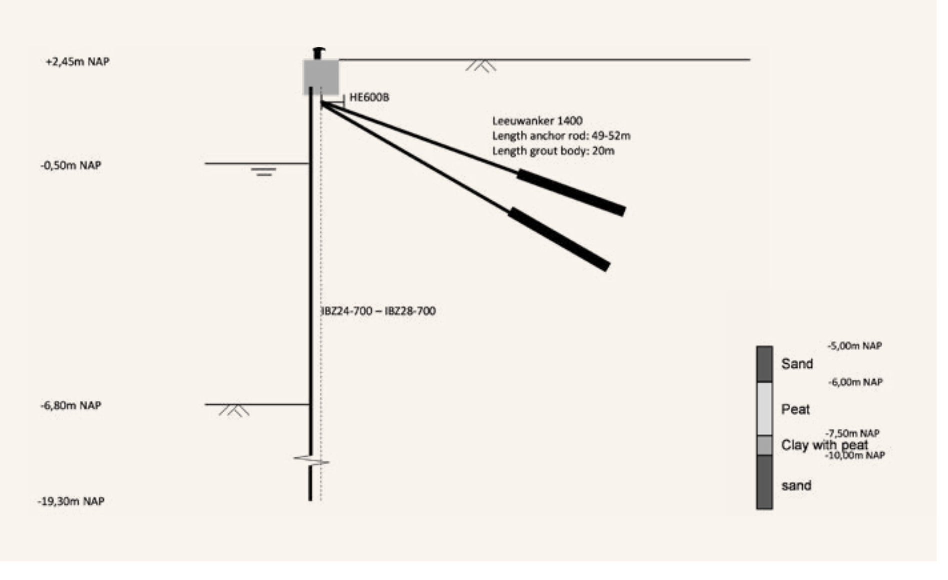

FIGURE 4

Cross-section sheet pile wall with anchor.

Developments in the future that could affect the quays' safety or functionality were considered, resulting in the following being taken into account in the design of a future-proof quay. In Europe, regulation states that inland waterways must be able to receive vessels with a normative draft of 3 metres (CEMT VI). As the past has shown, ships are expected to increase in size; the next step in the modernisation of the inland waterway network is an upgrade to class CEMT-V. This has led to a design that is able to receive vessels with a normative draft of 3.5 metres (CEMT Va/Vb). A logical consequence is larger mooring forces, therefore instead of a line pull force of 200 kN for class VI, 250 kN for class V is taken into account.

Moreover, anticipating the transshipment of containers results in a quay that endures higher loads from both storage and heavy port equipment. Finally, approximately one metre will be added to the retaining height to protect the quay from weather conditions such as extremely high water causing wave overtopping for example.

Cantilever wall

The reinforced concrete cantilever wall represents one of two traditional quay wall structures that is used for the comparison with the innovative quay wall. The design is the basis for the bill of quantities with which the material costs can be estimated. General rules are used for the dimensions and proportions of the wall. The dimensions of the design are as shown in Figure 3.

After designing the construction, all forces on the wall are determined. This is necessary in order to calculate the moments of force including safety factors. Checking the design on geotechnical failure mechanisms according to the Dutch guideline for geotechnical designs, the KIVI-reader provides the following calculations: tilt stability, vertical loadbearing capacity (drained and undrained situation) and horizontal sliding of the structure.

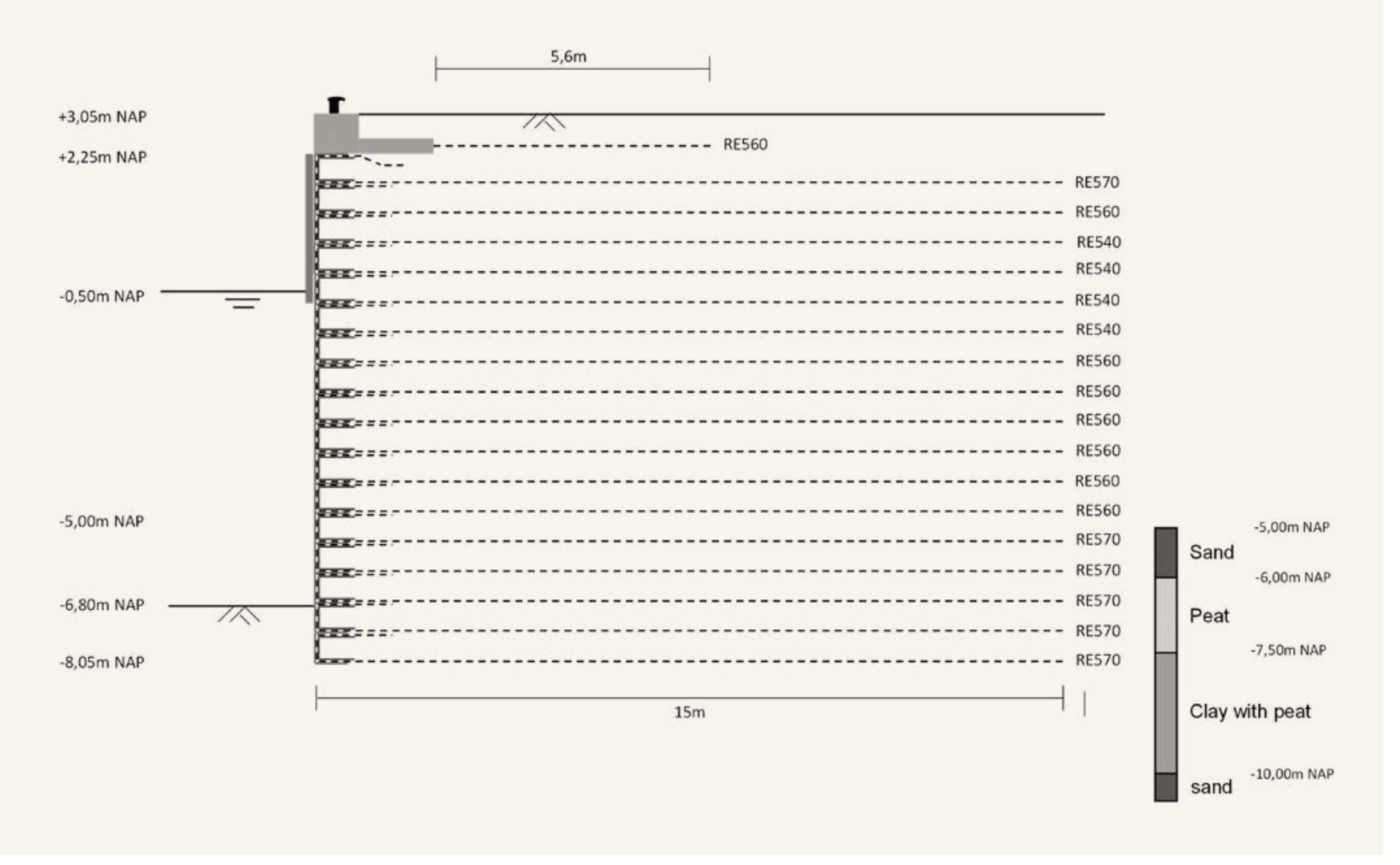

FIGURE 5

Cross-section reinforced soil structure.

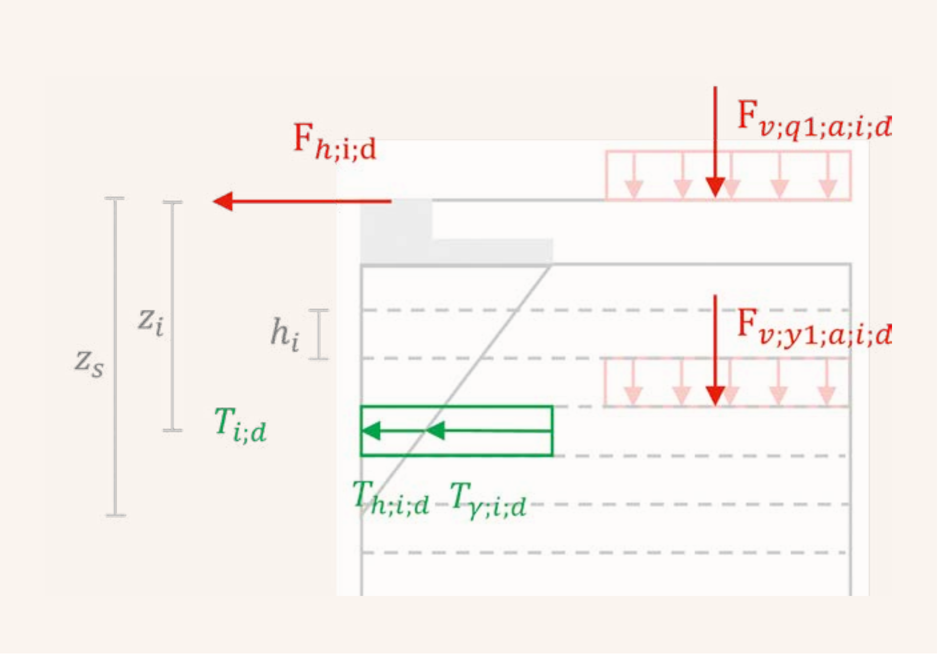

FIGURE 6

Loads leading to internal tensile forces.

Assuming the cantilever wall is a rigid construction, a neutral earth pressure K_n on the wall is applied in the calculations. On the bottom-left side of Figure 3, the soil structure of the case is presented, which has been used for the calculations. A reinforcement calculation is made to gain insight in the internal forces in the retaining wall and to determine the steel quantities.

The cantilever wall is on top of compressible layers of soil. A layer of 2.5 metres of clay with peat causes a settlement of 0.5 metres, which is compensated to add extra height to the retaining wall. Adding 0.5 metres to the initially required retaining height gives a retaining wall height of 9.75 metres. The quay is in varying contact with water; therefore, the concrete structure is classified in environmental class XC4.

Various types of reinforcement carry the tensile stresses in the concrete. The main reinforcement is applied in the wall where the biggest bending moments occur, in the inner corner between the wall and the floor, and in the toe of the floor. The bending moment in the wall decreases once the cut in the wall is made higher to determine the forces. At the top of the wall, the bending moment is 0. By dividing the height of the wall and determining the required reinforcement per segment, a lot of reinforcement can be saved. Besides, compression reinforcement, distribution reinforcement and bollard reinforcement are needed to carry and distribute loads properly.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

A construction pit of temporary sheet piles with a strut frame makes it possible to excavate approximately 2.5 metres of the soil and lower the water level. After excavating several teams can work in shifts to apply the formwork, processing the reinforcement bars and to pour concrete. Once the construction and backfill have been finished, the temporary sheet piles can be removed.

Anchored sheet pile wall

The steel anchored sheet pile wall is the second traditional quay wall structure that is used for the comparison. The design as shown in Figure 4 is in reality designed and constructed for the Flevokust haven. Because it concerns a validated design, no constructive calculations have been made.

The construction consists of permanent sheet piles with an average length of 21 metres. Two grout anchors per 3-metre quay wall carries the bending moments in the sheet pile resulting in shorter sheet piles.

Construction starts with the installation of sheet piles into a load-bearing layer. Lowering the water level and backfilling sand on the existing soil including preload speeds up the settlement process. When soil is sufficiently settled, the grout anchors can be installed.

Reinforced soil structure

The third design is the innovative reinforced soil structure. The retaining function of the design is derived from the use of a high density polyethylene (HDPE) reinforcement, geotextile and sand. Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction. The elongated perforated structure allows the backfill material to interact with the reinforcement through frictional resistance. Meanwhile the aperture structure of geogrids could cause the backfill material to washout. Geotextile provides a barrier to confine the backfill material. Open graded sand is desired to ensure a drained effect of the backfill.

The design is checked for internal and external stability in accordance with the CUR-198 guidelines. In order to ensure the local internal stability, it is important to know that a reinforced soil structure can internally fail due to two reasons. The first being that the tensile strength of the reinforcement is exceeded causing the reinforcement to break. The second is that the reinforcement can be pulled out due to insufficient bonding when the reinforcement length is not sufficient to transfer the tensile force to the backfill material. A check on pulling out is disregarded because this is only decisive in situations where very short reinforcement lengths are used.

Initially, the tensile force must be determined for each reinforcement layer. There are four types of loads that directly affect the tensile force, taking into account the self-weight, surcharge loads, concentrated horizontal and vertical loads. The self-weight of sand and surcharge loads causes a vertical force in the construction. This vertical force results in a horizontal force due to the active ground pressure because the sand is enclosed by the geotextile. Concentrated vertical loads due to a bearing are not applied to this design.

The total tensile force $T_{i;d}$ is the sum of all the tensile forces due to self-weight, surcharge loads $T_{y;i;d}$ and concentrated horizontal loads $T_{h;i;d}$. Simplified, the equation is as follows:

$$T_{i;d} = T_{y;i;d} + T_{h;i;d} \qquad (1)$$

Calculating the tensile forces due to self-weight and surcharge loads $T_{y;i;d}$ is done by multiplying the active ground pressure factor $K_{1;d}$ with the reinforcement layer height h_i (0.6 metres) and the vertical effective stress $\sigma'_{v;i;d}$.

$$T_{y;i;d} = K_{1;d} \times h_i \times \sigma'_{v;i;d} \qquad (2)$$

The vertical effective stress $\sigma'_{v;i;d}$ is derived by the sum of the vertical forces divided by the effective width.

$$\sigma'_{v;i;d} = \frac{F_{v;\gamma 1;i;d} + F_{v;q1;i;d}}{b'} \qquad (3)$$

Determining the influence of the concentrated horizontal load of the bearing in the considered layer, gives the following equation. Basically, the load is spread linearly on the depth z_s depending on the active shear wedge $\theta = 45° - \varphi'/2$ and the distance between the point of engagement (centre bearing) to the facing of the reinforced soil structure.

$$T_{h;i;d} = 2 \times h_i \times \frac{F_{h;opl;d}}{z_s} \times \left(1 - \frac{z_i}{z_s}\right) \qquad (3)$$

As shown in Figure 5, varied geogrid types are used that differ in tensile strength. The tensile force in the geogrids increases once they are lower in the structure due to the increasing ground pressure. The unfavourable horizontal loads are carried by the top layers of the reinforcement resulting in higher required tensile strengths. A deviation in geogrid type can also be found below the water level where the active earth pressure on the geogrids is reduced due to the saturated conditions, resulting in a lower effective weight of the soil fill.

The global internal stability can be calculated with the compound method. A shear wedge with a fixed angle $\theta = 45° - \varphi/2$ produces a load that needs to be caried by the intersected reinforcement layers. The global internal stability check has not led to a normative load case.

Checking the design for external stability resulted in an analysis of consolidation, settlements, tilt stability, vertical load bearing and horizontal sliding. A geogrid length of 13.6 metres provided enough resistance against all these failure mechanisms.

The global circular shear failure mechanism as a final check showed to be normative in determining the geogrid lengths, resulting in a 15-metre-long reinforcement.

The construction consists of 17 layers of soil, each 0.6 metres high; two layers for the embedding depth and 15 for the required retaining height, including settlement compensation. Settlement calculations showed that a settlement of 0.72 metres occurs, resulting in an extra layer of reinforced soil of 0.6 metres to meet the settlement requirement.

The construction of a reinforced soil structure in this case is as following. A construction pit of temporary sheet piles with a strut frame makes it possible to excavate approximately 3 metres of the soil and lower the water level. Then the reinforced soil structure can be built layer by layer. A steel mesh formwork is repeatedly applied followed by rolling out and extracting geogrids and geotextile, and applying and compacting the backfill material. Finally, the geogrids and geotextile are folded back to enclose the backfill material.

Costs

The total costs for all three designs i.e. the concrete, steel and reinforced soil structure can be divided into two categories, construction costs and material costs. Focussing on the material costs, the limited use of steel within the reinforced soil structure results in a solution with the lowest material costs (total material costs 1.950.000 EUR). In the case of both the conventional structures, only the costs of steel are more expensive (cantilever wall: 1.971.000 EUR and sheet pile wall: 2.010.000 EUR) than the total material costs of the reinforced soil structure. For each construction, the backfill material costs are approximately 1 million EUR.

> **The material costs of the reinforced soil structure are considerably lower compared to both the cantilever wall and the sheet pile wall quays.**

Compared to the material costs, the construction costs are somewhat different. The respectively high construction costs of the cantilever (1.720.000 EUR) and reinforced soil structures (1.106.000 EUR) are caused by using temporary sheet piles to create a construction pit. Therefore, the sheet pile wall is a less labour-intensive construction method resulting in lower construction costs.

Nevertheless, the total investment cost of the geogrid reinforced soil structure is still significantly lower than the total investment costs of either conventional structures. The material and construction costs show that the total investment cost for the soil structure is approximately 3.1 million EUR compared to 5.9 million EUR and 4.1 million EUR for the cantilever wall and sheet pile wall respectively.

Environmental effects

During the total lifetime of a project, for each material or construction process it is possible to determine the societal cost to compensate the environmental effects. Using the Environmental Cost Indicator (ECI), the effects can be determined by multiplying the quantified emissions of a material or process per functional unit with the total amount. The outcome of this calculation is for each material or process an environmental impact expressed in euros. It is important to note that all materials are calculated with a life span of 100 years.

The ECI can be divided into different system phases or impact categories. The dividing by lifecycle phase is shown in Figure 8. The production phase of the materials has the highest contribution in the total ECI. Sand mining and transportation is for all three constructions the main cause of this high ECI. This is due to the relatively high density and the large volumes of sand used, and the large number of transport movements required. Both conventional structures further increase these ECIs within this phase due to the large amount of steel. During the production of steel, a vast amount of heat is necessary to deform the material, which in turn effects the Global Warming Potential (GWP).

The environmental impact during construction is almost equal to each other. The three structures include almost the same amount of sand. Processing the sand has in all cases the highest impact and effects the Global Warming Potential (GWP), Acidification (AP) and Human Toxicity (HT) the most.

The last phase assesses to what extent the materials can be reused or recycled for the next production system. Sand and concrete can easily be reused or recycled. Sand is an extremely circular product and mining of new sand can be avoided by reusing the product. Meanwhile, according to the Dutch National Environmental Database, 45% of steel in the sheet pile will be lost during its lifetime due to corrosion. This negative fund is taken into account by reproducing the lost steel. The environmental costs of reproducing the corroded steel do not outweigh the positive funds of reusing sand.

The construction processes other than the application of the materials, such as excavating the soil, water extraction and the temporary sheet piles cover around 50,000 EUR for the cantilever wall and the reinforced soil structure. In case of the sheet pile wall, these costs are only 25,000 EUR by not applying temporary sheet piles.

Instead of using concrete and steel as main materials, the retaining function of the reinforced soil structure is derived from the use of polymers. However, like steel and concrete, polymers also have major environmental impact. High density polyethylene (HDPE) and polyethylene (PE) – the polymers that are used – are mainly obtained from petroleum, yet the reinforced soil structure has significantly lower environmental costs. The low ECI of these polymers originates in the very limited volume that is used. Thin layers of stretched HDPE collectively have a low volume.

The environmental effects can also be expressed in 13 impact categories as shown in Figure 9. Global Warming Potential (GWP), Human Toxicity (HT) and Acidification (AP) are the most notable categories indicated in shades of blue. GWP is caused by greenhouse gasses, such as CO2, methane and nitrous oxide. This category is expressed in an equivalent with CO2 as reference. Greenhouse gasses hold warmth that results in a (faster) rising temperature on earth. Human toxicity includes the emissions of toxic substances that are

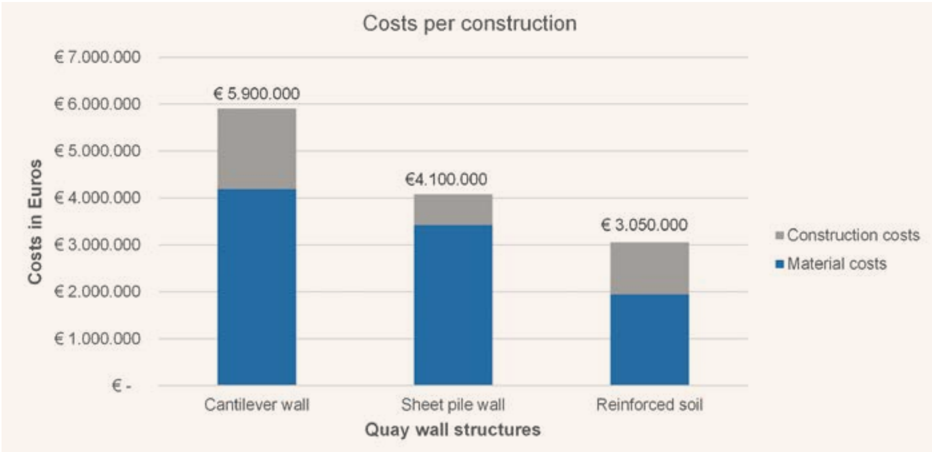

FIGURE 7

Total costs per quay wall structure.

The study showed it is technically feasible to design a reinforced soil structure quay.

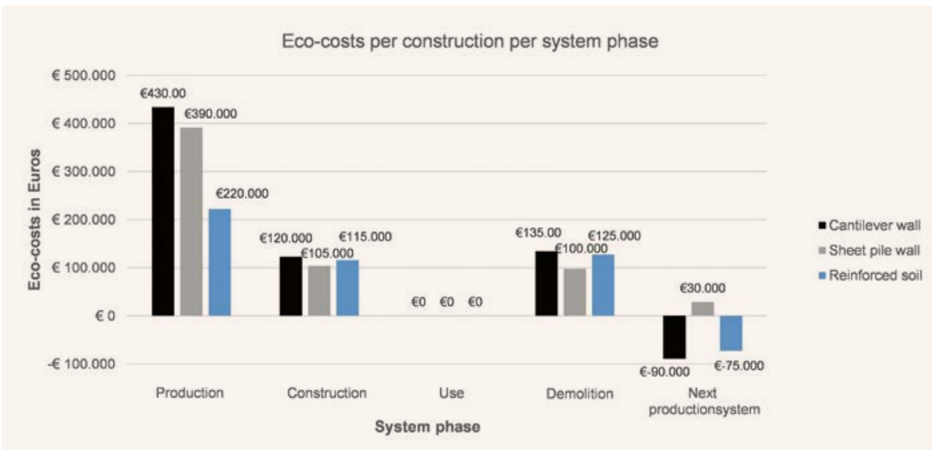

FIGURE 8

Environmental cost indicator (ECI) per life cycle phase.

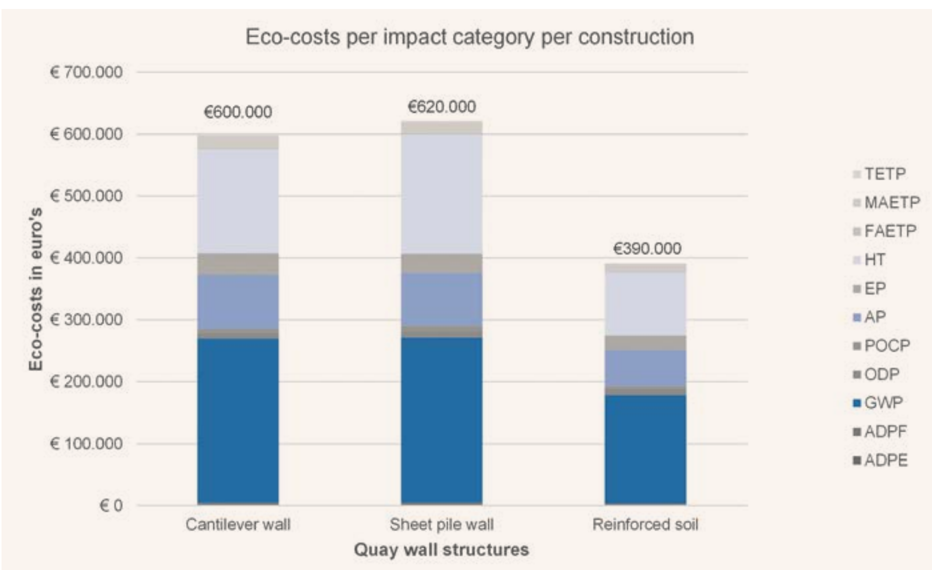

FIGURE 9

Environmental Cost Indicator (ECI) per quay wall structure.

exposed to human beings. This exposure finds its way by breathing or consuming products like meat and fish. Acidification arises after releasing sulphur oxides. The acidification of soil and water has a negative influence on ecosystems.

Conclusions

The purpose of this research was to design a future-proof, inland quay wall structure in a delta area that has the potential to be more cost effective and more sustainable than conventional quay walls. Initially the study showed it is technically feasible to design a reinforced soil structure quay. Solutions to implement quay elements, such as the L-shaped capping beam and the anchored facing panels were necessary to expect a reinforced soil structure to perform properly as a quay. How much the design is in fact future-proof is derived from the following three developments: upgrading the quay wall to receive CEMT-class V vessels, including those with increasing loads and load conditions, and finally by adding 1 metre to the retaining height for extreme weather conditions.

The material costs of the reinforced soil structure are considerably lower compared to both the cantilever wall and the sheet pile wall quays. The combined material and construction costs are 25% lower than the most favourable quay wall structure. The same is true for the environmental costs, which are 35% cheaper with the reinforced soil structure.

Summary

Nowadays, most inland quay walls mainly consist of concrete or steel materials. As a result of ongoing climate change and rising costs of materials, an investigation into more sustainable and more cost-effective structures for inland quay walls has been carried out. Various innovative quay wall structures have been designed after which a Multi Criteria Analysis (MCA) concluded that a reinforced soil structure has the highest overall value for implementation as an inland quay wall. Various solutions to implement quay elements such as bollards were necessary to use a reinforced soil structure as a quay. Designing three quay wall structures under equal circumstances, including the innovative quay and two reference quays of steel and concrete, made it possible to compare the criteria costs and sustainability. By calculating the material and construction costs, a cost estimation could be made. Determining the environmental effects on so-called impact categories was completed using a Life Cycle Analysis (LCA). The result is that a reduction of 25% on investment costs and reduction of 35% on the environmental cost indicator is achievable with a reinforced soil structure.

FIGURE 10

Lars van Rouwendaal receiving the award from Dirk-Jan Walstra, chairman of the Dutch hydraulic engineering prize jury (*Waterbouwprijs*), for best hydraulic engineering graduation research 2022.

Berend Schmidt

Berend graduated in 2022 with a degree in Civil Engineering from Windesheim University, in the Netherlands. Throughout his studies, his interest in hydraulic and future-proof solutions has grown. Berend's internship at Arcadis gave him insights into the world of port and waterway designs. These experiences provided him with better knowledge about these topics during his thesis on innovative quay wall structures. Berend's joint research was awarded the *Waterbouwprijs* – the prize for best hydraulic engineering graduation research of 2022 in the Netherlands.

Lars van Rouwendaal

In 2018, at the age of 16, Lars started the civil engineering programme at Windesheim University, in the Netherlands. The lessons in hydraulic engineering and internships working on both the Afsluitdijk and IJburg projects further inspired his interest in hydraulic engineering and specifically in the offshore wind industry, land reclamation and port development. In November 2022, together with Berend, Lars' graduation thesis on innovative quay wall structures was awarded the *Waterbouwprijs*.

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UPCOMING COURSES AND CONFERENCES

Dredging for Sustainable Infrastructure Course
20-22 June 2023
Venue to be confirmed
Beveren, Belgium

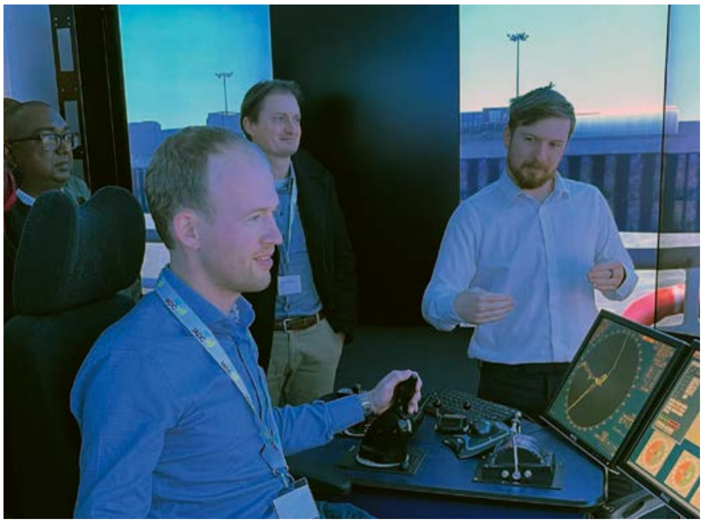
How to achieve dredging projects that fulfil primary functional requirements, while adding value to the natural and socio-economic systems. This is just one of the questions addressed during the 3-day course that is based on the philosophy of the book, *Dredging for Sustainable Infrastructure*.

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.

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?"

Register for the course at https://bit.ly/DfSI-June2023.



Dredging and Reclamation Seminar
3-7 July 2023
IHE Delft Institute for Water Education
Delft, The Netherlands

2nd Seminar
9-13 October 2023
Venue to be confirmed
Manila, Philippines

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: seeing is believing

Practical experience is priceless and it sets aside this seminar from all others. There will be a site visit to a dredging yard or a dredging project of an IADC member to allow participants to view and experience dredging equipment first-hand to gain better insights into the multi-faceted field of dredging operations.

Networking

Networking is invaluable. A dinner where participants, lecturers and other dredging employees can interact, network, and discuss the real, hands-on 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.

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

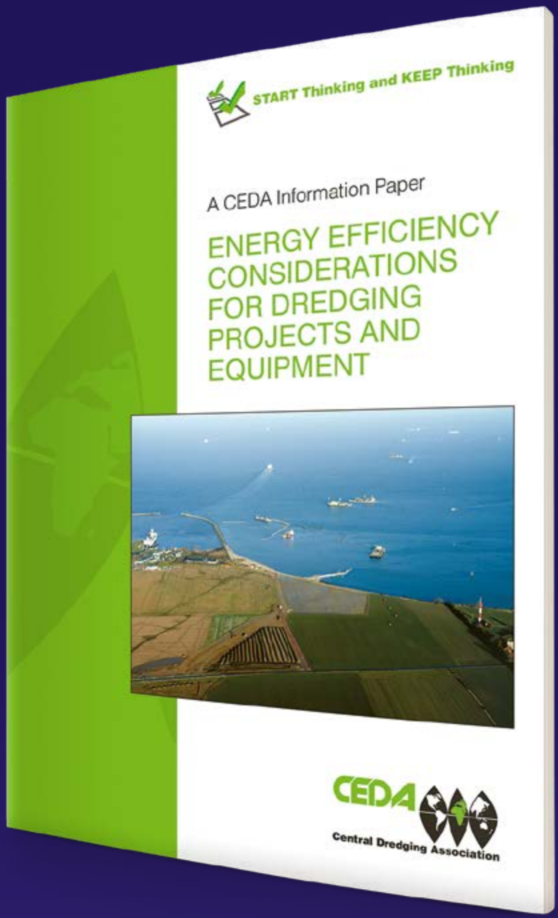
Submissions for IADC Safety Awards 2023

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

Two safety awards will be presented in 2023: 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 submitted and the awards are open to both IADC members and all other dredging contractors. Summit your submissions before 31 May 2023 via https://bit.ly/SafetyAward2023.

ENERGY EFFICIENCY CONSIDERATIONS FOR DREDGING PROJECTS AND EQUIPMENT



The information paper by CEDA's Working Group on Energy Efficiency (WGEE) aims at raising awareness and supporting informed decision-making by members. The paper promotes sustainable and cost-effective measures in support of energy efficiency.

The quest to improve the energy efficiency of dredging projects and equipment has been a constant goal within the industry, particularly as fuel prices rise and the IMO's greenhouse gas emissions strategy comes under revision this year.

Through the exploration of concepts, such as the life cycle of infrastructure projects, alternative fuels and technical improvements, the paper determines that for energy efficiency to be sustainable, it needs to factor in both environmental practices and the economy. This creates a business case for owners of dredging equipment to be early adopters of new technologies for their fleet to keep pace with market trends.

The paper is divided into five sections. Section 1 defines the drivers behind the quest for energy efficiency and benchmarks the CO2 emissions of the dredging industry. Section 2 summarises actual global, interregional and national policies, and legislation with a focus on Greenhouse Gas (GHG) emissions. Section 3 considers the topic from the perspective of a dredging project and section 4 with a focus on the dredging equipment. A final section provides practical examples in the form of three case studies.

The authors argue that investing in new technology to optimise energy efficiency can help reduce inefficiencies within operational procedures, ensure regulatory compliance and reduce operational costs by using less fuel. Thus, dredging companies making these investments will see benefits to their business.

The paper also highlights the importance of reducing a dredging project's impact on air quality (local impact) and climate (global impact).To implement this, project managers must take into account the phases of life cycle infrastructure projects to address the energy efficiency of dredging campaigns.

As emission legislation becomes stricter, it is imperative that decisions are made early on in the project initiation phase to ensure that energy consumption is managed in a sustainable manner throughout all subsequent lifetime phases of the project.

Author: Members of the CEDA Working Group on Energy Efficiency Considerations (WGEE) for dredging projects and equipment.
Publisher: Central Dredging Association (CEDA)
Published: January 2023
Language: English
Price: free to download

Available from
https://dredging.org/resources/ceda-publications-online/position-and-information-papers

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