

TERRA ET AQUA

CONTRACT SELECTOR

Procure a project with a quantifiable contract model

NATURE'S CURE

To solve large-scale problems with nature or not is the question

PROTECTIVE SAND

FROM IDEA TO REALITY: THE UK'S FIRST SANDSCAPING PROJECT

PROTECTIVE SAND FROM IDEA TO REALITY: THE UK'S FIRST SANDSCAPING PROJECT

The Bacton Sandscaping scheme is a large-scale beach nourishment designed to protect the Bacton Gas Terminal from cliff and beach erosion. The project reduces flood and erosion risk to the communities of Bacton and Walcott, buying the time needed for adaptation to coastal change. The scheme was inspired by the Sand Engine project in The Netherlands but is a translation of the concept to a different geography and governance setting of the UK. It can be seen as the Zandmotor's 'little nephew'.

This article describes the context of the challenge, how the sandscaping approach works and tells the story of how this project developed from a seed of an idea to reality. Technical expertise, passion, trust, flexibility and lateral thinking have come to the fore in a unique collaboration between multiple private and public sector organisations. Read more on page 32.



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From idea to reality: the UK's first Sandscaping project

The Bacton Sandscaping scheme is a large-scale beach nourishment designed to protect the Bacton Gas Terminal from cliff and beach erosion while also reducing flood and erosion risk to the communities of Bacton and Walcott, buying the time they need for adaptation to coastal change.



EVENTS

Expand horizons abroad

Go to the UN Environment Program's Sixth Adaption Futures Conference in New Delhi, India, discuss technologies in remediation in Portland and submit a paper for PIANC COPEDEC X in Manila, Philippines. CEDA and IADC launch the Dredging for Sustainable Infrastructure Course.



BOOK REVIEW

Dredging Engineering Special Topics

In dredging, trenching, (deep sea) mining, drilling, tunnel boring and many other applications, sand, clay or rock has to be excavated. For the design, operation and production estimation of the excavating equipment, predicting the cutting forces and powers is important.

CAN THE DREDGING INDUSTRY BE A LEADER IN SUSTAINABLE DEVELOPMENT?



Frank Verhoeven
President, IADC

As it enters a new decade, IADC continues to take on projects to fulfil its mission of informing the world about the fundamental need for dredging and the benefits of the industry's innovative work. It also enters the new decade with three new members – Adani, Group De Cloedt and Rohde Nielsen – which joined in the last year, bringing the total membership to 13 main members and more than 100 associate members. As the umbrella organisation for these dredging companies, the Association spearheads diverse activities and projects to educate, excite and engage an international audience within the dredging sector, its related industries and beyond.

IADC's message to the world is clear: the global dredging industry is the front-runner on sustainable infrastructure developments.

As the IADC spreads awareness on this issue, other organisations and sectors have crossed paths on a comparable quest. New in 2020, the IADC launches the Dredging for Sustainable Infrastructure Course. This new course is based on the IADC-CEDA industry-leading book, *Dredging for Sustainable Infrastructure*, which after more than five years of development was launched just one year ago. The new course is one more way of sharing this important philosophy. The two-day course is officially presented in this issue's Events section. Discover more about nature-based solutions which maximise the social, economic and environmental value of waterborne infrastructure projects.

Another noteworthy event: the PIANC COPEDEC X in Manila, Philippines. Authors under 35 should mark their calendars! IADC will give its Young Author Award 2020 to one young author and presenter of a paper which makes a significant contribution to dredging literature. Qualifying authors should make sure to submit papers to PIANC COPEDEC X before the deadline this Spring. Check the call for papers in the Events section of this issue.

Recognising the growth of safety innovations in the dredging industry, IADC will now introduce another Safety Award category. Innovations which make the dredging industry safer come from many sources. Dredging contractors which develop innovations to improve safety will still be eligible for the Safety Award, while a second Safety Award will be given to an innovation by a subcontractor or supplier of goods and services which increases safety in the industry. These two awards encourage diverse innovations which support the multi-faceted nature of the dredging industry's operations.

Also in this issue are articles with guidance about selection of the appropriate type of contract, an analysis of the viability of natural building solutions for the dredging industry, and an overview of the UK's first 'Sandscaping' project in Bacton which was inspired by the success of the Sand Engine in The Netherlands.

The IADC spearheads diverse activities and projects to educate, excite and engage its members with an international audience within the dredging sector, its related industries and beyond.

MANAGING RISKS:

HOW TO
SELECT THE
APPROPRIATE
DREDGING
CONTRACT

The contracting environment for dredging and offshore works is diverse. Moreover, increasing financial and/or managerial constraints are requiring contracting parties to change the apportionment of commercial risk. Contractors and suppliers have to adapt to the contractual set-up, which is chosen unilaterally by the owner, and they need to reconsider how to manage their risks and how to procure their service providers. Turnkey and engineering, procurement, and construction (EPC) contracts are becoming more common in the industry and bring their own benefits and challenges.

Different types of dredging have different inherent risks and require different procurement solutions in order to be effective.

The Working Group on Effective Contract Type Selection (WGECS) provides guidance on contracting for key stakeholders participating in a contract. This article has three component parts:

1. The first part is a generic procurement process flowchart that visualises the procurement process as a whole. Five stages are described and explained that set out the main considerations to be taken into account by those procuring works, resulting in the selection of the contract type;
2. The second part, a table setting out certain key aspects that may be taken into account when assessing the contracting method, ties seamlessly in with the CEDA Checklist for Successful Dredging Management. The strength of this table is that it is established by a DMC-recognised group of specialists operating at both sides of dredging and offshore industry – both owners and contractors. The table includes six key aspects of procurement route/ contract selection and details numerous sub-aspects that can be used to assess the optimum procurement strategy;

3. The third part combines the output of the first two parts, resulting in an objective scoring methodology that allows users to compare their specific project with various standardised contract types.

The principle of this guidance article is two-fold. Firstly, it is meant to provide a simple, easy-to-access guide to the general procurement path, including the overall process, important points of consideration that may be taken into account, and guidance on the various factors influenced by certain standard contract types. Secondly, it provides a more in-depth, analytical method of objectively measuring a user's specific project and related requirements/constraints and comparing this measurement against standardized contract types. This allows a user to apply a more scientific, auditable, and demonstrable basis for the ultimate contract selection, and it compares with the more generic and basic methods of selection.

The drafting of this guidance article is specifically made to allow each part of it to be used either independently or together as

a whole (i.e., depending on a user's specific requirements, value can be gained from referring to only one section or the document as a whole in assisting the selection of a suitable contract type).

Further, this article is specifically designed to be able to be read alongside, and be complementary to, the CEDA Checklist for Successful Dredging Management (CEDA, 2017). Together, these publications set forth tailored guidance that can be utilised by organisations involved in the practical and contractual delivery of dredging projects worldwide.

Procedure for contract/procurement selection

Introduction

Choosing an effective contract type for dredging projects is not just a simple decision made by selecting an 'off the shelf' standard. It takes time to properly consider the risks and the conditions of the project. In Figure 1, CEDA seeks to provide a structured approach to the relevant steps and options that bear consideration.

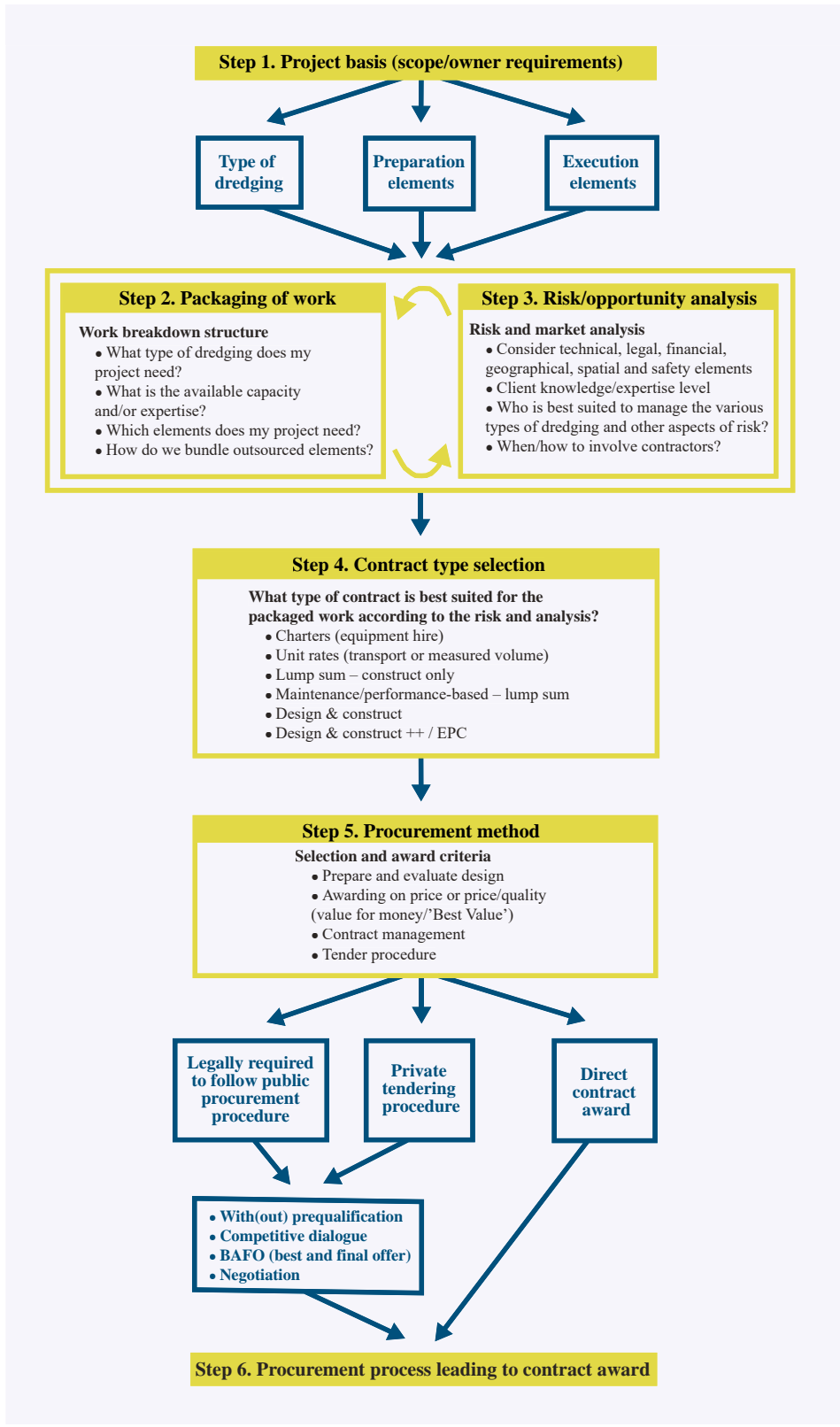


FIGURE 1

Staged flowchart outlining transition from establishment of project basis to procurement of works contract.

Step 1: Project basis

[scope/owner requirement]

Firstly, the type of dredging work that needs to be performed requires consideration ('What is the goal of the project?'). Different types of dredging have different inherent risks and require different procurement solutions in order to be effective. During this step, all the phases of a particular project merit consideration, as well as the goals sought to be achieved by the project. An approach whereby these points are already considered comprehensively during the procurement phase is of assistance to better design the overall procurement strategy.

The different types of dredging that a project requires are to be considered:

- maintenance dredging (e.g., a fairway needs to be dredged to guarantee nautical depth or minimum discharge);
- capital dredging (e.g., deepening and/or widening of a fairway);
- land reclamation (e.g., building a new harbour or an island at sea, perhaps with protection of flooding and new quay walls, etc.);
- coastal protection (e.g., beach or foreshore nourishments);
- offshore (seabed) dredging (e.g., trenches for pipelines and cables).

Notwithstanding the type of dredging envisaged to be employed, the following (preparatory) elements also warrant consideration, all of which may be required for a particular project:

- preliminary studies, including surveys, incl. multibeam, hydrographic, soil, environmental, UXO (unexploded ordnance), underwater installations/ infrastructure, archaeological, morphological;
- design;
- engineering;
- permits;
- financing.

During this first phase, various elements that might be of relevance during the contract execution also need consideration:

- contract management requirements;
- monitoring;
- inspections;
- surveys;
- research as required internally or by other stakeholders.



FIGURE 2

Equipment/vessel availability and capacity are part of contract type selection.

The CEDA Checklist for Successful Dredging Management (CEDA, 2017) can be of further assistance to gather all elements that need further consideration.

Step 2: Packaging of work (iterative with step 3)

If the project is sufficiently defined, the phase of packaging of the project work commences. Packaging of work can best be achieved by dividing the project into different components of work. Most projects are based on a work breakdown structure to assist the engineering. The following non-limitative questions merit consideration:

- The 'make or buy' decision: Is outsourcing the best decision for each component of work? If so, in how many contracts are the works divided? While considering which and how many contracts are outsourced, the following should be considered:
 - what type of contracts are appropriate (i.e., integrated contracts, stand-alone contract for various disciplines and contract work types (e.g., basic and detailed) engineering, surveys, civil construction, blasting, maintenance,

finance], different contracts for various geographical locations where works have to be performed or through another logical combination of works relating to market characteristics and the number of potential competitors);

- which party has the best capacity to prepare, tender, execute, and manage (a particular type of) the contract works;
- more contracts increase the dependency of various contractors and lead to more interfaces.

Step 3: Risk/opportunity analysis

A risk and opportunity analysis needs to be performed to establish a procurement strategy. The packaging of work should be considered simultaneously with the risks and opportunities involved in a particular division of works. While considering various combinations for the division of works, the risks involved with each combination should be weighed. Dividing works into various contracts may lead to more interfaces and, consequently, a risk for the owner to be responsible for disputes arising out of improper alignment of the interfaces. The same division may also lead to the

opportunity that the overall project contract expenditure is less.

After careful analysis of the division of work and risks and opportunities associated therewith, project owners should decide which division is most appropriate for it and/or the project. During a risk/opportunity analysis, at least the following elements should be considered: technical aspects, legal and financial matters, geographical locations, and spatial and safety elements. For the main work components, it is important to properly consider what negative consequences there may be and if and how these can be avoided. Elements like health and safety, the environment, the schedule, budget overruns, and the quality of work should be considered, as well as what the causes might be of negative consequences and which party is best suited to take and to influence the risk.

A good market analysis, including an estimation of the equilibrium of demand (for services) and supply (of providers), is very useful in procurement. Such an analysis

CONTRACTS

TABLE 1

In the following table, a number of standard contract types with different risk allocations are set out. The last column gives boundary conditions and key checks to be considered.

*This is based on a generalisation – the specific risk allocation is always dependent upon the specific terms of a particular contract.

Contract type	Characteristics	Responsibility allocation*		Boundary conditions/checks the Owner should consider
		Owner	Contractor	
Construct only Charter (for capital and maintenance work)	<ul style="list-style-type: none"> Price variable – per m³/hour Flexible arrangements Less information needed Availability can be defined in the contract 	<ul style="list-style-type: none"> Production risk Quality/outcome risk Risk of quantities Soil conditions Availability equipment 	<ul style="list-style-type: none"> Availability of equipment 	<ul style="list-style-type: none"> Knowledge of what is suitable equipment for the dredging needs Ability to give the right directions Inspection of performance needed
Construct only Remeasurable (for capital and maintenance work)	<ul style="list-style-type: none"> Volumes are measured by in- and out-survey Quantities can be defined in the contract 	<ul style="list-style-type: none"> Risk of quantities Soil conditions Design 	<ul style="list-style-type: none"> Production risk Performance risk 	<ul style="list-style-type: none"> Correction of tender volumes after in-survey
Construct only Lump sum (for capital work)	<ul style="list-style-type: none"> Clear scope required to allow effective pricing Risk for unknowns to be allocated 	<ul style="list-style-type: none"> Scope change/flexibility Lack of flexibility/ability to influence 	<ul style="list-style-type: none"> Production risk Result risk Risk of quantities 	<ul style="list-style-type: none"> Allocation of risk Setting clear scope Design development
Maintenance Performance-based Lump sum	<ul style="list-style-type: none"> Price is higher Result is described and contracted Focus on performing to contract Less flexible 	<ul style="list-style-type: none"> Level of price Lack of flexibility/ability to influence 	<ul style="list-style-type: none"> Production risk Result risks Risk of quantities Soil conditions Risk availability of equipment reduces 	<ul style="list-style-type: none"> Having historical data to calculate the needed volumes to be dredged Ability to control the quality and result (performance)
Design & construct	<ul style="list-style-type: none"> Higher risk on contractor Owner has to clearly define scope Lack of flexibility for owner 	<ul style="list-style-type: none"> Production is as foreseen/expected Sufficiency of preliminary design Soil conditions 	<ul style="list-style-type: none"> Output Quantities Soil conditions Quality Design responsibility/liability Resource availability 	<ul style="list-style-type: none"> Quality of preliminary design Permits/approvals Clear scope of work and/or functional requirements Define design liability
Design & construct +/-EPC	<ul style="list-style-type: none"> Highest risk on contractor Owner has to clearly define scope Lack of flexibility for owner 	<ul style="list-style-type: none"> High cost Definition of scope Lack of ability to influence High cost of changes 	<ul style="list-style-type: none"> Output Quantities Soil conditions Quality Design responsibility/liability Resource availability 	<ul style="list-style-type: none"> Quality of preliminary design Permits/approvals Clear scope of work and/or functional requirements Define design liability

A good market analysis, including an estimation of the equilibrium of demand (for services) and supply (of providers), is very useful in procurement.

TABLE 2

Key aspects and parameters or considerations.

Key Aspects	Parameters/Considerations
A. Project Scope	How fixed or open is the scope of work?
B. Physical/Environmental Site Conditions	How well known are the physical conditions at site?
C. Risk Allocation/Liabilities	What balance of risk do the parties wish to make? Who is best placed to manage risk?
D. Owner's Control/Contractor's Flexibility	How much control does the owner want? How much flexibility to work will the contractor have?
E. Time & Schedule	Is the end date critical or is there flexibility regarding when the works can be completed?
F. Price & Valuation	How much security of price does the owner want?

TABLE 3

A. Project scope	
Sub-category	Remarks/clarifications
(Environmental) Permitting	Final (environmental) permitting can be granted before a tender is issued, or environmental permitting might be made during tendering phase, or even with input by contractor, after project award.
Complexity of project	Complexity of project to be appreciated by owner for contract and procurement type selection, influencing content or project outlining documents and determining pricing and risk assessment by contractor.
Fitness for purpose	Checks to be made by owner if deliverables/products are fit for purpose.
Achievability of the owner's requirements	Owner to verify if requirements indeed can be/are met, contractor to accept during contracting.
Selection of placement site	Selection of placement site to be defined as often restricted by authority regulations, largely affecting pricing of the works.
Design effort needed	Design effort needed to be reflected by party in charge of design development: (consultant on behalf of) owner, (consultant on behalf of) contractor, or jointly.
Design requirements	Design requirements to be unambiguously specified, in principle by owner, but depending on contract type, with input by contractor, especially when cost savings are achievable.
Technical requirements	Achievability of technical requirements to be checked and accepted by contractor.
Measurement of volumes	Method of volume measurement to be specified and adhered to, as basis for acceptance and payment.
Survey requirements	Survey requirements are to be specified, to provide essential data for contract evaluation.
Material supply	Owner's specifications on material supply to be priced, accepted and adhered to by contractor.
Performance/quality of service	Checks to be made by owner if deliverables/products are of required quality.
Quality control	Owner's specifications on quality control procedures to be priced, accepted, and adhered to by contractor.

TABLE 4

B. Physical/environmental site conditions	
Sub-category	Remarks/clarifications
Material to be dredged	Characteristics of material to be dredged are essential for project development options and directly influence contract pricing and risk assessments by contractor. Owner to provide required information, possibly in combined effort with (tendering) contractors. Responsibility for correctness of data to be identified.
Site conditions	Site conditions, influencing design and construction limitations, to be provided by owner. Consequences thereof to be incorporated by contractor in work plans and pricing, with adequate margin for natural or operational variability.
Site information/data quality	Reliability of site information/data quality clearly to be specified by owner, with adaptive procedures if deviations are encountered.

should lead to a balanced decision as to what procurement strategy is employed, how work is divided, and which party can be best suited in controlling and managing risks.

Step 4: Contract type selection

After a work division is decided upon following a risk and reward assessment, the question turns to which type of contract is best suited to allocate the risks and rewards in accordance with the outcome of steps 2 and 3. If the previous steps lead to the conclusion that various project works are combined, this will lead to an integrated contract. In addition, in this phase the risk allocation of the work packages is important. Although the previous steps may result in shifting risks towards a contractor, it may not always be feasible to exclude all risks sought to be shifted away. It will therefore be necessary to consider which party is best equipped to absorb certain types of risk.

Among the important risks are the quantities of material to be dredged, the probability of variance of scope, the physical site conditions, the chemical substance of dredged material, and weather and wave conditions. The ability to ascertain if there is insufficient information may lead to one contract type or another.

General aspects such as permits, a legal framework, stakeholder engagement, financial boundaries, environmental impact, and political pressure might also play a part in the type of contract used. Parties

should, amongst other things, consider the following questions during this step:

- Is it clear what the result of the contract should be (functional, designed, engineered, service provided, needed production capacity of equipment hired, number of hours equipment rented)?
- Is it reasonable and calculable to ask for a lump-sum price or should there be unit rates or a mixture of both?
- What is the right proportion to allocate the risks in terms of money (think of the mentioned aspects of dredged material, survey, weather, tide, permits, etc.)?
- Is the project owner capable of managing the contract and the specified result?

Step 5: Procurement method

If the project is designed and the contract(s) is designed, the way to select a contractor needs to be chosen. For public authorities, in many countries there are public procurement laws that should be complied with. For private clients, it is important also to consider alternative procurement mechanisms. Important questions are:

- Should the contract be awarded only on price or also weighted between price and quality? This depends on whether the owner requires added value and whether a contractor can add value upon the minimum quality defined in the contract and if one is able to measure this added value and verify the promised efforts during the course of the contract.
- Should the number of competitors be limited? What are minimum requirements for subscribers?

- It is also important to consider the number of possible competitors and the complexity of the projects, the contract and the risk allocation standard, and an understanding of whether there should be a dialogue between stakeholders to manage expectations and clarify requirements.
- How much time and dialogue are needed for contractors to understand the contract, to investigate the situation, to calculate their price, and to offer the quality needed? The extent of the time and input needed will be dependent upon a number of factors, which should be allowed for.

Step 6: Procurement process leading to contract award

If the previous choices are made, the procurement strategy is designed, and the user will pass step 6. Thereafter, it will further be important for the project stakeholders to consider the ways to control the execution of the project. There should be a verification mechanism to learn if the contract deliverables are met and the quality is acceptable. Choices are to be made on:

- relying on quality management and certificates of the contractor;
- monitoring systems or mankind control of amounts or constructions;
- independent inspection to be hired.

TABLE 5

C. Risk allocation & liabilities	
Sub-category	Remarks/clarifications
Permitting issues	If permitting issues might be expected during procurement process and/or during execution of works, mechanisms to deal with implications are to be (basically) specified.
Risk allocation/management/ownership	Owner to specify and contractor to accept how project and process risks will be managed and who has ultimate ownership of implications thereof.
Risk compared against project value	Owner to assess project value in relation to project risks, in evaluation of overall project feasibility.
Impact on third parties/unavoidable consequence of the execution of the works	Owner to specify how to handle project impacts/process impacts, identifying task of contractor in monitoring and mitigation procedures.
Losses of material during beach nourishment	With open reclamation sites (beach nourishment projects), fill losses are to be foreseen and to be priced by contractor. Adequate frequency and method of volume determination for partial/sectional handover will reduce risk and price for both owner and contractor.
Scope variations	Effects of scope variations to be foreseen in contract, potentially influencing design and execution.
Equipment/vessel availability	Availability by (tendering) contractor(s) are welcomed by owner, it needs to be specified which freedom is accepted and how variations to original will be valued.
Innovative design	If innovative designs by (tendering) contractor(s) are welcomed by owner, it needs to be specified which freedom is accepted and how variations to original will be valued.
Dealing with innovations	When innovations are introduced during design and/or construction process, improving project quality or reducing project cost, benefit sharing mechanisms between owner and contractor shall be foreseen in contract documents.
Information required by owner from contractor – pre-contract and during contract	Owner may require extensive information from contractor during tendering and negotiations process and during execution of the works. It is instrumental that these requirements are clearly identified from onset of tendering.
Form of dispute resolution	Procedures on dispute resolution are to be specified in contract.
Suspension of work	Implications of suspension of works to be fixed in contract and to be administered during project execution and closing.
Force majeure	Consequence of force majeure to be foreseen in contract.
Defect liability	Liabilities for defects to be identified in contract.
Design liability	Liabilities for design faults to be identified in contract.
Liability for consequential losses	Liabilities for consequential losses to be identified in contract.
Delay damages	Liabilities for delay damaged to be identified in contract.

Within each key aspect, several sub-aspects have been identified that are of importance during various stages of a project and that need to be considered in assessing the scores for the key aspects.

TABLE 6

D. Owner's control/contractor's flexibility	
Sub-category	Remarks/clarifications
Freedom of execution/opportunities for innovation	In case new developments are welcomed, mechanisms to handle these are to be addressed in contract documents and work plans.
Equipment/vessel selection	Contractor requested to identify equipment (intended) to be used.
Flexibility in dealing with unforeseen circumstances/ variations/risk/events/change	Flexibility to control deviation from original specifications to be tailored in contract documents and work plans
Managing interfaces	Owner to identify who best can/has to/will handle each project interface, possibly in consultation with contractor.
Contract management/administration	Management and administration requirements to be specified by owner and to be fixed during final procurement.

TABLE 7

E. Time & schedule	
Sub-category	Remarks/clarifications
Programme/schedule/ milestones	Owner is to set milestones for project from start to finish. Realistic timing with ample float for natural variations and some unforeseen events will reduce tender price and risks for both owner and contractor.
Tendering time	Adequate time for tendering is to be foreseen, depending on tender requirements. Extension of tendering time, if needed, cannot shift construction period to unfavourable seasons without cost and time implications.

FIGURE 3

There are contract types where the Owner should consider having knowledge of equipment's suitability for the dredging needs.



Users can quantify the various key aspects based on their specific and project requirements.

TABLE 8

F. Price & valuation	
Sub-category	Remarks/clarifications
Attractiveness to tenderers/supply chain	Owner to put project on the market in a way which is attractive to potential bidders for works and for supplies.
Tender costs	Owner to indicate in tender documents whether, and to what extent, tender costs will be reimbursed to non-successful tenderers.
Price/costing certainty	Owner will aim for reliable pricing by (tendering) contractor(s) with adequate securities against uncontrolled cost overruns and non-performances
Cost/time overruns	Mechanisms to handle cost and/or time overruns are to be specified in contract.
Stand-by/demurrage	Procedures whether and how stand-by times and demurrage will be handled at end of project to be specified in contract documents.
Funding	Owner to assure proper funding when initiating project and when closing project.
Market conditions	Owner to consider market conditions in its final project investment decisions and in contract award.
Payment and securities	Contractor will aim for reliable and secure payment by owner against (partial) handover certificates.
Tax	Regulations on taxes to be informed by owner to contractor, next to contractor taking care of his own obligations.
Insurance	Owner to clearly specify which insurances he has taken out and which insurances are to be taken by contractor.
Currency exchange rate and fluctuations	Procedures regarding whether and how payments in different currencies will be handled to be specified in contract documents.



Key Aspects

When assessing the most suitable procurement method/contracting type, CEDA considers the matter to comprise certain 'key aspects', being general categories of consideration of significant importance, which can be appraised or 'scored' in determining the optimum method.

The selection of key aspects is specific to individual projects and users, but for guidance, six key aspects represent common influential factors to a party awarding a contract. These can be found in Table 2.

Within each key aspect, several sub-aspects have been identified that are of importance during various stages of a project and that need to be considered in assessing the scores for the key aspects. Although many sub-aspects are of relevance in many more stages than indicated, they are primarily related to the marked stages – either governing decisions to be made by the contractor awardee or affecting actions by the (tendering) contractor(s), even those influencing the owner's interests. The users can utilise, amend, or prioritise the

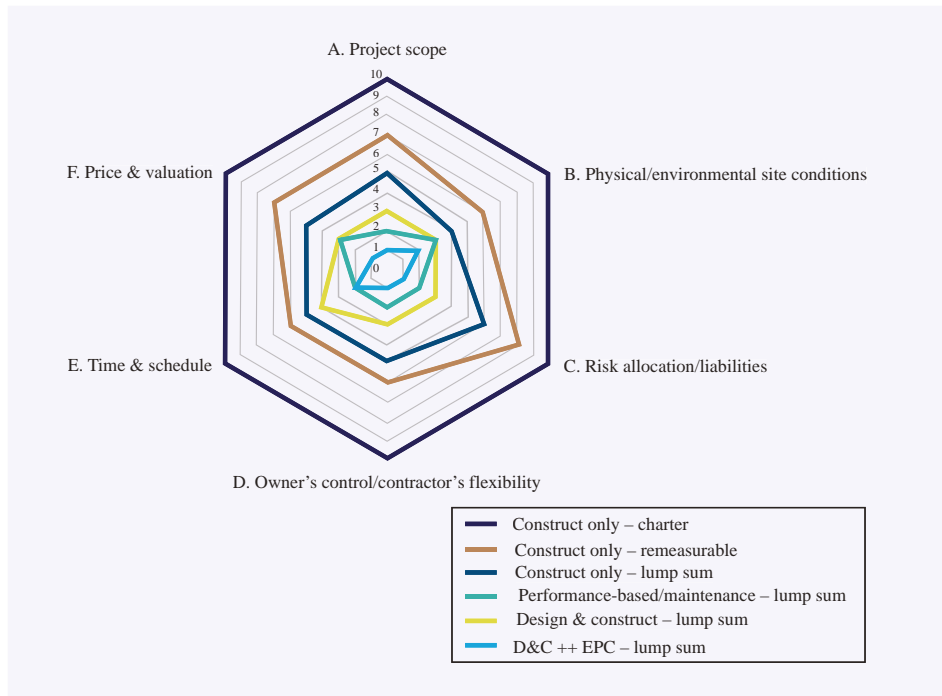


FIGURE 4

In this 'Visualisation of Owner's Uncertainty', the higher value indicates increased uncertainty.

TABLE 9

Key aspects	Qualification – uncertainty for owner to be assessed within upper and lower end of range		Standard/typical types					
	Lower end (score = 1)	Upper end (score = 10)	Construct only – charter	Construct only – remeasurable	Construct only – lump sum	Performance based / maintenance – lump sum	Design & construct – lump sum	D&C++/EPC – lump sum
A. Project scope	Fully fixed	Very open/uncertain	10	7	5	2	3	1
B. Physical/environmental site conditions	Fully explored	Very uncertain	10	6	4	3	3	2
C. Risk allocation/liabilities	Risks and liabilities with contractor	Risks and liabilities with owner	10	8	6	2	3	1
D. Owner's control/contractor's flexibility	Contractor freedom to operate	Owner in control	10	6	5	2	3	1
E. Time & schedule	Strict time frame	Flexible time frame	10	6	5	2	4	2
F. Price & valuation	Fully fixed	Remeasurable based on rates	10	7	5	3	3	1

sub-aspects, giving relevant weight in 'scoring' these items. The key aspects and their sub-categories are found in Tables 3-8.

For example, for key aspect 'project scope', the first listed sub-aspect is the '(environmental) permitting'. The user may wish to consider how much of the permitting process has been completed, how many permits are secured at the start of the procurement process, and what implications will the permitting conditions have on the project scope. An assessment of this sub-aspect, if included, can be made by the user and appropriate weighting applied.

The remarks/clarifications on the right side of the table provide (limited) information on why and how the specific sub-aspect might influence procurement and contract type selection, and possibly indicate directions on how the user can prepare a suitable procurement process.

The scoring matrix

Introduction

The principle of the method developed by CEDA in advising the procurement route/contract type selection is the 'scoring' and subsequent comparison of the six key aspects set out in Tables 3-8. For each of the key aspects, a relative 'score', ranging from 1 to 10, can be assessed and applied. This scoring range can relate to either the amount of

variability/fixity the user can accept, based on matters such as the ability to manage and control risk, or the level of knowledge/certainty of a specific key aspect.

In assessing the score for each key aspect, the user can choose to utilise or develop its own sub-aspects and to weight the importance of each of these sub-aspects within each key aspect. For example, for key aspect 1 – project scope, CEDA has identified 13 subcategories.

The user may consider these are all relevant or may wish to remove some or add others. In addition, the user may then wish to place more importance on half of the sub-aspects and can carry out objective scoring on that basis.

Each of the six 'scored' key aspects can then be plotted against other, standardised results, providing valuable insight, advice, and guidance to inform the user on what the optimum contract type may be for any particular project.

Standard Scoring Charts

Six standard types of contract model are addressed including:

- Construct only – Charter;
- Construct only – Remeasurable;
- Construct only – Lump sum;
- Maintenance – Performance-based – Lump sum;

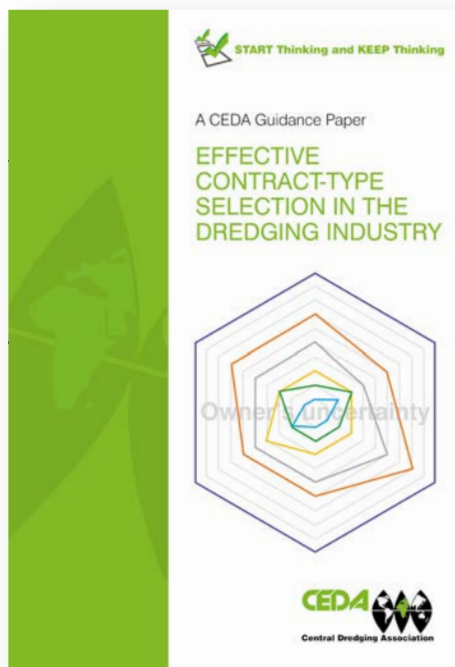
- Design & construct – Lump sum;
- D&C+/EPC – Lump sum.

For each contract type noted, typical scores against each of the key aspects are found in Table 9.

This plotting of the key aspect scores graphically illustrates the differences between the contract requirements/parameters in question against the six standard contract types listed in Table 9. The farther away from the centre of the chart, the higher the uncertainty/variability of the key aspect for the user.

As an example: lump sum contracts (should have) greater fixity of outturn cost than a remeasurable or charter/hire form of contract. Accordingly, for the 'price & valuation' key aspect, this scores highly for 'Construct only – Charter' and low for lump sum forms of contract (see Figure 4).

This approach can be utilised by a user wishing to carry out a comparative assessment. It can also be used to illustrate the basis of a decision on the type of contract that may be appropriate for the project to be procured, which can be presented or used accordingly internally within the user's organisation.



By using this guidance, a party selecting and procuring contracts can extract and utilise any or all of the different sections to provide points of consideration when making such a selection.

TABLE 10

Key aspects	Qualification – uncertainty for owner to be assessed within upper and lower end of range		Sample score compared against standardised scores						
	Lower end (score = 1)	Upper end (score = 10)	Sample Score	Construct only – charter	Construct only – remeasurable	Construct only – lump sum	Performance based / maintenance – lump sum	Design & construct – lump sum	D&C+ / EPC – lump sum
A. Project scope	Fully fixed	Very open/uncertain	5	0.50	0.71	1.00	2.50	1.67	5.00
B. Physical/environmental site conditions	Fully explored	Very uncertain	7	0.70	1.17	1.75	2.33	2.33	3.50
C. Risk allocation/liabilities	Risks and liabilities with contractor	Risks and liabilities with owner	10	1.00	1.25	1.67	5.00	3.33	10.00
D. Owner's control/contractor's flexibility	Contractor freedom to operate	Owner in control	10	1.00	1.67	2.00	5.00	3.33	10.00
E. Time & schedule	Strict time frame	Flexible time frame	5	0.50	0.83	1.00	2.50	1.25	2.50
F. Price & valuation	Fully fixed	Remeasurable based on rates	5	0.50	0.71	1.00	1.67	1.67	5.00
			Score	0.60	0.91	1.20	2.71	1.94	5.14
			Delta from unity	0.40	0.09	-0.20	-1.71	-0.94	-4.14

Example: utilisation of the scoring method

Against this standard table, users can apply and compare their own assessed key aspect 'scores'. This comparison can be made either to the standardised scores in the table or using the radar charts.

These sample scores can then be compared, on a proportional basis, against the standardised scoring for each key aspect and each standard contract type. This comparison is represented by way of variance, as a factor, from each of the standardised scores for each specific item.

(dashed line) closely to 'Construct only – Remeasurable' (the orange line) based on the summation of each proportional scoring assessment. This scoring method provides valuable assistance to the user when making an informed decision on the contract mechanism to be adopted.

It can be seen that the smallest delta relates to Construction Only - Lump Sum.

The sum of the variances between the sample project and the standardised scores can then be made. The closer the sum total for each standard contract type is to the value of 1, the closer the sample is aligned to that standard contract type overall (see Table 10).

It can be seen that the smallest delta relates to Construction Only – Lump Sum. The resulting project requirement profile, shown in Figure 5 as the orange dashed line, can be compared against the standard contract type profiles visually.

In the case of the example provided, the user's sample project scores (red

Conclusions

By taking into account and giving careful consideration to all salient matters relating to the delivery of a project, a procuring party can optimise the contractual model used. This can have the advantage of selecting a model that is most suited to both the procuring party's specific requirements and those of the project itself. This can allow flexibility for the user to manage contractual risks and opportunities and to suitably assist in allocating such management in the most appropriate manner.

In considering the procurement flowchart included in stage 1, users can compare this model process with their own internal procurement and contract selection

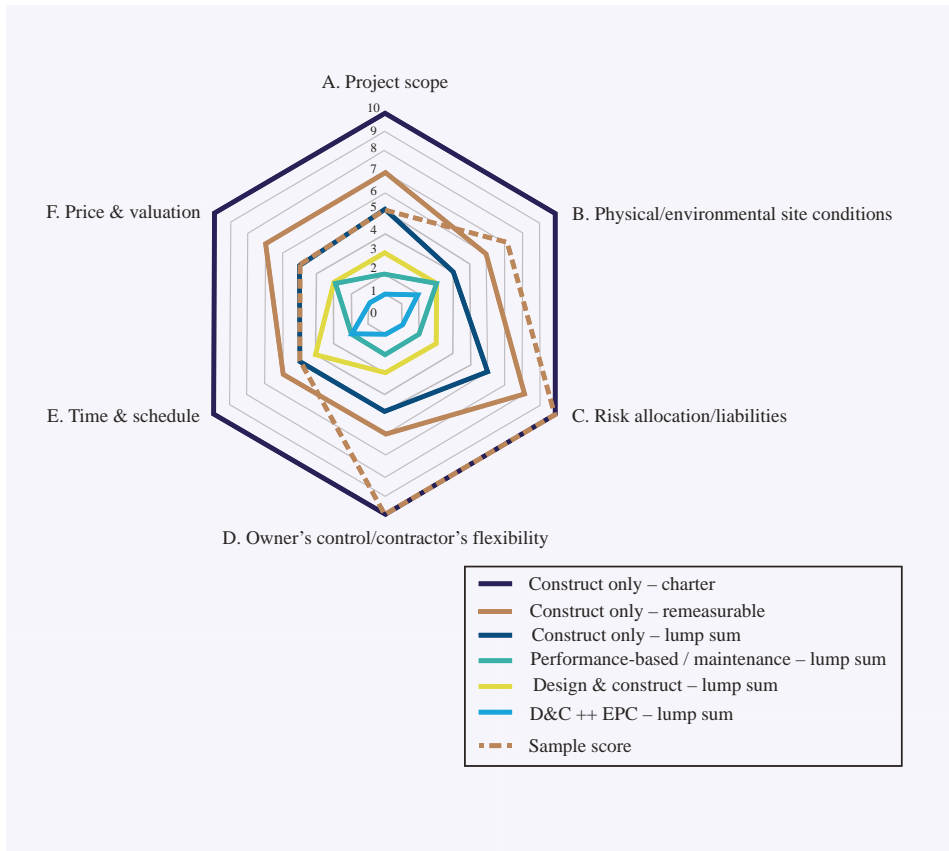


FIGURE 5

In this 'Visualisation of Owner's Uncertainty', where the higher value indicates increased uncertainty, it can be seen that the smallest delta relates to Construction Only – Lump Sum. The resulting project requirement profile, shown below as the red dashed line, can be compared against the standard contract type profiles visually.

processes and procedures. From this, users may adjust, amend, or otherwise update their processes as may be deemed appropriate.

Stage 2 allows users to look at, consider, and appraise their own specific project and contract key aspects. These are based upon the six listed key aspects which include numerous sub-categories (which will be of greater or lesser relevance to individual users) and can be taken into account when determining the most appropriate contracting route.

Finally, users can quantify the various key aspects based on their specific and project requirements. This quantification can be directly compared with the standard contract type scores. This can provide helpful, visual assistance in considering the optimum contracting route, along with the ability to calculate the level of overall parity between a specific project and the standard profiles explained.

By using this guidance, a party selecting and procuring contracts can extract and utilise any or all of the different sections to provide points of consideration when making such a selection. In this way, CEDA hopes to have provided a means by which dredging contracts can be further optimised and delivery efficiency can be improved.

Summary

This paper has been prepared by the Central Dredging Association (CEDA) Working Group on Effective Contract Type Selection (WGECS). The Working Group was initiated by the CEDA Dredging Management Commission (DMC).

The WGECS was established by the DMC to follow on from and complement its Checklist for Successful Dredging Management (CEDA, 2017). This checklist has been produced by a group of industry experts with various backgrounds, perspectives, and a broad range of expertise and experience with dredging projects. It presents a number of topics and subtopics that may give rise to problems/issues in the different stages of a (dredging) project. The first edition of this checklist is currently freely available for download from the CEDA website to all CEDA members (www.dredging.org).

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This paper has been prepared by the Central Dredging Association (CEDA) Working Group on Effective Contract Type Selection (WGECS).



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NATURE-BASED SOLUTIONS:

CHALLENGE OR OPPORTUNITY?

Nature-based solutions are actions to protect, sustainably manage, and restore natural or modified ecosystems.

The European Dredging Association (EuDA) participated in a Horizon 2020 project sponsored by the European Union. The project named ThinkNature had as objective to promote the application of nature-based solutions (NBS). NBS have obvious advantages but have not been embraced at wider scale. In this article, the authors reflect as to why NBS are not mainstream solutions, why it is necessary to promote the concept and whether there are barriers that hinder wide-scale application. In this article the authors describe how relevant the topic is to the dredging community.

What are nature-based solutions?

The concept of nature-based solutions (NBS) is relatively recent. It has emerged during discussions at the United Nations Framework Convention on Climate Change (UNFCCC) in 2009. This concept has the advantage of encompassing a broad range of diverse approaches and is thus convenient for promotional purposes. Nevertheless, a definition is needed for practical use.

The International Union for Conservation of Nature (IUCN) has proposed a useful definition:

Nature-based solutions are actions to protect, sustainably manage, and restore natural or modified ecosystems. NBS address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.

The IUCN also clarified that: *NBS are designed to address major societal challenges, such as food security, climate change, water security, human health, disaster risk, social and economic development.*

It is clear that IUCN considers NBS as a very wide-ranging concept that should play a role in solving humanity's main challenges. In order to make it more operational, the concept needs more focus and further refinement. To this end, the European Commission (EC, 2015) refers

to nature-based solutions as sustainable responses to specific societal challenges:

- solutions that are inspired and supported by nature,
- which are cost-effective,
- simultaneously provide environmental, social and economic benefits and,
- help build resilience.

Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.

Even with this more explicit description, the concept of NBS still remains very broad covering a wide variety of ecological approaches and ecosystem-based disciplines. In other words, NBS can be viewed as an umbrella concept that covers more common terminology such as conservation, restoration, mitigation, adaptation or more familiar approaches such as building with nature, ecological engineering and so forth.

Table 1 illustrates this large scope. It should be noted that there is considerable overlap between the various categories or approaches.

TABLE 1

An overview of possible categories of NBS and examples of each category.

Categories of nature-based approaches	Examples
Ecosystem restoration approaches	Ecological restoration Ecological engineering Forest landscape restoration
Issue-specific ecosystem-related approaches	Ecosystem-based adaptation Ecosystem-based mitigation Climate adaptation services Ecosystem-based disaster risk reduction
Infrastructure-related approaches	Green infrastructure Building with nature Engineering with nature

The ThinkNature project

In view of the large number of possible approaches, the TN project took a pragmatic start by listing good examples. They made an inventory of case studies that are thought to be representative of NBS and compiled them in a data bank OPPLA which is publicly available (<https://platform.think-nature.eu>).

Next, the project reviewed the conditions for wider application of NBS type projects. This resulted in an overview of barriers and benefits of these NBS projects. While the benefits of nature-based approaches may be apparent, they are not yet well known by the public at large. Moreover, several institutional barriers related to financing, procurement practices and organisational structures slow down wide-scale introduction of innovative solutions, including NBS.

A further step in the analysis considered more specifically the type of problems for which a nature-based solution would be required.

The prime examples of such problems are found in the consequences of climate change (temperature, precipitation, drought and sea level rise) and the disasters they may cause. 'Green' projects can form building blocks for climate change adaptation.

In the current OPPLA data base some 80% of the reference cases relate to urban situations. As representatives of the dredging sector participating in the project, the authors pointed out that besides solving urban problems, the NBS concept can be meaningfully applied to broader fields. There is a huge potential for instance to use 'green' or 'blue' civil infrastructure to combat risks of flooding and natural disasters.

The authors proposed a framework as shown in Table 2, which clearly differentiates the various NBS approaches used in urban environments, rural landscapes, river catchments and for coastal protection. Two cases – in Seoul and West Africa – illustrate this.

Via this framework, it becomes evident that the dredging sector can tackle many problems or threats in river and/or coastal environments by implementing NBS. It is therefore important to articulate the major role that dredging and marine contracting can play in this context.

So, why have NBS not been embraced at wider scale? Why is it necessary to promote the concept? Are there barriers that hinder wide-scale application?

The ThinkNature project explored these issues. Hereafter, the article discusses the major aspects that distinguish NBS from more traditional approaches. A more exhaustive coverage of these topics may be found in the ThinkNature Handbook (ThinkNature, 2019).

Wide range of ecosystem benefits

Variability

As explained with Table 2 above, Nature-based Solutions (NBS) necessarily build on natural processes and functions, both of biological and

TABLE 2

Framework for NBS applications.

I. Pressures/issues	II. Drivers/catalysts	III. Relevant ecosystem process	IV. Typical NBS responses
Urban environments Heat islands Pluvial flooding Shortage fresh water Air pollution peaks	Temperature rise Precipitation increase Droughts (Air) Emissions	Air filtration Evaporation Water infiltration Phytoremediation Energy flows Bioretention water	Green roofs Rain gardens Create green spaces Urban forestry Swales for infiltration Room for water retention De-culverting urban streams
Rural landscapes Soil degradation Invasive species Pesticides Poor fauna and flora	Droughts Biodiversity loss Poor agricultural practices	Phytoremediation Water management Bio-diversification Pollination Nutrient cycling	(Re)constructed wetlands Crop diversity modes Restore landscape diversity Re-forestation Water retention Eco-agriculture
River catchments Fluvial flooding Shallow waters Water quality	Precipitation increase Drought periods Chemical pollution	Hydro-morphology Floodplain function Water management Flows (water, sediment) Buffering	Restore floodplains Re-connect oxbows Water retention capacity Flow capacity Natural river banks and riparian zones
Coastal zones Increased erosion Coastal flooding Wave attack Sediment shortage Urbanisation	Sea level increase Storm intensity Wave energy	Sediment transport Energy dissipation Hydrodynamics Bioturbation Carbon cycling	Restore natural sea defences (sandy, mangrove, marsh, etc.) Stimulate natural defences (sediment supply, barriers, etc.) Combinations of soft and hard defences Management strategies

Two Examples

Seoul

Problem/causes: A densely built-up city experiences negative effects such as heat islands (I) during high temperature (II) periods.

Processes and NBS: Providing open space in a city section could be combined with a process of evaporation (III). A river flows through the town, but has been covered since many years (poor smells!). The water quality of the river has improved over the years and there is the possibility to re-open the river and develop river banks inside the city by de-culverting (IV).

Results: The effect will be to lower the temperature during a hot spell (water temperature lower, evaporation), and by developing the banks as green space there are multiple benefits for nature and for the population. The example of Seoul that can be found in the data base illustrates this solution very well.

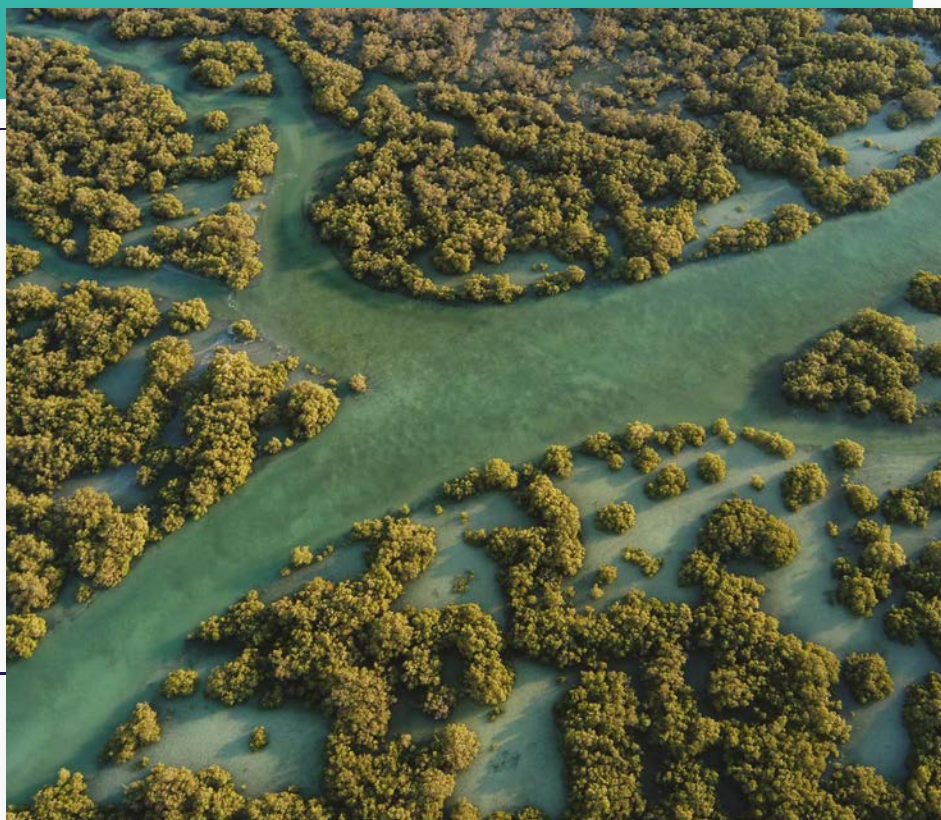
Mangroves in West Africa

Problem: In a West African country a long period of drought (II) has caused the death and destruction of a mangrove forest in brackish water causing poor flora (I). The local population has lost a significant source of income (e.g., firewood, shrimps culture, medicinal plants); also the groundwater is now subject to siltation because the barrier provided by mangrove roots is no longer there.

Processes and NBS: Once the period of drought is over, support to the local population to replant the mangroves for buffering (III) is an effective NBS leading to restoration (IV).

Results: The local economy will be re-established, the local society is stabilised and the benefits of this ecosystem materialise again. Wider ecosystem benefits include also the positive effects for the carbon balance, since mangroves form important carbon sinks.

The local economy will be re-established, the local society is stabilised and the benefits of this ecosystem materialise again.



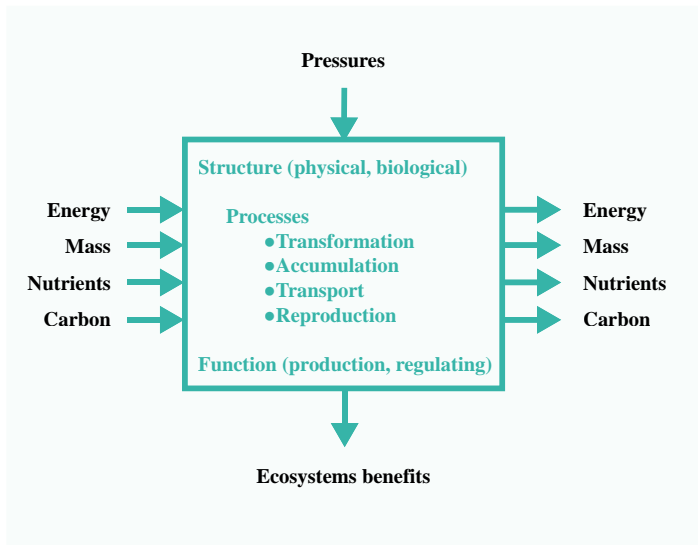


FIGURE 1
Ecosystem schematic.

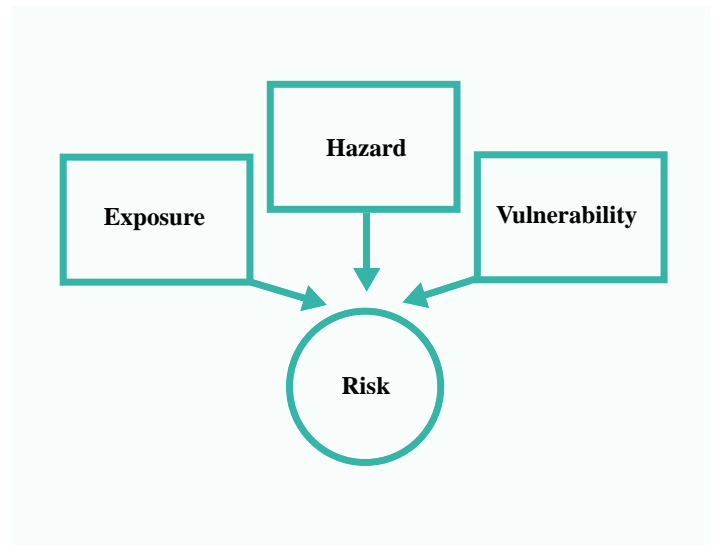


FIGURE 2
Risk illustrated.

of physical nature. This observation points immediately to the first difficulty experienced when implementing NBS: the evolution of natural systems can be influenced by human action to some extent, but there remains always an element of uncertainty and limited predictability. The limits of predictability and knowledge represent the first significant barrier to the acceptance of NBS. Project proposals encounter scepticism, simply because the outcome of the projects cannot be guaranteed in the same manner as for traditional grey infrastructure projects.

Ecosystems as cornerstone

Ecosystems form the building blocks of NBS. The majority of NBS involve the creation or restoration of ecosystems. This category of solutions is commonly referred to as ecosystem-based approaches. It is therefore relevant to recall some propensities of ecosystems.

An ecosystem is defined as a biologically qualified open system formed by a dynamic complex of living organisms within a well-defined boundary where the organisms interact with each other and with their a-biotic environment.

Note the importance of ecosystems as open systems; this implies that energy and mass exchange with the surrounding environment

takes place and as a consequence the system can evolve towards higher levels of biodiversity; they usually have the capacity to recover from disturbances (resilience).

Within the ecosystem one can further distinguish several aspects or attributes:

- **Ecosystem structure** refers to the internal organisation of the ecosystem and the relationship between its various elements (habitats, species populations, etc). It is helpful to differentiate between the a-biotic structure (type of substrate, special habitats) and the biological structure (the interaction between biotic elements and the a-biotic substrate).
- **Ecosystem processes** are any changes or reactions, physical, chemical or biological, that occur within the system and which influence the flows, storage and transformation of materials and energy. These processes connect also the trophic levels via food chains. Processes include production and reproduction, decomposition and purification.
- **Ecosystem functions** are the outcome of physical, chemical and biological activities that uphold the stability and biodiversity of the ecosystem. They may be seen as the result of the interaction between structure and processes. Here one distinguishes between production functions (food, raw materials, etc) and the regulating functions

(nitrogen, carbon and phosphorus cycling; see Figure 1).

Ecosystem benefits

Healthy functioning ecosystems provide benefits for nature and for mankind. In the Millennium Assessment (2005) these benefits have been called ecosystem services and have been classified as provisioning, regulating, cultural and supporting services, but other classifications are possible. Besides, the terminology 'ecosystem services' has not been uniformly accepted. (R.Gunton, 2017; S.Diaz, 2018). Therefore, in this article the general term 'ecosystem benefits' is used in accordance with the definition of NBS suggested by the European Commission. A distinction is made between environmental, social and economic benefits.

Benefits are by definition 'beneficial', so what is the problem? The main issue with environmental, social and economic benefits is the differences in valuation: not all environmental and social aspects can be quantified, some need qualitative evaluations which cannot always be meaningfully compared with other quantified variables. This may lead to a lack of mutual understanding and endless discussions between stakeholders.

Moreover, ecosystems provide a variety of benefits, but for different categories of

beneficiaries or stakeholders (private versus public, local versus generalised, short term versus long term). This may create additional complications for the correct assessment of investment costs and for valuation and allocation of future benefits. This is especially an issue for private investors. More on this under 'Valuation' below.

Risk and Resilience

Many of the problems listed in the first column of Table 2 could result in disastrous consequences. A natural phenomenon is a physical process such as an earthquake, storm, flood and so forth while a natural hazard is the occurrence of a natural phenomenon in or near a populated area. A natural disaster occurs when a natural hazard leads to financial, environmental and/or human losses.

The probability of catastrophes occurring increases as the climate continues to change. For example, the probability of fluvial flooding due to more intense precipitation is increasing. Measures should then be taken in river basins to mitigate the effects of high water. Clearly the consequences of the flooding of a large city are disastrous and can be very costly (in terms of human lives and economic assets). But in order to plan for appropriate measures in the river catchment and to justify investments, it is necessary to get a better handle on the quantification of risks.

Risk

Risk can be seen as the probability to experience serious losses (disaster). This is a concept used by the insurance industry. This risk concept can be further refined as 'the probability that a hazard results in severe consequences'. Or, in a formula: (Risk) = (Probability of hazard) x (Vulnerability of defences) x (Exposure to hazard effects). (see Figure 2).

In fact, disasters occur when hazards meet vulnerability: the resulting loss depends on the vulnerability of the affected population or its incapability to resist the hazard.

In other words, there are three dimensions to risk. While we may have little or no influence on the hazard to occur (flood rains, seismic event, hurricane, etc), humans have increased the frequency of the hazards linked to



FIGURE 3

Hondsbosche Dunes. Photo Ecoshape

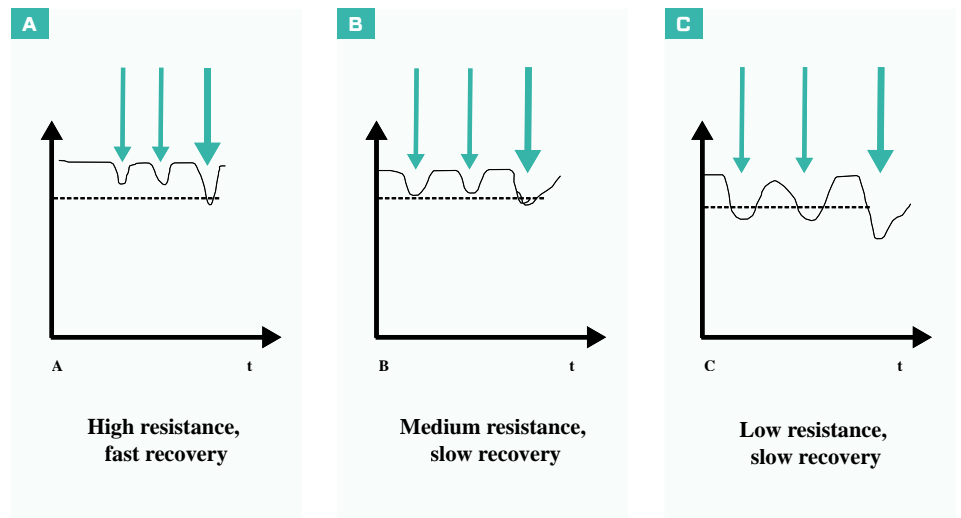


FIGURE 4

A schematic depiction of ecosystem resilience. High resistance with fast recovery (A), medium resistance with slow recovery (B) and low resistance with slow recovery (C).

Coastal protection can form a variety of combinations of soft and hard structures, of grey and green approaches.

climate change. Human actions can also influence the risk by reducing the vulnerability (strengthening defences) and/or by limiting exposure to hazards. Vulnerability is the trickier element of the three. Vulnerability is generally described as 'predisposition for damage and/or loss', but in the context of risk it must be applied strictly to the effectiveness of defences against extreme events.

Example of risk reduction in the case of river flooding:

- one can reduce vulnerability by building hard or soft flood defences, restoring flood plains, create more buffer capacity;
- one can reduce exposure by taking specific measures such as construction of houses in the floodplain on elevated piles to avoid damage.

From this example it is evident that NBS can play a significant role in reducing vulnerability and thus risk. In river basins many nature-based measures can be taken upstream in order to reduce the flood levels downstream near a city. Along coastlines threatened by severe storms or extreme tides, natural defences can be strengthened or enhanced, again in view of reducing vulnerability and thus overall risk. But nature-based solutions have no direct results for exposure. A thorough discussion of these issues is provided in a

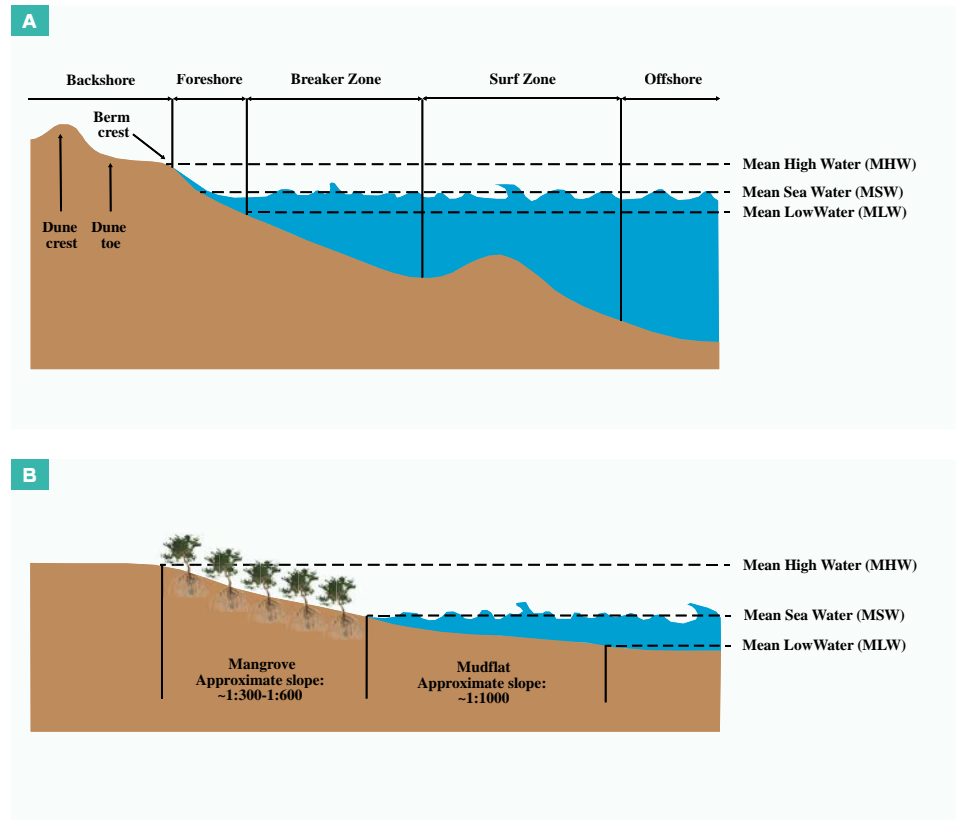


FIGURE 5 Natural coastal defence systems in a sandy beach system [A] and mangrove system [B].

TABLE 3

Coastal defences possible options.

	Hard (grey)	Natural defences	Nature-based
Primary defence	Structures Seawalls Dykes Revetments Rock walls Barriers	Dunes Mangroves Saltmarsh Cliffs Rocks	Dune reconstruction Re-growing mangroves Development saltmarsh
Supporting structure	Breakwater Groynes Artificial reefs Rock structures	Sandbanks Barrier islands Sandy beaches Pebble beach Mangroves Wetlands Reefs/Coral reef Seagrass	Beach nourishment Sand Engine Building barrier islands Hardening sandbanks Intro bio-engineers Re-grow coral reefs Seagrass beds/kelp dvpt. Eco-friendly substrate

publication by the IPCC (International Panel on Climate Change), (IPCC, 2012).

An excellent example of reducing vulnerability by natural means is provided by the Dutch sea defence 'Hondsbossche Dunes'. The existing dike needed strengthening because of sea level rise, which forms a potential hazard. Rather than building more grey infrastructure (higher dike), the natural dynamics that existed locally centuries ago were restored by providing sand from the sea. The sand was used to rebuild dunes and nourish the foreshore. In this manner the natural dynamics of a sandy coastal defence system were restored and the vulnerability is reduced.

Resilience

When grey infrastructure is built to protect against extreme events (e.g., flooding), there are basically two outcomes: the structure holds or it fails. Nature-based features are different, they may resist the attack or they may degrade, but even in case of severe disturbance there is the potential to protect partly or to recover from the damage. This characteristic is called resilience.

Resilience of ecosystem functions is the capacity for these functions to resist and recover from disturbances. Ecosystems are dynamic systems that tend to return to an equilibrium state following events that upset its equilibrium. This propensity has its limits; when the disturbance as a consequence of hazardous events is too important, tipping points may be reached that result in the system functioning at a different (but less productive) equilibrium level.

The opposite of resilience is the vulnerability of the system. For NBS as the defence against extreme events, one would hope to find ecosystems with high resistance and reasonable recovery rates. The features of ecosystems that enhance its resilience include a high degree of biodiversity, a rich variety in species, functional redundancy, and connectivity to nearby ecosystems (Oliver, 2015, Linkov, 2014, Ulanowicz, 1997). For ecosystems where physical processes are dominant, such as for the coastal system of sandbanks or barrier islands, beaches and dunes-, the interaction between the a-biotic elements of the system is also an important parameter. Figure 4 illustrates the concept of resilience.

TABLE 4

Mangrove benefits.

Planting/re-developing Coastal Mangrove Forest for coastal protection Environmental/ecologic benefits	Expected ecosystem benefits (mainly long term) Erosion protection, barrier against saline intrusion, enhanced biodiversity, carbon sequestration, water purification
Social benefits	Support local community ('commons'), social cohesion, (bird watching, tourism)
Economic benefits	Fish nursery, seafood production, honey production, construction material, substances for medicines, reduced flooding risk

Nature-based solutions in coastal defence

Coastal protection can form a variety of combinations of soft and hard structures, of grey and green approaches. In practice one will often encounter such hybrid solutions. Since these hybrid approaches include nature-based features, they qualify as NBS, even if not all the features are eco-engineered.

For natural systems the coastal defence function is primarily based on the healthy functioning of the a-biotic elements in the ecosystem and supported by the biotic processes. The functional challenges are: how to deal with the incoming (wave) energy, with erosion phenomena and with the threat of flooding from high sea levels or extreme events. One should distinguish between the primary defence function or structure that protects against floods and the supporting structures that deal more specifically with wave energy and erosion. In many cases there are two different supporting structures. Well known examples in nature are provided by a system of dunes, sandy beaches and barrier islands, or by the combinations of mangroves, wetlands and muddy foreshore. (see Figure 5).

The following categories are distinguished:

- Natural and nature-based defences;
- Hybrid systems. The hybrid systems respect the dynamics of natural processes

and resist the pressures on the coastline by combinations of green and grey elements;

- Hard engineered structures.

These different classes of systems and structures can be allocated to the primary and the supporting structures to form the coastal defence. The author's observations in this section have benefited from the paper by (Van der Nat, 2016).

The possibilities are listed more explicitly in Table 3.

While the difference between natural defences and hard engineered structures is clear, for hybrid systems some clarification is necessary. Both combinations of grey primary defence plus NBS supporting structures and NBS primary defence plus grey supporting structures form hybrid solutions. In both these categories NBS are part of the defences and the overall system solution should qualify as nature-based.

Valuation

For NBS to be considered as realistic candidates for projects, one needs to leave the comfort zone of business-as-usual. The costs of an investment in NBS will have to be justified, but in non-traditional manners. In this section several of the issues at stake are highlighted.

The provision of nature-based sustainable infrastructure requires business models that involve long-term exchange-value creation. A business case must be developed that is both comprehensive and convincing.

For traditional grey infrastructure a cost-benefit analysis (CBA) is developed at this stage which considers mainly the upfront investment costs. For the case of NBS, there are other important factors that need to be taken into account:

- firstly, total life-cycle costs, including the build-operate-maintain-decommission phases, must be assessed; while upfront investment for NBS projects may be higher than for traditional infrastructure, the maintenance costs over the life cycle are likely to be lower;
- as referred to above, NBS life cycle evolution is not predictable in the same way as for grey infrastructure; there remain elements of uncertainty in predicting the dynamics of the project over time. In a cost-benefit context this means a negative evaluation for lack of guarantees;
- the total suite of expected benefits must be valued and these benefits are typically much broader than for the traditional case; when ecosystems are at the heart of the NBS, they will bring a range of benefits that can conveniently be split up into environmental, social and economic benefits; (see separate Box to appreciate the wide range of benefits associated with replanting coastal mangroves);
- with regard to direct economic benefits the valuation should not be an issue, as they are calculated and expressed in monetary value; there may also be long term economic benefits that will materialise only over time; there is uncertainty in estimating and quantifying the latter, and then there is the question if and how expected benefits should be discounted;
- for expected social benefits (cohesion of society, room for recreation, aesthetic enjoyment, etc) the question is: how should these be valued? Shadow pricing is hardly a credible proposition and, in any case, does not capture the real added value for society; nevertheless, they must somehow be accounted for in the business case;
- similarly, for environmental benefits (carbon capture, contribution to biodiversity, air purification, etc) shadow pricing will likely lead to disagreements (What is the cost

of 1 tonne of CO₂?) and thus uncertainty for the business case; estimating environmental benefits is important, but the valuation in monetary terms is questionable: it provides little indication on the quality improvement of the environment and the positive impact on society;

- as mentioned already, a further complication is that many of the benefits may not be of interest to the investor, but accrue somehow to the local population or neighbourhood; should third parties be invited to become partners in the NBS project, to share some of the risks and to co-invest in exchange of their share of social or environmental benefits?
- for those NBS projects playing a critical role in reducing the risks of extreme events (fluvial flooding, coastal threats, etc), the vulnerability of the landscape needs to be quantified somehow, in order to develop an estimate of reduced vulnerability due to and avoided damage costs thanks to the project; this needs to be assessed as it should translate in lower insurance costs.

Through a number of workshops and conferences, The ThinkNature project led a reflection on these issues, but this has not yet provided final answers. It should nevertheless be pointed out that one possible approach is to compare the three alternative scenarios: NBS, grey infra or 'do nothing'. On that basis the advantages of NBS can be shown, even if no complete monetary valuation can be made.

One thing is clear: the classic cost-benefit analysis cannot be applied as such to NBS. New business models, other governance models and different decision-making rules are required to support the development, and the valuation of NBS projects.

It may also be apparent that large scale NBS projects lend themselves better to financing from public sources than by private investors. Nevertheless, even in the public sector there are fundamental barriers. There is a long tradition in public procurement to award projects to the bidder that offers the lowest price for the initial construction work (building phase). This model is not compatible with the characteristics of NBS projects.

Can NBS compete?

During the EuDA annual conference in November 2019, Mrs Oshana Perera from

the International Institute for Sustainable Development (IISD) welcomed the important role that nature-based solutions can play in sustainable infrastructure development. She challenged the audience to mainstream NBS and cross the 'valley of death' to make NBS a viable alternative in the infrastructure market. In her experience the preconditions are that NBS have to meet the criteria of:

- verifiability: demonstrate robust track records (monitoring performance over time, achieving design criteria);
- predictability: (sufficiently) predictable in their performance;
- comparability: be functionally comparable under varying conditions (e.g., geo-zones).

The concrete suggestion to the contracting industry was that the time has come to move beyond the pilot stage and propose 'a catalogue of NBS products'. But can these criteria be satisfied?

Important work has already been done by the EcoShape foundation. The NBS pilots realised under the EcoShape platform have been closely monitored and their performance compared to predictions or theoretical modelling. The evolution of other pilots is similarly being followed with detailed monitoring campaigns such as the US Army Corps of Engineers' programme Engineering with Nature.

The NBS pilots realised under the EcoShape platform have been closely monitored and their performance compared to predictions or theoretical modelling.

The criteria of robust performance and reasonable predictability appear to be within reach.

But there remain other issues that distinguish NBS from grey infrastructure in a fundamental manner:

- as remarked, evolution in nature is never entirely predictable and performance cannot be guaranteed in the same manner as for grey infrastructure. Some form of adaptive management is necessary;
- NBS will have a degree of vulnerability under extreme events. This must be quantified to some extent and the outcome influences the predictability;
- the third test of comparable performance under varying conditions may be too much to ask.
- Indeed, NBS need to be functional in different climate zones under widely different conditions, and the specific applications may therefore be different. Mangrove development along coastal zones is realisable in many areas in tropical and semi-tropical zones, but in temperate climate zones similar defensive functions can be realised only by other NBS (e.g., seagrass beds, bio-engineering on sandbanks, etc).

Finally, while there are natural solutions that function as alternatives to grey infrastructure (for ex. constructed wetland for water

purification), in other cases NBS will function in tandem with grey solutions and form hybrid systems. In these cases, the choices are not between green and grey, but it becomes a matter of optimising design alternatives.

We conclude this section by observing that a catalogue of 'off-the-shelf' nature-based solutions is not realistic, because there are too many variables involved (climate zone, type of hazard, existing features, hybrid systems, etc). Nevertheless, a variety of nature-based approaches is available for application in river catchments and for coastal defences.

Conclusions

Nature-based solutions represent valid options for integration into coastal and flood defences. They can be applied as purely nature-based or combined with grey infrastructure to form hybrid systems. The evolution of nature-based features over time implies an element of uncertainty. Traditional public procurement methods, decision-making and governance as well as the traditional cost-benefit assessment models are not suitable for nature-based solutions and projects. The business case for nature-based solutions needs to account for a range of specific issues, including life-cycle costs and benefits estimates, assessment of vulnerability, allocation of multiple benefits, different types of guarantees.

Nature-based solutions represent valid options for integration into coastal and flood defences.

Summary

The concept of nature-based solutions (NBS) is relatively recent. It has emerged during discussions at the United Nations Framework Convention on Climate Change (UNFCCC) in 2009. This concept has the advantage of encompassing a broad range of diverse approaches and is thus convenient for promotional purposes. A definition is needed for practical use.

The European Dredging Association (EuDA) participated in a Horizon 2020 project sponsored by the European Union. The project named ThinkNature had as objective to promote the application of NBS. NBS have obvious advantages but have not been embraced at wider scale. In this article, the authors reflect as to why NBS are not mainstream solutions, why it is necessary to promote the concept and whether there are barriers that hinder wide-scale application. In this article the authors describe how relevant the topic is to the dredging community.

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The evolution of nature-based features over time implies an element of uncertainty.



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FROM IDEA TO REALITY:

THE UK'S FIRST SANDSCAPING PROJECT

All Photos © Chris Taylor

The northeast Norfolk coast has been subject to long-term coastal change. It is likely that the cliffs have been eroding at around the present rate for the last 5,000 years.

The Bacton Sandscaping scheme is a large-scale beach nourishment designed to protect the Bacton Gas Terminal from cliff and beach erosion while also reducing flood and erosion risk to the communities of Bacton and Walcott, buying the time needed for adaptation to coastal change. The scheme was inspired by the Sand Engine project in The Netherlands but has translated the concept to the different geography and governance setting of the UK. It can be seen as the Sand Engine's 'little nephew'.

The northeast Norfolk coast has been subject to long-term coastal change. It is likely that the cliffs have been eroding at around the present rate for the last 5,000 years. The cliffs are made of soft deposits – mainly sand and soft clays – which are very vulnerable to erosion. This long-term coastal change puts pressure on communities, infrastructure and business in the coastal zone.



FIGURE 1

Defences at Bacton Gas Terminal prior to Sandscaping.

The Bacton Gas Terminal is situated on the North Norfolk coast, approximately 30 kilometres north of Great Yarmouth. The Terminal has infrastructure near the cliff edge, within the cliff and under the beach. It is a piece of nationally important critical infrastructure supplying up to one third of the UK's gas demand from the North Sea extraction fields and to and from the continent. The Terminal is owned by Shell, Perenco as well as other oil and gas businesses. The Gas Terminal requires protection from cliff erosion and beach lowering for as long as the Terminal is needed to avoid national impacts in the event of the gas supply being interrupted.

The Terminal was defended by a series of timber groynes which sought to manage beach levels and a timber revetment to reduce cliff erosion (see Figure 1). These structures were more exposed due to beach lowering, suffered damage during storm events and only provided protection against 10% Annual Exceedance Probability (1:10 per year) storms.

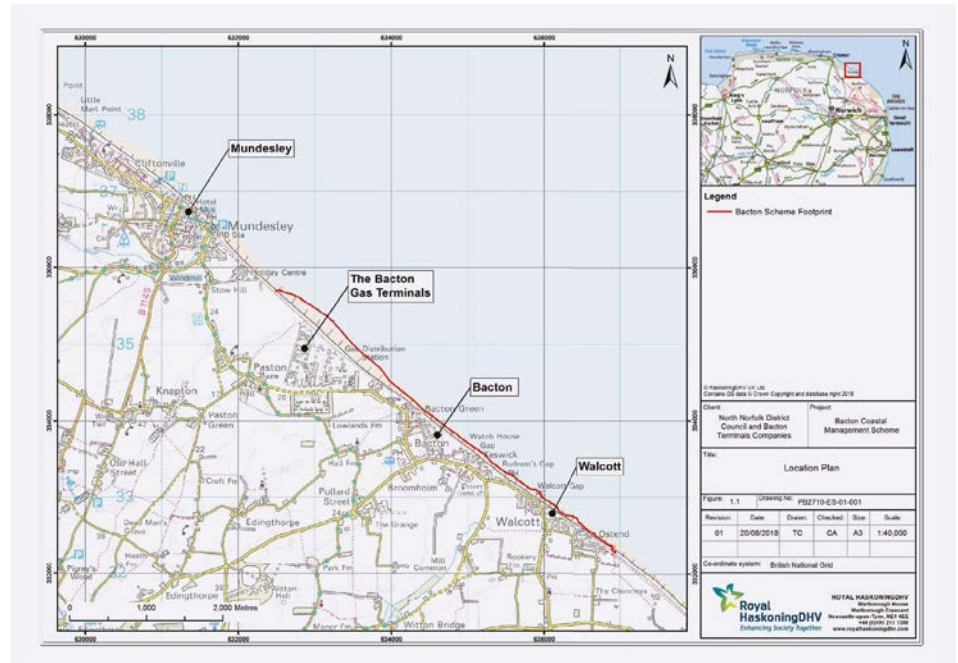
Despite these defences, cliff erosion at the Terminal had progressed rapidly over the years, notably during storm surges in November 2007 and December 2013. Following the December 2013 storm it became clear that erosion was starting to threaten the infrastructure at the Terminal. This included the cliff top infrastructure itself and pipelines

buried within the cliffs and beach. There was therefore an urgent need to provide protection against further erosion. In January 2017, due to the immediate risk, Shell constructed a temporary coast protection solution along critical lengths of their section of the Terminal frontage. This temporary solution consisted of rock-filled gabion baskets placed at the toe of the cliffs on a gabion mattress and backfilled with sand. The temporary solution was designed to provide intermediate protection and assumed construction of a full permanent scheme would be performed in the near future. The vulnerability of the Gas Terminal infrastructure to erosion was highlighted again in the storm surge event of January 2017 which caused significant lowering of the beach and damage to the existing timber revetment and the temporary coast protection solution which was in the process of being constructed.

Southeast of the Bacton Gas Terminal, continued coastal protection of the villages of Bacton and Walcott (referred to as 'the Villages' within this article) was only likely to be economically viable in the short-term under current UK treasury rules. The Villages form an integral element of the community and socio-economic structure of northeast Norfolk, providing residential areas supporting the population and overall housing stock of the area. They contribute to the important tourism potential to the area and sustain small

FIGURE 2

Location Plan with red line denoting Sandscaping placement (Royal HaskoningDHV, 2018).



businesses that also form part of the support structure to the wider rural hinterland. The Villages are protected from coastal erosion and flooding by a concrete seawall along most of their length, flanked by timber revetment. These defences were supported by a timber groyne field which, due to falling beach levels preventing access, were in varying states of repair. All the defences relied on the beach as the first line of defence to reduce water depth and, therefore, the height of the waves that can reach the defences, as well as protecting the lower part of the seawall from direct exposure to waves while also providing structural support. The beach had eroded significantly since the construction of the seawall in the 1950s and 60s to a point where the seawall was predicted to have a residual life of only 5 to 15 years. The erosion of the beach also increases flood risk: the storms of 2007, 2013 and 2017 caused significant flooding of the coastal road and properties due to waves.

The challenges

As the coastline changed, parties were faced with complicated decisions about how and where to defend. Economics, communities, the environment and physical geography all played a part in these decisions. Full 'hard' defences along the entire coast were not an option because they were not affordable, environmentally acceptable or sustainable and can exacerbate erosion.

Bacton Gas Terminal urgently needed to be protected against coastal erosion. The Shoreline Management Plan (SMP), adopted in August 2012, set out the agreed intent of management of the coast for the short, medium and long term. The SMP states that protection of the Terminal is acceptable but only if it does not increase erosion at the neighbouring villages of Bacton and Walcott. For the Villages, the SMP states that the sea defences should be maintained as long as

economically viable. This is only expected to be possible in the short term, but before the sea defences fail, measures will be required to manage the risk and mitigate the displacement of people and loss of property and facilities in the medium term.

This means that any 'hard' solutions could only work if complemented by significant beach nourishment to counteract the negative impact to the Villages due to wave overtopping. 'Hybrid' solutions were also considered, including the placement of rock armour with additional sand. However, these were discounted. Initial appraisal subsequently determined that these 'hybrid' solutions would be less attractive than sand-only solutions.

In 2013, Royal HaskoningDHV had already identified that a large-scale sandy solution could work for the northeast Norfolk coast through a study for North Norfolk District Council and The Crown Estate. This was part of the UK-wide sandscaping initiative which aims to explore application of coastal management approaches inspired by the Dutch Sand Engine project. Sandscaping solutions are large-scale beach nourishments that are designed to work with natural processes and with the intention of achieving multiple objectives. However, the Bacton-specific study still had to confirm the preferred concept (in terms of scale and shape) for the sandy solution,

ranging from a traditional regular nourishment to a sandscaping solution with its larger scale, intent to work with natural processes and intent to generate multiple benefits. In particular, the Dutch Sand Engine project has demonstrated major recreational benefits and would be ideally replicated by the scheme.

Development of the solution

From terminal-only to a combined solution

The North Sea tidal surge of 5 December 2013 was the key event which spawned the project, leading to the UK's inaugural sandscaping scheme. In this event, several metres of soft cliff in front of the Gas Terminal were lost to the concern of the terminal's operators. Similarly, at Bacton and Walcott there was infrastructure and housing damage caused by the storm waves and flooding. The terminal's operators immediately secured the services of engineering consultants Royal HaskoningDHV to assess options to eliminate erosion risk to the Terminal.

While the team was developing solutions for the Terminal, meetings were held with North Norfolk District Council and Environment Agency to share initial findings and explore the possibilities around joint development of a project with North Norfolk District Council. These meetings and discussions led to an option being explored of a public/

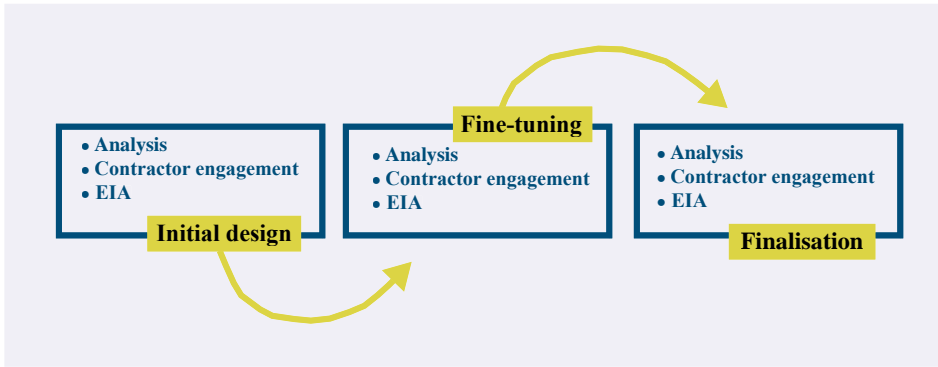


FIGURE 3
Design process.

The northeast Norfolk coast has been subject to long-term coastal change. It is likely that the cliffs have been eroding at around the present rate for the last 5,000 years.

private sector collaboration to deliver a collective solution to address erosion risk at the Terminal and flood and erosion risk at the villages of Bacton and Walcott. The work for the terminal companies had confirmed that a sandy solution could be designed to prevent downdrift impacts; now the challenge was to develop this to a sustainable and affordable solution that would improve the beach at the

Villages, thereby extending the life of the Villages and reducing their risk.

Design process

The aim of the subsequent stage was to refine the design of the sandy solution (in terms of volume, shape, renourishment interval and sediment size) while initiating the process toward the statutory consents, in particular

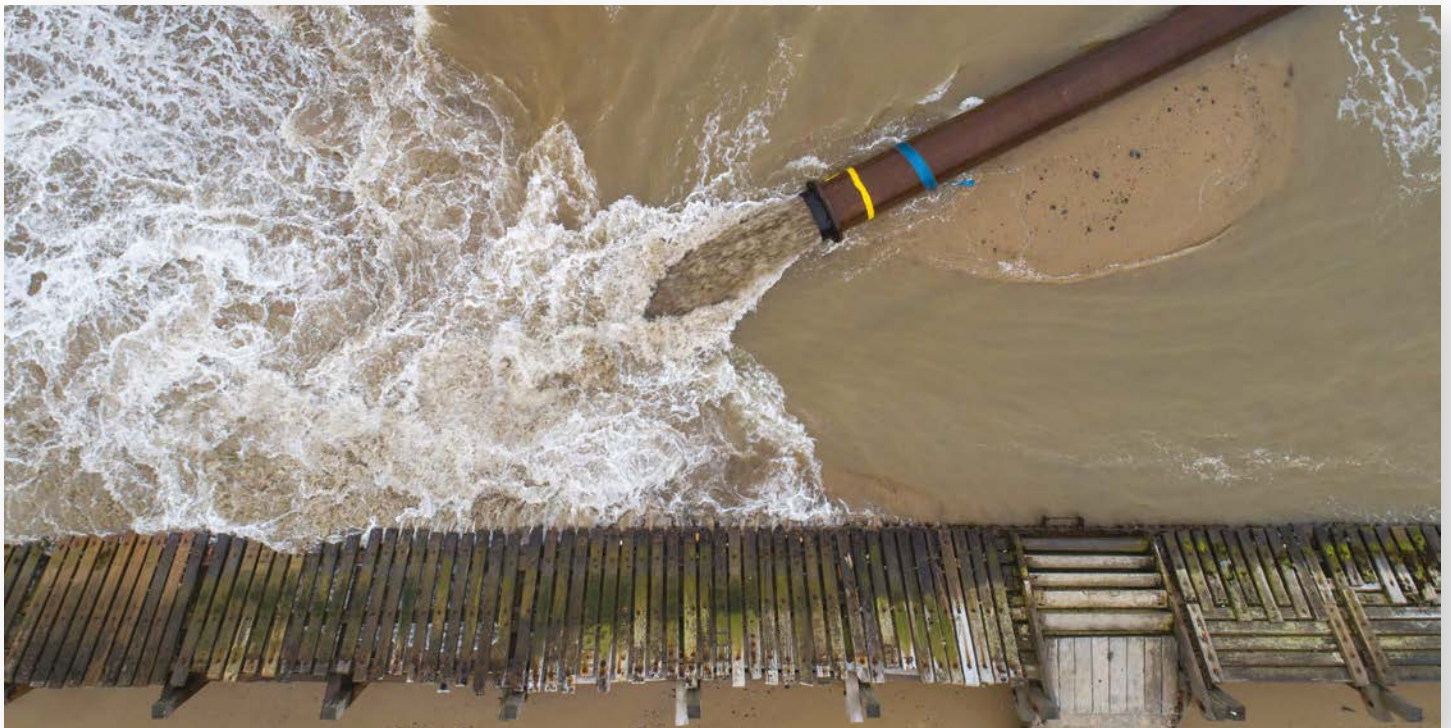


FIGURE 4
Sand extracted from the seabed is pumped onshore through a pipeline.

The team made a special effort to engage closely with all contractors on the Environment Agency framework throughout the design process.

the Marine License and Planning Permission. The team followed an iterative approach with three parallel tracks:

1. analysis (including modelling),
2. environmental study, and
3. engagement with contractors (see Figure 3).

The iterations concerned sediment volume, various configurations and shapes, distribution between Terminals and Villages, sediment size. The process converged gradually toward the finally chosen selection, informed by insights derived from each of the three workstreams.

Modelling and analysis

To assess the technical performance, a conceptual model was used that combined the strengths of a one-dimensional (Litline) and a two-dimensional area model (coupled wave, TOMAWAC, flow, TELEMAC-2D and sediment transport, SISYPHE, models within the TELEMAC-MASCARET modelling system; run by HR Wallingford) with appropriate use of expert knowledge and judgement and local information (in particular from the Coastal Monitoring Programme). The resulting

conceptual model was agile enough for optioneering while fully representing the beach processes. The conceptual model uses the one dimensional Litline model as the central engine and uses the other tools to add cross sectional processes which cannot be captured by the one-dimensional model on its own. This relates specifically to the loss of sediment toward deep water and the development of the cross-sectional shape of the beach (i.e. the long-term balance between offshore losses and onshore recovery). The overall shape and volume of nourishment at the Terminal was technically assessed and optimised using cross-sectional modelling. The Terminal element was designed to provide protection against cliff erosion in storms up to a 0.01% Annual Exceedance Probability (1:10,000 per year) event. The team developed an innovative approach using hydrodynamic wave modelling with AMAZON to compare design wave loading on the cliff face with known historic storms that did not cause erosion. In addition, plume modelling was carried out to inform the Environmental Impact Assessment (EIA) and for wind-blown sand, a research model developed for the Dutch Sand Engine



FIGURE 5

View of shoreline nourishment with various equipment at work.

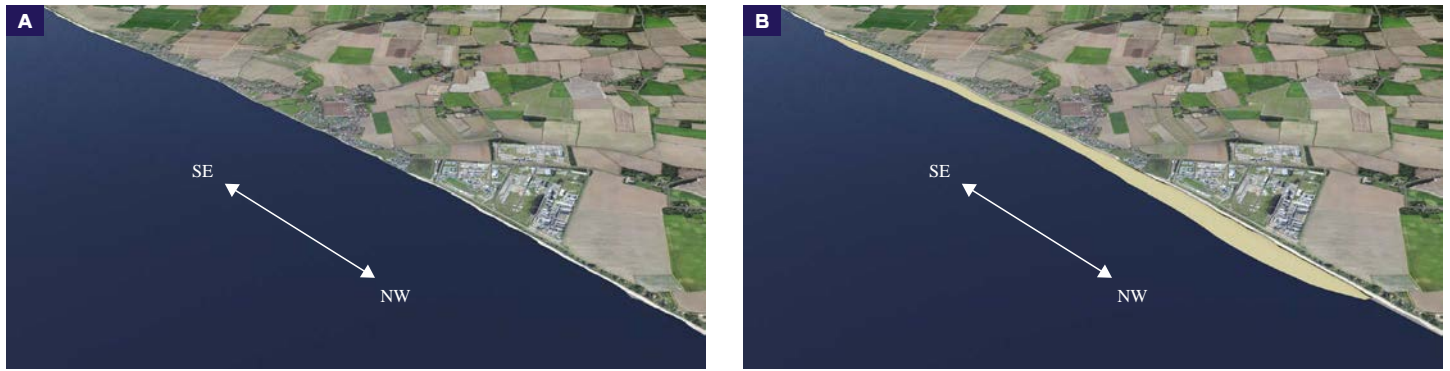


FIGURE 6
Schematic overview looking from north to south along the coast, before (A) and after (B).

was used to test impacts on the terminals and community as well as inform the design of mitigating measures. Modelling studies considered placing greater volumes of sand around the Terminal in a hemispheric shape, similar to the Dutch Sand Engine. However, limited benefit was offered by the additional volumes. Modelling showed that tidal currents in the area washed the additional volume away very rapidly.

Environmental study

The environmental study was not only carried out to meet statutory requirements (EIA, Habitats Regulations, Marine Conservation Zone Assessment, Water Framework Directive) but played a strong and driving role through the design process, both in terms of designing out negative impacts and incorporating mitigation as well as in terms of incorporating opportunities for enhancement. The project identified a chalk bed near the coast within the Marine Conservation Zone and this influenced the design to minimise the risk that the chalk bed would be impacted by the scheme. The environmental study also influenced the grain size and spawned the idea of stimulating dune growth on the nourishment with the added benefit of limiting wind-blown sand.

Contractor engagement

The team made a special effort to engage closely with all contractors on the Environment Agency framework throughout the design process. All potential contractors were invited and all became very positively involved, helping to optimise scheme design and increasing confidence in the cost estimates to the benefit of the clients. This is particularly

important for a scheme like this – which was dominated by dredging and nourishment operations – because operations depend on the specific (often commercially sensitive) characteristics of the contractors’ equipment. The team initially considered engaging with a single selected contractor but the chosen approach of working with multiple contractors in parallel has proven to work well, also because it helped sustain a level playing field for contractor procurement. This process has influenced size, shape and grain size of the nourishment.

What was proposed?

The Sandscaping scheme consisted of the placement of sand along the coastal stretch between the Terminal and the south-eastern end of Walcott. This is a stretch of coast of 5.7 kilometres. The scheme comprises two distinct but connecting elements: the nourishments in front of the terminals and in front of the Villages (as shown in Figure 2).

Element 1: Terminals

This element aims to prevent significant cliff erosion up to a storm event with a 0.01% Annual Exceedance Probability (1:10,000 per year). The initial placement of sand is expected to last approximately 15 to 20 years from first placement with the intention to potentially re-nourish after that period. The terminals element covers the terminals frontage down to the adjacent Holiday Park and contains approximately 1 million cubic metres of sand. The nourishment here is at its widest and highest: 3.5 to 5 metres higher than the current beach at the cliff toe (7 metres Above Ordnance Datum (AOD)), with a crest width

up to 80 metres, and then sloping down to the existing sea bed. The existing outfall pipes were replaced with a new single buried pipe.

Element 2: Villages

This element provides additional protection in front of the Villages from Bacton to Walcott for which the proposed scheme is considered the only viable solution. The initial sand placement improves beach levels which in turn increases the life of the existing sea defences. Over time, tide and waves will transport sand from the Terminals nourishment to feed the beaches of the villages. The higher and wider beach will also reduce wave overtopping and therefore flood risk for the Villages. The Villages element runs from the south-eastern end of the Terminals down to the end of the scheme at Ostend, Walcott and contains approximately 0.8 million cubic metres of sand. The initial beach level covered the exposed sea wall toe, at 4 to 5 metres AOD with a crest width up to about 25 metres, and then sloped down to the existing seabed. The crest at 4 metres AOD means that there would (at least) initially be a beach at high water. The coast would still erode, including temporary rapid losses during storm events. However, the scheme would have ‘turned back the clock’ by several decades and the extra sand would make the beach more robust with the ability, under the right conditions, to naturally recover.

Overall

The total sand volume of 1.8 million cubic metres was extracted from the seabed, from an existing licensed site, off Great Yarmouth. The extraction sites are approximately 20–25 nautical miles from Bacton. The sand grains



will be similar to the current beach (D50 of 0.35mm), or slightly coarser (D50 up to 1.2mm). Generally, coarser sand is more stable so will create a more stable beach but it is also more expensive to place, and if too coarse, it could have impacts on amenity use or habitats. The sand placement in front of the Terminal provides immediate protection and narrows towards the villages (see Figure 6). Modelling

has shown that this alignment is the most favourable.

The placed beaches will adapt rapidly to the natural conditions. The sand will spread out along the coast in both directions. The scheme is expected to provide the required level of protection at the Terminal's coast for approximately 15-20 years (with the exact

timing dependent on weather conditions and to be confirmed through ongoing monitoring and review). A future placement may be designed to continue to protect the Terminals – probably without future placements in front of the Villages – depending on considerations at that time. The improved beach in front of the villages of Bacton and Walcott is expected to enhance the lifespan of the



FIGURE 7

Total sand volume of 1.8 million cubic metres was extracted from the seabed, from an existing licensed site, off Great Yarmouth.

The beach plays an important role of absorbing the energy from the sea before it reaches the cliff and defences while also providing support and protection to the defence foundations.

existing sea defences. The sandscaping scheme could delay sea defence failure by 15 to 50 years depending on the state of the seawall and beach development over time. This significantly delays the loss to erosion of nearly 300 households. It is also predicted to reduce flood risk due to overtopping to the coast road and over 100 households. Therefore, the scheme is delivering

approximately 400 OMs (Outcome Measures) under current UK Government funding criteria.

Benefits

The scheme will have very large benefits to the Gas Terminal, extending its functional life as a piece of nationally critical infrastructure, preventing potential (very expensive) national disruption of supply and its consequential

damages, and the direct damages to the Terminal facilities.

For the Villages, the scheme is expected to delay the loss of the seawall, and thereby delay the loss to erosion of the coast road and nearly 300 households. In addition to these measurable benefits, the scheme is expected to provide time to the communities to adapt to

coastal change, for which they currently have very little time and opportunity.

Following discussion with DEFRA and the Environment Agency the village element of the scheme is eligible for government Flood and Coastal Erosion Risk Management (FCERM) Grant in Aid (GiA) funding as set out in the following list:

- Properties protected from erosion, determined by applying the standard methods from the Environment Agency approved Economic Appraisal Manual. Essentially, the benefits are generated by the delay of the loss to erosion of properties in Bacton and Walcott, using appropriate property values to calculate the damage. The year of loss of individual properties and their respective access roads was estimated for each option. For the initial situation this was based on the estimated year of seawall failure. For each option, the extensive modelling carried out for scheme design was used to determine how the enhanced beach would delay this year of failure. This was combined into a Present Value Damage (PVD) amount for each option. Note that this leads to a 'duration of benefits' that varies along the frontage, which has been incorporated in the calculation of GiA.
- Properties protected from flooding. Bacton and particularly Walcott were vulnerable to flooding from wave overtopping over a coastal seawall. Reflecting the relatively low importance compared to erosion, the team took a pragmatic approach to calculating the benefits. First, the economic flooding damages for Walcott Gap calculated in

previous studies, updated to the current date, were used to estimate how the scheme options would generate benefits. In addition, the number of households for which the scheme options reduce the probability of flooding, was estimated on the basis of data from the Environment Agency's coastal modelling study. These two results were combined to determine the scheme options' economic benefits and their contribution to Outcome Measure 2 (households moved from a high flood risk category to a comparatively lower category).

- Highways protected. The benefits concern the delayed need to reconstruct the B1159 road at Walcott on a more inland alignment. In practice, it is more likely that the road would not be repaired, and calculations confirmed that the economic impact of the resulting delays would be higher. However, in line with UK Treasury rules the lowest damage scenario is used as part of the calculation.
- Loss of recreational value. This was calculated as the loss of visitor spend, based on available economic data. Alternative analysis based on reduced value of enjoyment produced higher impacts, but was considered less reliable. Therefore, the lower value has been applied.

Additional benefits

There are also be additional benefits further downdrift from the Villages frontage. The scheme is expected to provide additional sediment which will, over time, also generate benefits downdrift from Walcott: first at

Happisburgh and then also at Eccles and Sea Palling. Due to the significant uncertainty regarding these possible benefits, and the fact that its inclusion is outside of current policy guidance, these additional benefits have not been calculated within the approved business case submitted to LPRG.

The scheme is expected to create other benefits which are not eligible for GiA because they do not relate to reduction of flood and erosion risk. This concerns the enhancement of the communities' capacity to adapt to coastal change (likely to improve

Royal HaskoningDHV has been working with The Crown Estate and other partners since 2011 to explore the application of sandscaping solutions in the UK.

FIGURE 8

Coastal nourishment looking southward from the Terminals toward the Villages.



economic productivity and reduce the burden on the UK's health care system) and the improvement of tourism facilities (in addition to prevention of losses, which is potentially eligible for in GiA). These benefits are relevant for alternative sources of funding.

Local stakeholders showed overwhelming support for the scheme and were keen to see the sandscaping solution implemented. Initial concerns regarding potential negative impacts during construction, either to tourism or fishing, were largely overcome through active engagement and consultation.

The loss of existing recreational value described above is eligible for FCERM GiA. In contrast, the improvement of tourism economy concerns the positive impact on the local tourism economy of the options, for example by improving the beach.

The scheme is also likely to improve the adaptive capacity of the communities. The understanding that a large number of households were expected to be lost in the coming 20 years has far-reaching impacts on people. One key aspect is the loss of mobility (i.e. the reduction in house prices restricting ability to move elsewhere and therefore find

work). In addition, the loss of households puts an additional burden on health and social care.

These non-financial benefits are challenging to report quantitatively, but were considered within the choice of the preferred Sandscaping option.

How it will work

The beach plays an important role of absorbing the energy from the sea before it reaches the cliff and defences while also providing support and protection to the defence foundations. The larger beach will absorb more energy and supports the defences. Detailed studies have



The Bacton scheme will be a very useful case study for other coastal managers in the UK and elsewhere to consider sandscaping solutions for their area.

been done to assess how coastal processes along this dynamic stretch of coast will work with the scheme, and this provides confidence that the scheme will perform. Over time, the bulk of sediment protecting the Terminal is expected to feed the beaches in front of Bacton, Walcott and beyond, sustaining the initial sand placement in front of those villages.

Experience with the Dutch Sand Engine shows that (mainly in the 12 months following construction), the shape of the sediment placements will change and this is to be expected. With a new 'dry beach' above mean high water, there is a risk of windblown sand, particularly in the first 18 months. This will need to be monitored and managed.

Funding

The funding for the Bacton to Walcott Coastal Management Scheme came from a number of private and public sources. The FCERM GiA was a critical element of the project to enable the joint Terminal and villages scheme to proceed but did not form the primary funding source. The private funding was led by Shell UK and Perenco UK who oversaw an umbrella of other infrastructure provider contributions. Opportunities for external funding were comprehensively explored with the Terminal and UK Government. The total cost of the project was approximately £21 million including the re-provision of a surface water outfall for

the gas terminal. The following funds were intended to be made available to the project.

- Terminal's contribution to the cost of the Terminal protection and new surface water outfall, totalling two thirds of the overall funding.
- FCERM GiA capital funding allocated from the Environment Agency's Flood and Coastal Erosion Risk Management Investment Programme;
- North Norfolk District Council contribution;
- Local Levy agreed allocation from the Anglian Eastern Regional Flood and Coastal Committee (RFCC);
- Environment Agency's agreed allocation from the Natural Flood Management (NFM) funding stream;
- Norfolk Business Rates Pool contribution from Norfolk Local Government sources;
- New Anglia Local Enterprise Partnership Growth Funds contribution; and,
- Contributions from the local community and other beneficiaries collected through the JustGiving account set up by North Norfolk District Council.

With regards to the NFM funding stream, as part of the original application for funding, the importance of post construction monitoring was emphasised. As such, and in order to maximise the learning from this project, there is an expectation that a proportion of the NFM allocation will be attributed to such monitoring. Post-construction monitoring in beach nourishment projects is covered by FCERM GiA monies elsewhere (for example the Eccles to Winterton scheme).

The capital funding requirement for the Bacton to Walcott scheme is included in the Environment Agency's flood and coastal risk management investment programme (2015-2021), Terminal investment programmes and North Norfolk District Council capital investment programme. The revenue for future maintenance is limited and will be shared as identified in the Development Agreement.

Ongoing costs with regards to maintenance are expected to be low as the scheme will naturally decommission over time. Monitoring costs are to be shared and it is expected that a significant proportion of the costs can be captured in the Environment Agency's Anglian Coastal Monitoring programme. Monitoring is likely to include several fields, including: ecological, bathymetric, geomorphological

and social science aspects. In addition, further research will be supported and encouraged.

Sandscaping and wider applicability in the UK

Royal HaskoningDHV has been working with The Crown Estate and other partners since 2011 to explore the application of sandscaping solutions in the UK. This consisted of technical work to develop the concept, carry out a UK-wide assessment of potential sites and location specific feasibility studies. In addition, the sandscaping partnership has engaged with decision makers and influencers at various levels in order to understand the constraints for and opportunities around this innovative solution in the UK. The approach was strongly driven by the clear realisation that sandscaping schemes will only happen if it is the right solution locally, and is 'consentable' and affordable. As a result, a key aim has been to convince coastal managers to include sandscaping on longlists for projects and to create a level playing field so that it can be appraised against more traditional options.

There have been a number of specific engagement initiatives in the UK. In April 2015, a workshop was held in London hosted by The Crown Estate. During this workshop, which encompassed coastal practitioners and community representatives from across the country, the advantages and disadvantages of such an approach were explored for a number of coastal locations from around the country. Concurrent to this, consultants Royal HaskoningDHV funded by The Crown Estate, undertook a technical assessment of coastal locations. More recently (April 2018), an event was held at the Dutch Embassy to explore sand engine/sandscaping approaches in the UK environment. The technical audience included coastal practitioners from Environment Agency, Coastal Risk Management authorities, DEFRA, Natural England and Marine Management Organisation. Part of the afternoon discussion centred on the potential for a sandscaping approach to be taken at other locations in the UK. There was consensus that there were other specific locations in the UK where such an approach could be valid. However, other factors such as already planned interventions could affect timings.

Clearly, after completion of the Bacton to Walcott Sandscaping scheme, the monitoring

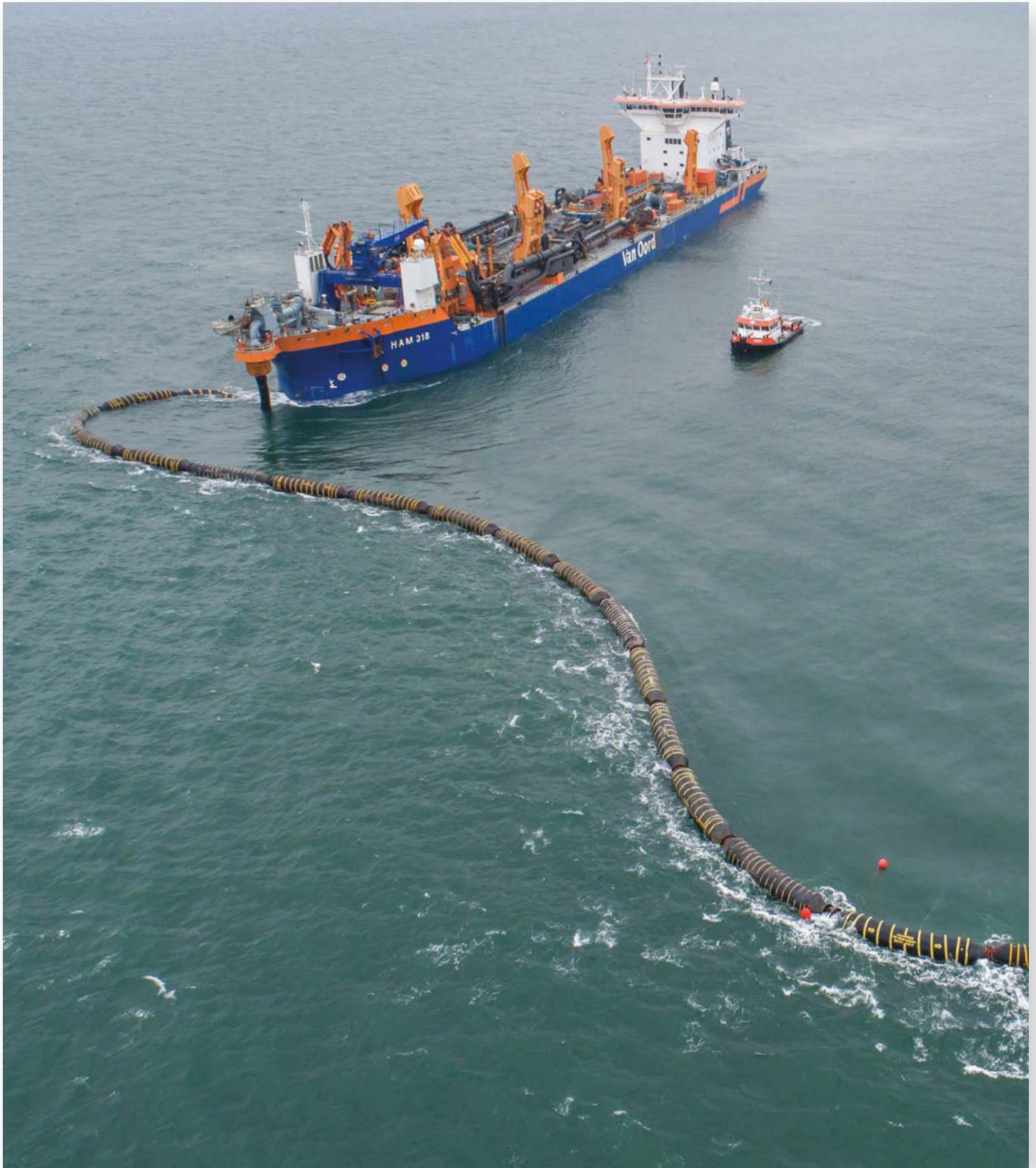


FIGURE 9
Floating pipeline delivering sand to the shore from an offshore site.

and sharing of results more widely is possible. At this point, coastal practitioners will be in a good position to consider the merits of this approach for other locations.

Conclusions

The Bacton to Walcott Sandscaping scheme shows that it is possible to design, fund and gain consent for a sandscaping scheme in the UK – a large-scale nourishment that is designed to work with natural processes and with the intention to achieve multiple benefits.

Such an approach not only provides erosion and flood risk benefits but also has the potential to improve tourism income and adaptive capacity of communities, while working with natural processes. The higher and wider beaches will delay failure of the defences, reducing uncertainty and providing more time for adaptation. Future engagement around coastal adaptation will be critical, North Norfolk District Council continues to engage locally while also lobbying national for wider inclusion of adaption in the national approach.

By taking a coastal zone approach, considering longshore interactions and taking partnership opportunities, the Bacton scheme has created a solution to not only protect nationally important infrastructure but to support the communities of Bacton and Walcott where this would otherwise not be possible.

The success of this collaborative project development has been due to all parties, private and public, playing their part. In simple terms, having the 'right' people doing the 'right' things at the 'right' time. This concerns both personalities and organisational remsits.

The Bacton scheme will be a very useful case study for other coastal managers in the UK and elsewhere to consider sandscaping solutions for their area.

**It can be seen as
the Sand Engine's
'little nephew'.**

Summary

The Bacton Sandscaping scheme is a large-scale beach nourishment designed to protect the Bacton Gas Terminal from cliff and beach erosion while also reducing flood and erosion risk to the communities of Bacton and Walcott, buying the time needed for adaptation to coastal change. The scheme was inspired by the Zandmotor project in The Netherlands but has translated the concept to the different geography and governance setting of the UK. It can be seen as the Zandmotor's 'little nephew'.

This article describes the context of the challenge, how the sandscaping approach works and tells the story of how the first project of this type outside the Netherlands has developed from the seed of an idea to reality. Technical expertise, passion, trust, flexibility and lateral thinking have all been to the fore in a truly unique collaboration between multiple private and public sector organisations.

This article was presented as a paper at an Institution of Civil Engineers Conference in 2019. It is updated here and published with permission.

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The success of this collaborative project development has been due to all parties, private and public, playing their part.



Mark Johnson

Mark has worked for 35 years in various roles for the Environment Agency and its predecessor organisations. For the majority of this time he has been focused on the East Anglian Coast.

During the last 14 years he has overseen delivery of many large flood and coastal erosion risk management projects, many of which have realised multiple benefits for the protection of people and property, important wildlife sites and rural land. Mark has been actively working with various groups on the East Anglian coast to help progress projects where partnership approaches are pivotal in helping to address the challenges of the UK coast. He has been the Chairman of the East Anglia Coastal Group (EACG) since 2012 and chaired elected members during the development phase of the Shoreline Management Plans.



Robert J.W. Goodliffe

Rob is a Coastal Manager for North Norfolk District Council/Coastal Partnership East working across local authorities on the Norfolk and Suffolk coasts. Rob works with communities and organisations to deliver practical coastal management approaches for business and communities including traditional coast protection and pioneering coastal change adaptation projects. Rob entered the coastal management field to deliver innovative adaptation projects, such as the relocation of business and community assets and purchase and relocation of at risk homes. He has since developed opportunities and funding packages for coastal protection and maintenance schemes and, more recently, has led North Norfolk District Council's role in the development and delivery of a UK first Sandscaping scheme to protect communities and major national gas infrastructure. Rob holds a BSc honours degree from Wye College/Imperial College London, Institute of Leadership and Management certificate alongside a breadth of experiences ranging from tourism, environmental management, public open space management, planning policy and coastal management.



Gökhan Doygun

Gökhan is a Senior Commercial Advisor at Shell and is currently working as Opportunity Lead/ Commercial Lead on Energy Transition projects in the Netherlands and in the UK Southern North Sea. He played a key leading role, as the Business Opportunity Manager (BOM) acting on behalf of Shell UK, in the success of the public and private collaboration for the joint protection of the nationally critical infrastructure Bacton Gas Terminal and the adjacent Bacton & Walcott villages – UK's first 'Sandscaping' solution for Bacton to Walcott Coastal Management Scheme.



Jaap Flikweert

Jaap is a flood and coastal management advisor and a Leading Professional with Royal HaskoningDHV, and a Fellow of CIWEM. He has twenty-five years of experience in flood and coastal management, in the Netherlands, the UK and worldwide. Jaap's career started in 1994, working from the Netherlands until 2004 and based in the United Kingdom since then. His expertise covers flood and coastal management: from detailed design to strategy and policy level, as well as planning, preparation, protection and response. He produced the guidance for the statutory flood defence assessment in the Netherlands; led three of the 20 Shoreline Management Plans for England and the review of flood defence performance after several of the recent floods in the UK (including Winter 2015/16); and established the method that the US Army Corps of Engineers applied to incorporate resilience in New Orleans' levees after Katrina. Jaap is the technical lead for the Sandscaping initiative that aims to introduce Dutch Building with Nature concepts into the UK. He led the RHDHV team that developed the design, Environmental Impact Assessment, business case and monitoring plan for the Bacton to Walcott Sandscaping scheme.



Gerard Spaan

Gerard is a Senior Civil Marine Engineer at Shell Projects & Technology and is currently working on the development of LNG import terminals globally, from their early definition to the actual execution. For the Bacton Sandscaping Project, Gerard was the Technical Lead on behalf of Shell, providing technical assurance and guidance for the design and execution of the works, including concept selection as well as procurement for the different work packages. Gerard holds an MSc degree in Civil Engineering from Delft University of Technology in the Netherlands. Prior to joining Shell in 2009, Gerard worked as a Civil and Coastal Engineer at Deltares, an independent institute for applied research in the field of water and subsurface, and at Van Oord Dredging and Marine Contractors.

EXPAND HORIZONS ABROAD

UNEP Sixth Adaptation Futures Conference

29 September–1 October 2020

India Habitat Centre

New Delhi, India

<http://adaptationfutures2020.in>

Adaptation Futures is the flagship event of the World Adaptation Science Program which is one of the four components of World Climate Programme (WCP) based on the World Meteorological Organisation Congress XVI Resolution 18. As a premier event in the global adaptation spectrum, Adaptation Futures is a unique platform to facilitate dialogues towards action oriented solutions from a diverse range of stakeholders that includes academia, practitioners, scientists and policy makers from across the world.

The sixth such conference – and the first to be held in Asia – will be co-organised by the Energy and Resources Institute and the World Adaptation Science Programme. India is the chosen location due to its high reliance on climate sensitive sectors such as agriculture, water and forestry for resources, and livelihoods face an urgent need for adapting to the risks posed by climate change.

The Adaptation Futures 2020 envisages to advance the overall theme of ‘accelerating adaptation action and knowledge to support action’. The conference seeks to explore this overarching need through multiple thematic tracks. Topics to be addressed include Governance of Adaption, Limits to Adaption, Fairness and Equity in Adaption, Knowledge for Action, Financing Adaption and Nature Based Solutions, a topic high on the agenda of the global dredging industry.

The conference aims to Manoeuvre the intrinsically linked roles of practitioners, academicians, policy-makers and communities towards scaling adaptive capacities across vulnerable landscapes and people. Navigate the theme of ‘accelerating adaptation action’ with prominent Asia focus. Facilitate knowledge sharing, evaluation and learning of actionable solutions across the global north and south.

2020 Chlorinated Conference

31 May–4 June 2020

Oregon Convention Center

Portland, Oregon, USA

www.battelle.org/chlorcon

The Twelfth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, known as Battelle’s Chlorinated Conference, is one of the world’s largest and most comprehensive meetings on the application of innovative technologies and approaches for characterisation, monitoring and management of chlorinated and complex sites.

The 2020 Conference will include more than 1,000 platforms and posters in 88 breakout sessions. Five panel discussions will be conducted. Sessions and panels are organised according to thirteen major topic

For professionals involved in dredging-related activities for water infrastructure development, CEDA and IADC launch the Dredging for Sustainable Infrastructure Course.

FIGURE 1

Held at the IHE Delft Institute for Water Education, IADC’s Seminar on Dredging and Reclamation gives participants the opportunity to complete a mock tender process in groups, competing against fellow participants for a prize.



FIGURE 2

The winners of this year's mock tender each won a copy of *Dredging for Sustainable Infrastructure*.

areas, seen on the Program page, that will address the innovative application of existing and new technologies and approaches for characterisation, treatment and monitoring of chlorinated and other recalcitrant compounds and emerging contaminants in various environmental media. Risk, regulatory, site management/closure and sustainability issues associated with these technologies will be discussed. Presentations will emphasise cutting-edge research to address current environmental challenges, recent advances in site characterisation, new developments in remediation technologies, and field applications to achieve site closure.



Photo © Marco Hofste

60th Seminar on Dredging & Reclamation

8-12 June 2020

IHE Delft Institute for Water Education
Delft, The Netherlands
www.iadc-dredging.com

For (future) decision makers and their advisors in governments, port and harbour authorities, off-shore companies and other organisations that have to execute dredging projects, IADC organises their International Seminar on Dredging and Reclamation for the 57th time. This time the seminar will be held in cooperation with the IHE Delft Institute for Water Education, in Delft, The Netherlands. Since 1993, this week-long seminar has been continually updated to reflect the dynamic nature of the industry and is successfully presented in cities all over the world. IADC's Seminar on Dredging and Reclamation is a five-day course which covers a wide range of subjects, from explanations about dredging equipment and methods, rain bowing sand and placing stone to cost estimates and contracts.

Programme

The in-depth lectures are given by dredging experts from IADC member companies, whose practical knowledge and experience add an extra value to the classroom lessons. Amongst 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
- environmental aspects of dredging

Activities outside the classroom are equally as important. An on-site visit to the dredging yard of a IADC member is therefore an integral element in the learning process. This gives the participants the opportunity to see dredging equipment in action and to gain a better feeling of the extent of a dredging activity.

Face-to-face social contact is invaluable. A mid-week dinner where participants, lecturers and other dredging employees can interact, network and discuss the real, hands-on world of dredging provide another dimension to this stimulating week.

Each participant receives a set of comprehensive proceedings and a Certificate of Achievement in recognition of the completion of the coursework.

Register for the seminar at
<http://bit.ly/SeminarDelft>

For further questions, contact:

Ria van Leeuwen, Senior PR & Communications Officer of IADC
Email: vanleeuwen@iadc-dredging.com



Photo © Marco Hofste

EVENTS

FIGURE 3

A copy of *Dredging for Sustainable Infrastructure* will be given to each course participant.

Dredging for Sustainable Infrastructure Course

23-24 June 2020

Hotel Van Der Valk Den Haag

Nootdorp, The Netherlands

<https://dfsi-course-0620-nl.iadc-events.com>

For professionals involved in dredging-related activities for water infrastructure development, CEDA and IADC launch the Dredging for Sustainable Infrastructure Course. The course is based on the association's flagship guidebook with the same title.

At this two-day course, participants will learn how to achieve dredging projects that fulfil



Photo © Mees van den Ekart

FIGURE 4

Contact IADC's PR Officer Ria van Leeuwen regarding the 60th Seminar on Dredging & Reclamation taking place in Delft, Dredging for Sustainable Infrastructure Course in The Hague, and 61st Seminar on Dredging & Reclamation in Singapore.



Photo © Mees van den Ekart

primary functional requirements while adding value to the natural and socio-economic systems by acquiring an understanding of these systems in the context of dredging as well as stakeholder engagement throughout a project's development. This course, just like the book it is based on, fills a gap: it gives guidance to professionals on how to bring into practice the new thinking that in many ways has transformed dredging in the last decade. Therefore, the course is essential for professionals driven by the ambition to achieve sustainable and resilient water infrastructure with a dredging component that contribute to the UN's Sustainable Development Goals. People involved in designing or implementing such projects – such as port development, river deepening and flood defence to name a few – as well as those working in government, port authorities, consultancy firms, dredging companies, NGOs, suppliers, or ship-builders – would benefit from this course. Engineers, ecologists, nature and social scientists, regulators or financiers will all return home from this course with new insights and knowledge that can be put to practice right away.

This course is based on the CEDA-IADC guidebook *Dredging for Sustainable Infrastructure* which was published in 2018. Experienced lecturers will inform about the latest thinking and approaches, explain methodologies and techniques as well as demonstrate – through numerous practical examples – how to implement this information in practice with challenging workshops and case studies.

PIANC-COPEDEC X

16-20 November 2020

Manila, Philippines

www.pianc-copedec2020.org

The Philippine Ports Authority (PPA) is delighted to host the 10th International Conference on Coastal and Port Engineering in Developing Countries (COPEDEC). The event theme 'Enhancing Waterborne Transport and Sustainable Coastal Development' is indeed timely as the Philippines and other developing nations address a myriad of port issues ranging from climate change impact to cyber security and logistics efficiency.

PPA welcomes local and international port planners, engineers, as well as experts from the academe, business and industry to share their knowledge and experience in a week-long event full of technical presentations, dialogue and collaboration that aim to provide solutions and implementation strategies going into the future. The conference is expected to provide participants with a greater and deeper understanding of the various technologies and IT applications available, and learn how to align technology to their business strategy.

The success of the First International Conference on Coastal and Port Engineering in Developing Countries (COPEDEC), held in Colombo Sri Lanka in March 1983, resulted in the subsequent holding of this special conference series once every four years in a developing country. Successful conferences were held in Beijing, China (September 1987),

Mombasa, Kenya (September 1991), Rio de Janeiro, Brazil (September 1995), Cape Town, South Africa (April 1999), Colombo, Sri Lanka (September 2003), Dubai, UAE (February 2008), Chennai, India (February 2012) and Rio de Janeiro, Brazil (October 2016).

The active mission of the PIANC-COPEDEC Conferences is:

1. To provide an international forum where coastal and port engineers from developing countries can exchange know-how and experience amongst themselves and with their colleagues from industrialised countries;
2. To enable the developing countries to have a sustainable human resource pool of coastal and port development professionals.

As with previous conferences, the emphasis on technical subjects remains. Papers will focus on practical applications, planning, management and environmental aspects of coastal, port and inland waterway engineering in developing and industrialised countries, including documentation of case studies. The language of the Conference will be English.

Technical tours and social events will also be arranged during the week of the Conference. Pre-conference tours to interesting places in and around Manila and other places of interest in Manila will be arranged. A Final Announcement including a listing of accepted papers and detailed practical information such as registration and hotel booking forms will be issued in April 2020.

Call for papers

A reminder that the call for abstracts is now open for the Navigating a Changing Climate 'conference-within-a-conference' at COPEDEC in the Philippines in November 2020. Submission requirements for abstracts can be found here: <https://navclimate.pianc.org/about/navclimate-news/call-for-abstracts-navigating-a-changing-climate-conference-at-copedec>

The deadline for the receipt of abstracts is 30 March 2020.

Those that have not yet prepared and submitted their abstracts may be interested to know that the extended abstracts from the Navigating a Changing Climate conference-within-a-conference will be included in the COPEDEC conference Book of Abstracts. In this case, however, the Navigating a Changing Climate conference abstracts will need to be submitted in the same format as those for COPEDEC. Instructions for submissions can be found here: <https://www.pianc-copedec2020.org/call-for-abstract>.

NaCC at COPEDEC

16-20 November 2020
Manila, Philippines
<https://navclimate.pianc.org>

Navigating a Changing Climate is a PIANC-led international initiative that provides a platform for the exchange of technical advice and information. The initiative aims to support the maritime and inland navigation infrastructure sector in responding to climate change. NaCC will hold a conference within a conference during PIANC's COPEDEC X.

On 19 and 20 November 2020, the Navigating a Changing Climate partners will organise a two-day conference as part of the 10th International Conference on Coastal and Port Engineering in Developing Countries (COPEDEC) to be held in The Philippines, hosted by The Philippine Ports Authority.

The themes of this 'conference within a conference' will include:

1. Moving towards 'net zero' emissions of greenhouse gases from port infrastructure including the port estate
2. Ports' role in enabling the reduction of greenhouse gas emissions from vessels
3. Intermodality and system-level climate change resilience

4. Effects of extreme weather, including risk assessments, contingency plans and warning systems
5. Monitoring and adaptive management for responding to change
6. Climate change adaptation, including theory and practice, methodologies and case studies
7. Optimising operational resilience, including the role of inspection and maintenance
8. Flexible and adaptive infrastructure design
9. Nature-based solutions to improve navigation infrastructure resilience
10. Other climate change topics

The conference will deepen your knowledge on de-carbonisation and the move to net zero greenhouse gas emissions being taken by leading organisations in the sector. It will also enable you to find out more about practical approaches to climate change adaptation, and to intermodal-, system resilience- and nature-based solutions.

SAVE THE DATE

61st Seminar

on Dredging &

Reclamation

5-9 October 2020

Singapore

DREDGING ENGINEERING SPECIAL TOPICS

In dredging, production estimating is carried out mainly with analytical physical models of the different dredging processes. This book, the third in a series, addresses processes not covered in the two preceding editions including hopper sedimentation and erosion, water jet fluidisation, cutter head spillage, pump/pipeline dynamics and clamshell dredging.

In dredging, trenching, (deep sea) mining, drilling, tunnel boring and many other applications, sand, clay or rock has to be excavated. The productions – and thus the dimensions – of the excavating equipment range from mm^3/sec – cm^3/sec to m^3/sec . In oil drilling, layers with a thickness of a magnitude of 0.2 mm are cut, while in dredging, this can be of a magnitude of 0.1 mm with cutter suction dredgers (CSDs) and metres for clamshells and backhoes. Some equipment is designed for dry soil while others operate under water saturated conditions. Installed cutting powers may range up to 10 MW. For both the design, operation and production estimation of the excavating equipment, it is important to be able to predict the cutting forces and powers.

After the soil has been excavated, it is usually transported hydraulically as a slurry – over a short or long distance, with TSHDs or CSDs respectively – or mechanically. Estimating the pressure losses and determining whether or not a bed will occur in the pipeline is of great importance. Fundamental processes of sedimentation, initiation of motion and erosion of the soil particles determine the transport process and the flow regimes. In TSHDs, the soil has to settle during the loading process where also sedimentation and erosion will be in equilibrium. In all cases, soil and high density soil water mixtures as well as its fundamental behaviour are dealt with. Special topics like cutter spillage and waterjet production have been added to this edition.

The author views this publication's compiled topics as being too 'small' to merit their own book, but too interesting not to be published. The content will be updated in the future but represents the last in the series. The first book, *The Delft Sand, Clay & Rock Cutting Model*, is about soil mechanics and the second, *Slurry Transport: Fundamentals, A Historical Overview & The Delft Head Loss & Limit Deposit Velocity Framework*, is about two-phase flow: how to transport soil, sand and water through pipes that can be hundreds of kilometres long.

The series' three titles are self-published on Open Textbooks, a platform run by TU Delft Library where lecturers can publish their textbooks license-free. Launched in late 2018, the digital platform is part of the Delft University of Technology's effort to make scientific education available to as wide an audience as possible, an initiative supported by the author. Textbooks can be downloaded for free by anyone, anywhere in the world and includes a print-on-demand option.

In addition to accessibility, Open Textbooks brings another benefit: ease with which additions and/or corrections can be made. The platform allows authors to upload a new edition whenever a change is made, the library automatically requests a new ISBN.



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<https://www.webedu.nl/bestellen/uniportaal/?action=order&og=14904&orderableobject=22510530>

Sape Miedema

Sape obtained his MSc in Mechanical Engineering with honours at the Delft University of Technology in 1983 and his PhD in 1987. From 1987 to the present, he has been an assistant, then associate, professor at the Chair of Dredging Technology, then as a member of the management board of Mechanical Engineering and Marine Technology. From 1996 to 2001, he was appointed educational director of Mechanical Engineering and Marine Technology whilst remaining associate professor of Dredging Engineering. In 2005, he was additionally appointed educational director of the MSc programme of Offshore Engineering.

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IADC stands for 'International Association of Dredging Companies' and is the global umbrella organisation for contractors in the private dredging industry. IADC is dedicated to promoting the skills, integrity and reliability of its members as well as the dredging industry in general. IADC has over one hundred main and associated members. Together they represent the forefront of the dredging industry.

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