On 5 September 2023, IADC published a paper by the same name in response to a 2022 United Nations Environmental Program (UNEP) report “Sand and sustainability: 10 strategic recommendations to avert a crisis”. In this report, UNEP calls for actions to set the global sand agenda in addressing environmental needs alongside justice, equity, technical, economic and political considerations. IADC’s paper highlights the dredging industry’s best practices for optimal use of scarce sand resources. This article is a condensed version of that paper.

SAND AS A RESOURCE: BEST PRACTICES TO CONDUCT RESPONSIBLE DREDGING PROJECTS

“Sand, gravel, crushed stone and aggregates (hereinafter sand resources) are the second most exploited natural resource in the world after water and their use has tripled in the last two decades to reach an estimated 40-50 billion metric tonnes per year, driven by factors such as urbanisation, population growth, economic growth and climate change.

Sand is the key raw material in concrete, asphalt and glass that built our infrastructure. It is also used for land reclamation as well as flood protection in coastal areas, part of the efforts to protect eroding coasts and address climate change impacts such as sea-level rise and increasingly severe storms. Satisfying a growing sand demand without transgressing planetary boundaries represents an important and insufficiently recognised sustainability frontier” (UNEP, 2022)

Global sand consumption
For hundreds of years, dredging activities have shaped the interface between land and water to support a variety of human activities including navigation, coastal
The increasing pressure on the natural environment associated with depleting sand resources is a global concern, as the extraction of sand for construction purposes is accelerating. This depletion threatens the sustainability of construction projects and the integrity of ecosystems. The impact of sand extraction on environmental and social conditions is significant, necessitating responsible and sustainable management practices.

**Socio-economic concerns**

The increasing demand for sand is driven by the growth of the global population, infrastructure and development projects. The extraction of sand and other natural resources is crucial for social and economic development, providing necessary materials for infrastructure projects and contributing to regional economies. The withdrawal of sand from natural sources and its replacement with alternative materials is a key aspect of responsible sand management.

**Environmental concerns**

Sand extraction activities can have detrimental effects on local ecosystems, affecting aquatic, terrestrial, and coastal environments. The extraction process can lead to habitat destruction, loss of biodiversity, and changes in hydrological and sediment dynamics. For example, sediment extraction can alter the balance of marine environments, impacting marine ecosystems and their biodiversity.

**Societal concerns about sand consumption**

Dredging projects are a response to the increased demand for sand, particularly in urbanized areas and coastal regions. However, these projects are often accompanied by environmental and social challenges, such as the impact on local ecosystems, the displacement of communities, and the loss of traditional livelihoods. The local community’s participation and consent in the planning and execution of such projects are crucial for their success and sustainability.

**Governance and responsible sand management**

Effective governance structures are essential for the responsible management of sand resources. This includes the establishment of regulatory frameworks, the implementation of environmental monitoring, and the promotion of sustainable practices. The involvement of stakeholders from various sectors, including the local community, industry, and government, is key to achieving sustainable solutions.

**Technological innovations**

Technological advancements, such as the development of alternative materials and construction techniques, hold promise for reducing the demand for sand. These advancements can offer more sustainable solutions, leading to environmental and economic benefits.

**Conclusion**

The challenges associated with sand extraction highlight the importance of sustainable and responsible practices. Addressing these challenges requires a holistic approach, encompassing environmental, social, and economic aspects. Collaboration between stakeholders is essential to ensure that sand extraction projects contribute to rather than detract from the sustainability of ecosystems and the well-being of communities. The future of sand management is thus tied to the development and implementation of innovative, responsible, and sustainable practices.
In an ideal scenario, there are recharge plants in place [with required consent] for vulnerable and suitable sites so that sediments of all types can be used effectively and quickly when they are available [AIP; Mar 2018]. Although other alternative materials are available, such as crushed rock, quarry dust, fly-ash and metal slag, they do not play a significant role as a sand alternative.

Example: Between 1990 and 2023, dredged sediments were placed onto intertidal habitat to achieve both habitat restoration and coastal protection objectives at Horse Island on the eastern coast of England. Sand and silt from capital and maintenance dredging at the nearby ports of Harwich and Felixstowe were used to create a mix of habitats including mudflats, marsh and a shingle spit to be used to create a mix of habitats including mudflats, marsh and a shingle spit by using birds. The project has demonstrated that the environmental benefits can persist over decades (LSEFa, USACE, 2007). Case studies such as this one were collected by the CEDA Working Group on the Beneficial Use of Sediments (CEDA, 2023).

Local effects of sand extraction: When sand is extracted from marine deposits, sediment layers are removed that have different ecosystem functions, such as hosting nutrients and benthic fauna and flora in the top layer and newly formed chemical and biological processes in the sub-layer. These processes are key to the maintenance of the ecosystem’s health.

Dredging in or near sensitive sites with high natural or cultural value is only feasible with extensive monitoring, adherence to strict limits and adequate super vision. These sites can be protected by defining marine conservation areas, setting up a marine spatial plan and enforcing compliance. This is applicable to areas with living coral reefs, coastal wetlands and other habitats with high biodiversity or endangered species and similarly to sites with historical or cultural importance, including indigenous values.

Habitat and biodiversity losses are best tackled in the conception and design phase of a project. In this early project phase, abundance and biodiversity can be inventoried. With this knowledge, the sand extraction zone with the lowest impact can be selected and mitigation, compensation and restoration measures can be included in the project scope. Loss of substrate or alteration of sediment composition can be transformed into the creation of a habitat that is regionally in decline or specifically targeted for valuable or endangered species.

When an area is approved for sand extraction, authorities monitor dredging activities in order to ensure that extraction remains within the boundaries of the licenced zone. In many countries, the representative on board of the dredging has been replaced by a black box computer system that is installed before the vessel arrives on site. The system transmits the dredging location and production data in real-time without the interference of the crew or computer systems on board.

Due care has to be taken that vessels do not inadvertently carry species that are considered invasive species to its destination. For this reason, international and local regulations may require cleaning of hull water intakes and ballast tanks before the start of a voyage. Such regulations also apply to dredging vessels.

Example: For the extension Maasvlakte 2 of the Port of Rotterdam, 230 million m³ of sand were extracted between 2009 and 2013. The maximum extraction depth was 20 m below seabed, which is tenfold the traditional limit. This method reduced the directly impacted surface area from 110 m² to 11 m². Two sandbars mimicking natural sand waves were left behind after extraction to increase habitat heterogeneity (Da Jongh, 2018). This is one of the optimisations researched in ORE USE (recommendations for Ecosystem-based large-scale sand extraction). A consortium of 21 partners led by the Dutch Research Council (NWO) programme.

Regional effects of sand extraction: Extraction of sediments results in a local depression of the seabed. This changes the local bottom friction and may have an impact on local hydrodynamics. Currents and waves may be less attenuated on their way to the coast when the seabed is deepened. Waves encountering a depression in the seabed at specific angles may refract or reflect in a different direction and hit previously sheltered coastlines.

In rivers and deltas, the tidal flow is in dynamic equilibrium with bottom level, shape and roughness. When sand is extracted from these systems, the equilibrium is disturbed and this may lead to increased tidal amplitude (floods) and increased flow (change of habitat conditions). When impermeable layers are removed, salt water may infiltrate into nearby coastal areas.

All these issues can be identified through modelling during the planning and permitting phase of a project. Modelling of coastal zones outside the dredging area is however not a requirement for a dredging permit. A marine spatial plan may define exclusion zones for dredging in highly dynamic zones such as reefs, sandbars, river beds, beaches and beach foreshores.

Example: Since 2021, the extraction depth limit of 5 metres in the Belgian Continental Shelf was replaced by a limit based on scientific principles. The limit ensures the preservation of the surface sediment characteristics, the structure of the sandbanks, a maximum use of sand from mobile structures and limited impact on hydrodynamic conditions. The implementation of this new reference level led to a reduction of less than 2% of available quantity, whereas the extraction area was reduced by 25% excluding the ecologically most valuable areas (Degrande, 2021).

Regulations and due diligence: Restricting sand extraction to responsible practices inevitably comes down to regulation and enforcement, which can be carried out in several ways. Next to local national and regional legislation, the responsible party has to hold accountable for the impact of the projects they are funding (e.g. by the IFC performance standards (IFC, 2012)). Project owners can reward contractors for their efforts with a competitive advantage.

Prequalification criteria can include company-level compliance with requisite minimum environmental and labour standards.

The management of sand resources is necessarily a task of the competent authority. Income from sand concessions can be used for monitoring, assessing the quantity and quality of the resource and drafting a responsible sand resource strategy and marine spatial plan.

Still, the contribution of the dredging industry to a safe and healthy work environment for its employees and its supply chain is essential. Responsible companies promote a safety culture in company-wide programs, organise mandatory courses for their employees, which enable them to recognise signs of modern slavery and conduct due diligence on subcontractors and their subcontractors. These initiatives are recorded in a register that can be consulted by clients during their due diligence.

Example: The Safety Culture Ladder (SCL) is a certified assessment method for measuring safety awareness and conscious and safe and healthy acting in companies, with an emphasis on safety culture. The higher the safety culture, the higher the assigned ladder step. Steps range from ignorance about safety to full integration of safety in the business processes. Since 2022, the SCL is mandatory for project owners that have underwritten the Dutch construction governance code (Van de Mieriks, 2022).

Stakeholder engagement: Stakeholders can be defined as “any” group or individual who can actively affect or be affected by the project development (Theman, 1984). As such, stakeholders can be anything from individuals affected by a project through to government NGOs whose organisational goals are related to aspects of the project.

Connecting with all relevant stakeholders and partners as part of any project planning and design is key to unlocking positive potentials.
Through systematic and equitable involvement across partners and stakeholders, a comprehensive system perspective can be derived and local voices equally heard.

Infrastructure projects operate across the boundaries of physical, ecological, and socio-economic domains. A multitude of interests and backgrounds are involved in the successful development of such projects. Thoughtful management of these interests— as well as combining them in a specific design— contributes to project success (Bienaure, 2021). Effective incorporation of interests can only be achieved by careful engagement of stakeholders. Key for the organiser is to be attentive to the incitement of the public by project opponents with misinformation and covered funding.

There are several ways to engage stakeholders in a project:
• Public consultation as part of an ESIA process helps to identify societal concerns and impacts on local communities.
• Citizen participation in project capital incorporates the stakeholder’s agenda into the project’s objectives.
• Design process based on co-creation where working group sessions of stakeholders decide on focus and phasing of the project within the physical and economic boundaries set by the project team.
  
- Real-time access to a monitoring platform relevant to the dredger’s activity and environmental parameters.
- Periodic newsletters and grievance mechanisms.

Example
Port Philip channel deepening project, Melbourne, Australia, that involved the removal of 2.3 million m³ of sediment of which 3 million m³ was contaminated, met with strong and continued opposition. The client and contractor formed an alliance contract to share responsibilities and risks, as well as communication efforts. Stakeholder acceptance of the project was a result of the accurate and transparent public communications, which included public consultations, public hearings, a dedicated website, a 24-hour toll-free telephone number, weekly press conferences, media releases, making lists, signage around the bay and notices to mariners. A vessel tracking system and online video data was used to prove that the operation proceeded in accordance with the environmental management plan. These joint efforts led to successful completion of the project (Bienaure, 2021).

Nature-inspired design
An infrastructure project is part of a system. It affects and is affected by the processes operating within that system. The concept of ecosystem services supports this very notion. Ecosystem services are benefits that humans derive from nature. Ecosystems generate human welfare because they produce goods and use services that humans can use directly or indirectly through the use of other goods or services. Examples of indirect forms of use are “nutrient recycling” and “fish nurseries”, which result in “clean water” and “fish production”, respectively (Reed, 2005; TEEB, 2010).

The more ecosystem processes are taken into account over the full life-cycle of a project and the more natural processes and materials are incorporated into the project, the more sustainable a project can be. These practices are commonly referred to as Nature-inspired Design (NID) or Nature-based Solutions (NbS). In practical terms, the sustainability of an infrastructure project is increased by:
1. Increasing the overall value of the project by increasing the range of services it provides;
2. Reducing costs associated with the project, where costs include all monetary and non-monetary (e.g., environmental impacts) costs and resources consumed by the activity; and
3. Balancing the distribution of the value and costs among the social, environmental and economic domains over time.

For more than a decade the dredging industry has invested in nature-based solutions and has developed multiple initiatives such as


Example
Inchir Atafalaya River (Louisiana, USA), dredged sediment was placed in the middle of the river just upstream of a natural shoal and contributed to the formation of an island. In 10 years’ time, a 3.5 hectare island was created that hosts a rich wildlife habitat with access for recreation and a better aligned navigation channel (Sueldal, 2015).

Adaptive management
Alternative building methods and concepts address risks and uncertainties on top of difficult-to-predict natural processes, climate change and the effects on environmental and socio-economic receptors. Adaptive management addresses these uncertainties by incorporating flexibility and robustness, and allowing decision-making based on continuous data/information that is acquired during the project.

In the early stages of the project, project goals on environmental, social and economic levels are defined. The preferred strategy is then selected and implemented based on an inventory of alternatives. As the project proceeds, goals are translated into warning indicators that are monitored and evaluated continuously. These indicators are the basis of adjustments in design, construction, maintenance and monitoring.

Example
During the dredging works at Teluk Rubiah in Lumut, Malaysia, continuous water quality monitoring was combined with hindcast plume modelling to safeguard the nearby sensitive receptors. Based on the forecast, the dredging schedule was adapted, resulting in a zero exceedance of trigger levels and ahead-of-schedule completion of the project. The setup also allowed the contractor to avoid the necessity of 14 km sit screen (Sivasol, 2013).

Early Contractor Involvement
The involvement of contractors and specialist suppliers is from time to time solicited by project owners prior to setting construction phase contracts. Contractors have expertise on construction methods, the availability of equipment and alternate materials, the implications of design for the ease and safety of construction, the resilience and sustainability of the constructed works.
Stakeholder impacts can be identified and mitigated with appropriate regulations and ESIA procedures in place.

and the cost and time required to provide the designed works (PIANC, 2022). Early Contractor Involvement (ECI) is a tool to introduce sustainable project approaches such as the beneficial use of sediments. While ECI has many benefits, prior knowledge and equal treatment of tenderers is a concern that needs to be addressed.

Procurement process

The procurement process is decisive for prioritizing different objectives and risks associated with infrastructure projects and natural processes (CEDA, 2019b). It can therefore contribute to more sustainable practices.

A wide variety of procurement principles are used:
• Prequalification of contractors, and minimum standards for safety, financial stability, experience and competences.
• Competitive dialogue during tendering: meetings are organised between the client and tenderers where concepts and strategies are exchanged and adjusted.
• Design and build: the contractors undertake to design and build the project, with safety and quality assurance.

Environmental impacts can have consequences that affect other marine users. The livelihood of local fishing communities may be affected by decreased fish stocks, caused by degradation of their fishing grounds. Coastal communities may be deprived of habitable land, cultural areas and natural wealth as a result of erosion or salinisation. Addressing these impacts is a requirement for project permits in many countries. This is usually done under “Areas of Operations” in an ESIA.

However, prohibiting sand extraction in vulnerable habitats also has an inevitable impact on the livelihood of local communities. Even if some of these activities may be illegal, they provide the means of survival for many communities. Any change in regulations to protect the environment should therefore be accompanied by measures to provide alternative local employment.

These stakeholder impacts can be identified and mitigated with appropriate regulations and ESIA procedures in place. Although in most projects, these regulations and procedures are beyond the contractor’s scope and responsibility, contractors can exercise due diligence and apply leverage and assist project owners with that responsibility.

A dredging project is short-lived and requires large deployment of human resources and equipment, often in little-developed areas. Yet it has the potential to contribute significantly to the local economy in the form of:
• salaries for the local workforce;
• local expenses (office, housing, transport, catering);
• local purchases and subcontract (fuel, civil construction, fabrication, equipment rental);
• tax revenues (import duties, royalties, withholding tax, corporate tax, personal income tax on salaries).

The local content in the project budget can be improved by different incentives:
• Onboarding and awareness training of local workforce with a focus on health and safety, environmental care, diversity, equality and respect.
• Training of local workforce when gaps are identified between required and available skills.
• Selection and training of local suppliers based on labour and human rights, biodiversity, emissions, waste management and business ethics.
• Advertisement of supply opportunities in local media.
• Unbundling of contracts into units that are tailored to the local market.
• Engagement in local community projects.

Innovation and contribution

Knowledge and best practices to increase sustainability in dredging projects are not written in stone. They develop with changing conditions, with learning by doing, with scientific knowledge and awareness. Knowledge and best practices require a strategy to develop and to disseminate them to the stakeholders.

Development strategy

Many countries and regions have research and innovation funds to encourage scientific institutions and industry to develop new goods and services with the aim to increase competitive advantage and employment. Research and innovation funds can be a tool for authorities to:
• stimulate co-operation between local players in order to create sector-specific communities and local supply chains;
• stimulate the inclusion of small and medium-sized enterprises as they already have the means to innovate on their own;
• create programmes where industry, scientific institutions and authorities work together to ensure that the solution is endorsed everywhere;
• develop performance metrics and facilitate demonstration projects with tangible results that are accessible to potential clients.

Knowledge and best practices to increase sustainability in dredging projects are not written in stone. They develop with changing conditions, with learning by doing, with scientific knowledge and with public focus. The dredging industry is committed to help build a better future and continues to:
• contribute to the understanding of the ecosystem by exchanging information and know-how with knowledge institutions and scientific communities, by encouraging research and participating in joint research programmes;
• invest in innovations that increase sustainability and biodiversity to reduce accidents and impacts and improve operational excellence;
• contribute to new and upcoming standards and regulations; and
• engage in dialogue with a wide group of stakeholders. The dredging industry’s concerns are addressed and projects benefit the entire society.

The dredging industry has an important part to play in seizing these opportunities. Operating globally, dredging contractors are working within a wide variety of physical, environmental, social and legal conditions. Their first-hand experience can serve as a guide to formulating recommendations for responsible use of sand resources. Every stage of a project presents opportunities to increase the sustainability of sand extraction. This article presents best practices for the optimal use of scarce sand resources, on both project and operational levels.

Knowledge and best practices to increase sustainability in dredging projects are not written in stone. They develop with changing conditions, with learning by doing, with scientific knowledge and with public focus.
Jan Fordeyn

Jan studied naval architecture and started working at Jan De Nul in 1994. Since 2007 he has helped develop projects throughout the world that fall outside the classic canon of marine construction and that rely on the synergies of different disciplines. For that purpose, he maintains close relations with experts, consultants, universities and manages innovation projects.

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Wihan MSc in mechanical engineering on the Chalmers University in Sweden. Tom joined the DEME Group in 2001 as a project engineer. During his career he has worked on such multi-disciplinary marine construction projects and has been involved with all aspects of rock involvement works, as well as complex environmental projects for DEME’s environmental division for 10 years. Since 2017 he is responsible for DEME’s Building Materials (DBM) specialist in the licensing, environmental, planning, processing, certification and supply of marine aggregates for the European construction industry in 2019, he joined the board of ZEEDA, the Belgian federation of importers and producers of all type of aggregates, where he became chairman in 2021.

Sjon Kraneendonk

Sjon Kraneendonk studied civil engineering and joined Van Oord in 1990 as a production engineer in the engineering department. He has worked on dredging projects all over the world, including major reclamation projects in Hong Kong and Dubai. In 2003, he became head of the production department, responsible for the tendering, design and fabrication of the dredging equipment unit. Since 2022, Sjon has worked as MT member in the tendering department of the dredging and infrastructure business unit, responsible for the production and research for dredging projects executed by Van Oord worldwide.

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Thomas has a background in civil engineering with specialisation in coastal engineering and morphodynamics. After his graduation, he worked for Royal IHC in the Netherlands as a consultant from 2006-2016 before joining Boskalis. Thomas is currently deputy manager of Boskalis’ engineering department and also responsible for the morphology, environmental and social impact team. In addition, he is one of the course leaders of the Dredging for Sustainable Infrastructure course for AEC.

References


Sand mining, environmental impacts and selected case studies


