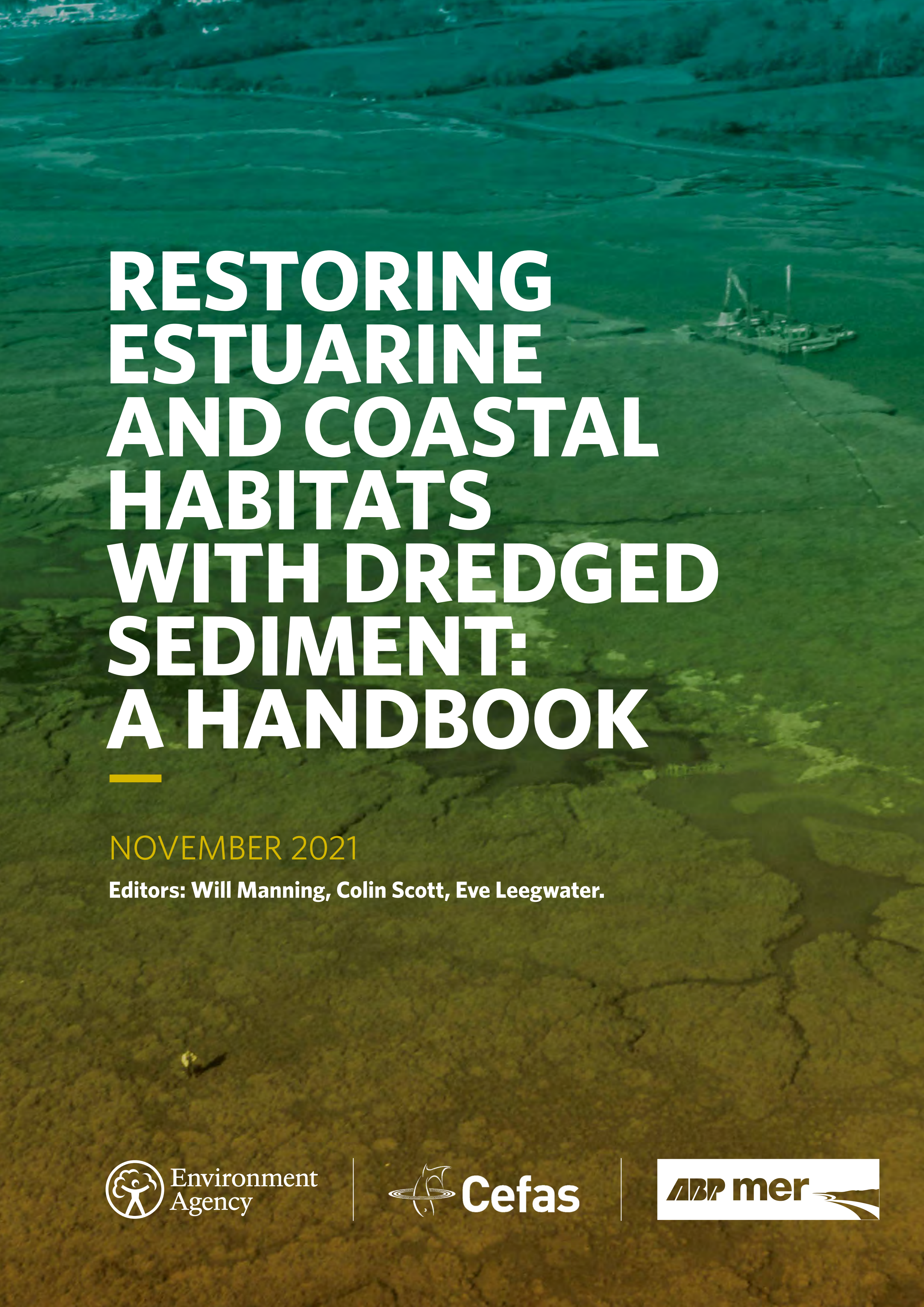


RESTORING ESTUARINE AND COASTAL HABITATS WITH DREDGED SEDIMENT: A HANDBOOK

NOVEMBER 2021

Editors: Will Manning, Colin Scott, Eve Leegwater.

Environment Agency | Cefas | ABP mer

ACKNOWLEDGEMENTS AND FUNDING INFORMATION

This publication has received funding from the Environment Agency Water Environment Investment Fund and from Defra. It has also been enabled by substantial in-kind support and contributions from the authors' organisations (Environment Agency, Cefas, and ABPmer). This publication reflects the authors' views only. Defra and the contributing organisations are not responsible for any use that may be made of the information it contains.

Contributions and reviews have also been provided by members of the Beneficial Use Working Group (BUWG). The BUWG is a consortium of UK regulators, industry representatives and NGOs that aims to review and support the beneficial use of dredged material for estuarine and coastal habitat restoration. The BUWG was established in 2017 following the recommendations of the RSPB report 'Precipitating a Sea Change in the Beneficial Use of Dredged Sediments (SEABUDS)' (Ausden *et al.*, 2018).

We are also grateful to Peter Barham of the Seabed User and Developer Group (SUDG) and Jamie Gardiner of Royal Haskoning (RH DHV) and the Central Dredging Association (CEDA), who reviewed the draft text.

BUWG contributing authors:

- Charlotte Clarke (Centre for Environment, Fisheries and Aquaculture Science)
- Uwe Dornbusch (Environment Agency)
- Mark Johnston (Natural England)
- Rosie Kelly (The Crown Estate)
- Leigh Lock (RSPB)
- Anni Mäkelä (Marine Scotland, Licensing Operations Team)
- Trevor McQuoid (Department of Agriculture, Environment and Rural Affairs, Northern Ireland)
- Nicola Rimington (Natural Resources Wales)
- Chris Turner (Marine Management Organisation)

We thank the authors of the "Restoration Guidelines for Shellfish Reefs" and the Native Oyster Network UK & Ireland for provision of the handbook design template and infographic formats.

This handbook supports the goals of the UN Decade on Ecosystem Restoration (2021 – 2030). Find out more about this UN Decade here: https://www.decadeonrestoration.org/

The ecological, societal and economic benefits of restoring estuarine and coastal habitats has become more widely recognised over the past decade. This has meant that habitat restoration has become a priority for the general public and government agencies.

Saltmarsh vegetation colonising recently placed dredged sediment (Lymington Harbour Commissioners).

EDITORS

Will Manning, Centre for Environment Fisheries and Aquaculture Science, Cefas Laboratory, Pakefield Road, Lowestoft, NR33 0HT, UK.

Colin Scott, ABPmer, Quayside Suite, Medina Chambers, Town Quay, Southampton, SO14 2AQ

Eve Leegwater, Environment Agency, Horizon House, Deanery Road, Bristol, BS1 5AH, UK

Suggested citation for publication:
Manning, W.D., Scott, C.R and Leegwater. E. (eds) (2021). *Restoring Estuarine and Coastal Habitats with Dredged Sediment: A Handbook.* Environment Agency, Bristol, UK.

CONTENTS

EXECUTIVE SUMMARY

This handbook is a practical guide for those interested in beneficially using dredged sediment for estuarine and coastal habitat restoration. It has been written with a broad audience in mind, not just specialists in the field. It is hoped that it will be of value for a range of individuals and organisations including policy makers, nature conservation bodies, local communities or anyone interested, or involved in, dredging, coastal management and ecosystem restoration.

Estuarine and coastal habitats in the UK and globally are under threat and there is an increasing need to tackle the challenges of climate change, rising seas, elevated flood risk, declining biodiversity and a growing world population. As we enter the UN decade on 'Ecosystem Restoration' (https://www.decadeonrestoration.org/) and 'Ocean Science for Sustainable Development' 2021 – 2030, we also recognise humanity's dependence on healthy, robust and functioning marine ecosystems. With this, comes the need to protect and restore ecological systems that provide nature based solutions and resilience to the challenges we face.

One method to help manage coastlines and to protect or restore estuarine and coastal habitats is to use sediment that is dredged from the seabed. Dredging is a vital socio-economic activity. It is needed to maintain safe navigable routes for shipping that access the UK's ports, as well as the many vessel berths, marinas and sheltered harbours located around the UK coastline. There is no shortage of available sediment from these activities that could be suitable for habitat restoration, with large volumes dredged across the UK every year.

Dredged material can be used to reshape shorelines, restore habitats, provide the conditions to aid ecological recovery, or to slow habitat decline and allow time for other coastal adaptation measures to be implemented. For example, there are many instances of sand being dredged, often at large scale and specifically for the purposes of beach nourishment and coastal defence works. However, there are comparatively fewer examples of dredged material being used directly for habitat restoration in the UK. Projects that have been undertaken to date, are typically small in scale.

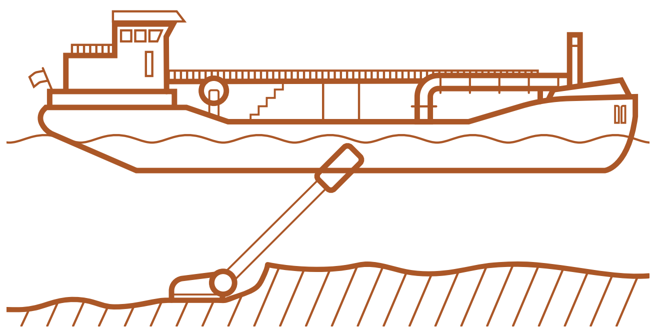
Most of this sediment resource (which is often comprised of recently deposited fine silt and mud) is disposed offshore and only a very small proportion is used to restore these declining habitats. This is because, using sediment beneficially for habitat restoration and moving it from the dredge area to the restoration site is not simple. There are many technical, financial and regulatory challenges to overcome.

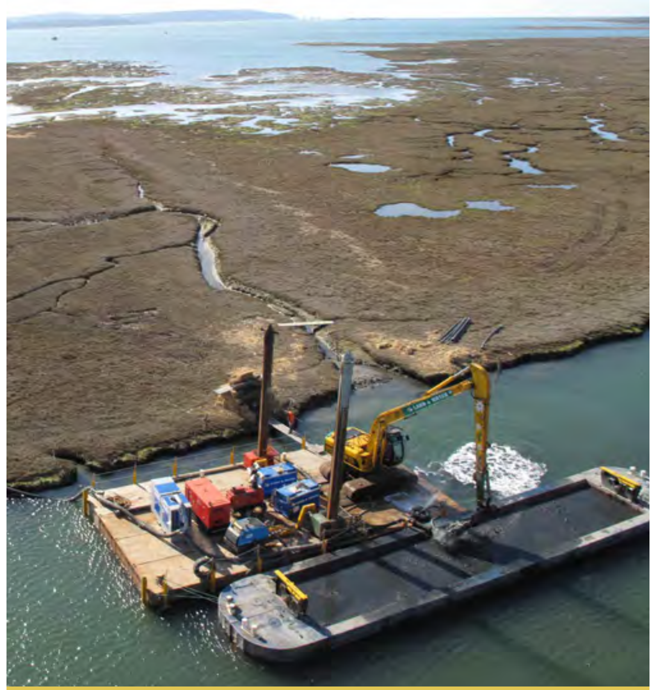
This handbook highlights these challenges, it describes the ways in which dredge material can be used to protect and restore habitats, the issues that need to be considered and the regulatory processes involved. The handbook also outlines best practices to be adopted for using more dredge material for habitat restoration in future. It describes, particularly, how there is a need to adapt existing approaches and consider in greater detail, where sediment can be used for achieving multiple benefits and providing added value.

To make this change will require more active strategic planning, with more integrated management and licensing processes, at the national, regional and local scales. This is needed to help set clear intentions for the future, match sediment supply and demand, address obstacles and manage risks. Such careful planning and review are needed to select appropriate sites and overcome technical challenges and funding requirements. This includes adopting adaptive and collaborative approaches to agree the fairest mechanisms for delivery so that projects are equitable to all parties, with a full recognition of the benefits and beneficiaries.

Through this approach, the relevant licences and permissions can be obtained and used to create a foreseeable 'pipeline' of future projects, which can then be delivered as and when dredge material becomes available. Targeted monitoring and the sharing of results across projects will also allow for the continued improvement in our collective understanding about the technical methods and benefits of using this restoration approach.

To this end, it is hoped that this handbook can facilitate both the use of dredged material in more and larger estuarine and coastal habitat restoration projects, as well as supporting more general strategic and effective management of this sediment resource in the future.





Dredged material being excavated from a hopper barge and hydraulically pumped to restore an eroding marsh (Land and Water Ltd.).

HANDBOOK CONTEXT AND STRUCTURE

Over recent decades, the field of habitat restoration has grown substantially. This is partly due to our increased awareness of the extent of the degradation of valuable marine habitats, combined with our ability to identify the value that they provide.

The UK Marine Strategy commits to "*securing clean, healthy, safe, productive and biologically diverse ocean and seas*". Production of this handbook was jointly commissioned by the Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency (EA), as part of the cross-agency 'Restoring Meadow, Marsh and Reef (ReMeMaRe)' initiative (pronounced 're-memory'). The **vision** of the ReMeMaRe initiative is for restored estuarine and coastal habitats that benefit people and nature, with a **mission** to restore at least 15% of our priority habitats along the English coast by 2043, which fits into the 25 Year Environment Plan (25YEP) time frame.

This handbook is one of a quartet. The other three handbooks in the 'habitat restoration series' describe the restoration of the following priority habitats, seagrass meadows, saltmarshes and native oyster reefs and include specific details of their history, ecology, functionality and value, all of which are important considerations for successful restoration. This handbook focuses on being a practical guide for the use of dredged material as a method to support such habitat restoration efforts. It describes the relevant ecological and policy context, the practical approaches and the regulatory framework. This information is presented in four chapters.

- **Chapter 1: Using dredged sediment for habitat restoration** is an introductory review that provides a basic description of the relevant topics and principles that govern beneficial use, provided to support understanding of the following chapters. This includes a summary of the current status of estuarine and coastal habitats, existing dredging and disposal activities, the underpinning legislative framework for dredged material management and the concept of beneficial use for habitat restoration;
- **Chapter 2: Dredging and beneficial use in practice** reviews the main dredge and disposal methods available, the implications of these methods for sediment behaviour and the retention options that can support both sediment and water management. These are illustrated with a selection of UK and international examples. It then outlines strategic approaches to plan and maximise beneficial use opportunities, providing details about the more important logistical and economic factors that require consideration to support delivery;
- **Chapter 3: A guide to the regulatory processes** provides a guide to the regulatory and licensing processes specific to beneficial use, namely, sediment sampling within the dredge and disposal areas to assess the physical and chemical characteristics of the material and the authorisation of beneficial use disposal sites to receive the dredged material. Further information is also provided regarding more general processes, such as impact assessment, monitoring and mitigation; and
- **Chapter 4: Recommendations and moving forward** provides a final overview and a set of recommendations regarding the way forward. It describes how the beneficial use of sediment needs careful strategic and collaborative planning if it is to be done in an effective and equitable manner.

Beneficial use is a versatile tool and it is recommended that the basic principles detailed in this handbook are considered by those planning the restoration of their target habitat(s) and how the design and success of their project could be improved, or even made viable in the first instance, by the availability of additional sediment. The guidance provided herein is not specific to one habitat. Nonetheless, saltmarsh and intertidal mudflats are the main habitats considered here. This is because they have the greatest potential to benefit from the the large volumes of fine sediment that are dredged annually across the UK.

RESTORING ESTUARINE & COASTAL HABITATS WITH DREDGED SEDIMENT HANDBOOK MAP

Chapter 1:
Using dredge sediment for habitat restoration

- Need to restore estuarine and coastal habitats
- Social and economic importance of dredging
- Using dredged material beneficially for habitat restoration
- Legal framework governing beneficial use
- Barriers to beneficial use
- Environmental conditions and basic principles

Chapter 2:
Dredging and beneficial use in practice

- Dredging methods
- Transport and disposal methods
- Sediment retention methods
- UK and international examples of beneficial use
- Indicative project stages and timelines
- Importance of partnerships and regional strategies
- Project feasibility and planning considerations

Chapter 3:
A guide to the regulatory processes

- Relevant authorities
- Sediment sampling and characterisation
- Authorising beneficial use disposal sites for habitat restoration
- Impact assessments, monitoring and mitigation

Chapter 4:
Recommendations and moving forward

- Final overview
- Recommendations for the future

Foreword

By Tom McCormack, Chief Executive Officer for the Marine Management Organisation

As an island nation, we have an innate connection to the estuarine and coastal habitats that mark the boundary between land and sea. It is a dynamic space, influenced by a complex mix of natural processes and human interactions, from the distant past to the present day.

Development across both land and sea and the artificial stabilisation of large swathes of this boundary, have however, curbed the inherently organic nature of these environments that have suffered substantial declines over recent centuries. As a result, the habitats we see today are often much reduced from their historical extents and are declining in many areas. We are also faced with the unprecedented challenges associated with climate change and biodiversity loss. Undeniably, restoration of these habitats is crucial.

Dredging and disposal activities are uniquely positioned in the discussion of sustainable development and management of the estuarine and coastal zone. They are essential for maintaining safe navigation and facilitating coastal development, they support our island way of life and can produce vast volumes of sediment resource.

However, we need to rethink and improve our approach to how we use this resource. Using dredged material to restore coastal habitats is one nature based solution that can benefit both society and the natural environment.

We know from UK and international examples, that by working with natural processes to help redistribute dredge material, we can add environmental value to development, improving the resilience of existing habitats and buying precious time to develop more sustainable solutions to long term threats such as sea level rise. Using sediments in conjunction with other tools that address such threats, will further improve the strategic and sustainable use of sediment and the management of our estuarine and coastal habitats.

This is easily said and we know there are numerous difficulties limiting real-world application. This handbook has been produced to help address these difficulties and advocate the concept of beneficial use for habitat restoration more widely. In this regard, it is noteworthy that this handbook is being published alongside those promoting the restoration of seagrass meadow, saltmarsh and native oyster reef habitats.

Thank you to those that have collaborated to deliver the project, including the Environment Agency, Cefas and ABPmer, as well as the range of sector specialists, members of the Beneficial Use Working Group (BUWG) and Defra that have contributed. It is hoped that from here, we can continue to drive sustainable and strategic sediment management forward together, delivering more ambitious habitat restoration projects over greater scales, using this available resource where appropriate. In doing so, we can learn more, normalise the practice and all come to develop a greater appreciation for the muds, sands and gravels beneath our feet and keels.

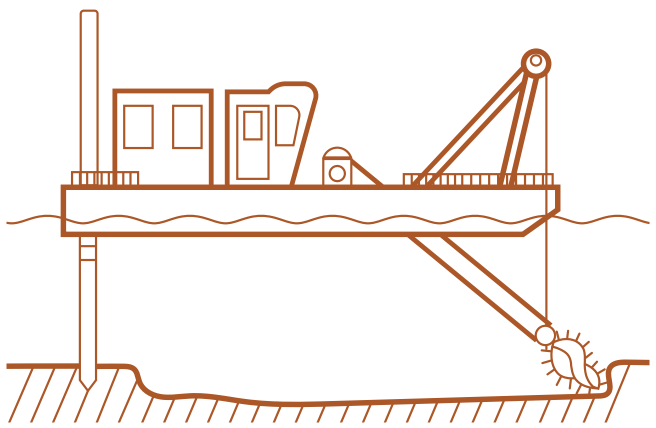
GLOSSARY

In addition to this glossary, the definitions of key terms relating to dredge and disposal activities that require particular attention are also presented throughout the handbook in an attempt to provide further clarity.

- **Abiotic:** the non-living factors in an environment that will influence living organisms, such as sunlight, temperature, waves, tides and geology.
- **Action levels:** contaminant concentration thresholds that provide a proxy risk assessment for potential long term impacts to biological features such as fish and benthos. They are used as part of a 'weight of evidence' approach to determine whether dredged material is suitable for disposal at sea (including for use in habitat restoration projects).
- **Adaptive management:** a framework that facilitates flexible decision-making that can be refined in response to future uncertainties, as the outcomes from current and future management actions become better understood.
- **Baseline:** the existing conditions of the physical, chemical, biological and human environment before an activity starts.
- **Baseline shift:** imperceptible changes in the environmental condition of the baseline that typically occur over multigenerational time frames.
- **Beneficial use of dredged material:** using dredged material in a manner that will benefit society and the natural environment.
- **Biotic:** the factors associated with, and interactions between, living organisms.
- **Blue carbon:** all biologically driven carbon fluxes and storage in marine systems that are amenable to management.
- **Bulking:** volumetric increases in sediment due to changes in soil pressure and disturbance of the original packing of sediment grains.
- **Coastal squeeze:** the loss of natural habitats or deterioration of their quality arising from human structures or actions, preventing the landward transgression of habitats that would otherwise naturally occur in response to sea level rise (SLR) together with other coastal processes. Coastal squeeze affects habitat on the seaward side of existing structures.
- **Confined disposal facility (CDF):** engineered structures designed to provide containment.
- **Critical angle of repose:** the greatest angle relative to the horizontal plane that sediment can maintain without slumping.
- **Critical bed shear stress:** the frictional force, exerted by hydrodynamic flow per unit area of the seabed, that is required to initiate the movement of (entrain) sediment particles.
- **Dewatering:** the removal of water from solid material or sediment by various separation techniques or processes.
- **Dredging cycle:** the time required to complete a full loading – transport – unloading – return operation of a trailing suction hopper dredger, or, the time required for backhoe or grab dredgers to complete one excavation – lifting – disposal – lowering sequence.
- **Ecosystem:** the complex of living organisms, their physical environment (abiotic factors), and all of their interrelationships in a particular unit of space.
- **Ecosystem service:** the benefits that humans derive from nature.
- **Grain size:** the diameter of individual sediment particles.
- **Hopper:** an on-board storage facility that collects dredged material during operation before it is transported. A hopper may be incorporated into the design of the dredger vessel or may be a separate vessel (a hopper barge).
- **Hydraulic dredger:** equipment that excavates and transports dredged material using water.
- **Mechanical dredger:** equipment that excavates and transports dredged material using mechanical force.
- **Mitigation:** measures to avoid, reduce or remedy significant adverse or negative environmental impacts associated with a project.
- **Nature-based Solutions (NbS):** actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human wellbeing and biodiversity benefits.
- **Sediment cell:** sections of the coast that are relatively self-contained and include defined sources, transport pathways and sinks of sediment.
- **Sediment plume:** the horizontal and vertical extent of the water column, containing an elevated level of suspended material associated with natural or human processes (e.g., river discharge or dredge and disposal activities).
- **Source Pathway Receptor (SPR) model:** identifies the linkages (pathways) between an activity (source), the resultant environmental change and a feature (receptor) that is exposed and sensitive to that change.
- **Stakeholder engagement:** the process by which an organisation involves people who may be affected by the decisions it makes, or who can influence the implementation of its decisions.
- **Transport water:** the water added to dredged material during dredging, transportation or disposal.

ACRONYMS

ALs	Action Levels (AL1 and AL2)
A/SSSI	Area/Site of Special Scientific Interest
BHD	Backhoe Dredger
BNG	Biodiversity Net Gain
BPEO	Best Practicable Environmental Option
BU	Beneficial Use
CDF	Confined Disposal Facility
CEDA	Central Dredging Association
CSD	Cutter Suction Dredger
EIA	Environmental Impact Assessment
GD	Grab Dredger
GHG	Greenhouse Gases
HELCOM	Helsinki Commission
HMWB	Heavily Modified Water Body
HRA	Habitats Regulation Assessment/Appraisal
IADC	International Association of Dredging Companies
INNS	Invasive Non Native Species
LCLP	London Convention London Protocol
LNRS	Local Nature Recovery Strategies
MCZ	Marine Conservation Zone
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLW	Mean Low Water
MPA	Marine Protected Area
MSL	Mean Sea Level
NbS	Nature-Based Solutions
NCMPA	Nature Conservation Marine Protected Area
NRN	Nature Recovery Network
NTL	Normal Tidal Limit
OSPAR	Oslo and Paris (Convention and Commission)
PSA	Particle Size Analysis
PSD	Particle Size Distribution
RBMP	River Basin Management Plan
RTE	Regulated Tidal Exchange
SAC	Special Area of Conservation
SCDF	Semi-Confined Disposal Facility
SDG	Sustainable Development Goals
SLR	Sea Level Rise
SMF	Sediment Management Framework (online tool)
SMP	Shoreline Management Plan
SNCB	Statutory Nature Conservation Body
SPA	Special Protected Area
SPR	Source Pathway Receptor (model)
SSC	Suspended Sediment Concentration
TDD	Target Dredge Depth
TSS	Total Suspended Solids
TSHD	Trailing Suction Hopper Dredger
WID	Water Injection Dredger



CHAPTER 1
USING DREDGED SEDIMENT FOR HABITAT RESTORATION

KEY SUMMARY POINTS:

- **Estuarine and coastal habitats in the UK and globally, have suffered substantial losses and continue to face extensive declines. As they are being lost, we are also losing the valuable ecosystem services (benefits) they provide. Sediment is an important resource and its strategic and sustainable management, is important for the health and functioning of these habitats.**
- **Dredging plays a vital socio-economic role. It is needed primarily to provide safe navigation for global shipping within the UK's ports, through which over 95% (by volume), of the UK's imports and exports pass. It also supports the management and operation of the historic waterways and many sailing clubs, marinas and fishing harbours around the UK coast.**
- **Dredging and associated disposal activities are subject to legal and licensing controls that require 'alternative' or 'beneficial' uses of dredged material to be considered. Beneficial use is defined as using dredged material in a manner that will benefit society and the natural environment.**
- **One valuable way to beneficially use dredge material, is to physically protect or restore declining or lost habitats such as saltmarshes and mudflats (using fine sediments) or vegetated drift lines and oyster beds (using coarse sediments). For several reasons, only small amounts of dredge material are used to achieve these types of nature-based solutions and instead, a large proportion of available dredged material is often disposed of offshore, with an associated loss of sediment from the local environment.**
- **Beneficial use is one technique for restoring estuarine and coastal habitats and managing shoreline adaptation, but it is not necessarily applicable in all situations. The nature and functionality of the receiving environment as well as the local planning and policy context are key considerations. Other complementary methods, such as restoring saltmarsh through managed realignment, are also available and are described in the saltmarsh restoration handbook in this series. Using dredged material for habitat restoration is however, a very underused but valuable technique that can, when used in carefully selected locations, help delay or even reverse further habitat degradation.**

INTRODUCTION

ESTUARINE AND COASTAL ENVIRONMENTAL DECLINE

Estuarine and coastal environments exist at the complex interface of atmospheric, marine, freshwater and terrestrial systems. They can be immensely dynamic, reflecting natural variations in hydrological energy, geomorphological processes and biological interactions, all acting over varying temporal and spatial scales. These range from the submergence and emergence of saltmarsh vegetation and intertidal flats associated with the rise and fall of the tide, to variations in beach morphology associated with seasonal changes in wave energy, through to changing shoreline positions over longer timescales in response to sea level and long term patterns of erosion and accretion.

Unfortunately, these environments have suffered substantial declines from their natural state over the preceding centuries as a result of human impacts, such as historical land claim of coastal wetlands and reductions in water quality. Although existing conservation and restoration measures help in some respect, the reality is that at best, our current efforts do little more than maintain the depleted and degraded status quo. Many of these impacts remain today but, in some cases, even where pressures are abated, habitats and species are unable to recover without active intervention. Consequently, habitat and biodiversity losses are set to continue and are likely to be further exacerbated by the impacts of climate change and pressures resulting from an increasing human population. Further details of the historic declines and ongoing threats faced by the priority habitats can be found in their respective restoration handbooks.

With the loss of these habitats and associated species, we have also lost the valuable ecosystem services that they provide. Ecosystem services are defined as the benefits that humans derive from nature and are categorised into four different types of service: provisioning, regulating, cultural and supporting services (Figure 1.1).

The Office for National Statistics (ONS) have estimated that the UK marine natural capital assets for which we can estimate a value, have an asset value of £211 billion (based on 2018 values) (ONS, 2021). The UK National Ecosystem Assessment (UK NEA) estimates the total value of ecosystem services provided by all coastal habitats in the UK at £48 billion (based on 2003 values). The service and value provided depends on the specific habitat, but ecosystem services include flood and coastal defence benefits, carbon sequestration (Box 1.1), nutrient absorption, provision of nursery sites and supporting fisheries, enhanced biodiversity and improved water quality, as well as socio-economic benefits relating to recreation, tourism and improved health and well-being.

A number of frameworks have been developed for describing ecosystem services, such as the National Ecosystem Assessment Follow-On project (Turner et al., 2014). The NEAFO framework is useful for supporting the valuation of environmental benefits, as it focuses on the final ecosystem service benefits that humans derive from ecosystems and thus avoids the risk of double counting.

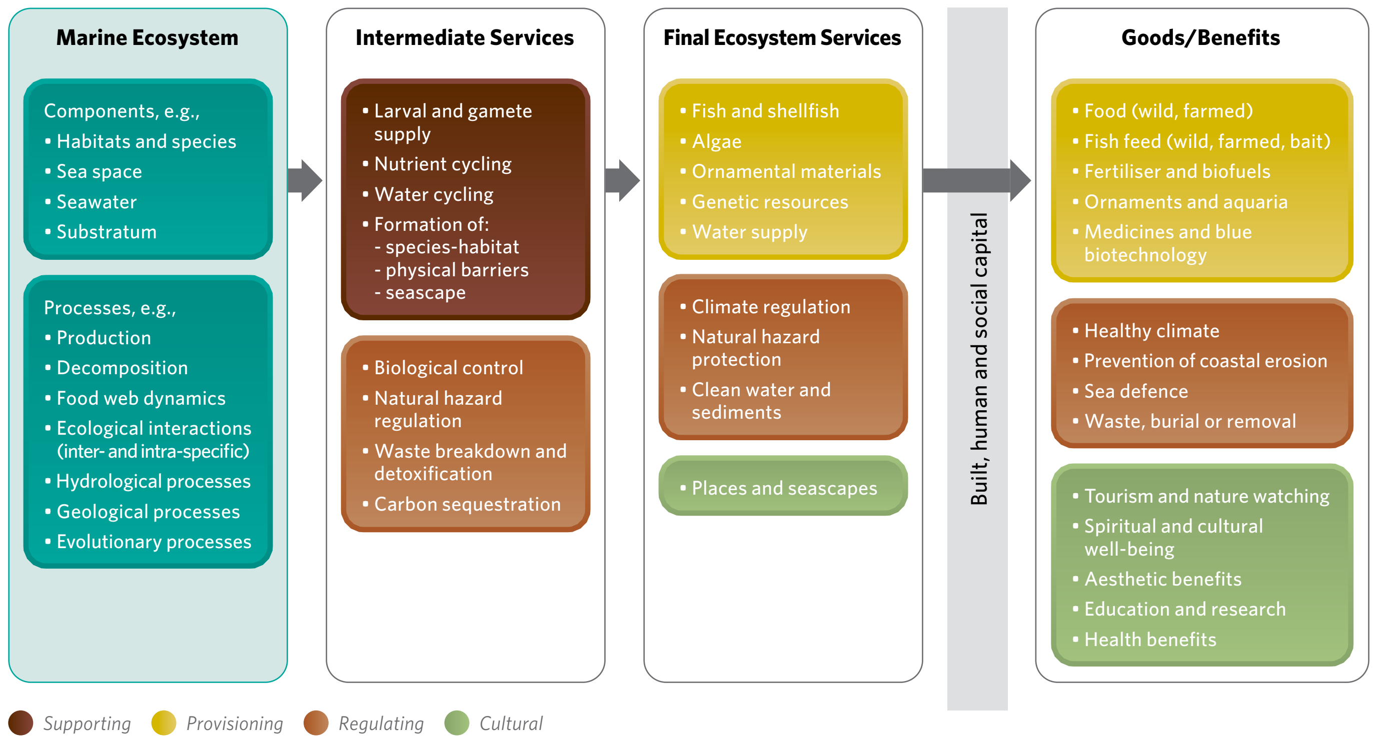


Figure 1.1: Ecosystem services (Turner *et al.*, 2014).

Over recent decades and owing to our increasing awareness and appreciation of the natural world, the value it provides and the extent and rate at which it has and is being lost, habitat restoration efforts have gained increasing attention, momentum and application. It is also recognised that we need practical intervention and restoration on a much bigger scale, alongside the management of pressures to help habitats and species recover naturally. This is encapsulated in the International Union for Conservation of Nature's (IUCN) concept of nature-based solutions (NbS), defined as **actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well being and biodiversity benefits.** Practical guidance and frameworks for delivering NbS now exists for a range of habitats and solutions (e.g., Bridges et al., 2021).

One example of NbS, is to use some of the large quantities of material that are dredged every year, primarily for maintaining ports, harbours and safe navigation channels, and dispose and redistribute the sediment in a way that supports habitat restoration. Sediments and soils are fundamental to environmental and therefore human health and we are increasingly recognising dredged material as a valuable sediment resource, which needs to be better managed in order to address the challenges we face. At the individual project level, this includes supporting the geomorphology and physical conditions that can facilitate and sustain the successful restoration of estuarine and coastal habitats.

Using dredged material to support restoration and the management of vulnerable shorelines is just one example of a NbS, but one that has distinct characteristics and challenges as described in this handbook. Further considerations required for undertaking specific habitat restoration are provided in the seagrass, saltmarsh and native oyster restoration handbooks.

BOX 1.1: BLUE CARBON AND ITS RELATIONSHIP WITH BENEFICIAL USE

The term blue carbon, refers to all biologically driven carbon fluxes and storage in marine systems that are amenable to management. This includes the carbon captured by living organisms and stored (sequestered) in both biomass and sediments.

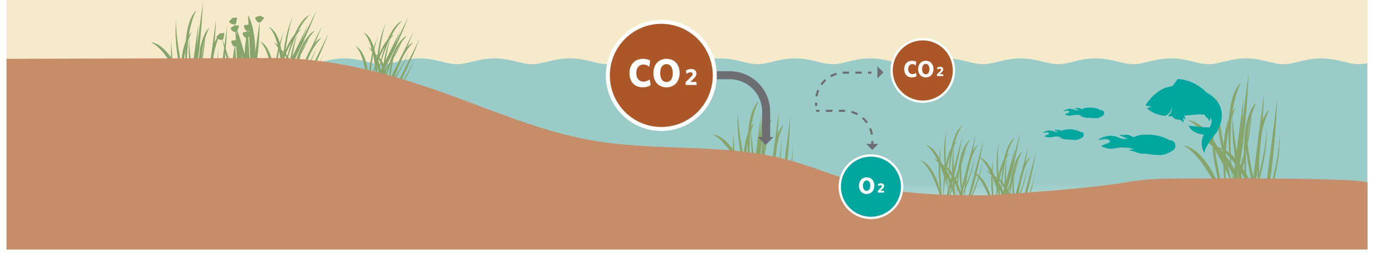
Accordingly, considerable attention has been given to the potential role that estuarine and coastal habitat restoration could play in climate mitigation by enhancing carbon removal from the atmosphere.

A summary of the current scientific evidence for blue carbon stocks and accumulation rates in marine habitats in English waters is reported in Parker *et al.*, (2021). This report also clarifies the gaps in understanding about these topics.

To improve the knowledge base, both organic carbon stocks and greenhouse gas (GHG) flux measurements are required. There is also a need to agree and apply standard techniques if these values are to be accounted and carbon credits are to be obtained, or if these measures are to be used in national GHG inventories. These approaches are continually under review and details on the monitoring of blue carbon are provided in Chapter 3.

For habitat restoration projects using dredged material, the relationship with blue carbon is complex. For example, dredging, transport and disposal activities may release carbon stored within the sediment and contribute their own carbon emissions during operation. However, where dredging is required, dredged material can be used to support the restoration of blue carbon habitats and protect existing habitats from further degradation. Therefore, it can, depending on the scale and nature of the project, help retain or even enhance blue carbon stocks and sequestration.

At present, there is insufficient evidence to understand this relationship in detail, partly due to a general lack of real-world applications of beneficial use and associated studies. However, the relationship will also be project and site specific due to a number of factors. These include: the target habitat being restored, environmental conditions on site, the volumes and types of sediments being used and temporal variations as the restored habitat develops over time. The monitoring of carbon across the project lifecycle, from carbon stored in the sediment prior to dredging, to carbon emitted during habitat restoration works, through to biogeochemical cycling as the restored site subsequently develops, would help develop our understanding of this relationship. It would also help inform and further develop agreed standards for valuing the role restored habitats play in carbon retention and sequestration.



DREDGE AND DISPOSAL ACTIVITY

The concept of using dredged material for habitat restoration is detailed further below in this chapter. However, to help understand the role that dredged material can play, this section first provides an initial overview of the dredging sector. This includes some of the terminologies and legal requirements that are important and useful to know, before starting a habitat restoration project using dredged material (which is the focus of Chapters 2 and 3).

Terminologies

Terminologies used in the dredging sector and associated regulatory processes may vary or be used interchangeably in the international literature. For example, there is no set or universal definition for the beneficial use of dredged material, which may also be referred to interchangeably as 'alternative use' or 're-use'. In a concerted effort to move towards a common language for sustainable sediment management, this handbook aligns with the terminologies used in the recent and detailed book, 'Dredging for Sustainable Infrastructure' (CEDA and IADC, 2018). 'Beneficial use' and 'use' of dredged material will be used interchangeably and **the beneficial use of dredged material is defined as using dredged material in a manner that will benefit society and the natural environment.**

According to the Oslo-Paris (OSPAR) Commission guidelines (OSPAR, 2014), beneficial use can be broadly divided into three categories.

- **Engineered uses:** land creation and improvement, beach nourishment, offshore berms, capping material and fill
- **Agricultural and product uses:** aquaculture, construction material and liners
- **Environmental enhancement:** restoration and establishment of wetlands, terrestrial habitats, nesting islands and fisheries

This handbook focusses on 'environmental enhancement' and aims to promote more sustainable sediment management, through targeted interventions that beneficially use dredged material arising from navigation dredging to support estuarine and coastal habitat restoration below MHWS, seaward of existing structures. Other notable examples of possible habitat restoration with dredged material beyond this scope are identified.

A summary of common terms and their definitions used in this handbook and of relevance to the UK regulatory processes, are also provided in Table 1.1

Table 1.1: Terminologies associated with dredge and disposal activities.

TERM	DESCRIPTION
Navigation dredging	The removal of material from areas below the waterline in order to maintain the target dredge depth (TDD) and ensure safe navigation. Referred to as 'dredging', unless otherwise stated.
Dredged material	Primarily sediments and/or rocks, with associated water, organic matter etc., removed from areas that are normally or regularly covered by water. May also be referred to as 'dredged sediment'.
Beneficial use	Using dredged material in a manner that will benefit society and the natural environment. In the context of this handbook, this definition focuses on its use in supporting estuarine and coastal habitat restoration below mean high water springs (MHWS), seaward of existing structures.
Disposal site (England, Wales and Northern Ireland)	An area of the seabed located below MHWS, or within tidal limits, which has been authorised for receiving dredged material. Disposal sites are authorised, not licensed.
Deposit site (Scotland)	Synonymous with 'disposal site'.
Beneficial use site	A disposal site, where the relocation of dredged material within the site will benefit society and the natural environment.
Disposal at sea	The relocation of dredged material to its final destination for storage within an authorised 'disposal site', with no further intended future use.
Deposit	Synonymous with 'disposal at sea' but relating to a 'deposit site (Scotland)'. 'Deposition' may also be referred to in the context of natural sedimentation.
Dumping	Generally an outdated term that is no longer used, but was used in previous legislation that remains relevant today.
Relocation and placement	Non-specific, overarching terms for moving dredged material to its destination.

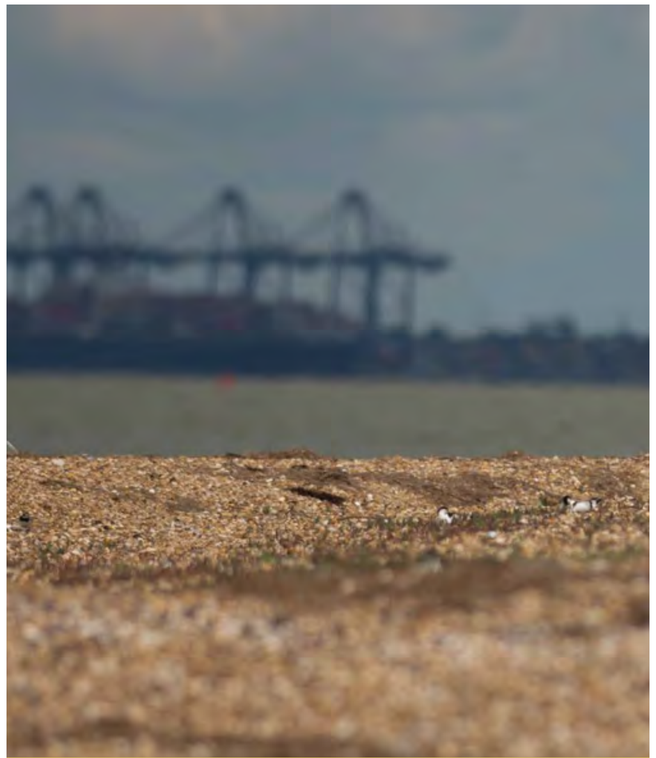
Navigation dredging

Ports and harbours have an important and legal role to play in providing safe navigation. Navigation dredging is an essential tool for achieving this (Box 1.2) and is vital to the economy, with ports carrying over 95% of the UK's imports and exports by volume and 75% by value (British Ports Association).

Dredging also maintains historic waterways and supports the various sailing clubs, marinas, fishing harbours and cruise terminals that line and dot the UK coast. It may also be required for residential or commercial coastal development. Although these contributions to the overall dredge volume are comparatively small compared with port maintenance and development, they are nonetheless a potentially useful source of local sediment and can hold substantial economic, social and cultural importance in their own right.

Legal framework

The UK is signatory to both the London Convention and London Protocol (LCLP) and the OSPAR Convention (Table 1.2). LCLP and OSPAR both aim to prevent marine pollution resulting from human activities, such as the potential release of any chemical contaminants found within the sediments being dredged. Legislation transposes the requirements of these international conventions into national law. This provides the necessary statutory means for contracting parties (nations) to assess and manage dredge and disposal activity, as well as their total contribution of pollution into the marine environment from all sources, thereby allowing the UK to meet its wider obligations.



Nesting birds on a vegetated sand and gravel barrier at Horsey Island, Essex, created using material from Harwich and Felixstowe capital dredges (Paul Davis, RSPB).

BOX 1.2: DISTINCTION BETWEEN MAINTENANCE AND CAPITAL DREDGING

The two main types of navigation dredging are 'maintenance' and 'capital' dredging. The typical characteristics of the arising dredged material play a key role in determining what beneficial use options may be available.

Maintenance dredging: the periodic removal of recently deposited sediment from areas below the waterline, in order to maintain the safe TDD within an existing navigation channel. Maintenance dredging is typically, but not always, characterised by:

- Variable quantities of material
- Weak or less-consolidated sediment
- Comprised of recently deposited fine sediments (e.g., silt and mud, with sand in some instances)
- Less likely to contain historical contamination
- Repetitive activity

Capital dredging: the process of removing sediment from previously undisturbed areas below the waterline (virgin ground) or after a prolonged period following the cessation of previous dredging activity, in order to achieve the TDD. Capital dredging is typically, but not always, characterised by:

- Removal of large quantities of material
- Compacted and undisturbed sediment
- Variable particle size dependent on the local geology, but generally includes coarser fractions and more consolidated material (e.g., rock, gravel and stiff clay)
- May contain historical chemical contamination
- Non-repetitive activity

The time period that differentiates between a maintenance and capital dredge varies across the UK nations. In Scotland, it is 7 years and in all other UK nations, it is 10 years. Although these definitions exist, it should be noted that they are used to support management decisions. In reality, there is little environmental difference between a capital dredge carried out after 10.5 years and a maintenance dredge carried out after 9.5 years, as according to the definitions in England, Wales and Northern Ireland.

'Remedial dredging' is a third type of navigation dredging that specifically refers to the targeted removal of contaminated sediments in order to improve environmental conditions. However, as high contaminant loading typically precludes the use of dredged material from habitat restoration projects, remedial dredging is not considered further in this handbook.

Table 1.2: Legislative framework governing the management of dredged material.

JURISDICTION	LEGISLATION
International (Global)	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972. Also referred to as the London Convention (LC)
	London Protocol 1996 (LP). An update and intended replacement of the LC. Often referred to in tandem as LCLP
International (Regional)	OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic 1992
National	Marine and Coastal Access Act (England and Wales) 2009
	Marine (Scotland) Act 2010
	Marine Act (NI) 2013

These obligations include several requirements that contracting parties must follow, forming the basis of the regulatory processes specific to dredge and disposal activities. These are described in detail in Chapter 3 but are useful to know from the outset. Namely, each nation must:

- **Assess the contaminant levels within the sediment against national guidelines**
- **Only dispose of dredged material within authorised disposal sites. This includes habitat restoration sites where dredged material will be beneficially used**
- **Based on the two requirements above, submit annual returns to LCLP and OSPAR Secretariats, quantifying the amount of dredged material and associated contamination disposed of within each disposal site (Box 1.3)**

Cefas is responsible for collating this information from the marine licensing bodies of individual nations and managing the returns process on behalf of the UK. Further details of the relevant regulatory authorities involved in this process are also provided in Chapter 3.

To help manage dredged material, the authorised disposal sites are given a unique identification code, 'XX###', where 'XX' denotes the location (e.g., 'HU' denotes the wider Humber Estuary) and '###' is the unique identification number for that disposal site (Figure 1.2). They are also assigned a category based on OSPAR terminologies and the purpose for which the dredged material is being disposed (Table 1.3). This is also in accordance with the tiers of the waste hierarchy (Box 1.4).

For example, if the disposal site is being licensed under Tier 2 of the waste hierarchy, 'preparing for re-use', the disposal site is assigned one of the seven 'beneficial use' categories (Table 1.3). If the disposal site is being licensed under Tier 5, 'disposal', the site is simply categorised as 'disposal'. In the context of this handbook, where dredged material is being used for habitat restoration under Tier 2 of the waste hierarchy, the process would be referred to as disposal within a beneficial use disposal site, which itself would be categorised as a disposal site for 'habitat generation'.

BOX 1.3: DISPOSAL STATISTICS

Based on the disposal returns collated by Cefas and the terminologies described herein, every year across the UK between 2009 and 2019, on average, around 27 million wet tonnes of dredged material were disposed of at sea. This equates to approximately 17 million cubic metres (m^3). Of this, approximately 68% was disposed offshore (Tier 5), with around 30% disposed of through local placement within the rivers and estuaries from which it was dredged, thereby retaining the sediment in the system (also referred to as 'sustainable relocation') (Tier 2). Only 0.4% of dredged material was used to directly support habitat restoration (Tier 2).

It should be noted that these statistics are based on the specific terminologies and categorisations used, which if not understood, can make the figures misleading. To clarify, firstly, the quantities refer to dredged material disposed of at sea below mean high water springs (MHWS) only, not the amount of material dredged. Dredging methods are described further in Chapter 2, but in the context of disposal returns, hydrodynamic methods such as plough dredging and water injection dredging (WID) are not considered to generate 'waste', as following agitation, material is moved via gravity and tidal or fluvial currents. Consequently, these methods do not give rise to dredged material requiring disposal and therefore, do not require authorisation of a disposal site and are not included in the figures reported above (except in very specific circumstances). Secondly, these statistics do not include material being disposed of outside of the marine environment, whether it be for legitimate beneficial uses in accordance with OSPAR (e.g., as fill material during construction of a coastal development project) or to be disposed of to landfill.

The statistics therefore tell a very specific story. Nonetheless, of the available resource, very little sediment is currently utilised to directly support habitat restoration. This situation persists because several barriers prevent this from happening. These barriers are described further below.

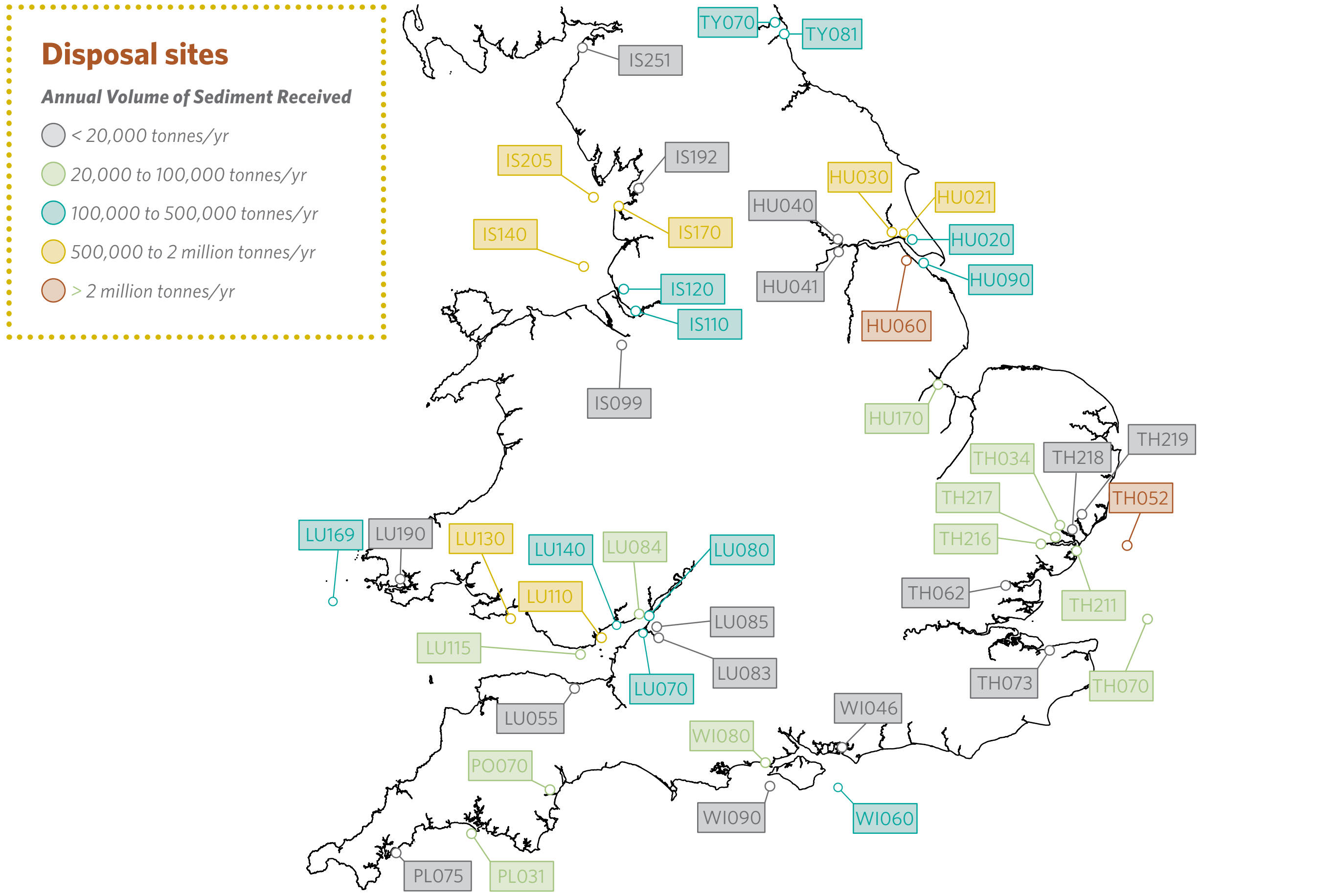


Figure 1.2: Examples of disposal sites in England and Wales, including their naming convention, locations and approximate quantities of material received (ABPmer).

Table 1.3: Categories used to classify disposal sites within the UK in accordance with OSPAR (2014).
** denotes disposal sites categorised as beneficial use.*

DISPOSAL SITE CATEGORY	DEFINITION
Local placement *	Retaining dredged material within the local sediment cell in order to support sedimentary processes and maintain the sediment budget. May also be referred to as 'sustainable relocation'.
Beach nourishment or recharge *	Restoring and maintaining beaches, primarily using sand or coarser material.
Land reclamation *	Supporting the reclamation of land from below MHWS by using dredged material as fill material.
Construction *	Engineering uses, such as using dredged material as fill material for a land reclamation project or as capping material for confined disposal facilities (CDFs).
Coastal protection (other than beach nourishment) *	Shoreline stabilisation, using dredged material to maintain or create erosion protection, dike field maintenance, berm or levee construction and erosion control.
Habitat generation *	Direct disposal of dredged material to enhance or restore habitats. Referred to as 'habitat restoration' in this handbook.
Other *	This category was relatively recently changed to 'local placement' and existing records are in the process of being updated. The category was retained to allow for 'new' beneficial use methods that may be developed in future that would not fall into the existing categories described above.
Disposal	Disposal of dredged material outside of the local sediment cell and where it is not considered to benefit society or the natural environment (Tier 5).

BOX 1.4: GUIDANCE ON APPLYING THE WASTE HIERARCHY

As transposed under national waste law (e.g., The Waste (England and Wales) Regulations 2011), dredged material is classified as a 'waste', defined as *"any substance or object which the holder discards or intends or is required to discard"*. Dredged material therefore falls under the remit of waste regulations, which requires consideration of the waste hierarchy and whether beneficial use options are available.

The waste hierarchy sets out the five tiers for managing all types of waste (e.g., wood, dredged material, plastics, fibre), ranked and prioritised according to the preferred management approach (Figure 1.3). The hierarchy strongly governs waste management policy in the UK and is considered by the relevant authorities when deciding whether or not to grant a dredge licence or authorise a disposal site.

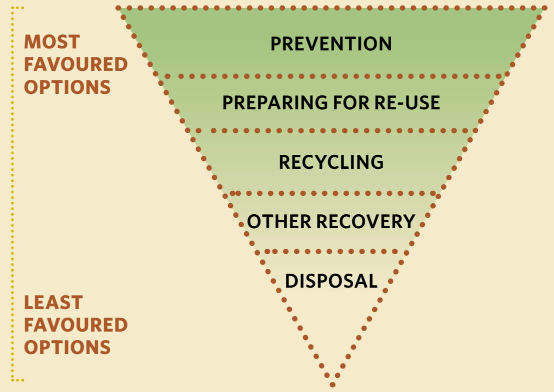


Figure 1.3: Waste hierarchy.

As described in this chapter and further detailed in Chapter 3, the levels of sediment contamination present within dredged material and the existing sediments at the beneficial use disposal site will need to be considered as part of the licensing process. The presence of contamination is typically one of the primary reasons why dredged material cannot be used beneficially for habitat restoration, particularly when using capital dredge arisings. However, for the purposes of this handbook, it is assumed that the sediment has been assessed and considered suitable for use by the relevant authority when describing project delivery. Further information and advice regarding the management of contaminated sediments is available in other texts (e.g., CEDA, 2019a).

Tier 1: The '**prevention**' of waste generation in the first instance is the primary aim. This may mean not dredging, or, where dredging is required (e.g., in order to maintain safe navigation) or deemed viable (e.g., as part of a licensed development), using methods that are not considered to produce 'waste' (e.g., plough dredging or WID), establishing self-scouring conditions, or minimising the dredge volume as far as reasonably practical.

Tier 2: For all arising dredged material, '**preparing for re-use**' is considered the most favoured management option. This includes habitat restoration and other applications (Table 1.3) and is defined as using dredged material in a manner that will benefit society and the natural environment.

Tier 3: '**Recycling**' includes approaches such as the creation of a new substance or product. Stabilisation is a common form of 'recycling' and is similar to concrete production, where dredged material is used as the base aggregate and mixed with binders, such as cement. In some instances, this can have the added benefit of improved resource efficiency by reducing demand on primary aggregate sources, or it can be used to create products for use in habitat restoration, such as artificial reef structures.

Tier 4: Descriptions of '**other recovery**' include processes such as anaerobic digestion and incineration with energy recovery. Descriptions can also overlap with 'recycling'. Some of these options are not considered viable for dredged material and this is partly due to the waste hierarchy's lack of specificity to a particular waste stream.

Tier 5: '**Disposal**' outside of the local sediment cell or to landfill and where it is not considered to benefit society and the natural environment, is always considered the least favoured option. It should only be carried out as a last resort when all other waste management options have been exhausted. Offshore disposal results in a loss of sediment from the natural estuarine and coastal system. It can also incur additional monetary and carbon cost, associated with increased fuel consumption due to the transport of material over greater distances.

Supporting policy, legislation and guidance

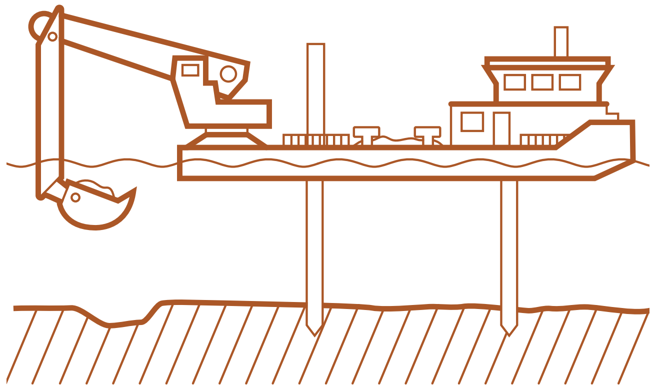
Beneficial use and the aim for improved sediment management, is both supported by and can contribute towards policy, legislation and guidance (Table 1.4). It has long been recognised that in carefully selected locations, using dredged material for habitat restoration is a genuine option that can help delay or even reverse observed habitat declines, whilst simultaneously providing multiple socio-economic benefits. Where there are gaps in existing policy or where policy is being developed, further integration and promotion of beneficial use is recommended.

Table 1.4: Examples of policy, legislation and guidance that support, or could be supported by, beneficial use.

POLICY, LEGISLATION OR GUIDANCE	DESCRIPTION	JURISDICTION
United Nations Sustainable Development Goals (SDGs)	***SDG 13:*** *Take urgent action to combat climate change and its impacts.* ***SDG 14:*** *To conserve and sustainably use the ocean, seas and marine resources for sustainable development.*	International (Global)
London Convention London Protocol (LCLP) revised guidelines	*"Sediment is an essential component of fresh water, estuarine and marine ecosystems. Sediment processes play important roles in determining the structures and functions of aquatic systems. Therefore, management processes applied to sediment, in relation to human activities, should recognise that sediment is an important natural resource".*	International (Global)
OSPAR guidelines	*"Sediment is a valuable natural resource. Beneficial uses of dredged material should be pursued to the maximum extent practicable. Beneficial use of sediments includes retaining sediments that meet national assessment criteria within freshwater, estuarine and marine systems".*	International (Regional)
UK Environment Defra 25 Year Environment Plan (25 YEP) (England) The Environment Strategy for Scotland The Environment Strategy Northern Ireland The Environment (Wales) Act 2016 – National Resources Policy	**Waste** Re-using sediment will minimise waste and improve resource efficiency in order to reduce impacts on the environment. **Restoration** The restoration, enhancement and protection of estuarine and coastal habitats is aligned with and will help achieve various UK policies and targets.	UK
Climate Change Act 2008	The UK government is committed to addressing climate change, including the aim for net zero greenhouse gas emissions by 2050. Restoration of blue carbon habitats through beneficial use could therefore, play a role in efforts to offset carbon emissions, whist simultaneously providing additional ecosystem services (e.g., coastal resilience, biodiversity, etc.).	UK
Waste (Circular Economy) (Amendment) Regulations 2020	Facilitate and ensure that waste undergoes preparing for re-use, recycling or other recovery operations in accordance with the waste hierarchy.	UK
UK Marine Policy Statement	*"Appropriately targeted disposal of dredged sediment can have an ancillary benefit in maintaining sedimentary systems and, where the sediment is constituted appropriately, can have social and economic benefit in providing material for alternative uses such as construction, beach nourishment or salt marsh restoration".*	UK
Marine licensing	Implements the requirements of the relevant national waste regulations, requiring all applicants to manage arising dredged material in accordance with the waste hierarchy.	UK
Regional Marine Plans	For example, *"Proposals for the disposal of dredged material must demonstrate that they have been assessed against the waste hierarchy. Where there is the need to identify new dredge disposal sites, including alternative use sites, proposals should be supported if they conform to best practice and guidance".*	England
National Marine Plan	*"The beneficial use of dredged material is encouraged. In accordance with the Waste (England and Wales) Regulations 2011, relevant authorities should apply the waste hierarchy".*	Wales
National Marine Plan	*"Dredged material may be disposed of at licensed marine disposal sites or used for alternative purposes such as land reclamation or coastal nourishment, if suitable, to minimise seabed disposal".*	Scotland
Draft National Marine Plan	*"Proposals that include the disposal of dredging waste, must demonstrate that appropriate consideration has been given to the internationally agreed hierarchy of waste management options for sea disposal".*	Northern Ireland
River Basin Management Plans (RBMPs)	River basin management plans aim to enhance nature and natural water assets. Where flexibility exists, when implementing programmes of measures to protect and improve the water environment and when choosing specific actions, the following principles should be followed: • Work with natural processes; where possible choose nature-based solutions to protect and improve natural water assets and deliver multiple benefits. • Promote restoration and recovery of freshwater, estuarine and coastal habitats and species; this will provide resilience to climate impacts.	England and Wales
Shoreline Management Plans (SMP)	SMPs can be used to identify options for beneficial use projects within the plan area that will contribute to coastal defence management and address threats associated with coastal change. SMPs also identify where flood defences have the potential to impact on coastal habitats through coastal squeeze and how this can be addressed through habitat compensation, including options to set back coastal defences and restore habitats, providing opportunities for beneficial use.	England and Wales
Biodiversity Net Gain (BNG)	The Environment Bill contains a new BNG condition for planning permissions, requiring a 10% uplift in biodiversity associated with development above mean low water (MLW). The BNG framework supports changes in land management that improve the diversity value of a site, including habitat restoration across the intertidal and may improve financial support for restoration projects, including those beneficially using dredged material.	England
Nature Recover Networks (NRN)	The Environment Bill requires the establishment of Local Nature Recovery Strategies (LNRS), providing the foundation of a national Nature Recovery Network. As individual restoration sites are mapped and networks developed, identifying a subset of those that may benefit from additional sediment could help establish regional beneficial use strategies whilst helping these networks achieve their restoration aims.	England
The Nature Recovery Action Plan	One of the five themes is 'Maintaining and Enhancing Resilient Ecological Networks', spatial action to deliver benefits for biodiversity, species and habitats, avoid negative impacts and maximise our wellbeing. Local actions under this theme may provide opportunities to support habitat creation and restoration at the coast, which have the potential to include the use of dredged material.	Wales
Environmental Land Management (ELM)	Farmers and land managers enter into agreements with the government to manage or carry out works on their land which help achieve the 25YEP and zero emissions targets. At the coast, these agreements can offer financial incentives for habitat restoration and natural flood management projects, which may be supported by beneficial use.	England
The Sustainable Land Management (SLM) policy framework	SLM aims to meet the requirements of domestic legislation and need to address climate change associated with land management and the continuing loss of biodiversity on farmland. The SLM policy framework and the proposed sustainable farming scheme may provide opportunities to support habitat restoration at the coast, which have the potential to include the use of dredged material.	Wales

BARRIERS TO BENEFICIAL USE

Despite being increasingly supported by policy, legislation and guidance, a number of barriers exist that inhibit wider uptake of beneficial use for habitat restoration, as summarised below. However, these key issues are difficult to resolve and despite previous studies that have sought to clarify these barriers and find solutions so that greater benefits can be achieved, such as PIANC (2009) and Ausden *et al.*, (2018), they still hamper wider application. There is however, increasing ambition to address these challenges in light of the imperative need.



Lack of leadership and co-ordination: There is a lack of strategic integration between those carrying out the dredging, those that regulate the sector and those that could use the sediment for habitat restoration or its associated benefits such as flood protection. There is therefore a broken market with a clear disconnect and a lack of communication between supply and demand. This is hampered by a lack of any central data store providing details regarding the nature of available sediment and a lack of consensus about exactly where the sites are that need this sediment and hence, what the 'demand' precisely is. There is therefore a need for better leadership, strategic management and communication across all parties involved.

Extra costs and different beneficiaries: In most instances, especially when working at anything but a small scale, beneficial use projects incur additional fees when compared to offshore disposal. This is because of the additional technical issues and regulatory costs involved. These projects also require input from different organisations who can each, depending on their interests, realise different benefits or losses, or incur different costs. It is also generally true that those doing the dredging and potentially bearing the highest extra costs of a beneficial use project, are not the main or only beneficiaries of the restoration. It is therefore important to understand where such projects can achieve net reductions in societal cost, based on a full understanding of all the ecosystem service benefits they deliver, not just the monetary fees for their implementation, in order to be assured of the societal case for proceeding with them.

Uncertainty about effectiveness and impacts: There can be a lack of confidence in the process of beneficially using dredge material for restoration, especially using fine sediments, as well as concerns that the activity itself will not work or will have an adverse environmental impact. Improved collaboration between all stakeholders is required and importantly, the lessons learned from completed projects need to be communicated across all interested parties as honestly and fulsomely as possible. In order to address residual project risks and uncertainties, an effective solution may also be to adopt an effective process of adaptive management (Chapter 2).

Technical and logistical challenges: Beneficial use habitat restoration projects introduce new ways of working and they can often be much more complex and technically challenging than existing and established approaches of dredging and disposal offshore. To address these challenges, there is a need to have better collaboration, planning and communication across all interested parties, as well as a need to move towards a situation where there is much greater clarity about where future beneficial use projects are available to allow for long term planning, preferably with all necessary marine licences and permissions in place. Further details about the available methods and the technical and logistical issues to be considered and support this process are presented in Chapter 2.

Legislation and consenting complexity: Whilst recognising the importance of good marine regulation, the consenting framework is often complex, adding to the costs of a project in the form of additional time required for the consenting process, extra fees needed to secure the necessary permissions or the monies required to carry out the monitoring in fulfilment of the licensing conditions. This is particularly apparent for small schemes where the licensing fees can amount to as much as half of the total project costs. The time required for the consenting process can also break the link between supply and demand, by preventing the relevant licences and permissions for beneficial use from being in place in time for when the dredging is due to occur. There is a need to think how the regulatory framework can be better understood and streamlined, whilst also establishing a 'pipeline' of habitat restoration projects well in advance of future dredging operations.

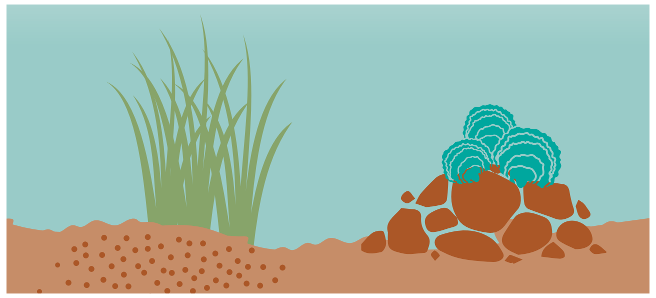
CONCEPT OF BENEFICIAL USE

It is hoped that this handbook can help address some of these barriers to: facilitate the delivery of more small scale projects, help start achieving larger, more ambitious restorations, including integrated multi-habitat restoration, and moving forward, support the more strategic management of this sediment resource.

At the individual project level, the basic aim of using dredged material for directly restoring estuarine and coastal habitats, is to provide, enhance or restore the physical conditions of the environment.

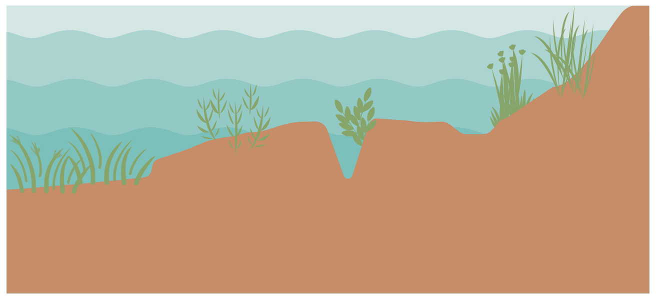
Those designing a beneficial use project for restoration should therefore follow the guidelines and physical requirements specific to the target habitat(s), such as those detailed in the restoration handbook series. Those planning a habitat restoration project should also consider how the design and success of the project could be improved, or even made viable in the first instance, if additional sediment was available.

For estuarine and coastal habitats, the importance of the physical environment and factors to consider in the project design can be broadly related to the four following factors:

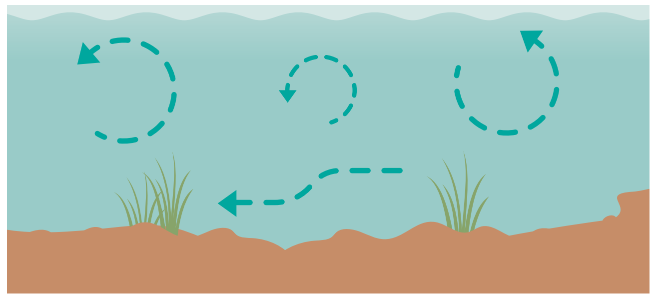


- **Provision of substrate** of a suitable particle size distribution (PSD) for a given species or habitat. For example, the availability of stable or relatively immobile coarse sediments and/or hard surfaces that provide suitable substrate for the spawning of some fish species, or upon which sessile (immobile) flora and fauna such as kelp, native oyster or blue mussels can colonise. This can also include the provision of sufficient mobile fine sediment within the system to support accretion across habitats such as intertidal flats, saltmarshes and sand dune systems.

- **Local scale morphology,** such as creek networks and salt pans, provide topographic diversity across intertidal flats and saltmarshes and govern tidal currents and drainage patterns. This has implications for sediment chemistry, geochemical cycling and the general health of such habitats. Variations in the physical environment and topographic features at the local scale also provide niche habitat, thereby supporting greater biodiversity, whilst also influencing the movement and feeding behaviours of fauna such as fish and birds. It is important that morphology is not fixed, but allowed to adapt and not considered in isolation at the local scale, but also in the context of regional scale changes.



- Determination and maintenance of the **elevation of the seabed relative to the tidal frame,** thereby controlling the frequency and duration of periods of tidal inundation and exposure. This governs the distribution and zonation of halophytic (salt tolerant) vegetation that comprise saltmarsh, which typically inhabits elevations above mean high water neaps (MHWN). Elevations exceeding the reach of tides and storm surges can also provide safe roosting and nesting sites for birds. In addressing this factor, consideration must also be given to the need for shorelines to have space and flexibility to respond to pressures arising from sea level rise (SLR).



- **Hydrodynamic energy** in the system, including local and regional fluvial and tidal currents and wave climatology, influences patterns of erosion, accretion and sediment transport. It must also be within the tolerances for a particular habitat or species that may require a degree of shelter or exposure. Whether or not there is enough energy to resuspend or maintain material suspended in the water column can also affect other factors such as light availability for photosynthesis, an important consideration for macroalgae (e.g., kelp) and seagrasses.

Individual beneficial use projects can support habitat restoration, however, if the underlying pressures causing habitat degradation are not treated, such as the loss of saltmarsh due to coastal squeeze, it may not be a long term solution in its own right. In this respect, where possible and appropriate to do so, individual beneficial use projects should be considered as a complementary tool to support other measures and habitat restoration efforts that do address these pressures, such as managed realignment and regulated tidal exchange (RTE).

Linked to this and at the more strategic level, managing the redistribution of sediment through beneficial use can also support habitats indirectly. For example, by helping to maintain sediment budgets (Box 1.5) whilst still retaining the dynamic nature of the estuarine and coastal environment. In so doing, beneficial use can support the conditions needed for habitats to flourish (e.g., sediment supply), while also protecting existing and restored habitats from pressures such as erosion. Individual projects should therefore also be considered in the wider context of SMPs (Box 1.6).

The benefits associated with habitat restoration are of course specific to the habitat being restored. However, when considering beneficial use in the context of estuarine and coastal habitat restoration, some of the more specific benefits of sustainably managing this sediment resource, at both the individual project and strategic level, are shown in Figure 1.4.

A selection of common saltmarsh plants, including: cord-grass, sea aster, common sea-lavender, sea purslane and glasswort (Colin Scott, ABPmer).

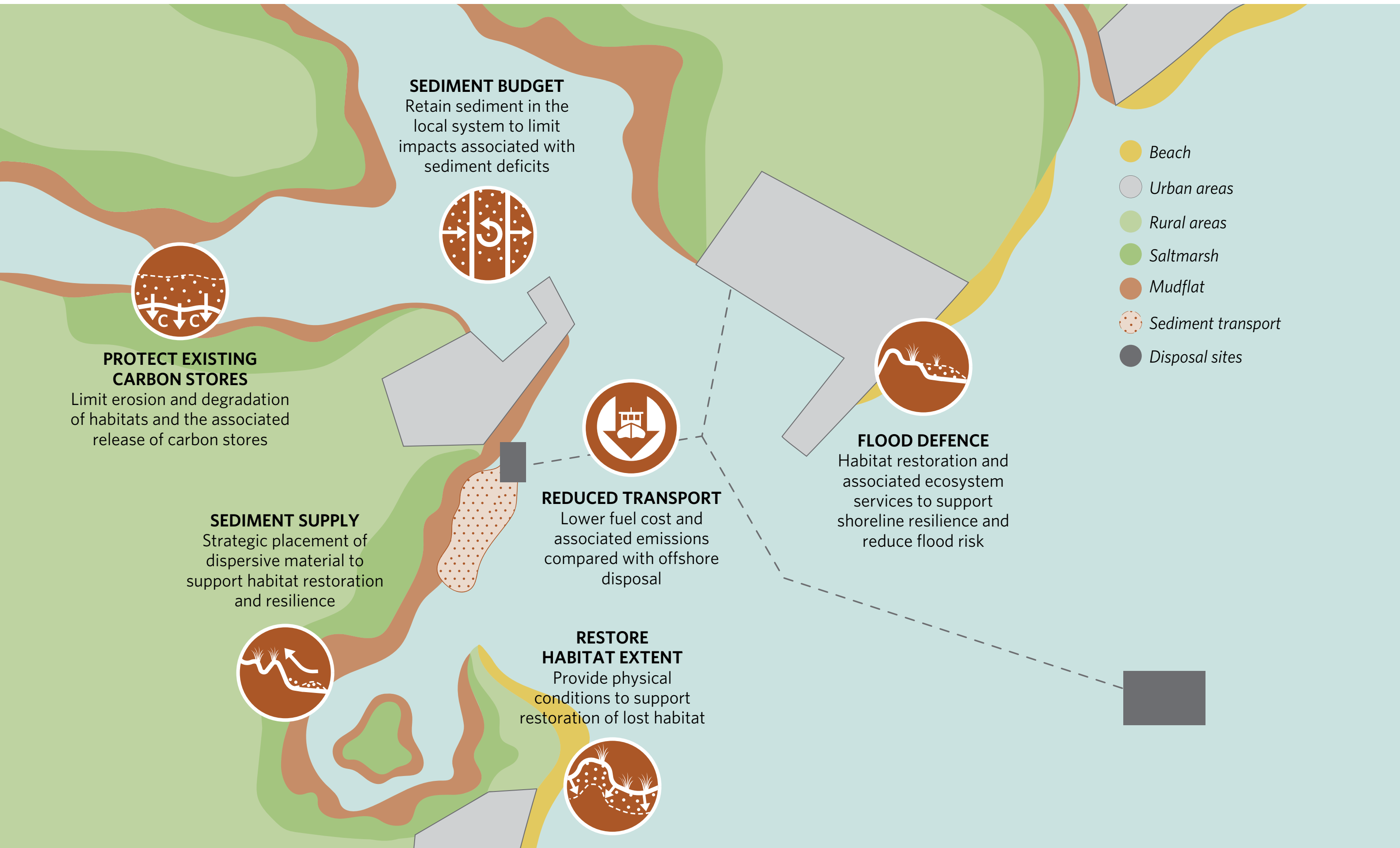


Figure 1.4: Examples of potential benefits specifically associated with using dredged sediment to support estuarine and coastal habitat restoration.

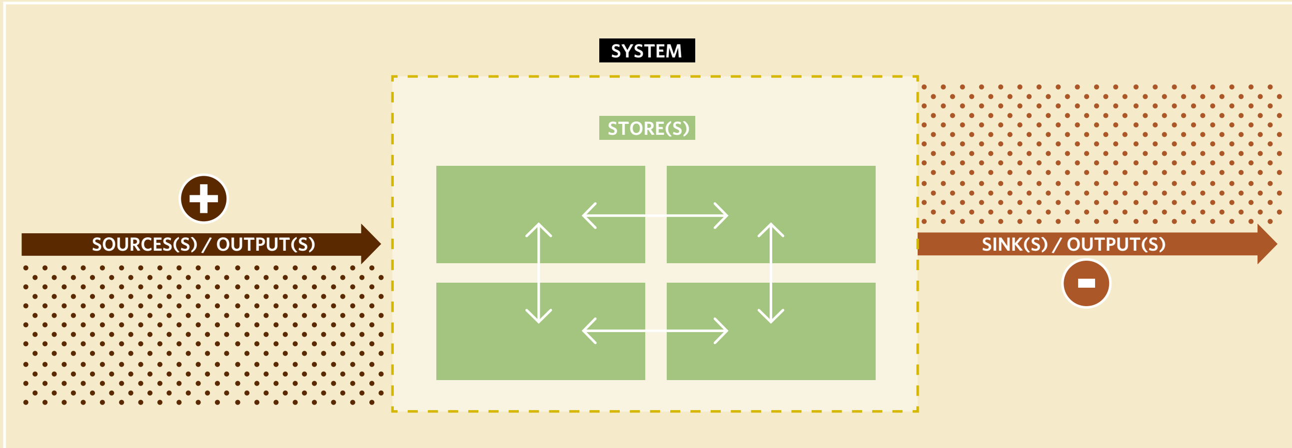
BOX 1.5: A DESCRIPTION OF SEDIMENT BUDGETS

A sediment budget can be described as a summary of the balance of inputs and outputs of sediment for a defined system (such as an estuary or coastal embayment) over a given time period. This helps determine whether that system has an overall surplus (accretion) or deficit (erosion) of sediment, and whether parts of a system are in dynamic equilibrium or likely to respond due to a persistent sediment budget imbalance (Figure 1.5).

To help illustrate the need for more sustainable management of dredged material, offshore disposal can be considered as increasing the sediment deficit, with implications for the system's natural resilience and ability to adapt. It is worth noting that offshore disposal of dredged material is not the only activity that has resulted in or causes a deviation from natural sedimentary processes and sediment budgets within estuarine and coastal environments. Land management, land reclamation and the artificial stabilisation of rivers and coastlines over preceding centuries have undoubtedly influenced the natural balance of sediment inputs, outputs and fluxes across lands and along rivers, estuaries and coasts.

The impacts specifically relating to the offshore disposal of dredged material are dependent on the sediment budget of the system, as well as the scale, frequency and location of the activity. From a habitats perspective however, in general, a loss of sediment or reduction in sediment supply can cause coastal habitats, such as intertidal flats and saltmarsh, to erode and/or hinder their ability to accrete and keep pace with SLR. Disruption to natural sediment transport can also impact on downdrift locations, with potential implications for coastal management, such as increased risk to flood defence. Conversely, an excessive import of sediment for the purposes of 'beneficial use' may cause sedimentation issues within the local system, unless other methods such as managed realignment are being employed in conjunction and which provide the necessary space to accommodate the additional sediment.

'Local placement' or 'sustainable relocation', involves the disposal of dredged material in disposal sites that are located within the local system (e.g., River Humber). This approach helps maintain the sediment budget and is generally seen as good practice and categorised as a beneficial use (Table 1.3). Although this should be considered as part of future regional strategies, it is not reviewed further, as this handbook focuses on more direct methods for restoring habitats with dredged material.



SYSTEM

The macro unit that contains all of the functioning elements and sub-systems to explain the behaviour of an area of coast and which can be schematically represented in a system diagram (e.g., estuary or coastal cell)

STORE

A location that may be able to receive and temporarily hold onto sediment, but may also subsequently contribute sediment back to the system under certain circumstances (e.g., saltmarsh, mudflat or water column)

SOURCE

A location that contributes sediment into a system (e.g., cliff erosion or riverine sediment)

SINK

A location which permanently removes sediment from a system (e.g., windblown sediment transport or accretional areas)

Figure 1.5: Basic system diagram for a sediment budget.

BOX 1.6: SHORELINE MANAGEMENT PLANS (SMPs)

SMPs outline the strategic approach to managing the coastlines of England and Wales. SMPs are also used in Scotland but they are not statutory and have been produced for only short sections of the Scottish coast. Strategic coastal management plans are not currently in use in Northern Ireland.

For England and Wales, each SMP proposes a management approach for discrete lengths of coastline (referred to as policy units) within a wider plan area defined by regional sediment cells (Figure 1.6). SMPs include four broad policy options:

1. **Hold the line (HTL):** maintaining and where necessary, improving the existing line of defence.
2. **Managed realignment (MR):** allowing the shoreline to move backwards or forwards, with management to control or limit movement (such as reducing erosion or building new defences on the landward side of the original defences).
3. **No active intervention (NAI):** no management required.
4. **Advance the line (ATL):** moving defence alignments seawards and converting currently intertidal or subtidal areas so that they cease to be tidal.

Each policy unit is assigned a policy for the short term (Epoch 1: 2005 – 2025), medium term (Epoch 2: 2025 – 2055) and long term (Epoch 3: 2055 – 2105). The Environment Agency is currently leading a project to review all 20 SMPs in England, known as the 'Shoreline Management Plan Refresh' (Environment Agency, 2020). The aim of the Refresh is to ensure that the SMPs are fit for purpose, prepared for impending policy transitions as we approach the end of Epoch 1 and will help to incorporate the latest legislation, policies and evidence. One of the main objectives of England's SMPs will be to contribute towards environmental and climate resilience ambitions, including those outlined in the 25YEP, such as BNG and NRN. Restoring and conserving intertidal habitats will be central to ensuring the resilience, sustainability and overall quality of SMPs.

It is important to recognise that coastal and estuarine systems are made up of a variety of connected components. For example, successful restoration may require more than just implementing measures directly to a single area of marsh, as updrift management policies can significantly affect downdrift marsh health and resilience. Updrift and downdrift are terms relating to the direction of net along shore movement of sediment. The direction that sediment generally moves from is known as updrift, while the direction that sediment generally moves to is known as downdrift. For example, holding the line (i.e., preventing erosion) along extensive areas of coastline that would naturally supply sediment to an estuary, can reduce the ability of saltmarsh to accrete sediment and grow vertically in response to SLR. Conversely, managed realignment and no active intervention policies can help respectively reactivate or sustain important sediment sources, to the benefit of downdrift habitat resilience. It is important to consult the local SMP to understand the wider management context of any coastal cell in which restoration is planned, including where policies are expected to change in the future.

Integrating regional beneficial use strategies into SMPs and aligning with the policy assigned, would also provide a good framework for sustainable sediment management, further to beneficial use solely for the purposes of habitat restoration in select locations. For example, the Essex and South Suffolk SMP (2010) includes an action plan that highlights the need to identify options for beneficial use projects within the project area that will contribute to coastal defence management.

As part of this, further work is also required to clarify and strengthen the case for a greater use of dredged material on land as part of future coastal management. For example, where considered useful and appropriate to do so, dredged material may be used within a managed realignment site, in order to support land raising or landscaping prior to breaching and to help reduce potential impacts on hydromorphology and geomorphology following reconnection to the tidal system. It can also be used in terrestrial or freshwater hinterland areas, such as in deep quarries or pits to create shallow wetlands (e.g., Cliffe Pools, Kent). There are, however, additional planning and legislative considerations, particularly around the requirement for proposals to pass the 'waste recovery test' as part of a 'bespoke waste recovery permit' application. However, in recent years, inconsistencies have emerged regarding whether this form of landside restoration method passes the waste recovery test. This topic of using sediments dredged from the marine environment for use on land as part of a habitat restoration project, is an area that requires further discussion in the context of sustainable sediment management and would benefit from greater clarity of the regulatory process in the future.

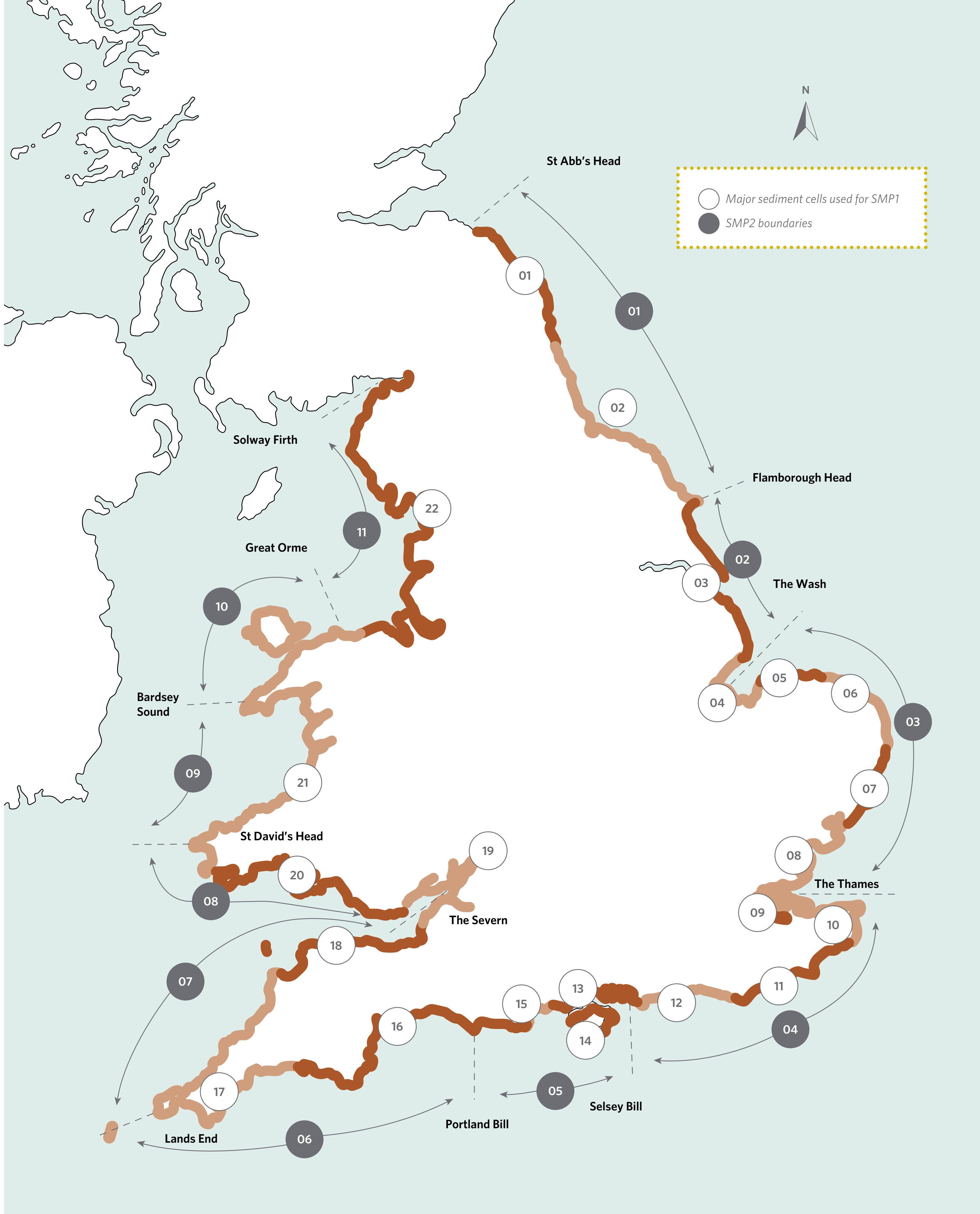


Figure 1.6: Map of Shoreline Management Plan (SMP) areas. The SMP areas are based on sediment sub-cells (smaller interconnected spatial areas) (Ballinger and Dodds, 2020).

CHAPTER 2
DREDGING AND BENEFICIAL USE IN PRACTICE

KEY SUMMARY POINTS:

- **As outlined in Chapter 1, there are many reasons why restoring habitat with dredged material is not done more often. In simple terms, it is because it requires a change to well established perspectives and ways of doing things. This includes practical changes to dredging and disposal activities as well as adjustments to existing policy, regulation and management. Realising this change can be both difficult and costly.**
- **To describe some of the technical and practical considerations associated with delivering beneficial use projects, this chapter provides more detail about existing dredging and disposal practices. It then reviews ways in which dredged material has been used to restore estuarine and coastal habitats, as well as suggesting other novel ideas that might be tried in future.**
- **Over the last 30 years several different beneficial use projects (often small scale) have been carried out at various sites across the UK. There are many more examples internationally (including large scale) and these projects demonstrate the benefits that can be achieved through beneficial use, while also illustrating the associated challenges and costs.**
- **To understand where and how future beneficial use projects can and should be carried out, there are several, often inter-related, technical, regulatory and practical issues that must be considered. These issues are outlined in the chapter to inform future feasibility studies. They include the characteristics and composition of the sediment (both at the receiving (disposal) site and of the dredged material itself), the nature and accessibility of the receiving site, the changes to costs and net benefits achieved.**
- **Based on recent experience in the UK, in future, it is clear that more proactive local and regional strategies will need to be developed and actively progressed, in order to drive change, overcome challenges and enable more and larger projects to be achieved. These should include building partnerships as well as finding and prioritising suitable beneficial use sites for implementation. This strategic approach needs to be supported by further work to identify project benefits, beneficiaries and funding sources.**

INTRODUCTION

The preceding chapter outlines some of the context and key issues associated with beneficially using dredge material for habitat restoration. Among other aspects it outlines the many reasons why restoring habitat with dredged sediment is not done more often and hence, why less than 0.5% of the sediment that is dredged every year ends up being used beneficially in this way.

In simple terms though, there is one overall reason why dredge arisings are not used more frequently to protect and restore habitats. This is because it requires a change to existing ways of doing things. It requires new licensing arrangements, new ways of thinking about environmental and coastal management and very often, it requires changes to long-established dredging and disposal practices.

Achieving such change is not simple and it can be expensive. Established dredging practices are costly and altering them, especially in any substantial way, can add large extra costs to the management and maintenance budgets of a port, a harbour area or an individual facility (e.g., berth or marina). These extra costs include fees for the hire, purchase and/or maintenance of new equipment as well as for new licensing and monitoring commitments.

To understand how change might take place, this chapter provides details about existing dredge and disposal practices and what these different methods mean for the available sediment resource. Firstly, it outlines the main types of dredging and then the main methods of sediment disposal. It then reviews the ways in which these practices can be applied to enhance and protect coastal habitats. It describes these beneficial use practices with reference to previous projects, both in the UK and internationally. These past projects are categorised here according to the particular methods used, in order to illustrate the spectrum of approaches that have been employed in the past and can be considered for the future.

This review highlights some of the main considerations and lessons learned from this past experience and identifies some methods that have not been tried and tested in the UK before, as well as novel concepts that might be possible.

The rest of the chapter provides further details regarding some of the other technical and feasibility issues requiring consideration during the planning and delivery of a beneficial use project, such as navigable access and timing. In addition to individual project level information, recommended approaches for establishing local and regional strategic beneficial use networks are also provided.

A number of technical terms are introduced to describe these methods, the definitions of which are provided in the glossary at the start of the handbook. Further details can also be found in the supporting literature at the end of this handbook.

DREDGING METHODS

There are many different approaches to dredging and many different types and sizes of dredging vessel. However, for this overview, dredging methods are simply divided into four main types (two types of mechanical dredging and two types of hydraulic dredging). These are described further in this section.

In advance though, it is also important to firstly reiterate and keep in mind, the distinction between maintenance and capital dredging. This was outlined previously in Box 1.2 but it is critical when considering the availability of dredge material for possible re-use.

Maintenance dredging typically provides a regular and reliable source of often quite fine sediment, such as muds, silts and sands in some instances. It is therefore the main resource to consider when thinking about any long term and strategic restoration of habitats such as saltmarshes or mudflats. Although less regular, capital dredging may include large volumes of more cohesive, consolidated or coarser sediments, such as rock, gravel, sand or stiff clay. These provide opportunities for other habitat restoration measures, such as preparing the seabed for native oyster, building up sand and gravel barriers (e.g., for annual drift line vegetation or nesting birds), or nourishing beaches and sand dune systems.

As well as the different characteristics of the dredged material itself, the methods used for dredge and disposal will further influence the sediments behaviour, both during handling and following disposal. For example, the method used will influence aspects such as: how much of the sediment's natural structure and mechanical strength will remain intact, the relative proportions of the sediment-water mix, the viscosity of that mix and how dispersive or stable the material will be following disposal. The dredging methods available and the resultant sediment composition and behaviour, are therefore critical factors when considering the feasibility, design and potential impacts of a beneficial use project.

Mechanical dredging

Mechanical dredgers use equipment that physically excavates sediment using mechanical force (Figure 2.1). These can be bespoke mechanical dredging vessels, or at smaller scales, separate excavating plant that is affixed to a barge or floating platform. During operation, the dredger or platform is stationary, typically moored using spud legs to counter the force of the dredging action, as well as to help with positioning and manoeuvrability. Once removed from the seabed, dredged material is typically placed into a hopper that collects material during operation before it is transported to the disposal site. Hoppers can form part of the dredger itself, or can be a separate hopper barge vessel.

Mechanically dredged sediment is more likely to retain a relatively high degree of consolidation and have a lower water content when compared with material arising from hydraulic dredging methods. Consequently, it is likely to be less prone to erosion and more persistent in the environment following disposal. Two main types of mechanical dredger are:

- **Backhoe dredgers (BHD):** use an articulating excavator bucket to remove material from the seabed. The material is raised to the surface through movement of the crane and bucket. Typically, material is then loaded into an on-board hopper or separate hopper barge for transport by vessel, or in some instances, pumping via pipeline. BHDs are limited by the reach of the crane and are more suited to smaller dredges. However, due to the force that they can exert, they are able to handle stronger sediments.
- **Grab dredgers (GD):** also referred to as 'clamshell' dredgers, are similar in setup to a BHD but use two wire-operated 'shells' that come together to cut and grab material from the bed. Whilst the horizontal reach of GDs is also limited by the crane, the use of longer wires allows them to operate in greater water depths. Similar to BHDs, they are more suited to smaller dredges and can handle a range of sediment types.

Hydraulic dredging

Hydraulic dredgers use equipment that excavates and transports dredged material using water (Figure 2.1). Mechanical action is often used in conjunction to help cut away or lift sediment into suspension at the bed, before pumping the material into a hopper or to another location via other disposal methods (discussed below).

When seeking to achieve a full hopper load, there may be a period of overflow during the dredging cycle. This may result in sediment release at the water surface.

Hydraulically dredged material has a higher water content than mechanically dredged material (although the consistency of the sediment-water mix can vary). As a result, following disposal, it can be prone to self level and be more susceptible to dispersion. It will also generally take longer to dewater and stabilise.

Two main types of hydraulic dredger, both of which use a form of mechanical action, are:

- **Trailing suction hopper dredgers (TSHD):** have an integrated hopper and combine a draghead with a suction system that moves slowly over the bed collecting the surface sediment layers. TSHDs are suited to dredging loose material such as silt or sand, as they mainly rely on a scratching action and suction to lift the surface material. Different draghead designs are available for stronger sediments (e.g., heavier or with teeth on harder beds).
- **Cutter suction dredgers (CSD):** have a cutting head that physically rotates to dislodge material from the bed. The loosened material is then sucked through the cutter head via a centrifugal pump and transported to the dredge vessel. The material is typically discharged hydraulically via a pipeline or into a separate vessel for transport. CSDs can handle a wide range of materials, including harder and more consolidated material such as stiff clays and rock. During operation, the dredger is stationary, and often moored with spud legs to help with positioning and manoeuvring.

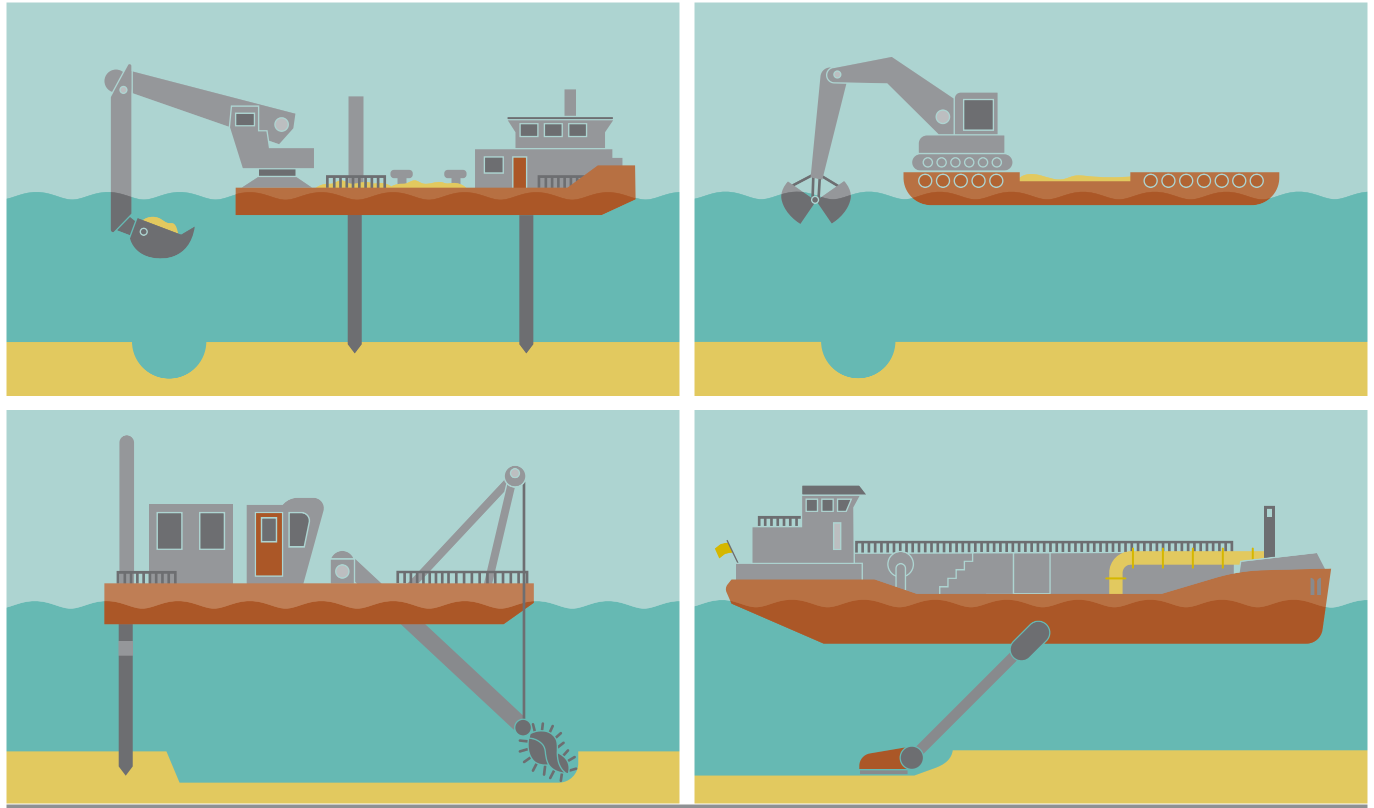


Figure 2.1: Different dredging techniques, clockwise from top left: Backhoe dredger (BHD); Grab (or 'clamshell') dredger (GB); Trailing suction hopper dredger (TSHD); and Cutter suction dredger (CSD) (© Colin Scott).

Hydrodynamic dredgers

Two other common dredging methods to be aware of and previously mentioned in Chapter 1, are plough dredging and water injection dredging (WID). These are categorised as hydrodynamic dredgers, which raise material slightly above the seabed, either by mechanical means, or by injecting water into the bed to create a fluidised layer, respectively.

The hydrodynamic approaches rely on gravity and/or local hydrodynamics to disperse the sediment throughout the system. These methods have the benefit of retaining the sediment next to the dredge site and within the local sedimentary system, thereby helping to maintain the sediment budget. However, as they do not give rise to material available for direct habitat restoration projects, they are not considered further in this handbook.

DISPOSAL METHODS

As well as the dredging and transport methods, the method for disposal and how it influences the behaviour of the material at the point of release are also critical factors when considering the feasibility and design of a beneficial use project. There are also four main disposal methods and these are described below.

Bottom placement

Many dredging vessels or hopper barges dispose of their loads by opening the hopper doors and releasing material beneath the hull. This is how sediment is typically deposited at offshore disposal sites. These vessels are termed 'split hopper barges' and for some, this will be the only viable way to discharge the sediment without bespoke on-board pumping or mechanical facilities.

Depending on the water depth and draught of the vessel, this approach can be used in intertidal or nearshore environments. The method is gravity based and benefits from being relatively quick and to a degree, retains the physical characteristics of the dredged material because no additional handling stage is needed.

Mechanical placement

This is a reversal of mechanical dredging (Figure 2.2). Here, the sediment stored in the hopper is re-excavated using a BHD or GD. This allows the sediment to be carefully placed at defined locations, subject to the location being within the reach of the excavator or crane being used. This process takes longer than bottom placement. However, if the material can be placed relatively high on the shore, it offers the best opportunity for the deposited sediment to remain in place, whilst also retaining a greater degree of the materials' original strength.

Hydraulic pumping via pipeline

Sediment can be pumped through a pipeline from an appropriately equipped dredging vessel to the receiving disposal site (Figure 2.2). In this approach, the material is mixed with water, either through the dredging process itself (e.g., CSD) or within the hopper. In situations where the dredger or hopper barge does not have this built-in capacity for hydraulic discharge, dedicated pumping equipment can be added either on the shoreline, on floating and stable platforms or to the vessels themselves.

Figure 2.2: Different disposal techniques, from top: Clam shell excavation from hopper (Carol Reid); release of hydraulically pumped sediment via pipeline (Exo Environmental Ltd.); spud barge and hopper barge at marsh transfer and hydraulic pumping station (ABPmer); and coarse sediment rainbow discharge (Boskalis).

The pipelines used can vary from steel to more portable and flexible materials depending on circumstance and project size. They can also be modular, of varying size and capacity and can be floated, sunken, or a combination of the two, depending on the requirements of the project.

Large distances can be covered (up to several kilometres) depending on the equipment, the use of booster pumping stations and the characteristics of the material. This is valuable when trying to restore distant intertidal habitats that are not directly accessible by dredging vessels, such as fragmenting marshes or those distanced from areas of safe navigation. However, factors such as management of the transport water, the pipeline configuration, risk of blockages and the potential for pipeline damage or risks to navigation, all need to be considered.

The sediment to water ratio of pumped sediment will vary depending on the dredged material, the methods used and the project design. Typically, the mixture is around 10% sediment, but, in some cases, 50% can be achieved. Discharging with a higher sediment content is generally preferable (e.g., to improve sediment retention), but this is generally slower and more suited to moving smaller volumes of sediment over shorter distances. For example, a concrete pump, which uses hydraulic rams to push 'slugs' of material along the pipeline, may theoretically be used and reduce the need for transport water. In some instances, a finer sediment-water mix is desirable in order to support sediment dispersion over a wider area. In the USA, this type of fluid sediment disposal is termed 'thin layer placement' and involves placing anywhere between 1 cm and 50 cm, with the aim of raising the surface elevation of saltmarshes and intertidal flats to increase their resilience.

Hydraulic pumping via 'rainbowing'

Some larger dredging vessels, especially modern TSHDs, are capable of hydraulically projecting the sediment-water mix through the air to the disposal site. This process is called 'rainbowing' because of the arc profile it creates (Figure 2.2). This rainbow approach is commonly used to discharge sand and gravel for beach or barrier nourishment schemes. The projecting distance from the vessels to receiving site is generally tens of metres, depending on the sediment type, the water content and the pumping pressure that can be generated.

SEDIMENT RETENTION

Structure types

Depending on the project, it may be necessary to carry out site preparation work and introduce structures to contain the sediment following disposal. This is especially true where a fluid sediment-water mix is to be discharged and where the aim is for this pumped sediment is to remain in place following disposal, such as to raise the level of a marsh. In this situation, the relatively fluid sediment will need time to settle, dewater and stabilise, which can be further supported following colinisation of the material (e.g., saltmarsh vegetation growth). There are several different sediment retention structures that can been used (Figure 2.3).

These include:

- **Wooden (brushwood) fences:** also referred to as brushwood polder fencing, commonly used at saltmarsh restoration sites. They typically comprise two rows of large posts hammered into the bed. Bundles of smaller brushwood (e.g., coppiced willow and hazel whips) are then laid between the posts in layers, akin to bricklaying, until the desired height is reached, typically a few tens of centimetres above the seabed. Once compressed and set to the desired height, the brushwood is pinned down by using rope or twine, fastened at the base of one post, before passing over the brushwood to be fastened at the base of the next post on the opposing row.
- **Hay bales:** used in some instances, to form the central core of fences, either in place of or in addition to brushwood. Bales can degrade relatively quickly where they are left proud of (raised from) the sediment surface. However, they are a useful way of facilitating sediment settlement and retention during the early stages of sediment placement and their impermanence can be a desirable outcome.
- **Coir logs:** (derived from coconut husks) also commonly used for small projects where the sediment will form a shallow deposit. They can be laid individually or in piles to achieve the desired height, but similarly to brushwood and hay bales, they need to be secured and bound to posts inserted into the bed.
- **Timber drop-board sluices:** similar in function to traditional sluices and can be used to retain fluid material in areas where there is a distinct physical 'bottle neck' between the disposal site and the wider environment (e.g., a narrow saltmarsh creek). The sluice is set into the bottle neck and plugged (e.g., using sandbags) so that it forms a retaining bund when the drop boards are in place and the sluice is closed. Once the material has been pumped into the disposal site and the imported sediment has settled out of suspension, the top boards can be removed to gradually drain the overlying water. Once the excess water is drained, the boards can be reinstated and the process repeated until the desired sediment fill capacity is achieved.
- **Clay bunds:** can be created in order to either help retain additional sediment disposed of within the site and/or to create environmental conditions (i.e., reduced hydrodynamic energy) that encourage future deposition. They can be created using suitably stiff clay material that has been mechanically excavated.
- **Sand and gravel barriers:** used in a similar fashion to clay bunds. In the UK, coarse sediments have been successfully used to build barriers that then provide a retaining feature for finer sediments to be placed behind.

Figure 2.3: Sediment retention structures, clockwise from top left: brushwood fence at Lymington (ABPmer); coir log near Levington (ABPmer); square hay bale enclosure at Lymington (Lymington Harbour Commissioners); area between clay bund and new seawall at Allfleet's Marsh (ABPmer); and timber drop-board sluice during draining operations at St Osyth borrow pits, Brightlingsea (Exo Environmental Ltd.).

Materials

The retaining structures listed are all made of natural and untreated materials. This is because there is an understandable preference for using such materials and not introducing and leaving artificial materials in place when managing estuarine and coastal habitats.

Other materials have however been used for tidal wetland protection. This includes more substantial and engineered structures such as rock mattresses, sheet steel piling, gabions, rock bags, concrete balls or geotextile tubing or matting. These can each play a role in certain situations, especially when seeking to provide ongoing physical protection from erosion as well as just retaining sediment during its placement. However, there are factors which count against them, including their artificial nature, the risk of micro plastics being released into the environment and the costs of construction and maintenance.

Ongoing efforts are being made to develop and test new biodegradable structures. These include matrices derived from potato starch or biodegradable geotextile matting. There are also examples of using stabilised dredged material, oyster shells and restored or artificial reef habitats as protective structures around marshes. These advances may introduce new and better ways of retaining sediment in the future, whilst the latter may offer additional benefits through full ecosystem restoration, restoring multiple habitats, with the functioning of one, supporting the development of another. Further details regarding protective structures are also included in the saltmarsh restoration handbook.

Considerations

For any given beneficial use location, a judgement needs to be made about whether retention structures are required and if so, the type, quantity and location best suited for the environment. These decisions will be informed by factors such as the conditions on site (e.g., the degree of wave exposure), the anticipated behaviour of the sediment, the overall objectives of the project and any possible ecological effects.

It will also depend on whether they are meant to be temporary and only encourage sediment retention briefly during single campaigns, or whether they will have a longer term role to play, such as retaining sediment over multiple recharge campaigns for several years. Structures can also be created with the aim of reducing hydrodynamic energy in order to help locally suspended sediment settle out within the site, to protect existing habitats from erosion, or to create conditions that are more tolerable to species that require a degree of shelter.

Ideally, the aim should be to avoid having too many retention structures in order to both maintain as much of a 'natural' habitat as feasible and to avoid unnecessary costs. A balance needs to be struck between having enough to help keep most of the sediment in place, but without unnecessarily adding to the maintenance and cost of the project or detracting from broader habitat enhancement goals.

Where hard structures are installed (e.g., fences or wooden sluices), they can be undercut or circumvented by water flows. Such scour or piping around or beneath the structures can be plugged with bales or dredged material (either loose or in sandbags) to provide a degree of stability during the recharge work itself.

The structure or restoration site needs to be permeable or low lying to allow for ongoing tidal exchange and in many cases, allowances should be made for sediment loss during the recharge period, especially when dealing with hydraulically pumped sediment. It is rarely appropriate to expect that all the material can, or even should, be retained in defined areas. Instead, dispersion across the surrounding habitats may well be beneficial. The structure design, location and construction schedule should also aim to avoid the potential for trapping mobile fauna such as fish.

Unless temporary by design, all structures will need to be maintained. Brushwood fences, for example, will progressively deteriorate over a few years. This is evidenced around the UK coastline where only the thicker vertical supporting posts of old brushwood fences remain protruding from intertidal mudflats, decades after being installed. Colonisation of hard structures by macroalgae can help moderate flows and improve the sediment retention or trapping function of structures over time. Where sediments have subsequently stabilised, maintenance of the retention structures may no longer be required, especially where colonisation and vegetation growth help bind the sediment, reduce water flows at the bed and facilitate accretion.

BENEFICIAL USE METHODS

To illustrate the ways in which dredged sediment can be used to restore and protect estuarine and coastal habitats, a selection of UK case studies are reviewed here, summarised in Table 2.1. They are divided into seven categories, based on the different dredging and disposal methods described above:

- **Mechanical dredge and mechanical disposal**
- **Mechanical dredge and bottom placement**
- **Hydraulic dredge and bottom placement (international example, Netherlands)**
- **Mechanical dredge transported for hydraulic disposal by pipeline**
- **Hydraulic dredge and direct hydraulic disposal by pipeline**
- **Hydraulic dredge transported for hydraulic disposal by pipeline**
- **Hydraulic dredge transported for hydraulic disposal by rainbowing**

These categories are based on past practices and they represent the main ways in which existing dredging and disposal methods and technologies have been used to achieve habitat restoration objectives. This categorisation has been used to provide a 'menu' of available options, which illustrate some of the benefits, challenges and lessons learned from each approach. These options can be used to inform future restoration projects and their associated feasibility studies.

This list of different approaches across the seven categories should not be viewed as the only available options. There may well be other, often more ambitious ways of carrying out beneficial use projects in the future. With this is mind, other possible approaches are briefly considered below. These include some approaches that are less common or have not yet been tried at all, either in the UK or elsewhere.

Note that most beneficial use projects undertaken in the UK to date, remain small scale (<10,000 m^3) in comparison with what has been achieved internationally. For an idea of other projects undertaken in the UK as well as what could be achieved through upscaling these methods, further UK and international examples can be found on the following websites:

- ABPmer OMReg habitat restoration sites
- Central Dredging Association (CEDA) beneficial use case studies page
- United States Army Corp of Engineers (USACE) 'Engineering with Nature (EwN)'
- EcoShape 'Building with Nature (BwN)'

Horsey Island in Hamford Water, Essex, where multiple beneficial use schemes have been undertaken, using a variety of methods and particle sizes to restore and protect coastal habitat since the 1990s (Jim Pullen Surveys).

Table 2.1: Selected examples of beneficial use projects from the last 25 years.

DREDGE AND DISPOSAL APPROACH CATEGORY	DREDGE LOCATION	BENEFICIAL DISPOSAL SITE	YEAR(S)	SEDIMENT TYPE	APPROXIMATE VOLUMES
Mechanical dredge and mechanical disposal	Berth maintenance, Chelmer Estuary,	Maldon Saltings and Northey Island, Chelmer and Blackwater Estuary	Annually since 1990s	Fine (silt or mud)	2,000 to 3,000 m^3 yr-1
	Woodbridge berth maintenance, Deben Estuary	Loder's Cut Island, Deben Estuary	2015, 2017 and 2018	Fine (silt or mud)	1,725 m^3 over three campaigns
Mechanical dredge and bottom placement	Lymington navigation channel and marina maintenance, Lymington Estuary	Boiler Marsh, Lymington Estuary	Annually since 2014	Fine (silt or mud)	6,000 m^3 yr-1
Hydraulic dredge and bottom placement	Port of Harlingen, Netherlands	Koehoal Marshes, Wadden Sea, Netherlands	2017 and 2018	Fine (silt or mud)	470,000 m^3 over two campaigns
Mechanical dredge transported for hydraulic disposal by pipeline	Lymington navigation channel and marina maintenance, Lymington Estuary	Boiler Marsh, Lymington Estuary	2012 and 2013	Fine (silt or mud)	4,500 m^3 over two campaigns
Hydraulic dredge and direct hydraulic disposal by pipeline	Brightlingsea Harbour maintenance, Colne Estuary	St Osyth Borrow Pits, Colne Estuary	2017 to 2020	Fine (silt or mud)	20,000 m^3 over two campaigns
	Suffolk Yacht Harbour maintenance, Orwell Estuary	Intertidal habitats, Orwell Estuary	Annually since 1997	Fine (silt or mud)	10,000 m^3 yr-1
	Yacht Haven marina maintenance, Lymington Estuary	Yacht Haven Marsh, Lymington Estuary	2012 and 2013	Fine (silt or mud)	3,125 m^3 over two annual campaigns
Hydraulic dredge transported for hydraulic disposal by pipeline	Harwich Haven maintenance and capital deepening, Stour and Orwell Estuary	Horsey Island, Hamford Water	1998 to 2006	Fine (silt or mud) and coarse (sand or gravel)	108,000 m^3 over four campaigns
	Harwich Haven maintenance and capital deepening, Stour and Orwell Estuary	Shotley (North), Orwell Estuary	1997	Fine (silt or mud), retained behind coarse (sand or gravel)	22,000 m^3 (fine) behind 75,000 m^3 (coarse)
	Port of Felixstowe maintenance, Stour and Orwell Estuary	Allfleet's Marsh Managed Realignment, Crouch Estuary	2006	Fine (silt or mud)	550,000 m^3 over one campaign
Hydraulic dredge transported for hydraulic disposal by rainbowing	Harwich Haven capital deepening, Stour and Orwell Estuary	Horsey Island, Hamford Water	Early 1990s	Coarse (sand or gravel)	148,000 m^3 over two campaigns

Mechanical dredge and mechanical disposal

For this approach, sediment is mechanically dredged and placed into a hopper. Following transport by vessel to the disposal site, material is then placed on the beneficial use site by the reverse process. This has been undertaken regularly for the last 20 years, using sediment dredged from the Chelmer Estuary, near Maldon, Essex. Here, dredging is carried out using an excavator mounted on a self propelled 80 m^3 hopper barge and fitted with a clamshell bucket (GD).

The material is disposed of during periods of high water, along the edges of the local marshes at different locations within the Chelmer and Blackwater Estuaries, including a saltmarsh spit on the Chelmer River and more recently, a vulnerable embankment on Northey Island. The work at Northey requires two stage handling in order to place the material in the correct position and profile. Sediment is first moved from the hopper into a temporary bund at high water, before being re-excavated and landscaped at the final receptor sites (the bank crest and in an eroding drainage ditch) by long-reach excavators and plant working on the embankment.

A mechanical dredge and placement approach was also adopted at Loder's Cut Island in the Deben Estuary, Suffolk. Here, material is excavated from Ferry Quay at Woodbridge using the same method as at Maldon. It is then transported 800 m downstream and disposed of directly from the hopper onto the marsh edge at high water (Figure 2.4). This has raised 1,400 m^2 of marsh by around 1 m to form a small 'island' at high water.

The sediments deposited by this type of approach help to expand and elevate marsh habitats. The sediment is rapidly colonised by saltmarsh vegetation and can be used by roosting birds during periods of high water. The work at Northey has also helped protect a vulnerable flood defence and enhanced saltmarsh biodiversity locally. These projects show how with repeated and careful placement, even small volumes of material can bring about clear benefits.

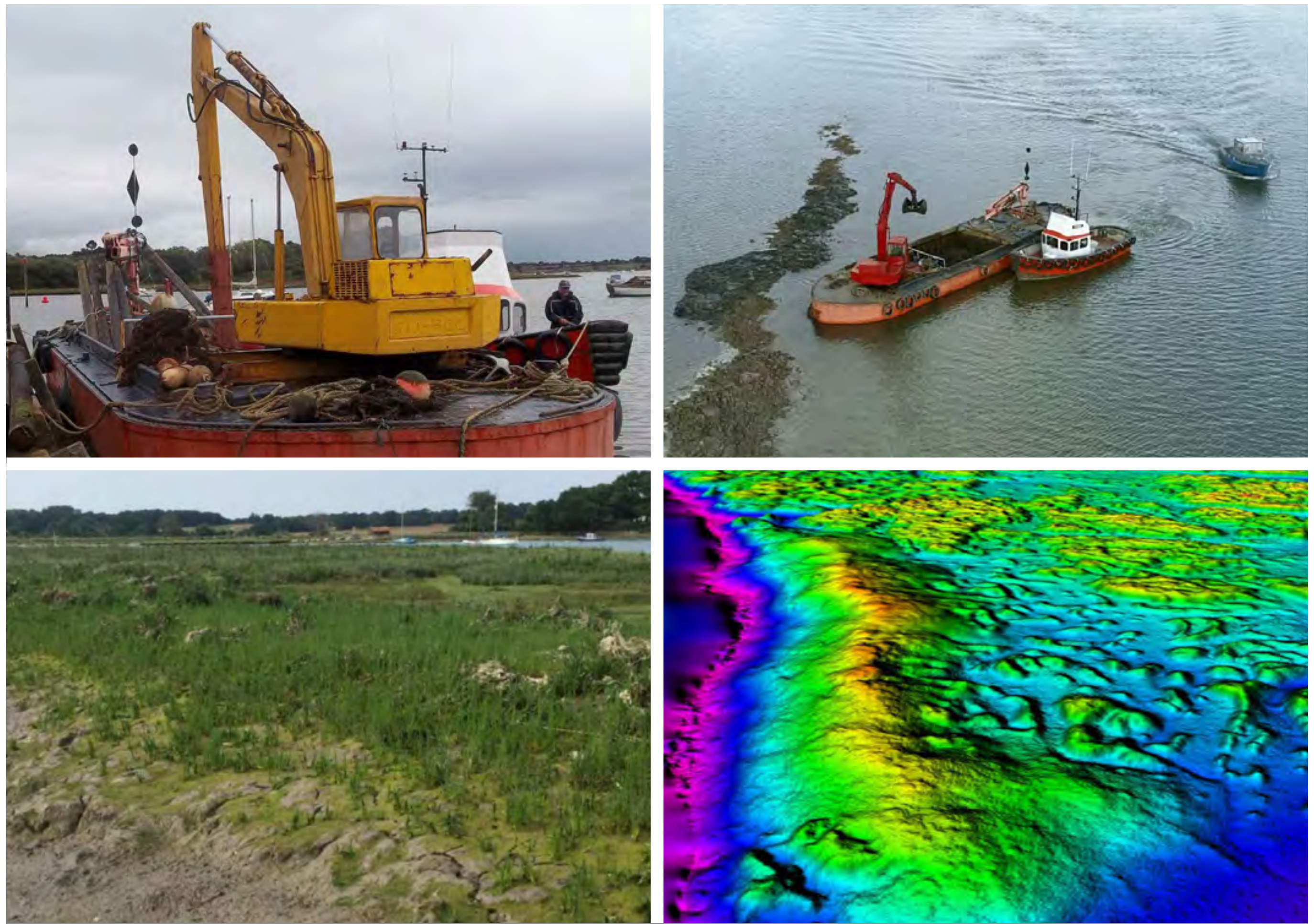


Figure 2.4: Loder's Cut Island, clockwise from top left: vessel mounted GD fitted with clam shell bucket (ABPmer); Disposal along the marsh edge at high water (Video east); 3D topographic image, showing elevations supporting high tide roosting sites (Jim Pullen Surveys); and dredged material colonised by saltmarsh vegetation (ABPmer).

Mechanical dredge and bottom placement

This approach involves mechanically dredging material, transporting it to the disposal site by vessel and bottom placing it within a beneficial location. This approach can be used as part of a sustainable relocation strategy (Box 1.6), however, the added emphasis here is on having a disposal site that more tangibly and directly benefits the intertidal habitat being restored.

This approach has been applied annually since 2014 at Boiler Marsh, in the Lymington Estuary, Hampshire. Material is dredged from the Lymington marinas and navigable channel before being placed as high up the intertidal mudflats and as close to the lower edge of a deteriorating saltmarsh, as possible. Disposal therefore only occurs at high water on the larger spring tides and as close to, or on top of previous disposals.

The aim is to create a raised 'sacrificial' mound that reduces wave energy arriving at the eroding marsh behind and as the mound itself erodes, supplies sediment to the local environment. The effectiveness and benefits of this work are being monitored and showing that much of the deposited material remains *in situ* several months after the recharge campaigns, primarily due to the relatively consolidated nature of the material and the mechanical means by which it is dredged.

This ongoing and regular recharge is maintaining a raised bed on the upper mudflat, covering approximately 1.4 ha (Figure 2.5). To date, there has been no detectable change to the marshes behind the disposal site, but benefits to these areas from reducing the rate of erosion of the local marshes and/or supporting bed accretion, may become apparent with an extended time series.

Hydraulic dredge and bottom placement

This approach is similar to the preceding one, in that the material is disposed via bottom placement. In this case though, the material is dredged hydraulically rather than mechanically. This means that the sediment is more fluid and will disperse relatively quickly from the disposal site.

The rate and pattern of dispersal is greatly influenced by the wave climatology and tidal or fluvial currents and there is comparatively little control over the settlement location, again, similar to the concept of sustainable relocation. For this to be distinctly recognised as a restoration strategy, clear evidence that the sediment will reach the target site is required. This can be difficult to verify without using comparatively large volumes of sediment when compared with the mechanical approaches described above.

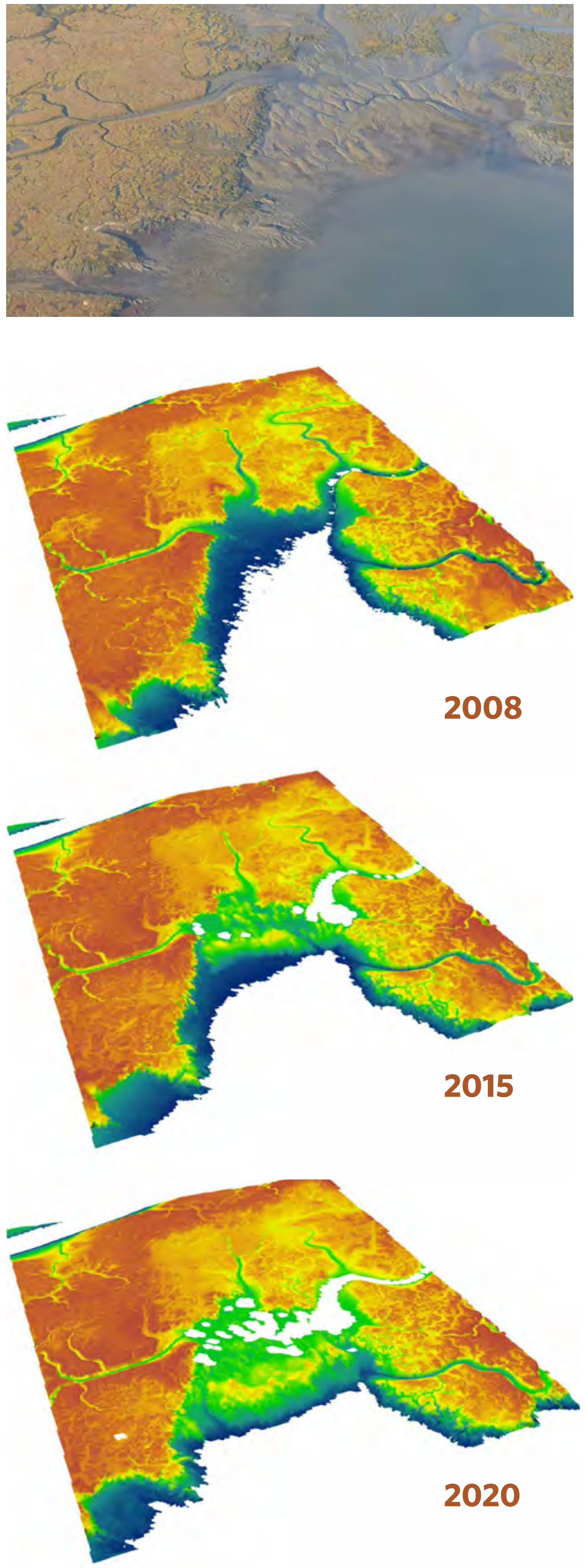


Figure 2.5: Lymington Harbour Commissioners dredged placement site showing the physical changes that have taken place since regular/annual disposal campaigns started in 2014 (Photo: © Simon Nunn, taken September 2018) (ABPmer)[1].

One example which shows how this might work, however, is the 'mud motor' initiative in the Netherlands. For this project, sediment is dredged from the Port of Harlingen by TSHD and disposed further north along the coast within a nearshore channel. Modelling work and sediment tracer studies indicate that the sediment from this site could migrate inshore to feed marshes several kilometres along the shore at Koehoal.

Around 300,000 m^3 of material was disposed of over two campaigns during 2017 and 2018. Monitoring at the Koehoal marshes identified some accretion, indicating that the concept could work in principle, although the sediment was mobile and also readily eroded. From these early trials, therefore, no detectable marsh expansion was observed. Over time, with regular placements and appropriate environmental conditions, the project might begin to have a detectable ecological effect.

Mechanical dredge transported for hydraulic disposal by pipeline

This approach involves mechanically dredging material, transporting it to a separate location and hydraulically pumping it to the disposal site. This is required for projects where the receptor site is inaccessible to vessels and 'out of reach' of mechanical disposal methods. These inaccessible areas include the interior of saltmarshes and areas of extensive intertidal flats, which prevent direct access by vessels for a sufficient duration to safely complete the disposal works. These areas are often distant from the navigable channels and are locations where there is often the greatest chance of retaining sediment and raising the elevation of the marsh. As the material is hydraulically pumped, retention structures may be needed to keep the majority of the fluid sediment within the target area.

While this approach can achieve large benefits it can involve double handling the sediment, from dredger to hopper and then from the hopper to the disposal site. This double handling incurs additional costs to cover the extra equipment and the extended working time needed.

Vessels are available, or can be designed, which can complete the whole process without the need to double handle and are therefore likely to be cheaper. This can involve using a vessel mounted BHD or GD to place material in the hopper, where screens or pressure jets break the material up before an integrated pump allows for remote sediment disposal via pipeline.

An example of the double handing technique, with targeted sediment placement, was applied at Lymington, also on Boiler Marsh, in 2012 and 2013 using sediment dredged by BHD. Material was placed in a hopper barge and transferred to a working platform housing a pumping station (Figure 2.6). From there, sediment was pumped via pipeline into a deteriorating area in the heart of the marsh.

At the disposal site, a series of ten polder and hay bale fences were installed to help retain the sediment. The approach proved successful, with the majority of the sediment still being present almost a decade later. This improved the quality of the habitat at the disposal site, changing it from a network of eroding clay mounds and anoxic channels, to a more diverse mixture of mudflat, vegetated saltmarsh and clay habitat that is used by feeding and roosting birds (ABPmer, 2020) (Figure 2.7). The recharge was also deliberately located at the end point of a large channel that was fragmenting the marsh into two parts, further accelerating erosion rates. Placement at this site slowed the progression of this channel and extended the lifespan of the surrounding marsh.

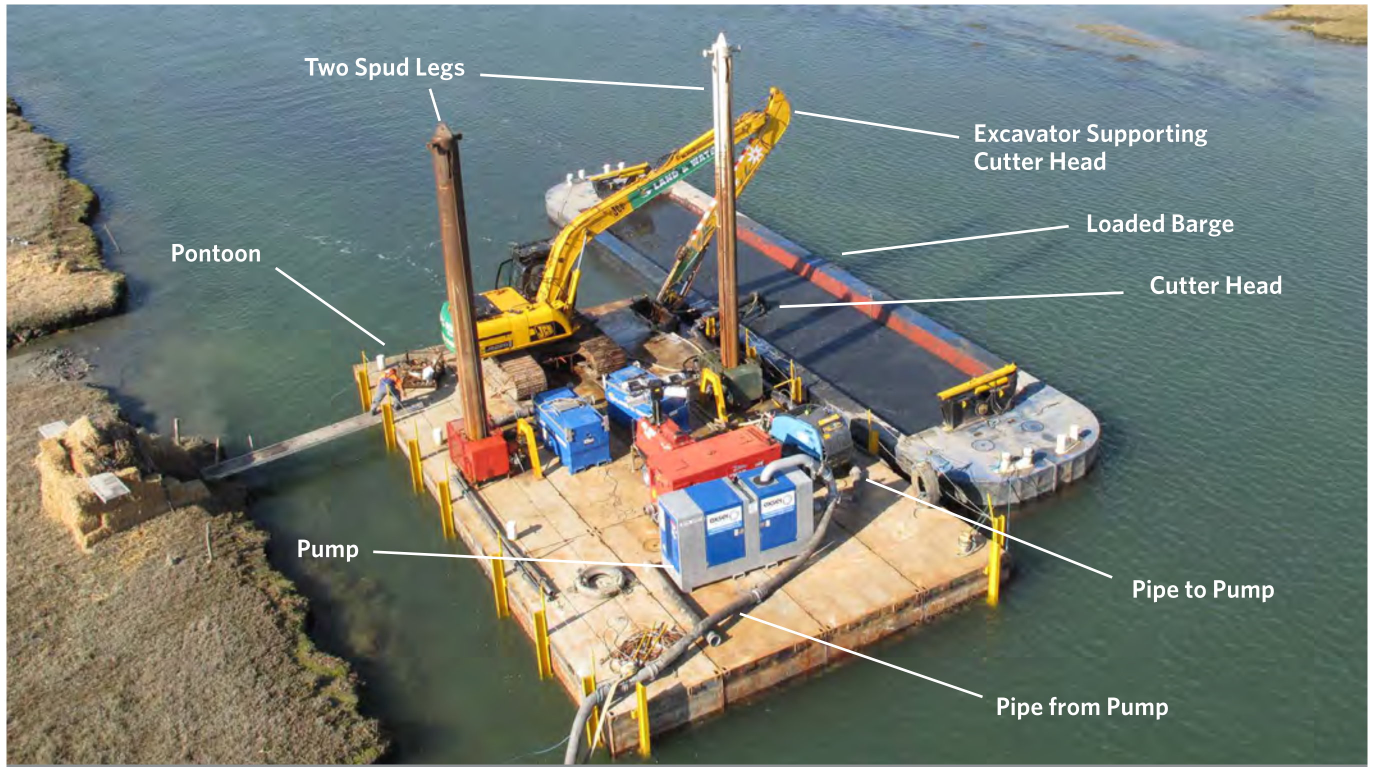


Figure 2.6: Double handling sediment at the transfer station used for the Wightlink Ltd. restoration at Lymington. Shows a hopper barge moored alongside a spud barge housing a pumping facility (Land and Water Ltd.).

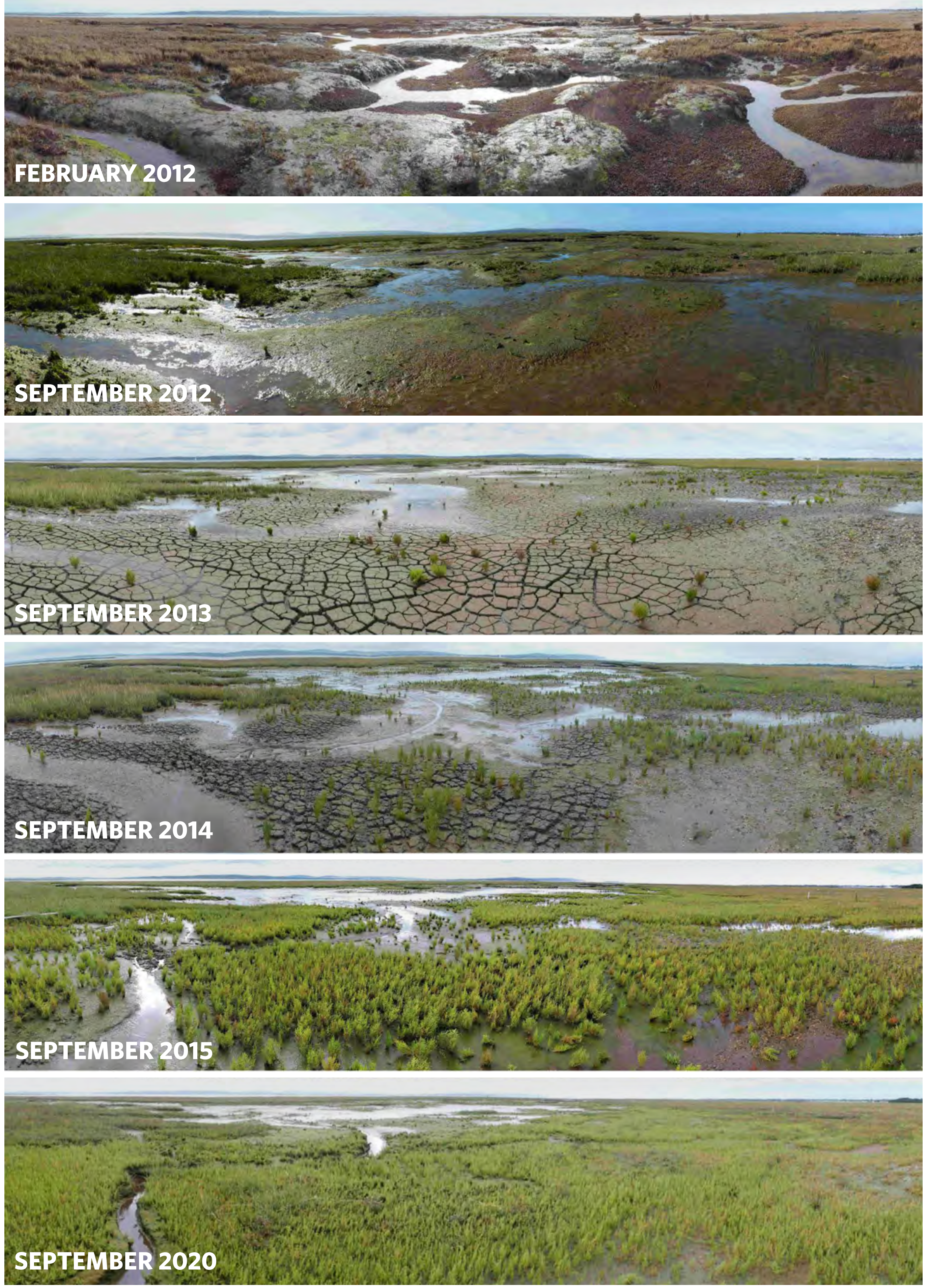


Figure 2.7: Development of the Boiler Marsh restoration site before, during and after the placement of dredged material in the winter months of 2012 and 2013 (ABPmer).

Hydraulic dredge and direct hydraulic disposal by pipeline

Examples of this approach involve using a CSD to pump sediment directly from the dredge location to a disposal site. This releases a fluid sediment-water mix at a defined location and consequently, typically requires the use of sediment retention structures. Examples include: at the Suffolk Yacht Harbour near Levington on the River Orwell, Suffolk; a further recharge project carried out in 2012 and 2013 at the Yacht Haven Marsh, Lymington[1]; and the St Osyth Borrow Pits on the River Colne, Essex.

At the Suffolk Yacht Harbour, this approach has been used since the late 1990s where maintenance arisings from the marina are pumped directly to adjacent foreshore areas. In 2014/15, sediment was pumped further away (500 – 600 m) to North Marsh. The fluid sediment there was retained in the creeks by small coir logs held by wooden posts, although it was also understood that sediment dispersion will occur into the wider environment.

A similar approach was used on the Yacht Haven Marsh, Lymington. Here the sediment was pumped directly over 400 m from the Yacht Haven to the marshes, where it was retained within hay bale fences and other structures.

At Brightlingsea, material was dredged for the maintenance of the navigation channels within the harbour. In 2017, approximately 12,000 m^3 of the arising material was pumped up to 1.7 km through a floating pipeline, extending from the channel, across the interior marsh and along the toe of the flood embankment, discharging into a series of 23 borrow pits (each around 900 m^2 (Figure 2.8). These pits had been excavated to strengthen the St Osyth coastal defences in response to the 1953 floods. They were divided into groups and connected by small excavated channels to allow sediments to disperse across each group from a single discharge point. A timber drop board sluice was installed for each group and used to retain sediments and control the repeated fill cycles until the desired bed height was reached. To maximise the fill level, the project was permitted to overflow the pits on the last fill cycle, allowing the sediment to disperse across the marsh during subsequent periods of inundation. Following a period of dewatering and associated lowering of the bed level, a second campaign was undertaken in 2019, using the same method to store a further 8,000 m^3 dredged from a local marina.

These projects have generally been successful in retaining sediment, raising saltmarsh levels, promoting saltmarsh growth and slowing the rate of fragmentation and erosion. Colonisation of these sites by saltmarsh vegetation and benthic invertebrates has occurred rapidly. They can also quickly develop topographic features, due to their generally low cohesiveness and erosion during repeated tidal inundations. At St Osyth, for example, the recharged borrow pits quickly developed shallow proto-channels across the self-levelled surface, facilitating subsequent drainage patterns.

Figure 2.8: St Osyth borrow pits, Colne Estuary, Essex, from top: borrow pits prior to disposal; cutter suction dredger in operation; pipeline used for transport and disposal; fine sediments being disposed by hydraulically pumping via pipeline; and subsequent colonisation of the borrow pits following disposal (Exo Environmental Ltd.).

[1] It is useful that three different recharge approaches have now been conducted at Lymington (see Table 2.1). This has offered a very valuable opportunity to compare and contrast the costs and benefits of these different approaches with offshore disposal options.

Hydraulic dredge transported for hydraulic disposal by pipeline

This is probably the most common approach to beneficial use in the UK and has been used at several sites throughout Essex and Suffolk. In contrast to the previous example, where there is a direct release from the dredge area to a restoration site (via a pipeline), here, the hydraulic dredger transports the sediment close to site, before hydraulically pumping the material to a defined location.

At Shotley in the Orwell Estuary, Suffolk, a sand and gravel barrier was created before finer sediment was used to fill in behind and stabilise the barrier, whilst creating a raised intertidal habitat and enhanced coastal protection. At Horsey Island, in Hamford Water, Essex, between 1990 and 2006, a series of individual projects were carried out by the Environment Agency in partnership with Harwich Haven Authority (HHA) and the private landowner. In total, around 255,000 m^3 of silt, sand and gravel have been used, obtained from various capital and maintenance projects at the nearby international ports of Harwich and Felixstowe, located 7 km to the north. Some of this coarse material was disposed via rainbowing and is described in the following section.

This approach was also used to support managed realignment works at Trimley in the Orwell Estuary and at Allfleet's Marsh, in the Crouch Estuary, Essex. At these two locations, the aim was to raise the bed levels and accelerate habitat development before breaching the seawall and allowing the introduction of tidal waters over the hinterland. The project at Allfleet's Marsh remains the largest single silt recharge project in the UK. In total, 550,000 m^3 of sediment was placed along a 4 km stretch of new counter wall and contained between that wall and a fronting clay bund (Figure 2.9). An international example of sediment being pumped into a managed realignment site to raise the land level is the Hamilton Wetland restoration in San Francisco Bay, California, USA. Here 4.5 million m^3 was used from the Port of Oakland deepening project to raise tidal areas by around 0.5 m.

These projects were successful in protecting eroding coastal habitats and defences. The recharge works carried out in conjunction with managed realignment can also help to accelerate the development of intertidal habitats.

Dredged sediment can also be used for land raising and landscaping inside managed realignment sites to ensure they are carefully integrated with the adjacent waterbody and to avoid major and potentially damaging changes to local hydrodynamic and geomorphological processes. The landscaping work on Wallasea Island (Jubilee Marsh managed realignment) provides an example of this, although that used tunnelling excavations rather than dredge arisings. One consideration when employing beneficial use as part of managed realignment projects however (and incurring the additional costs required), is that these sites often rapidly accrete with sediment following the seawall breach. This sedimentation is something to consider carefully as part of the design process for such an approach.

Figure 2.9: Hydraulic disposal by pipeline and the last disposal of 550,000m^3 of fine sediment prior to breaching of the flood defences at Allfleet's Marsh, Crouch Estuary, Essex (ABPmer).

Hydraulic dredge transported for hydraulic disposal by rainbow

This approach uses the rainbow disposal technique to transfer sediment directly from a dredger to a disposal site. This technique is often used to place sand and coarser sediment on to beaches during renourishment works, but it has also been used to create protective barriers and valuable coastal habitats.

At Horsey Island, this method was used to create a sand and gravel barrier in the early 1990s and was part of the many different beneficial use initiatives carried out at this site. Prior to the works, continued erosion of the saltmarsh had resulted in exposed outcrops of unvegetated London Clay. Sand and gravel dredged by TSHD from the approach channel to the international ports of Harwich and Felixstowe, was initially placed along a line of Thames lighter barges that had been previously positioned there in the 1990s to act as wave breaks to try and delay further loss of the remaining marshes. Following placement, the barrier initially rolled back and in places, welded to the shoreline and existing sea defences, before a subsequent fine sediment recharge via pipeline stabilised its position (Figure 2.10).

Collectively, the Horsey Island projects represent one of the largest uses of dredged sediment in the UK. They have demonstrated how both fine and coarse sediments can be used effectively together to build up and restore habitats, enhance biodiversity and provide coastal flood defence benefits. The barrier has also become the most important little tern (*Sternula albifrons*) nesting site in Essex.

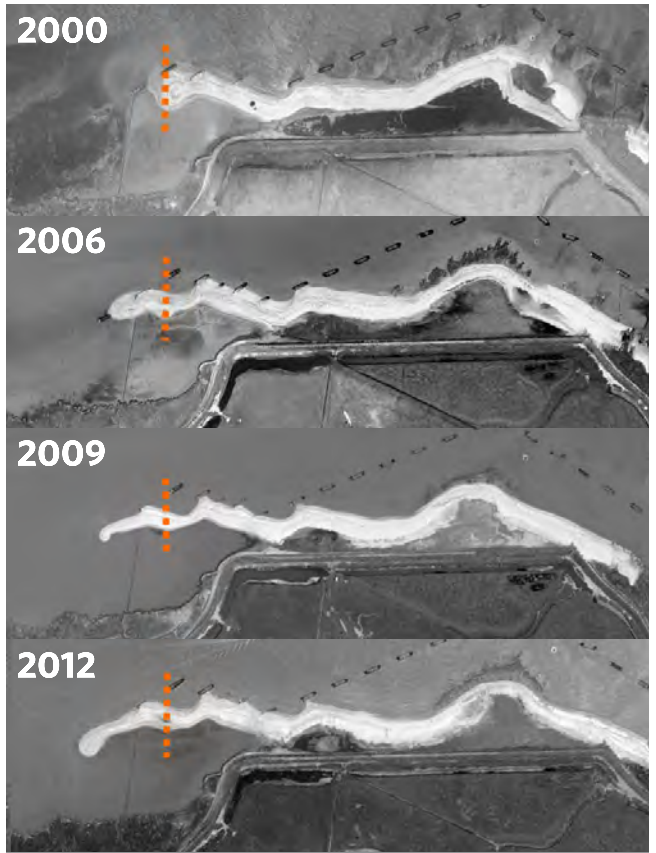


Figure 2.10: Evolution of the Horsey Island sand and gravel barrier between 2000 and 2012 (ABPmer, 2016)[1].

[1] Historical satellite imagery © Google Earth.

To maintain and improve the Horsey site, the RSPB has obtained the necessary approvals to use a spray pontoon to place a further 50,000 m³ of coarse sediments arising from the deepening of the Harwich and Felixstowe approach channel over the 2021/22 winter. The Mersea Harbour Protection Trust (MHPT) have also secured the necessary approvals to use a further 97,000 m³ of the same coarse material to recharge islands and promontories within the Blackwater Estuary, Essex, a repeat of works previously undertaken in the 1990s.

Alternative approaches

The case studies above, describe the main ways in which dredged material has been used for estuarine and coastal habitat restoration in the UK previously. However, it should not be viewed as the full spectrum of available options. In reality, dredging companies and sector specialists have the knowledge and technical capabilities to achieve almost any concept that can be realistically envisioned. The following bullet points provide examples of what else has been done, or might be possible, to help inform future feasibility studies.

- **Hinterland wetlands:** There are opportunities for restoring freshwater and brackish non-tidal wetlands behind existing sea walls, without subsequent reconnection to the marine environment via managed realignment or RTE, as previously described. This approach has been used at two sites on the River Thames, Cliffe Pools and Rainham Marshes (Figure 2.11).

Figure 2.11: The Strandway trailing suction hopper dredger at the sediment transfer pipeline to Cliffe Pools (Boskalis).

- **Dune enhancement:** There will also be opportunities to use sand to nourish beaches in front of dunes or within dune habitats themselves. At Talacre in North Wales for example, this was done using sand dredged from the navigation channel to the Port of Mostyn in the Dee Estuary. The dredged sediment then contributes to the supply of sand that is wind-blown to recharge the dunes at the top of the beach.
- **Seagrass seeding:** In the future, it will be better to think more broadly about the lower shore and shallow subtidal habitats that might be enhanced alongside saltmarshes and mudflats. For example, there may also be ways of enhancing seagrass beds, such as providing shelter from waves and fluvial or tidal currents, providing the appropriate rooting substrate, or distributing seagrass seeds into the hydraulically pumped sediment-water mix during disposal to help simulate seed dispersal over a large area.
- **Oyster beds:** Coarser sediments can be used to prepare the seabed and provide a suitable hard substrate to support shellfish restoration, such as native oysters. In the Blackwater Estuary, the Essex Native Oyster Restoration Initiative (ENORI) used terrestrially won commercial aggregates to improve conditions for spat settlement (see the Native Oyster Restoration Handbook for more details (Figure 2.12)). However, the same result could be achieved using appropriately sized dredged sediment.

Figure 2.12: Disposal of terrestrial-won gravels as part of seabed preparation works for native oyster restoration (ENORI and Zoological Society of London (ZSL)).

- **Island Creation:** A concept that would be new in the UK is creating 'nature islands'. International examples include Polder Island in Chesapeake Bay, Evia Island in Galveston Harbour and Ship Island on the Mississippi coast, USA (Figures 2.13 and 2.14), or) or the 'Ilot Reposoir' at Le Havre, France. There are also examples in freshwater and/or non-tidal systems, such as the Marker Wadden project in Markermeer Lake, Netherlands, or the island creation projects in the Szczecin lagoon, Poland. These examples highlight what can be achieved at the landscape scale when using very large quantities of material. Although the design, technical and logistical challenges are understandably far greater with this increasing size and complexity, such projects may be viable given the associated scaling up of potential storage volumes and resultant benefits.

Figure 2.13: Evia Island, created using local maintenance dredge arisings from the Houston-Galveston Channel improvement project and disposed of within a confined disposal site to provide a protected environment for rare and endangered birds (USACE Galveston District).

- **Seabed storage:** To avoid missed opportunities, where a beneficial use project cannot be found or licensed in the appropriate time frame to match the commercial schedule of a dredge campaign, there is an opportunity to temporarily place material on the seabed for later retrieval. This approach was taken when Southampton Water was deepened by ABP and Boskalis, where sand and gravel that might be of value in the future was disposed offshore alongside an established disposal site. These materials can be dredged at a later date, should either commercial or environmental opportunities arise, as and when the necessary marine licences and permissions have been acquired.
- **Bespoke dredging:** Where substantial benefits are identified, there may be a case where dredging is carried out specifically to provide sediment resource to meet a beneficial objective. Such a benefits-led process is commonplace for beach nourishment projects, where the need to achieve coastal protection and recreational enhancement drives the requirement to source sediment from new or existing aggregate extraction sites (e.g., Bacton and Walcott Sandscaping project, Norfolk). The same thinking could be applied to declining marshes if the need was better understood. There will still be concerns about the dredging impacts themselves, which will need to be resolved through standard regulatory processes. However, placing greater emphasis on NbS and the associated habitat restoration benefits, could tip the balance from a situation where bespoke dredging would not even be contemplated, to one where its value would make sense.
- **Dredging an accessible disposal site:** A novel approach would be to dredge a temporarily deepened berth pocket or find (and authorise) a suitably deep and accessible disposal site close to the intended restoration site. These sites could then receive dredged material from a range of locations and subsequently used to restore the beneficial use site. This approach could be very effective in certain conditions, potentially using more suitable material for the restoration, whilst simplifying the logistics of the operations. This approach was suggested for the Lymington saltmarshes and considered under the Solent Forum BUDS project, however, it remains untried.

Figure 2.14: Ship Island, where the individual east and west islands were reconnected, following successive storm breaches resulting from Hurricane Camille (1969) and Hurricane Katrina (2005), in order to restore beach and sand dune habitats and provide coastal flood defence benefits (USACE Mobile District).

PROJECT PLANNING AND DELIVERY

The preceding sections outline the different ways in which dredging, disposal and habitat restoration are, or could be, carried out. The links provided to other international examples highlight what can also be achieved with more ambition and at greater scales. The remainder of this chapter describes other important factors to consider when planning and delivering both individual projects, as well as more strategic regional approaches to beneficial use and seeking to change existing dredging and disposal activities.

Figure 2.15 illustrates the general phases and timeline of the process, assuming that funding is in place. However, different projects can experience very different requirements. This is to be expected given the inherent variability of beneficial use projects, which can vary greatly in their location, scale, duration and complexity, as well as in terms of the habitats they are supporting.

There is likely to be a degree of interdependence, reiteration and overlap between the different phases. Accordingly, timelines can also vary substantially but in general, Phase 1 and 2 can range from a few months to a few years, it is considered best to allow for around 1.5 years for Phase 3, whereas Phase 4 can extend from months to decades, depending on the approach.

It is emphasised also that consultation with relevant regulatory authorities should begin early and occur regularly throughout. They will be key stakeholders during the Phase 1 regional strategic planning element as well as being key consultees for the design, pre-restoration licensing and monitoring tasks of Phases 2, 3 and 4.

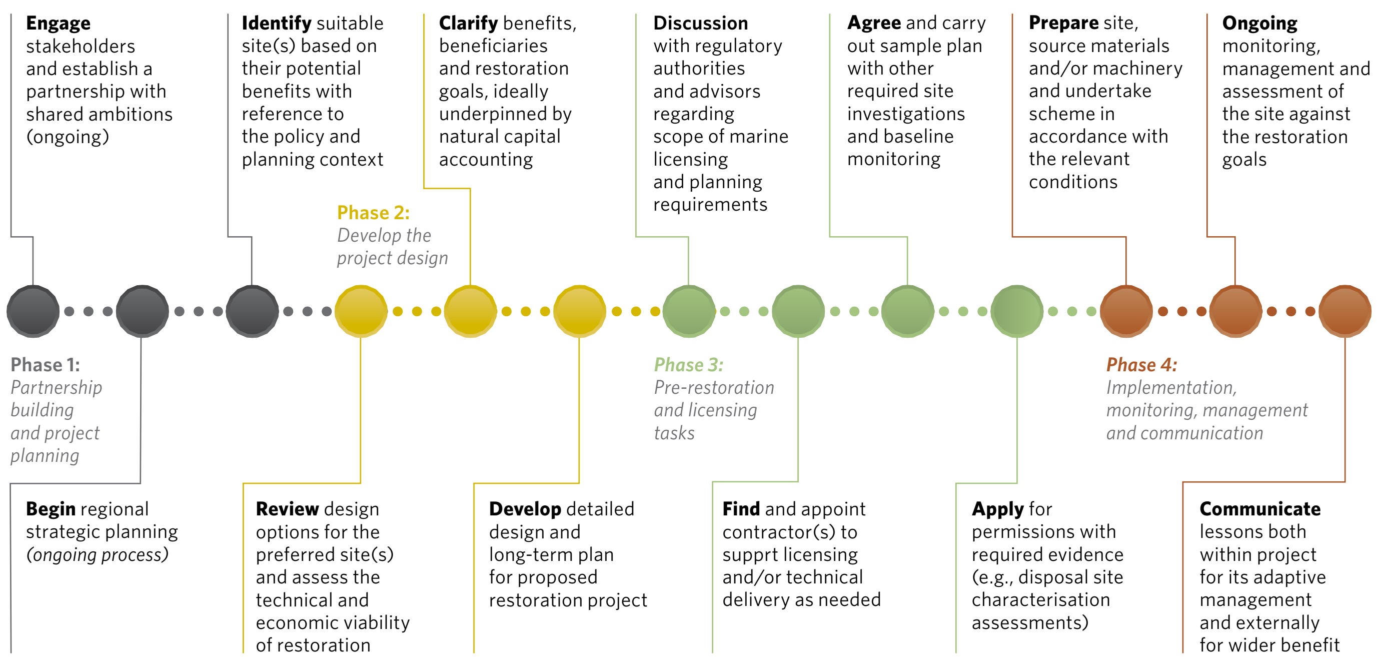


Figure 2.15: Indicative beneficial use project phases and timeline of progression.

Horsey Island, Essex, showing some of the range in volumes, particle sizes and locations of beneficial use campaigns, and other works, undertaken here over the last 30 years (Image: Jim Pullen Surveys).

Partnership building, site selection and regional strategies

The most important aspect to highlight when thinking about future project implementation is that, if we are to do more habitat restoration work using dredged material, then we need to have a clearer understanding about where the restoration sites are so that plans can be made to pursue projects at these sites. In the last few years, increasing effort has been made to do this. For example, the Marine Management Organisation (MMO) and Natural Resources Wales (NRW) have produced potential restoration maps for the English and Welsh marine plan areas.

The ReMeMaRe initiative is further developing and refining maps of potential restoration sites for seagrass meadow, saltmarsh and native oyster habitats in England. These are available to view and download from the Catchment Based Approach (CaBA) coastal data explorer. The habitat specific restoration handbooks in this series also provide further details and suggestions regarding aspects such as individual site selection and defining what habitat restoration success might look like (and is therefore not covered here specifically).

This mapping effort is expected to be an ongoing process, in order to help meet objectives such as those from the government's 25YEP and commitments made in the pending Environment Bill. For example, in England, there is an expectation that LNRS will be set up around the country, creating networks of sites to restore nature.

Such strategies will include estuarine and coastal habitats and a subset of these sites are likely to be suitable for, benefit from or require the use of additional sediment, thereby forming a potential beneficial use network. To ensure that sites selected are appropriate, more effort will be needed to identify where and why these projects are needed, before working backwards to identify how they can be achieved by considering the factors described in this handbook and other guidance. It is recommended that once established, these beneficial use networks become embedded in spatial planning tools, such as SMPs, with individual sites being prioritised based on their site specific benefits in order to proactively drive funding and project implementation. The necessary marine licences and permissions should then be sought in advance of the sediment being dredged, with the regulatory requirements made sufficiently flexible to allow such opportunities to be seized as and when the sediment becomes available.

This is a change to historical approaches, where beneficial use projects have previously been identified, developed and licensed on a more ad hoc basis or in response to a newly proposed dredge, often at relatively short notice in order to meet commercially and operationally time sensitive dredging schedules. They have typically been informed by local initiatives and dependent on the vision of selected individuals and interested groups. These factors, combined with complex regulation and a lack of readily available funding for such projects, has historically resulted in missed opportunities across the UK.

This change from the reactive status quo to a pre-emptive strategy is therefore needed if more projects are to be implemented. Developing a pipeline of projects that are ready to receive material as and when it becomes available through this process supports the logistical planning of the works in advance, thereby reducing uncertainty, cost and the potential for missed opportunities.

Increasing efforts are being made to pursue this approach but there is still much that needs to be done to achieve this goal, particularly at a large scale, not least securing the upfront resource and effort required to obtain the necessary marine licences and permissions for these sites.

The most recent works undertaken at the Horsey Island site (October 2021). A trailing suction hopper dredger was used to recharge the barrier with sand and gravels arising from the deepening of the Harwich and Felixstowe approach channel. Approximately 10,000 m³ of the total 50,000 m³ being used during the project can be seen on the right shortly after disposal. The sediment was hydraulically pumped via floating pipeline and will allow natural processes to redistribute the material along the coast. These works were undertaken through a partnership between the local landowner, the RSPB, Harwich Haven Authority and the Environment Agency (Will Manning, Cefas).

This approach also needs to be developed in a phased way and requires a planned and active, adaptive and collaborative approach, with stakeholders across sectors developing partnership-based local and regional strategies in order to maximise the opportunities for implementing projects. The individual habitat restoration handbooks provide further details about establishing stakeholder groups and who may be involved in such partnerships. For beneficial use projects, this will involve the addition of representatives of organisations undertaking dredging works (e.g., ports, harbours, marinas and dredging contractors), as well as the relevant regulatory authorities. National efforts to guide and support this collaborative process will certainly help, but this approach will only work if it is actively driven and funded on an ongoing basis, fine tuned at the local and regional scales and inclusive of the communities that will be affected. Examples of this approach are already in development across the UK. The Solent 'Beneficial Use of Dredged Sediment (BUDS)' project is an exemplar of this process and is outlined further in Box 2.1.

At an even very basic level, but critical for beneficial use, such partnerships facilitate cross sector collaboration and will help all involved to: better understand the timings, locations, methods, volumes and compositions of sediment resources arising from dredging activities; provide a mechanism for prioritising habitat restoration options; and in doing so, identify the locations, volumes and compositions of sediment required to support beneficial use, including any project or site specific, technical or logistical considerations.

BOX 2.1: CASE STUDY EXAMPLE OF A STRATEGIC INITIATIVE – THE SOLENT FORUM BUDS PROJECT

In 2017, the Solent Forum coastal partnership set up the innovative Solent 'Beneficial Use of Dredge Sediment (BUDS)' project. This project was initiated because the partnership is keen to see more of the Solent's dredged sediment used to restore its eroding intertidal habitats. Around 1 million m^3 of fine sediment is excavated each year in this region. This is mainly placed offshore with no more than 0.02% of this material being directly used to beneficially protect and restore the Solent's deteriorating habitats.

The BUDS project recognises that a new collaborative and strategic management approach is needed in the Solent region if change is to be achieved. This needs to be built on a systematic, inclusive and evidence based process and to achieve this, the project is being carried out progressively in discrete phases as follows:

- **Phase 1 (2017 to 2018):** This involved an initial strategic overview of the region. It included a mapping study (Figure 2.16) to illustrate the dredging and disposal activities that are taking place and to identify areas that could benefit most from using dredge sediment. There was also a consultation and partnership building process. During this phase stakeholders were actively involved and potential locations for beneficial use were prioritised.
- **Phase 2 (2019 to 2020):** This involved a detailed review of the practical options for carrying out restoration in one of the areas prioritised during Phase 1. The location identified was in the West Solent, near Keyhaven and Lymington. The Phase 2 review also included a uniquely detailed cost:benefit analysis of the available options, based on a natural capital assessment approach.
- **Phase 3 (2021 to 2022):** This phase will involve actively securing the necessary marine licences and permissions for beneficial use at a preferred site (or, ideally, a series of sites) in the West Solent. This will facilitate future beneficial use projects that will then take place during Phase 4. The process will also further improve understanding about the practicalities, costs, benefits and funding of beneficial use measures to underpin other projects across the Solent in the future.

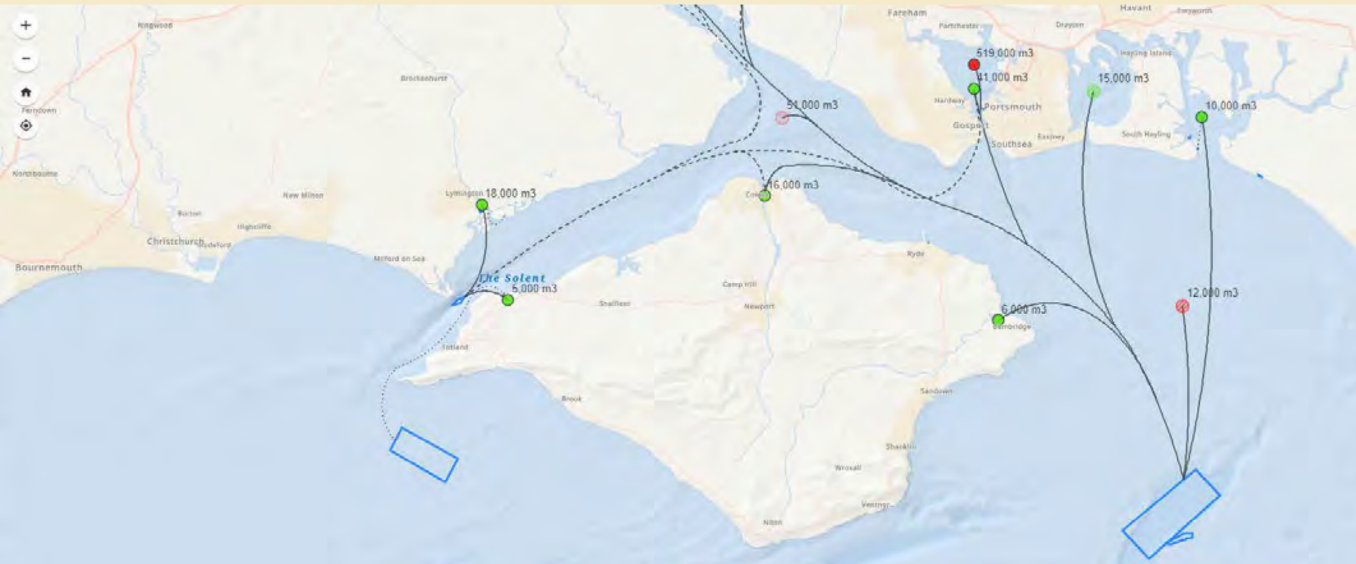


Figure 2.16: Interactive map of dredging and disposal activities in the Solent, created during Phase 1 of the BUDS project (ABPmer).

Considerations, feasibility studies and development of the project design

When selecting potential restoration sites and developing beneficial use proposals, existing dredging and disposal activities must be considered. Some of these have been described above and include the location of the activities, the arising sediment volumes and its physicochemical composition, the methods used and the resultant behaviour of the dredged material.

There are many other, often inter-related ecological and technical issues that must also be addressed. These include the nature and accessibility of the beneficial use disposal site, as well as the overall costs and net benefits (Figure 2.17). Developing a new project is therefore not always a simple process. To help with future feasibility studies and development in this sector, some of the main issues more specific to beneficial use to be aware of are reviewed in the following sections.

It is reiterated here, that the habitat specific restoration handbooks in this series also provide further details to inform the development of beneficial use projects, such as habitat specific project design, monitoring and potential funding streams.

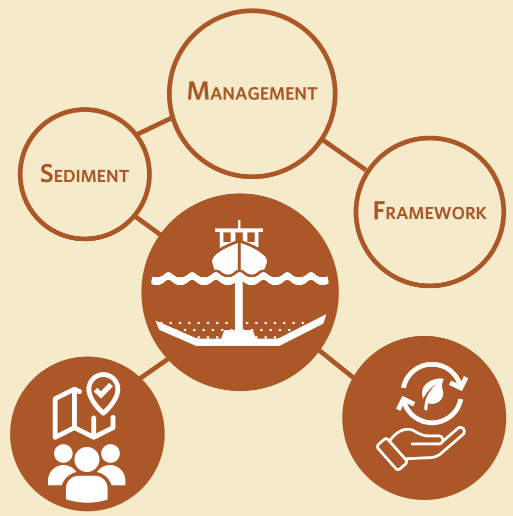
Access to relevant information

One key issue worth emphasising, is that much of the information needed to make decisions and develop project plans is not readily available or clearly audited. There is no central database from which information can be readily drawn about existing dredging methods or other key issues, such as the location of potential beneficial use sites, as described in the preceding section.

Some details are contained within and can be selectively extracted from individual and publicly available marine licences. Sediment sampling results and the locations and volumes associated with previous disposal works across the UK that form the LCLP and OSPAR returns, can also be obtained from Cefas. To do so, an 'Environmental Information Request' can be submitted to the Regulatory Assessment Team, providing a short description of the reason for the enquiry and either the boundary co-ordinates of the area of interest, or the name of the existing disposal sites of interest (e.g., to assess historical usage). However, a lot of other information can only be derived from further local and regional research and through consultations with sector specialists. Without any central database, bespoke investigations are required to obtain the main required information as part of any feasibility studies.

This lack of detail and transparency is itself a constraint to progressing projects. Moving forward, it is recommended therefore, that many of the details discussed here are collated as part of the 'Sediment Management Framework (SMF) online tool' currently being developed (Box 2.2). Any such efforts to improve data collation and communication will help with project planning and feasibility studies in the future.

Figure 2.17: Examples of factors to consider during planning and delivery of a beneficial use project.



BOX 2.2: PLANS FOR A SEDIMENT MANAGEMENT FRAMEWORK ONLINE TOOL

Cefas is currently developing an online Sediment Management Framework (SMF) tool, due for completion in early 2022 (England only). It will provide a publicly available online GIS resource, containing among other data, authorised disposal sites, their categorisation (Table 1.3) and the location of sediment samples acquired during the relevant licence applications, including the respective particle size and contaminant concentration results. This data will be linked to the LCLP and OSPAR returns process and updated annually in arrears.

The SMF aims to provide operators with a visualisation of sediment quality that places their own sediment sampling results in the regional context. It will also provide details on sediment management best practice and help manage the disposal of dredged material, including contaminant characterisation, in accordance with LCLP and OSPAR requirements.

As the SMF is adopted, there are major opportunities for further development. By hosting additional data and key information (that is not considered commercially sensitive), the SMF would facilitate the co-ordination and delivery of more beneficial use projects, thereby improving the management of dredged material at a national level.

It is therefore recommended that the SMF is adopted by all stakeholders involved in any aspect of a beneficial use project and that further development and information sharing should be supported and focused on the inclusion of the following additional details where possible:

- **Proposed dredging (sediment sources)**, including the location, volumes, particle size distribution (PSD) and chemical concentration data, dredge methods and schedule of works.
- **Authorised and proposed beneficial use sites (habitat restoration and other uses)**, including the location, volume of sediment required (capacity), PSD required and chemical concentrations accepted. Any additional project considerations should also be provided, such as suitable disposal method(s), access constraints (e.g., distance to stated water depth) and contact details of the 'project owner(s)' (e.g., local partnership).

Developing the SMF would improve the identification of potential and authorised beneficial use sites in proximity to existing or proposed dredged sediment sources. This would support improved sediment management, as well as enhancing the ease, consistency and transparency of the regulatory process. Beyond the logistical and regulatory support that the SMF could provide, in future, compliance or surveillance monitoring associated with beneficial use projects (Chapter 3) could also be linked to the framework. This would further facilitate better systems understanding, knowledge exchange and research, public engagement and potential funding models (e.g., carbon market models and BNG).

Temporal variations in dredging activities

Dredging is only carried out when needed and therefore, the timings and dredging methods used can vary year on year in a way that is often not fully evident in marine licences, which tend to identify the maximum and approximate annual dredge requirements only. In reality, the timing and scale of dredging commitments will depend on factors such as:

- The **variability of environmental conditions**, such as river flows and storm events. These can lead to changes in rates of sediment accumulation which then dictates the timing of the dredging activities
- Changes to **economic conditions** and commercial need will influence how frequently and at what depth, the seabed needs to be maintained
- The **availability of dredging vessels** can influence when a dredging project goes ahead. This is because vessel mobilisation can be one of the costliest elements of a project (especially for short term deployments) and the timing works for periods when vessels are already on site can greatly influence the overall cost.

Vessel draught and navigable access

The draught of the dredging vessels or hopper barges used dictates the safe water depth in which they can operate, including both the minimum water depth and at what tidal state. This influences how accessible or how close to the beneficial use site the vessel can approach and as a result, may influence the type of equipment needed to discharge the sediment to the restoration site. For example, if material can only be disposed of at high water, the operational windows may only allow for a single hopper barge load per tide, whilst a pipeline will probably be required for sites where direct navigable access is a limiting factor.

Transport distance and project duration

Haulage distances, project duration and the proximity of individual receptor sites are all inter-related factors that have a major influence on how a project can be implemented and its cost. The transport distance between the dredge and restoration sites dictates the fuel costs and can, if the distances are large, greatly prolong the duration and scale of the dredging campaign.

Project duration and both the transport times and distances can also be influenced by weather conditions and the availability of alternative disposal sites that can be accessed during periods of poor weather. The duration of a project is also influenced by specific requirements or constraints such as the need to place materials by certain methods or at certain states of the tide. In this respect, a network of licensed sites can further support an adaptive approach to beneficial use and improve the overall efficiency at which multiple projects are delivered as part of the collective strategy.

The location of any beneficial use sites and the methods used for disposal will therefore have a major influence. Where the project location and design can substantially reduce transport distance or project duration relative to existing disposal activity, cost savings may be achieved that could encourage the uptake of beneficial use.

Sediment composition, compatibility and contamination

There is a need to think carefully about whether the dredged sediment is suitable for use at any proposed beneficial use receptor site, including the particle size, the presence of any contamination, the degree of consolidation and the purpose for which it is intended. As described earlier in this chapter, sediment that has been hydraulically dredged will be relatively fluid in the hopper and may require more consideration regarding sediment and water management at the point of disposal. Sediment that is mechanically excavated is typically more consolidated and easier to manage at the receptor site. However, the operation is comparatively slower and very stiff or consolidated material may prevent vegetation from colonising.

The sediment type and its compatibility with the receiving environment will therefore need to be reviewed and assessed from the earliest stages of project planning and design. Sediment sampling from a licensing perspective is described in Chapter 3.

Costs and funding

Ultimately, the costs of beneficial use projects vary greatly on a case by case basis depending on factors discussed, such as the location, method and scale of the operation. Whether and how a project can be carried out will be strongly dictated by the costs. It is therefore important to understand whether a beneficial use project will either incur additional fees above existing practices or achieve cost savings. For example, the case studies summarised in Table 2.1 include those that are cheaper than offshore disposal options, primarily due to the transport distances that would otherwise have been involved. It also includes case studies that have incurred additional fees ranging between £15,000 and £1.5 million.

Altering existing practices in any substantial way, can often add large additional costs to the management and maintenance budgets of a port, a harbour area or individual facility (e.g., berth or marina). For beneficial use projects, cost increases can arise, for example, from having to subcontract new tasks originally completed in house or from having to seek new suppliers to achieve novel, less familiar tasks. They can also result from the purchase and maintenance of new equipment or from wastage of existing equipment that is either used less or even made redundant. There will also be new fees for the licensing and monitoring of any new beneficial approach. The process of identifying beneficial use sites and securing marine licences and permissions can also be a protracted one and delays could adversely influence existing site operations.

In instances where cost savings can be achieved, this may support reinvestment and the development of further restoration projects in the future. Where a cost increase is incurred, there is every indication that the 'cost differential' between exiting practices and the new beneficial approach can be reduced over time by regularly undertaking the work. However, the upfront expenditure required for establishing projects is often prohibitive, especially at a large scale. For this reason and to inform future projects and their funding applications, it is valuable to undertake a cost:benefit analysis based on an understanding of all the benefits that can be achieved (as discussed below).

Benefits and beneficiaries

To inform any feasibility review and understand the appropriateness and viability of beneficial use approaches, it is important to better understand all of the known benefits (ABPmer, 2017). It is then necessary to balance the anticipated costs against these benefits over the life of the project to determine whether there is a net benefit to society and to understand who will pay.

As part of this process, it should be emphasised that saltmarshes and other intertidal habitats are important 'natural capital' assets that provide many valuable ecosystem services. As described in Chapter 1 and their own respective restoration handbooks, they have inherent environmental value in their own right, but they also provide many other economic, social and cultural benefits. Restoration measures can therefore help maintain and enhance these benefits.

Another way to view this issue is that many estuarine and coastal habitats have been and are disappearing. The absence of protection and restoration is itself costing society as these valuable functions are being lost. Any beneficial use project should recognise the full values of the project, whether this is to help motivate participants and inform regulators or, more fundamentally, to justify funding and source payments from beneficiaries. Understanding who benefits and who potentially funds the project will be especially important.

This is in line with the natural capital accounting and ecosystem service valuation approaches often used in the UK. At the present time however, there are many gaps in our understanding about many of the ecosystem services values. There is a good understanding of the generic values, but beneficial use decisions need to be made with an understanding of site specific benefits and this site specificity is currently lacking and inherently tied to the establishment of regional networks.

Valid arguments can be made that these decisions should not just come down to money and that high costs should not be a reason to put off beneficial actions. It is certainly true that we should not rely solely on 'pound sterling equivalence' as a decision-making tool. However, it is also clear that the 'business as usual' approach needs to change somehow.

Overview of the feasibility study process

Through feasibility studies, applying and considering the above factors and others, such as habitat specific, regulatory and policy elements, it is possible to identify from a network of potential habitat restoration sites, a long list and priority list of potential beneficial use sites that would themselves form their own network. Three short and simplified examples illustrating the feasibility study and project review process are presented in Box 2.3.

Although there are many considerations, there are perhaps two ways to think about how change can be achieved to bring about more new habitat restoration projects. The first is to ask whether any sensible beneficial options can be achieved by adjusting, even just modestly, the existing or previously adopted way of doing things. This is a 'resource focused' approach which identifies what more can be done with the material. The second, more 'benefits-led' approach, is to determine whether and where, there is value in making substantial changes to existing practices.

In general, a modest change to an existing practice is likely to incur a low fee. In some instances, it may even lead to cost savings. For example, reduced haulage distance can lead to lower fuel costs and shorter timeframes for the dredging work. However, a modest change may also only achieve minor or negligible benefits.

By contrast, a major adjustment to existing approaches is generally required to achieve larger projects bringing about material societal benefits. This will typically cost more and take longer to achieve cost savings or cost neutrality. However, to make any meaningful changes that address biodiversity loss or the challenges of climate change, large scale habitat restoration is going to be needed.

This distinction between a 'small cost modest value resource led' approach and a 'high cost larger value benefits led' strategy is simplistic, but it is a helpful way to start thinking about beneficial use options. It is also a useful way to frame discussions about the best way forward at any given location. These discussions then need to be informed by factors described above, such as a greater understanding about the practical realities and costs of implementation, alongside a clear understanding of the net benefits that can be achieved. Adopting more substantial interventions and overcoming the extra difficulties associated with them, will require improved regulatory mechanisms and a very clear understanding about the costs, the benefits and who will fund it.

BOX 2.3: EXAMPLES OF RECENT AND ONGOING FEASIBILITY STUDIES

Three contemporary feasibility studies are summarised here to illustrate how the different factors influence a project review process. These projects are yet to be implemented but describe two perspectives. The first is resource focused. It asks what better options are there for using sediment? The other two are more benefits driven and ask whether locally dredged sediment can be beneficially used to help restore saltmarshes and if so, how?

1. Peel Ports are exploring whether sediment dredged from the Clyde Estuary (Clydeport, Glasgow) can be used beneficially without leading to disproportionately additional costs. They set up a regional stakeholder group which reviewed several options and identified a possible site in the lee of the Victorian era training wall, the 'Langdyke'. Depositing here would reduce the established haulage distance but there is still work to do to characterise the site and to agree the deposition methods, impacts and net benefits. An adaptive management approach has been agreed, in that an initial smaller scale intertidal recharge project will be undertaken and monitored, aiming to help better understand these factors and help develop a longer term strategy.
2. Natural Resources Wales (NRW) is considering how best to protect the sea defences and saltmarshes at Rhymney Great Wharf on the Severn Estuary (near Cardiff). The potential for beneficial use is being considered but it may not be a suitable option. This is because sediment that is suction dredged locally is quite fluid and disperses rapidly on release. In an estuary that already has a high suspended sediment load, placing it at or near Rhymney may have no particular or detectable advantage over other options such as establishing conditions to promote sediment deposition and retention.
3. Bournemouth Christchurch and Poole (BCP) Council has examined options for recharging the declining marshes in Holes Bay (Poole Harbour). Following a detailed review, it was concluded that a CSD and hydraulically pumped disposal approach would be the most productive method. Bottom placement was considered but vessels could not approach close enough to the marsh due to the bathymetry (i.e., too shallow). A 'double handling' approach was also considered that involved BHD and separate pumping, but it is unlikely that this option could provide the same productivity as the CSD method. The proposed CSD approach will still incur an additional fee because bespoke equipment and sediment retention structures will be needed. However, the proposed action is likely to represent the best balance between benefits and cost.

Adaptive management

For any project, it is important to be very clear about the motives, environmental objectives and measures of success. The aim of any beneficial use project for the purposes of habitat restoration, will be primarily focussed on achieving net environmental benefits over the long term, in keeping with nature conservation and shoreline management objectives. However, in order to inform the licensing process, it will also be necessary to understand both the positive and negative, short term and long term environmental effects (Chapter 3).

As with most habitat restoration projects, during project design and implementation of a beneficial use project, there will often be a certain degree of residual uncertainty or risk around the outcomes and potential impacts associated with the works, both positive and negative. In this respect, establishing an adapting management strategy may be an effective tool to aid project delivery.

Adaptive management provides a framework that facilitates flexible decision making that can be refined in response to future uncertainties, as the outcomes from current and future management actions become better understood (CEDA, 2015). This can relate to environmental, economic, regulatory, contractual and social considerations.

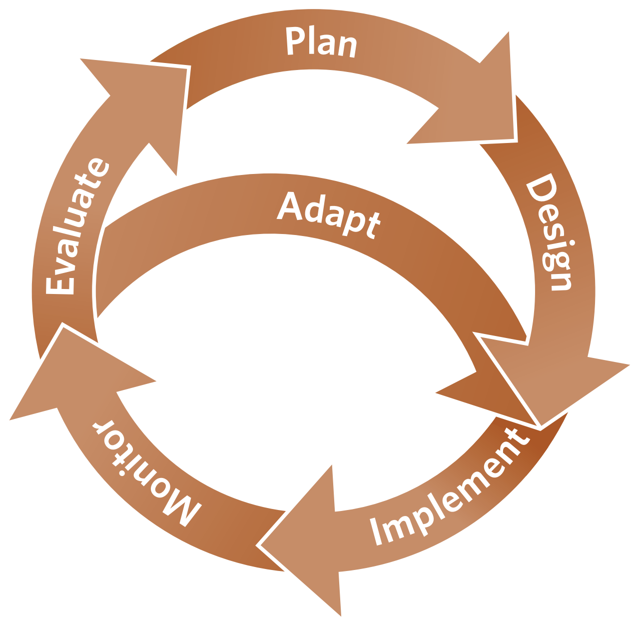
The adaptive management cycle (Figure 2.18) consists of iterations of targeted monitoring, evaluation and management actions, either continuously or on a regular basis during project delivery and following completion (where appropriate), to support the overall management of the project and any associated risk and potential impacts identified.

Practical applications include:

- Disposal of sediments at different beneficial use sites in response to changing environmental conditions (e.g., alternative disposal sites that can be accessed during periods of poor weather or at different states of the tide)
- Adjusting the disposal rate, or the timing and location of disposal operations, in order to minimise or maximise the negative or positive impacts respectively
- Contractual allowances to allow flexibility and reduce the potential for conflict
- Increase trust between stakeholders through clear decision making and communication of project developments

Beneficial use projects themselves are flexible in scale and they can also be important tools in adaptive management frameworks for dealing with uncertain impacts of other developments. Where another development's impacts are uncertain, a beneficial use project could provide habitats as mitigation or compensation for that development but recognising also that, if the development effects are larger than expected (based on monitoring) the scale and duration of a beneficial use restoration can be increased over time as needed.

Adaptive management solutions can have potential disadvantages if not managed appropriately. For example, changes to monitoring and management requirements throughout the project can cause difficulties and complexity that can be difficult to budget. Miscommunication of the rationale behind any changes can also lead to suspicion and mistrust from other stakeholders. Accordingly, the approach requires involvement and open dialogue with all stakeholders throughout the project and whilst there are both advantages and disadvantages, incorporating adaptive management into the project design may facilitate increased application of beneficial use projects in future.



1. **Plan:** defining the desired goals and objectives, evaluating alternative actions and selecting a preferred strategy with recognition of sources of uncertainty
2. **Design:** identifying or designing a flexible management action to address the challenge
3. **Implement:** implementing the selected action according to its design
4. **Monitor:** monitoring the results or outcomes of the management action
5. **Evaluate:** evaluating the system response in relation to specified goals and objectives
6. **Adapt:** adapting (adjusting upward or downward) the action if necessary to achieve the stated goals and objectives

Figure 2.18: Adaptive management cycle (CEDA, 2015).

CHAPTER 3
A GUIDE TO THE REGULATORY PROCESS

KEY SUMMARY POINTS:

- **Regulatory complexity is consistently cited as a barrier to delivering beneficial use projects, but regulation is of course also necessary. It is important however, that licensing procedures are proportionate, clear, and consistent. To underpin and support future beneficial use projects, ways of streamlining the regulatory process whilst remaining robust should be explored. This includes clarifying the processes involved, which is the focus of Chapter 3.**
- **Alongside the need for standard regulatory processes and assessments, there are bespoke requirements for dredge and disposal activities under LCLP and OSPAR commitments. These include the need to undertake an agreed sample plan to understand the on-site sediment quality (both in the dredge area and at the disposal site) and to prepare a disposal site characterisation assessment to authorise a beneficial use site to receive dredged material.**
- **Habitat restoration projects are primarily designed to achieve net environmental benefits. However, regulation still needs to be underpinned by the usual evidence requirements for any development in order to protect people and the environment, including the assessment of the anticipated short term, long term, positive and negative impacts.**
- **Early engagement with the regulators and more proactive partnership based strategic planning would certainly support future delivery of beneficial use (as recommended in Chapter 2). In particular, better communication of the issues and lessons learned from completed projects and their associated monitoring is recommended. From this collective learning, practices, regulations and their application can evolve as new information becomes available through this collaborative and iterative process.**

INTRODUCTION

A complex regulatory framework is often cited as one of the key barriers to achieving beneficial use projects (Chapter 1). Regulation is of course also necessary to protect both people and the environment, but it is important that licensing procedures are clear, proportionate and applied consistently.

To help with future project implementation, this chapter provides greater clarity on the regulatory processes for dredge and disposal activities. A simple illustration of the marine licensing process for habitat restoration projects using arising dredged material is shown in Figure 3.1. This forms the basis of this chapter's structure, briefly:

- **The relevant authorities that may need to be engaged with during the course of the project, including a brief summary of the licences, permissions and key topics that may require assessment**
- **Steps required to acquire and complete sediment sample plans and the assessment of sediment quality (physical and chemical characteristics)**
- **Details of the requirements for authorising beneficial use disposal sites**
- **Further information regarding impact assessment, monitoring and mitigation, which may be required to underpin the marine licence application and disposal site authorisation process**

When considering the regulatory process for beneficial use 'projects', it should be noted that beneficial use is a versatile and variable tool. As described in Chapter 2, projects can vary greatly in scale and complexity, ranging from small scale, intertidal recharges using 1,000s m^3 of fine sediments, up to the landscape scale management of coasts and the creation of islands using large quantities of variably sized material. They can also range from very familiar techniques to methods that have rarely or never been tried before.

Recognising that there is such a wide range of possibilities, no assumptions are made here about particular project scales or methods and the information provided is indicative only. The actual requirements agreed with the relevant regulators and their advisors will be both project and site specific to a degree. Typically, the regulatory requirements will be proportional to the project size, in that additional licences, permissions and evidence may be required for larger scale and more complex projects compared with smaller, simpler schemes. However, each beneficial use project will still follow the same basic processes that are specific to dredge and disposal activities.

In accordance with LCLP and OSPAR requirements, beneficial use projects will require the characterisation and authorisation of new disposal sites (if not already authorised). However, the dredged material being used may or may not have all of the relevant consents already (e.g., using maintenance dredged material available from a Statutory Harbour Authority (SHA), for which all dredge licences and permissions are in place). Although dredging and disposal are treated as distinct activities, the assessment of sediment quality follows the same process, whether it is the dredged material or the existing sediment at a disposal site that is being considered. Similarly, both dredging and disposal activities will require an assessment of potential impacts that will form part of the marine licence application for each activity. There will be similarities between these assessments but, the sources, pathways and potential receptors affected may differ slightly according to the project details and site specifics. The regulatory processes described in this chapter, provides the necessary information to support applications for the relevant licences and permissions for both dredge and disposal activities.

Approximately 4.5 million m^3 of dredged material was used to raise marsh levels and created vegetated berms that provide a seed source, disrupt fetch, reduce wave heights and encourage further deposition across the Hamilton Wetlands, USA (USACE San Francisco District).

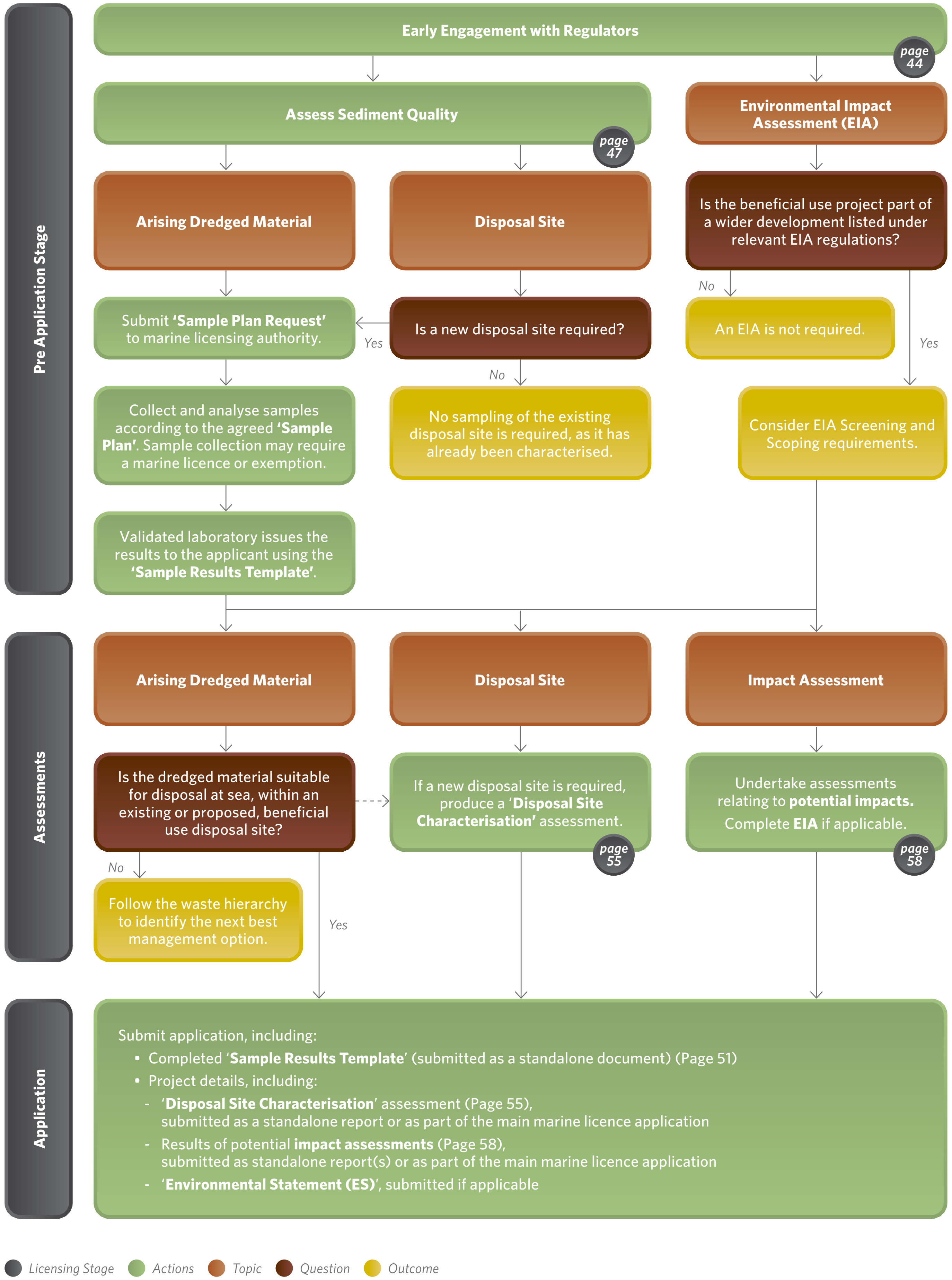


Figure 3.1: Indicative overview of the marine licensing process for a habitat restoration project using dredged material.

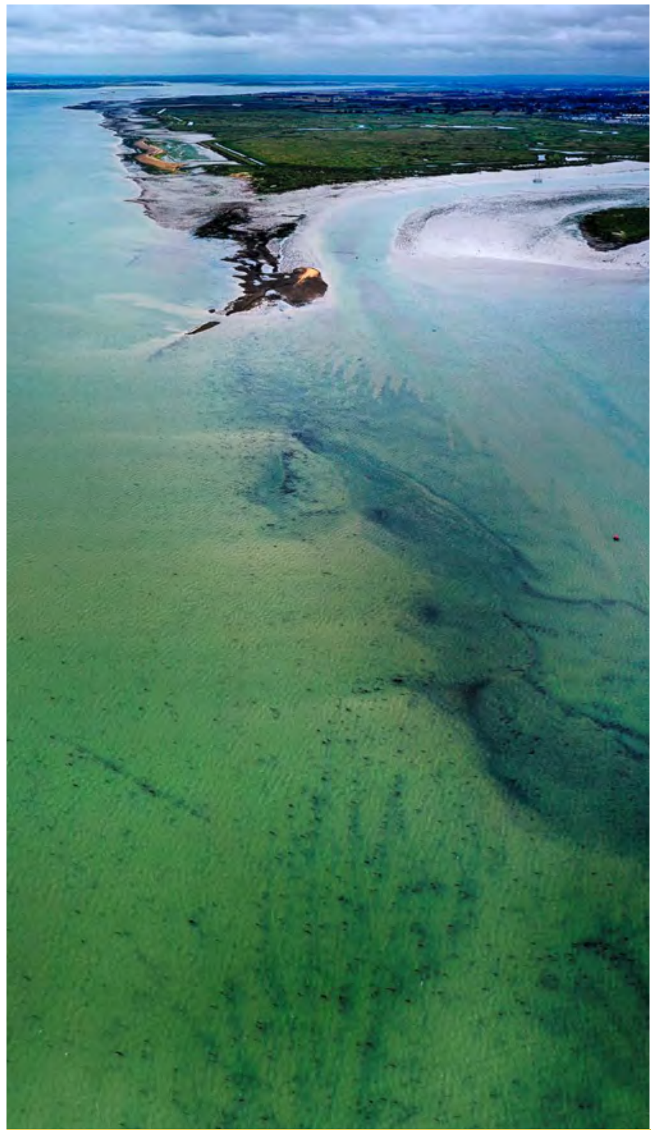
REGULATORY AUTHORITIES

For any project, early engagement with the regulatory authorities is important. Regulators and their advisors will be able to identify and agree the necessary approvals that need to be in place before carrying out any works. They can also identify and advise on potential impacts at an early stage, thereby allowing project designs to be optimised and potential mitigation measures to be agreed. This will also ensure that the relevant environmental impacts are assessed appropriately and proportionally, before the relevant marine licences and permissions are applied for.

Table 3.1 provides a general summary of the regulatory authorities that have responsibilities regarding particular key topics described in this chapter. It is important to bear in mind that some regulatory authorities are the competent authorities for some topics and statutory consultees for others. Those authorities listed are therefore simply a selection of suggested first points of contact for those developing a beneficial use project.

For example, in England, the Environment Agency and Natural England (NE) are regulators in their own right. At the same time, they will also be statutory consultees to the Local Planning Authority (LPA) for planning permission or to the Marine Management Organisation for a marine licence. The equivalent distinctions between competent authorities, statutory consultees and advisory agencies exist in all UK nations, with each competent authority taking the advice and assessments provided by others into account when making their own decisions.

Although there are policy, governance and legal aspects to habitat restoration that are common to all UK administrations, there are also differences and it is the responsibility of the practitioner to ensure that they seek advice and follow the required procedures. The other handbooks in this restoration series contain additional information regarding licensing requirements specific to the habitat being restored. Furthermore, as habitat restoration and the associated regulatory processes are evolving, those involved should be prepared for permission and licensing requirements to change over time and as restoration efforts are scaled up.



Tollesbury Wick Reserve and the surrounding Blackwater Estuary, Essex, where sand and gravel arising from the ports of Harwich and Felixstowe have been used to provide nesting bird habitat and flood defence benefits to local coastal communities and nature reserves since the 1990s. One example can be seen in the top left, middle distance, also shown below (Jim Pullen Surveys).

An aerial view of the sand and gravel barrier shown in the image above, located along the eastern seaward face of Tollesbury Wick Reserve. Since placement (1990s), this breakwater feature has facilitated accretion on its leeward side to the extent that saltmarsh vegetation is beginning to colonise the elevated mudflat in front of the defences (Jim Pullen Surveys).

Table 3.1: Suggested regulatory authorities for initial engagement based on the key topic. Acronyms expanded below.

KEY TOPICS		ENGLAND	WALES	NORTHERN IRELAND	SCOTLAND
Permissions	Marine management and licensing	MMO	NRW	DAERA	MS LOT
	Planning permission	LPA			
	Foreshore and seabed leases	TCE or private landowner			TCES or private landowner
Permissions and Assessments	Navigation	SHA, MCA and TH	SHA,MCA and TH	SHA, MCA and CIL	SHA, MCA and NLB
	Flood risk	EA	NRW	DfI	SEPA
Assessments	Marine Protected Areas (MPAs)	NE	NRW	DAERA	NS
	Water quality	EA	NRW	NIEA	SEPA
	Inshore fisheries	IFCA and Cefas	WG	DAERA	RIFG
	Archaeology	HE	Cadw	DoC	HES
	Sediment quality	Cefas	NRW and Cefas	DAERA	MS LOT

Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIL	Commissioner of Irish Lights
DAERA	Department of Agriculture, Environment and Rural Affairs
Defra	Department for Environment, Food and Rural Affairs
DfI	Department for Infrastructure
DoC	Department of Communities
EA	Environment Agency
HE	Historic England
HES	Historic Environment Scotland
IFCA	Inshore Fisheries and Conservation Authority
LPA	Local Planning Authority
MCA	Maritime and Coastguard Agency
MMO	Marine Management Organisation
MS LOT	Marine Scotland – Licensing Operations Team
NE	Natural England
NIEA	Northern Ireland Environment Agency
NLB	Northern Lighthouse Board
NRW	Natural Resources Wales
NS	NatureScot
RIFG	Regional Inshore Fisheries Group
SEPA	Scottish Environment Protection Agency
SHA	Statutory Harbour Authority
TCE	The Crown Estate
TCES	The Crown Estate Scotland
TH	Trinity House
WG	Welsh Government

Licences, permissions and assessments

A number of licences and permissions may need to be in place before regulated activities can take place, for example:

- **Marine licence:** required for licensable marine activities that take place within or on the sea, or on the seabed below mean high water springs (MHWS) and in any tidal river to the extent of tidal influence.
- **Planning permission:** required for any development above mean low water (MLW). The jurisdiction of the LPA responsible for planning permission and the jurisdiction of the marine licensing authority may overlap, in which case, in England, the relevant coastal concordat may be adopted where applicable, at the concerned authority's discretion.
- **Foreshore and seabed leases and landowner permissions:** The Crown Estate (TCE) and The Crown Estate Scotland (TCES) own the majority of the UK seabed from MLW to the 12 nautical mile (22 km) limit and more than half of the UK foreshore. Permission or a lease from TCE or TCES may be necessary in this area, including for access. Permission from other private landowners affected by the proposed development will also be required.
- **Navigation:** permissions may be required if working within the jurisdiction of a SHA. Impacts to navigation may also require assessment to ensure that changes in hydromorphology and sedimentary processes do not pose a threat to the safety of waterborne traffic, such as increased deposition and shoaling within navigation channels.
- **Flood risk activity:** an impact assessment and permit may be required if the activity will, or may potentially, cause changes to flood and coastal defences or any related physical and coastal processes (e.g., tide or flood regime and patterns of erosion and accretion).

Exemptions to a marine licence can apply in certain circumstances and can be discussed with the relevant authority. A summary of potential exemptions that are of relevance to beneficial use are shown in Table 3.2. For example, dredging activities can be considered exempted from the requirement of a marine licence if carried out by a SHA within the limits of its jurisdiction, provided the conditions of the exemption are met.

Table 3.2: Marine licence exemptions of relevance to activities associated with beneficial use (may be subject to conditions).

JURISDICTION	EXEMPTION	LEGISLATION
England / Wales	Dredging that is authorised by, and carried out in accordance with, a Harbour Order or Local Act	Section 75 of the Marine and Coastal Access Act 2009
England / Wales	Disposal of dredged material authorised by, and carried out in accordance with, a Harbour Order or Local Act	Section 75 of the Marine and Coastal Access Act 2009
England	Low volume navigational maintenance dredging activities	Article 18A of the 2013 Exempted Activities Order
England	Sediment sampling for analysis	Article 17A of the 2013 Exempted Activities Order
England	Deployment of monitoring equipment	Article 17 of the Marine Licensing (Exempted Activities) (Amendment) Order 2019
Wales	Deployment of monitoring equipment	Article 16 of the Marine Licensing (Exempted Activities) (Wales) Order 2011
Scotland	Harbour dredging	The Marine Licensing (Exempted Activities) (Scottish Inshore Region) Order 2011 (as amended)
Scotland	Sediment sampling for analysis	The Marine Licensing (Exempted Activities) (Scottish Inshore Region) Order 2011 (as amended)
Northern Ireland	Harbour dredging	The Marine Licensing (Exempted Activities) Order (Northern Ireland) 2011
Northern Ireland	Sediment sampling for analysis	The Marine Licensing (Exempted Activities) Order (Northern Ireland) 2011

To inform the marine licence decision-making process, potential impacts need to be assessed. Further details on the identification and assessment of potential impacts, including monitoring and mitigation, are provided later in the chapter. However, of relevance to beneficial use and Table 3.1 above, this will likely include the assessment of impacts that fall under key topics, such as:

- **Marine Protected Areas (MPAs):** assessment required if the project is located within, close to or may have the potential to impact on sites designated to protect marine features of nature conservation importance.
- **Water Quality:** assessment required if the project may cause or contribute to a deterioration in water body status or jeopardise the water body achieving good status.
- **Fisheries:** assessment required if the project will, or may potentially, impact on key species or areas of fisheries and shellfisheries interest and resource.
- **Archaeology:** assessment required if the project will, or may potentially, impact on wrecks and wreckage of historical, archaeological or artistic importance.
- **Sediment quality:** assessment required in accordance with LCLP and OSPAR requirements. Detailed in the following section.

SEDIMENT QUALITY

An assessment of sediment quality is carried out according to the guidelines produced by LCLP and OSPAR (IMO 2014; OSPAR 2014). These guidelines provide generic recommendations and are used by the licensing authorities to determine the conditions under which dredged material may (or may not) be disposed of at sea, as well as providing guidance on the appropriate sampling and analysis regimes for the proposed dredge and disposal operations.

Sample plans

The first stage of obtaining the necessary approvals for a beneficial use project, is to agree an approved sediment sampling plan with the relevant marine licensing authority during the pre application stage, by submitting a 'Sample Plan Request' (Figure 3.1). Sampling is required to assess the physical and chemical condition of both the sediment that is to be dredged and the sediment found within the beneficial use disposal site.

The sample plan request should contain as much detail about the project as possible at this early stage. Submitting a greater evidence base will improve regulatory understanding of the project, help identify potential risks and allow the most appropriate sampling plan to be developed. If the habitat restoration project requires the authorisation of a new disposal site, a sampling plan for the proposed disposal site can be requested in the same sample plan request as that submitted for the dredging works. At a minimum, the following details must be provided:

- **Capital or maintenance dredge**
- **Location of the dredge area(s) (e.g., co-ordinates of the polygon nodes)**
- **Dredge method(s) likely to be used**
- **Maximum predicted dredge volumes (per annum and total)**
- **Maximum dredge depth (note, this is not the same as the TDD)**
- **Length of the proposed dredge licence**
- **General description of the material type (e.g., particle size)**
- **Proposed existing disposal site(s) (if known), or, location(s) of proposed new beneficial use disposal site(s)**

The OSPAR guidelines recommend that the number of samples required is based on the volume to be dredged (Table 3.3). The guidelines also state that "*judgement and knowledge of local conditions will be essential when deciding what information is relevant to any particular operation*" and in this context, the number of samples required should be applied on a sliding scale. For example, dredging campaigns generating volumes at the lower end of each bracket or considered to be of lower risk, should be subject to the lower end of the bracket regarding the number of sampling stations requested. However, UK nations may interpret these guidelines differently, or have specific requirements in some instances.

For a regional beneficial use strategy, comprised of individual projects of a similar nature (e.g., where the same dredge and disposal methods are being employed using similar material to restore multiple sites across the area), multiple disposal sites may be licensed under a single application, but the sampling effort required to characterise the disposal sites may be 'shared'. For example, where areas of mudflat in close proximity within an estuary are to be recharged to help supply the adjacent marshes with fine sediments, sampling effort may be spread across the individual disposal sites proposed.

A curlew foraging across an area of exposed intertidal mudflat (Eleanor Bentall, RSPB).

Table 3.3: Indication of the number of separate sampling stations required to obtain representative results, assuming a reasonably uniform sediment in the area to be dredged (OSPAR, 2014).

VOLUME TO BE DREDGED (m^3)	NUMBER OF SAMPLING STATIONS
Up to 25,000	3
25,000 - 100,000	4 - 6
100,000 - 500,000	7 - 15
500,000 - 2,000 000	16 – 30
>2,000,000	extra 10 per million m^3

Overall, whilst the exact locations of samples may not be stipulated, the agreed sample plan should be proportionate and spatially representative of the proposed dredge and disposal areas, to ensure that the physicochemical characteristics of the dredged material are suitable for disposal at sea and compatible with the management objectives of the beneficial use disposal site.

Although both physical and chemical analysis will likely be required in compliance with the LCLP and OSPAR, given that the existing sediments at the habitat restoration site are to be buried during disposal, effort will generally focus on characterising the surface sediments. In comparison, for the dredge area, characterisation of the sediments at depth may also be required (samples from depth are typically only required if the dredge exceeds 1 m depth). A sample plan agreed with the relevant authority will detail the:

- **Number of sample stations required per dredge area(s)**
- **Number of sample stations required for the proposed disposal site(s) (if a new disposal site is required)**
- **Depths at which undisturbed samples should be collected at each location.**
- **Required physical and chemical analysis**

The results of previous sampling campaigns may also be used to support an application under some circumstances, subject to conditions (e.g., typically, samples must have been collected within the last 3 years and analysed by a validated laboratory in accordance with OSPAR recommendations). This should be agreed with the relevant authority.

Physical characterisation of the sediment involves undertaking particle size analysis (PSA), in order to determine the PSD of the sediment (Figure 3.2). This provides information to help assess any potential impacts associated with a coarsening or fining of the existing sediments at the beneficial use site as a result of disposal, unless that is the rationalised objective of the project. PSD information will also support the design of the restoration project and identify other potential impacts associated with the physical characteristics of the dredged material.

Chemical characterisation of the sediment is carried out to allow comparison with the relevant Action Levels (ALs) (Box 3.1). The chemical analysis suite required will be dependent on a number of factors, such as particle size (e.g., fines such as silts and clays have a greater adsorption capacity than coarse sediments), known regional concentrations and proximity to potential sources of pollution (e.g., vessel bunkering). For capital dredges where relatively little is known about the underlying material and may contain historic pollution, a more thorough assessment may be required.

Sediment sampling may also be used to differentiate and delineate areas containing sediments considered to be potentially unsuitable for habitat restoration without pre-treatment (e.g., areas where contaminants may be expected to exceed Action Level 2 (AL2)). In doing so, remaining sediments located elsewhere and considered suitable for disposal at sea may still be used for restoration.

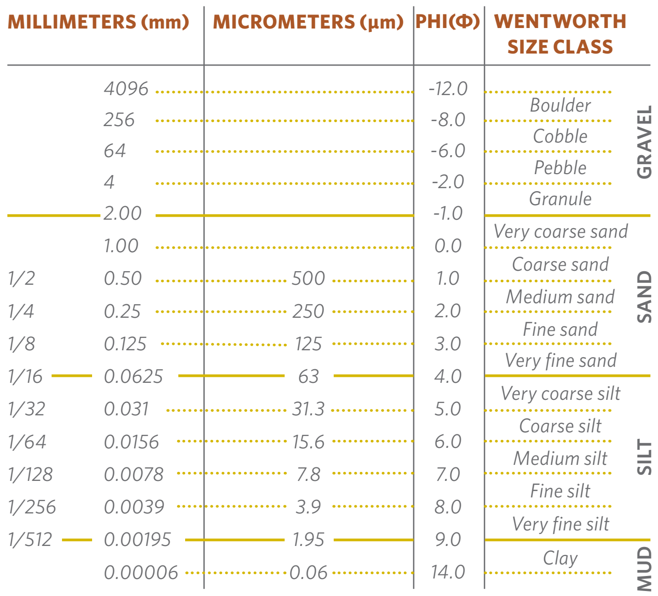


Figure 3.2: Particle size analysis (PSA) grain size classification (Mason, 2011).

BOX 3.1: ACTION LEVELS (ALs)

In accordance with OSPAR guidelines, all UK nations use Action Levels (ALs) (sediment quality criteria) to assess chemical contaminants on a primary list. **ALs are thresholds that are used as part of a weight of evidence approach, providing a proxy risk assessment for potential long term impacts to biological features** associated with dredge and disposal activities, such as fish and benthos. All UK nations use two thresholds to determine the suitability of material to be dredged and disposed of at sea. However, not all determinand groups have two ALs (Table 3.4) and the concentrations of contaminants used to define the thresholds differs across the UK nations. At the time of writing, the current ALs are under review (Mason *et al.*, 2020).

For all UK nations, Action Level 1 (AL1) is the lower threshold and Action Level 2 (AL2) is the upper threshold. Sediments with contaminant concentrations lower than AL1 are considered acceptable for disposal at sea and for use in habitat restoration projects, pending other considerations such as the physical suitability of the sediment.

Sediments with contaminant concentrations between AL1 and AL2 may still be suitable for habitat restoration and are evaluated using a weight of evidence approach on a case by case basis.

Alongside a measure of the sediment quality, this can include, but is not limited to, an assessment of:

- Comparison of contaminant loading between the dredge and disposal site
- Comparison of the particle size distribution (PSD) between dredged material and the disposal site
- Previous and current land uses at and in proximity to the dredge and disposal site
- Previous sediment sample analysis results
- Any reported pollution incidents
- Bioavailability and ecotoxicology data
- Volume of dredged material involved in the project
- Local and regional hydrodynamics and sediment transport pathways

Sediments with contaminant concentrations above AL2 are considered unacceptable for uncontrolled disposal at sea without special handing, treatment and/or containment, such as confined disposal facilities (CDFs). Contaminated sediments can still be used in a variety of applications that are preferred to offshore disposal or landfill in accordance with the waste hierarchy (e.g., CEDA 2019a). However, due to the technical requirements and additional level of regulation, these are beyond the scope of this handbook.

Table 3.4: Chemical determinands and associated Action Levels. [1] AL2 is for the 'sum of 25 congeners'. [2] AL1 is for total hydrocarbons (THC). [3] ALs have been proposed but are not currently implemented.

CHEMICAL DETERMINANDS	AL1	AL2
Metals	Yes	Yes
Organotins	Yes	Yes
Polychlorinated biphenyls (PCBs)	Yes	Yes[1]
Polycyclic aromatic hydrocarbons (PAHs)	Yes[2]	No[3]
Polybrominated diphenyl ethers (PBDEs)	No[3]	No[3]
Organochlorines (OCs)	Yes	No

Validated laboratory

In England and Wales, to ensure that sediment sample analysis data submitted to support a marine licence application is consistent and comparable between separate applications, applicants must ensure that the analysis set out in the approved sample plan is carried out by a validated laboratory (this includes any sub-contracted laboratories).

A list of validated laboratories for use in England and Wales, including the physical and chemical determinands that they have been validated to analyse can be found online. It is recommended that the agreed sampling plan is discussed with the validated laboratory contracted. They will be able to offer guidance and support with the interpretation of the plan, provide appropriate sample containers and help with other aspects of the sample collection, storage and transport process.

Sample collection and transport

Sediment samples can be acquired using standard techniques (Table 3.5). The most appropriate will depend on a number of factors, such as the depth of sample required, whether the sample location is in the intertidal or subtidal, as well as the need for any additional lifting gear required for the deployment and recovery of any sediment grab or corer being used (e.g., winch, davit crane or A-frame).

Following sample collection, there are a number of storage and transport requirements that the applicant must adhere to in order to maintain sample integrity (Figure 3.3). These are in accordance with the National Marine Biological Analytical Quality Control (NMBAQC) and Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME) standard procedures for physical and chemical analysis respectively, which themselves ensure compliance with LCLP and OSPAR regulations.

Table 3.5: Overview of common sediment sampling equipment.

SAMPLE TYPE	EQUIPMENT	DESCRIPTION
Grab	Spachelor	Simple and easy method for acquiring surface samples by hand in accessible areas in the intertidal.
	Van Veen and Day Grabs	Van Veen grabs may be used by hand. Other grabs will require lifting gear (e.g., winch and davit crane). Generally unsuitable for coarser material (e.g., gravel) due to trapping in the grab jaws, resulting in sample washout.
	Shipek and Hamon Grabs	More suitable for coarser material, but mixes the sample, precluding any sub sampling of an undisturbed sediment surface. Requires lifting gear.
Core	Push Corer	Manual corer that can be effective for retrieving depth samples, from up to a few metres within accessible areas in the intertidal.
	Gravity Corer	Achieve depths of up to a few metres. Generally unsuitable for coarser material and in use in shallow water. Requires lifting gear.
	Vibrocorer	Can achieve greater depths and are suitable for coarser materials, provided individual grains aren't bigger than the core barrel. May disturb the natural vertical structure of the sample to a degree. Requires lifting gear.
	Box Corer	Depth limited to height of the box, typically 0.5 m, but generally suitable for coarser materials. Does not disturb the sediment surface. Requires lifting gear.

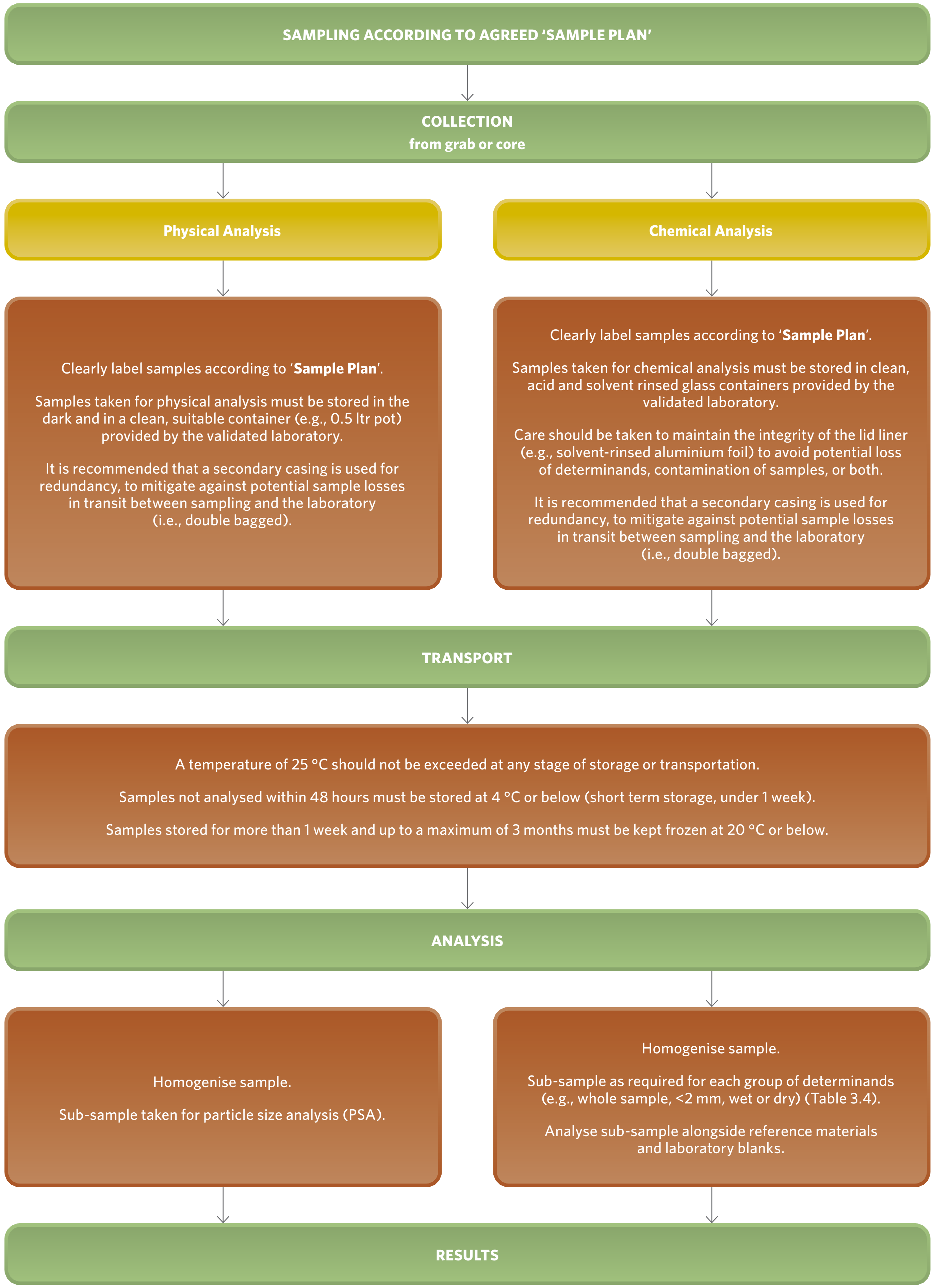


Figure 3.3: General overview of the requirements for collection, storage, transport and analysis of sediment samples.

Sediment analysis results

Following the completion of the agreed sediment sampling plan and associated analysis, the sample analysis results must be submitted to the marine licensing authority using the relevant sampling results template form. This should be completed by the validated laboratory and submitted to the relevant licensing authority by the applicant so that it can be added to the existing evidence base and support the disposal returns process. The presentation, interpretation and assessment of the sediments physicochemical characteristics should also be provided as part of the marine licence application itself and may be used to support authorisation of the beneficial use disposal site.

Physical characteristics

The physical analysis results should provide a sufficiently detailed description of the PSD, comprising each sample from the proposed dredge area(s), for example, as a PSD curve and/or in tabulated form. These results should be compared against the management objectives of the intended disposal site(s) to ensure that any sediment deposited will not significantly alter the physical structure of the seabed, unless that is the rationalised objective of the project (Box 3.2).

A measure of the dredge sediments' specific gravity is also required as part of a marine licence application, as all sediment disposal data reported on the LCLP and OSPAR returns must be submitted in both dry and wet weight (tonnes). This can be determined experimentally, however, in the absence of such data, the conversion factors provided in Table 3.6 can be used.

Table 3.6: Conversion factors between wet volume (m^3) and dry weight (tonnes) for dredged material that can be used in the absence of analytically determined values (HELCOM, 2006).

TYPE OF DREDGED MATERIAL	WET WEIGHT IN TONNES OF 1 m^3 OF WATER SATURATED SEDIMENT (WET VOLUME) ABOVE WATER SURFACE	DRY WEIGHT IN TONNES OF 1 m^3 OF SEDIMENT
Mud (containing organic matter)	1.2	0.3
Postglacial clay, consolidated	1.5	0.6
Glacial clay (boulder clay), consolidated	1.7	1.15
Silt, soft and muddy	1.3	0.5
Silt	1.6	1.1
Sand	1.9	1.5
Gravel or stone	2.0	1.8
Till	2.2	2.0
General (if the sediment type is unknown)	1.6	0.75

Monitoring dredged sediment placement as part of a 2 ha thin layer placement project at Jekyll Creek, USA (Clay McCoy, USACE Jacksonville District).

BOX 3.2: A HYPOTHETICAL EXAMPLE, COMPARING THE PSD RESULTS BETWEEN A DREDGE AREA AND TWO PROPOSED DISPOSAL SITES

As a hypothetical example, Figure 3.4 and Table 3.7 present the PSD results for four samples collected from within a small harbour and adjoining navigation channels. These were collected according to the agreed sampling plan developed for a proposed capital and maintenance dredge of 50,000 m^3. Approximately 15,000 m^3 of the material is to be hydraulically pumped 0.8 km into the interior of an adjacent saltmarsh, in order to rehabilitate an area of fragmented marsh associated with a series of artificial borrow pits. The remaining 35,000 m^3 is proposed to recharge eroding intertidal mudflats fronting the saltmarsh, through a think layer placement scheme. To characterise the proposed restoration sites, one sample was taken from the intertidal mudflat (BU_IM) and one from a borrow pit (BU_BP).

The majority of dredge samples were comprised of approximately 90% fines and 10% sands. S_01 showed a greater proportion of fines (approximately 98%), similar to that present across the intertidal mudflat. In comparison, BU_BP had a slightly greater proportion of sands (3.9%).

In general, given the similarity in the PSD of all samples representing both the dredge and disposal sites, the sediment is deemed suitable for its intended use. There is a potential for a slight coarsening of the intertidal mudflat. As mitigation, S_01 was prioritised for disposal within BU_IM. However, given the small deviation from the natural PSD envelope and the limited spatial extent of the works, the potential impact of any coarsening is not considered likely to have a significant negative effect on the wider system.

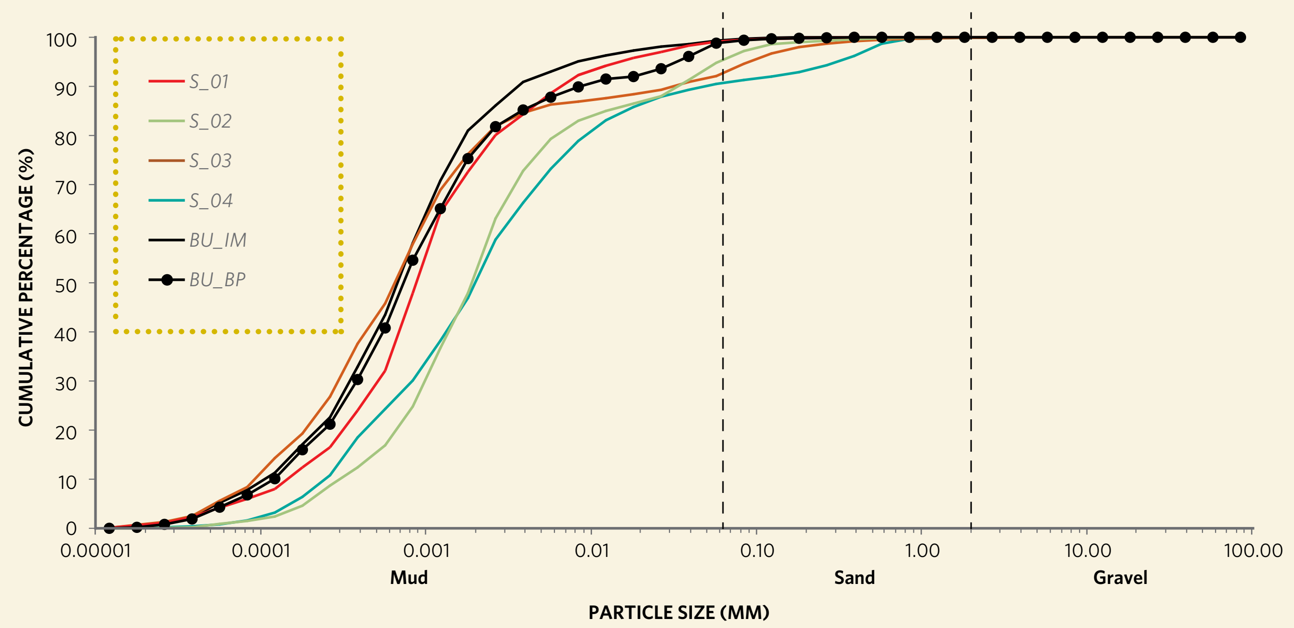


Figure 3.4: PSD results of a dredge area and two proposed disposal sites.

Table 3.7: Summary of the percentage composition of the dredge area and two proposed disposal sites.

PARTICLE SIZE FRACTION	PERCENTAGE COMPOSITION (%)					
PERCENTAGE COMPOSITION (%)	S_01	S_02	S_03	S_04	BU_IM	BU_BP
Gravel	0.0	0.0	0.1	0.1	0.0	0.0
Sand	1.7	8.7	9.0	10.6	1.4	3.9
Mud	98.3	91.3	90.9	89.3	98.6	96.1

Chemical characteristics

As part of the weight of evidence approach, the chemical analysis results should be assessed against the relevant ALs in order to evaluate the sediment quality, identify whether the sediment is suitable for disposal at sea and if it is, compare the contaminant loading with concentrations within the existing or proposed disposal site (Box 3.3). The data can also be used to support the assessment of the potential impact on other sensitive receptors such as water quality.

BOX 3.3: A HYPOTHETICAL EXAMPLE, COMPARING THE CHEMICAL SEDIMENT ANALYSIS WITH ACTION LEVELS

As part of the same hypothetical example described in Box 3.2, sampling for metals, organotin and PAHs was requested to assess sediment quality. The chemical analysis results are presented in Table 3.8.

Sediments within the main navigation channel are generally <AL1. Some instances of contaminants between AL1 and AL2 were found within the main navigation channel, but these were considered minor exceedances.

S_03 was obtained from within a confined area adjacent to the harbour, which also showed concentrations between AL1 and AL2, but a slightly greater exceedance. This was attributed to local surface run-off, low flushing rate/high residence time and resultant accumulation.

Both disposal sites also showed some concentrations between AL1 and AL2, but similar to the navigation channels, these were considered minor exceedances and a result of historic activity and dispersal throughout the local area.

In general, the sediment was considered appropriate for the proposed habitat restoration scheme. However, the phasing of the works was altered slightly, so that the sediment to be dredged from the confined area adjacent to the harbour (approximately 5,000 m^3) would be disposed of within the borrow pits first and subsequently capped with sediment dredged from within the main navigation channel. Although using hydraulic methods during the works may liberate contaminants contained within the sediment, burial of this material was considered suitable mitigation to help reduce the potential for longer term negative impacts on water quality.

Table 3.8: Summary of the chemical analysis of the dredge area and two proposed disposal sites based on ALs in England (dry weight (mg/kg)). LOD = Limit of Detection; [1] dibutyltin (DBT) and tributyltin (TBT); [2] THC.

SAMPLE	ARSENIC (As)	MERCURY (Hg)	CADMIUM (Cd)	CHROMIUM (Cr)	COPPER (Cu)	NICKEL (Ni)	LEAD (Pb)	ZINC (Zn)	ORGANOTINS[1]	PAHS[2]
S_01	17	0.4	0.3	<LOD	67	24	72	132	0.2	0.1
S_02	8	0.1	0.2	22	42	12	51	48	<LOD	<LOD
S_03	22	1.0	1.2	38	109	19	131	111	0.2	0.4
S_04	15	0.4	0.1	31	38	16	56	68	0.1	0.1
BU_IM	<LOD	0.3	0.3	32	58	16	52	62	<LOD	<LOD
BU_BP	<LOD	0.1	<LOD	<LOD	41	<LOD	41	32	<LOD	<LOD
AL1	20	0.3	0.4	40	40	20	50	130	0.1	0.1
AL2	100	3	5	400	400	200	500	800	1	–

DISPOSAL SITES

In accordance with LCLP and OSPAR regulations, dredged material can only be disposed of within authorised disposal sites. This includes areas where beneficial use for habitat restoration are proposed.

Designating a disposal site

To authorise a new disposal site or to change the use of an existing disposal site (e.g., increased use or changes to the management objectives), a disposal site characterisation assessment is required.

A disposal site can be authorised solely for the objectives of the beneficial use (e.g., frequency and volume of disposal, as well as the physicochemical characteristics of the sediment that it can accept) and essentially represents the direct 'footprint' of the habitat restoration project. Disposal sites are not themselves licensed, but a marine licence is required to dispose of dredged material within them.

The disposal site characterisation assessment should include an interpretation of the sediment quality sampling results, as well as the assessment of any other relevant environmental and socio-economic impacts resulting from disposal according to the overall design of the project. It may also include a summary of the results of any specific assessments required to address key topics (e.g., MPAs and water quality). This is to assess the significance of both the positive and negative impacts associated with the works and ensure that they are understood prior to the onset of disposal. Where negative impacts are identified, they should be removed or reduced as far as reasonably practical through refinement or embedded mitigation within the design. Further details on the identification and assessment of potential impacts, including monitoring and mitigation, are provided below.

Only following a disposal site characterisation assessment can the relevant marine licensing authority and their advisors make an evidenced-based decision as to whether a disposal site should be authorised or not. It will also allow any additional mitigation measures, appropriate monitoring conditions and adaptive management strategies to be agreed.

Given the potential range of beneficial use applications, the associated impacts, their significance and the level of assessment required will be project and site specific and dependent on the nature, complexity, location and size of the project. For relatively smaller and simpler projects generally posing less risk, a comparatively reduced assessment may be carried out in comparison to more extensive assessments that may be required for higher risk projects. **The impact assessment and regulatory decision making processes should therefore apply a pragmatic and risk based approach, to ensure that the evidence base, monitoring and associated costs of beneficial use projects are proportionate to their perceived risk.**

To support this process, Table 3.9 and Table 3.10 provide an example of a generic risk based framework, which has been adapted from Lonsdale *et al.,* (2021). This type of approach can be applied on a sliding scale, considering all risk criterion of relevance to the project, whilst weighting scores based on any individual criterion considered to be of particularly importance. This approach is not absolute, it is indicative only and will require a degree of expert judgement. It is purely intended to help guide a general understanding of the level of detail that may be required or expected for characterisation of the disposal site. In practice, the scope of the assessment should be agreed with the relevant authorities through early stakeholder engagement and the framework applied on a project and site specific basis.

Development of the Marconi Marshes following placement of dredged material arising from the Port of Delfzijl, in the Elms-Dollard estuary, Netherlands, including the experimental use of different compositions of fine sediment (EcoShape).

Table 3.9: Risk based framework scoring.

RISK CRITERION	NEGLIGIBLE	LOW	MED	HIGH	RATIONALE
SCORE	0	1	2	3	
Volume (m^3) of material disposed per annum	<1,000	1,000 - 10,000	10,000 - 100,000	>100,000	The larger the volume to be disposed, the higher the likelihood of impacts, such as from plume generation or smothering. Also related to the system's ability to cope with the relocation of large volumes and associated impacts on coastal and physical processes.
Sediment quality	Sands and gravels. Limited or no fines. Contaminants below AL1	Sands, silts and muds. Contaminants below AL1	Sands, silts and muds. Contaminants marginally exceeding AL1	Silts and muds. Contaminants close to AL2	Fines generally remain in suspension for longer and are more likely to form a sediment plume. Contaminants are generally more affiliated with fine sediments due to their increased adsorption capacity and so a greater proportion of fine sediment may imply a higher incidence of contaminants. Also related to factors such as proximity to potential contaminant sources and historic activity.
Location of the disposal site	In close proximity to dredge area	Within the same sediment cell	Within an adjacent sediment cell	Within or adjacent to a protected site or where an impact pathway between the disposal site and a sensitive receptor is identified	If in close proximity to the dredge area, the physicochemical characteristics of the material are more likely to be similar and therefore present a lower risk. Transfer of material to an adjacent sediment cell may be considered beneficial but may pose more risk. Locations considered high risk are those with a potential impact pathway to sensitive receptors, such as MPAs and shellfisheries.
Nature of the disposal site	Works with natural processes	Requires installation of small and/or temporary retaining structures	Requires installation of large and/or permanent retaining structures	Heavily dependent on permanent engineering	In the context of reliance on ongoing management, sites that work with natural processes are generally more sustainable, provided that the level of uncertainty or potential negative effects associated with uncontrolled dispersal are considered acceptable. Sites that are more dependent on greater levels of engineering and subsequent maintenance would generally be considered higher risk.

Table 3.10: Risk-based framework assessment.

SCORE	LEVEL OF RISK	LEVEL OF ASSESSMENT	DETAIL
0 - 4	Negligible	Description of the environment	Document the environmental conditions and assumptions (e.g., basic hydrodynamics, geomorphology and likely sediment flows). Receptors identified using existing information (e.g., MPA maps and associated conservation advice packages). Recommend visual observations during disposal operations to document potential impacts (e.g., the extent and duration of any plume).
5 - 6	Low	Expert assessment	Using existing knowledge of the area (e.g., tidal ellipses, tidal current velocities, natural SSC range, etc.) to carry out a desk based study of the likely fate of the material and the potential impacts from the disposal operations. Receptors identified using existing information (e.g., MPA maps and conservation advice packages). Site specific monitoring and mitigation measures may be recommended.
7 - 8	Medium	Full characterisation and assessment. Previous Modelling or conceptual assessment.	Dedicated characterisation surveys may be required, unless appropriate information is available to inform assessments. Understanding and full assessment of the potential extent, duration and significance of impacts on identified receptors. Above may require some simple numerical modelling or conceptual assessment. Site specific monitoring and mitigation measures likely to be required.
9 -12	High	Full characterisation and assessment, supported with numerical modelling.	Dedicated characterisation surveys highly likely to be required, supported with appropriate information if available to inform assessments. Detailed understanding and full assessment of the potential extent, duration and significance of impacts on identified receptors. Above will most likely require detailed numerical modelling study to inform assessment. Site specific monitoring and mitigation measures highly likely to be required.

The 488 ha Steart Marshes managed realignment project on the River Parrett, Somerset, has restored 305 ha of intertidal habitat. Although managed realignment sites experience accretion following reconnection to the local estuarine and coastal system, in some instances, dredged material may be used to support land raising or landscaping and help reduce potential impacts on hydromorphology and geomorphology (Sam Stafford, Wildfowl and Wetlands Trust (WWT)).

A 32 ha wetland restoration using approximately 150,000 m^3 of unconsolidated fines at Pierce Marsh, USA (USACE Galveston District).

Management

Once a disposal site is authorised, the applicant does not have exclusive use of that site and a licence may be granted to other dredging operators for disposal. However, those undertaking disposal must still conform to the management objectives and conditions agreed during the designation process (e.g., how much material can be disposed of and the sediment characteristic requirements). Once authorised, disposal sites may remain open without use for a certain period of time. The duration of this period varies and is based on the available evidence base and expert judgement. Re-characterisation of the sediment quality may be requested every 3 to 5 years in accordance with OSPAR recommendations or before a change in management or use of the site.

Disposal returns

As described in Chapter 1, Cefas collates the disposal returns data from each marine licensing authority for the UK, for all waste types deposited within the marine environment, including sites that receive dredged material for beneficial use. The collation of the UK disposal data supports the annual reporting to the LCLP and OSPAR Secretariats and provides evidence of UK efforts to reduce waste and improve resource efficiency. The disposal returns contain the following information per disposal site:

- **Type of waste material (e.g., dredged material)**
- **Reason for disposal (Table 1.3)**
- **Quantity of material disposed of (Table 3.6)**
- **Average contaminant concentrations (Box 3.1 and 3.3)**

Annual returns are generally submitted in the autumn and once approved by the LCLP and OSPAR Secretariats, are made publicly available on request. There is an obligation on those disposing of material (i.e., those dredging) to submit the relevant information. Those that fail to submit returns to the marine licensing authority in accordance with the schedule stipulated in the marine licence condition for disposal activity, may receive a compliance notice, which can result in prosecution.

IMPACT APPRAISAL

One of the primary aims of habitat restoration projects and NbS is of course, to provide added value and positive environmental benefits. As described in Chapters 1 and 2, recognising, understanding and valuing all of the positive impacts that will be generated over the life of the project is an important part of project development, such as supporting the identification of both potential sites and funding sources. However, an assessment of potential negative impacts will still be required. As with any development, weighing the positive and negative, short and long term impacts associated with the project design is part of the licensing and permitting process.

From an impact assessment perspective, an Environmental Impact Assessment (EIA) aims to protect the environment and ensure that the public are given early and effective opportunities to participate in decision making procedures. It should be noted however, that an EIA should not be undertaken for a beneficial use project, unless it forms part of a wider development listed under the relevant EIA regulations. However, an EIA provides a standardised and well established tool to systematically identify and evaluate both the positive and negative impacts of a project. The assessment framework may therefore provide a useful reference guide to support impact appraisals and beneficial use licence applications.

To support an impact assessment, Table 3.11 provides a summary of some of the potential impact pathways and receptors that may exist or may need to be considered, depending on project and site specifics. **The majority of impacts occur during the construction phase (e.g., preparatory works and dredging and disposal activity) and are generally temporary and short term in nature.** The most common potential impact pathways typically associated with beneficial use are sediment plumes (Box 3.4), impacts on the benthos (e.g., Bolam et al., 2011) and and the relocation and/or remobilisation of contaminants contained within the sediment (Section 3.2). Further information on working within or in proximity to MPAs and assessing the potential impacts on water quality is also provided in the following subsections, as these topics are considered pertinent to beneficial use for the purposes of habitat restoration.

Table 3.11: A summary of potential impacts that may require assessment.

PATHWAY AND/OR RECEPTOR	IMPACT DESCRIPTION
Hydrological regime	Changes in bathymetry or topography may affect hydrological processes such as current flows, wave climate and flood regime. The resultant changes may also have implications for other receptors.
Sediment transport	Changes to the hydrological regime may affect associated sediment transport processes, such as patterns of erosion or accretion and whether a site is dispersive or retentive. The resultant changes may also have implications for other receptors.
Sediment plumes	See Box 3.4.
Smothering	Direct disposal and/or increased rates of deposition may result in the smothering of sessile (immobile) or relatively immobile fauna, where the depth and/or rate of burial exceeds the vertical migration capacity or mobility of the organism. It may also cause short term changes in prey availability.
Reduced light penetration	Light attenuation due to increased suspended loads may reduce light availability for photosynthetic species, such as phytoplankton, seagrasses and macroalgae.
Reduced oxygen levels	A reduction in dissolved oxygen may occur due to the increased availability of organic matter in the water column during dredge and disposal activity, with and an associated increase in microbial metabolism. This can be important in some estuarine locations for species with a higher biological oxygen demand (e.g., some diadromous fish).
Changes in the physical composition of the sediment	Changes in the sediment composition may result in changes in both benthic fauna assemblages and biogeochemistry. Where this is the objective of the beneficial use project, the positive and negative impacts of this approach must be assessed and rationalised.
Changes in chemical concentrations	The relocation and/or remobilisation of contaminants contained within the sediment may impact sediment and water quality. Repeat use sites receiving long-lived or 'legacy' contaminants may present a potential risk of bioaccumulation (e.g., shellfish).
Barriers and trapping	Disposal activities or the installation of retaining structures may trap fish and other mobile fauna, resulting in fatalities (e.g., if the design impounds areas of the intertidal (i.e., drying areas) without sufficient access and egress points).
Habitat degradation	Direct physical impact to the site may occur (e.g., compaction or disturbance during preparatory groundworks).
Invasive Non-Native Species (INNS)	The transport of dredged material over greater distances may provide a pathway for the introduction or distribution of INNS.
Noise	Preparatory groundworks and dredge and disposal works may generate noise impacts for both humans and other environmental receptors (e.g., birds or marine mammals).
Shipping activity	Additional vessel activity and changes in hydromorphology and sedimentary processes may pose a threat to the safety of waterborne traffic, such as increased risk of collision, or sediment deposition and shoaling within navigation channels.
Marine Protected Areas (MPAs)	The project design and relevant activities cannot be to the detriment of the features for which the site is designated.
Sensitive habitats	Dredge and disposal may affect sensitive habitats, such as fish spawning grounds and nursery sites, or bird foraging, nesting and high tide roosts.
Sensitive species	Dredge and disposal may disturb or change the behaviour of sensitive species. Particularly during sensitive periods (e.g., bird breeding, fish spawning or migration).
Commercial fishing and shellfisheries	Dredge and disposal in or in close proximity to designated commercial fishing areas or shellfisheries may need to consider impacts to commercial species.
Bathing waters	Dredge and disposal may impact on water quality in or in proximity to designated bathing waters.
Infrastructure	Dredge and disposal may impact on infrastructure (e.g., coastal development, industry, tourism).
Archaeology	Dredge and disposal may impact on wreckage of historical, archaeological or artistic importance.

BOX 3.4: SOURCE-PATHWAY-RECEPTOR (SPR) MODEL

A Source-Pathway-Receptor (SPR) model identifies the linkages (pathways) between an activity (e.g., dredged and disposal (source)), the resultant environmental change (e.g., elevated suspended load) and a feature (e.g., a living organism, habitat or infrastructure (receptor)) that is exposed and sensitive to that change (Figure 3.5).

Direct and indirect impacts need to be considered. From an indirect impact perspective, all three components of the SPR model must exist in order for an impact to manifest. For example, an activity cannot have an adverse effect on a sensitive receptor if there is no pathway linking the two.

In the context of beneficial use, an SPR model may provide a useful framework during multiple stages of a project:

- **Project design:** where the strategic placement and subsequent dispersal of mobile sediment aims to supply sediment to a target site (e.g., dispersal of fines to support saltmarsh accretion);
- **Impact assessment:** identifying the timing, duration and/or magnitude of potential impacts associated with the works (e.g., sediment plume passing a sensitive receptor due to disposal occurring during a particular period of the tidal cycle); and
- **Monitoring and mitigation:** linked to an impact assessment, supporting monitoring design (e.g., the placement of appropriate monitoring equipment) and the development of mitigation strategies (e.g., avoiding disposal during particular periods of the tidal cycle).

For example, sediment plumes are defined as the horizontal and vertical extent of the water column, containing an elevated level of suspended material associated with natural or human processes (e.g., river discharge or dredge and disposal activities). Whilst natural features, sediment plumes can also occur temporarily during a beneficial use project. If not managed correctly, they can potentially manifest as a number of resultant impacts specific to the receptor.

Knowledge of local water currents, wave climatology and meteorological conditions, as well as natural levels, variation and longevity of suspended loads and plume events is important. For small projects, this may only require a basic understanding of suspended loads and current velocities (transport pathways) in order to identify the likely fate of any sediment plume and associated impacts. For larger projects, those within complex environments or where dispersal of the sediment is part of the project design, numerical modelling of flows and associated sediment transport pathways may be required.

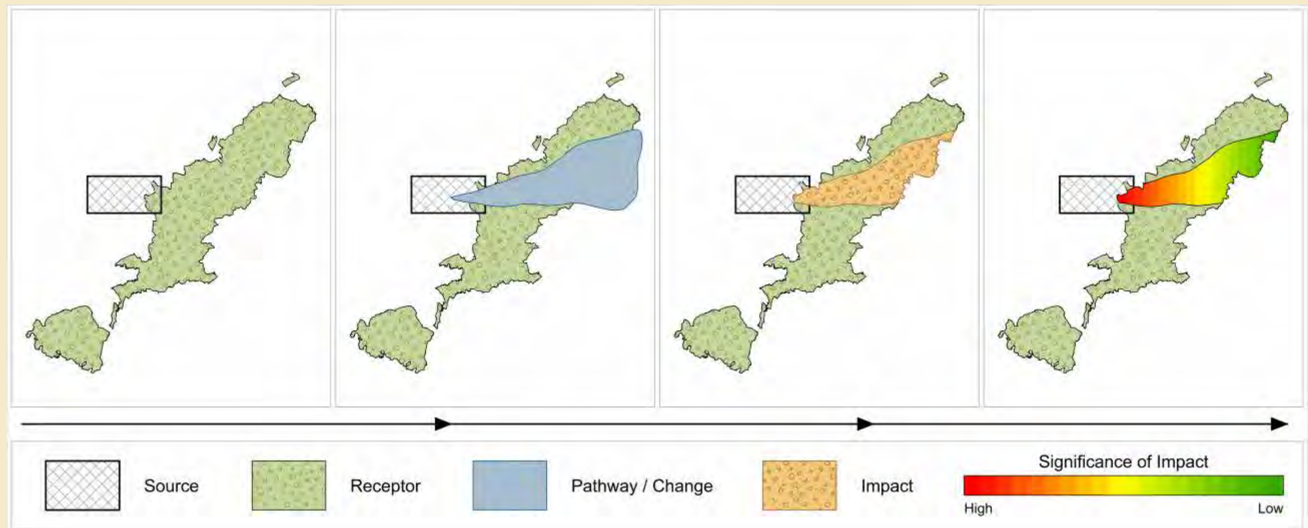


Figure 3.5: Illustration of an Source-Pathway-Receptor model associated with a potential sediment plume arising from a beneficial use scheme (taken from CEDA and IADC, 2018).

Marine Protected Areas (MPAs)

MPAs are designated sites to protect marine features of nature conservation importance (Table 3.12). The land-sea boundary is a dynamic and diverse space and accordingly, much of the UK estuarine and coastal environment is designated as part of the UK MPA network.

A beneficial use project cannot be to the detriment of the features for which the site is designated and of which there is a statutory duty to protect. The short term, long term, positive and negative impacts must all be considered when working within or in close proximity to these sensitive sites. This requirement is not specific to beneficial use, but true for all habitat restoration and other marine activities.

To determine how best to work within and support MPAs and avoid detrimentally impacting the qualifying features, the relevant statutory nature conservation body (SNCB) should be consulted at an early stage and the conservation advice packages produced for each site should be followed (Box 3.5).

In some locations in England, maintenance dredge protocols (MDPs) may have been developed in order to help identify and assess any likely significant effects of maintenance dredging activity on MPAs.

Although MDPs are not used ubiquitously, where they do exist, they may further support the establishment of regional beneficial use strategies.

The following list summarises the range of assessments relating to MPAs that are required before authorisation is granted for a beneficial use project.

Marine Conservation Zone (MCZ) Assessment: if the project takes place within or near an MCZ, an MCZ assessment will likely be required to assess whether the activity may significantly affect the qualifying features or hinder the MCZ conservation objectives.

Habitats Regulations Assessment/Appraisal (HRA): if the project takes place within or near a Special Area of Conservation (SAC) for habitats or Special Protected Area (SPA) for birds, competent authorities must carry out an HRA to consider whether a proposed development or activity is likely to have a significant effect on the protected features.

Areas or Sites of Special Scientific Interest (ASSI/SSSI) Consent: any potential impacts to A/SSSIs must be assessed before consent is granted by the relevant authority prior to the works.

Table 3.12: MPAs in the UK.

DESIGNATION	ABBRV.	JURISDICTION	LEGISLATION
Ramsar Site		International	Ramsar Convention 1976
Site of Special Scientific Interest	SSSI	England / Wales / Scotland	Wildlife and Countryside Act 1981
Area of Special Scientific Interest	ASSI	Northern Ireland	Environment (NI) Order 2002
Special Area of Conservation	SAC	UK	Conservation of Habitats and Species Regulations 2017
Special Protected Area	SPA	UK	Conservation of Habitats and Species Regulations 2017
Marine Conservation Zone	MCZ	England / Wales	Marine and Coastal Access Act 2009
		Northern Ireland	Marine Act (NI) 2013
Nature Conservation Marine Protected Area	NCMPA	Scotland	Marine (Scotland) Act 2010

BOX 3.5: CONSERVATION ADVICE PACKAGES

Site specific conservation advice packages are produced by the relevant SNCB's for each MPA, which set out the:

- Designated or qualifying features
- Habitats and species that they are dependent on and where they occur
- Conservation objectives
- Minimum targets that each feature needs to achieve to meet the conservation objectives
- Features that may be sensitive to human activity
- Condition of the designated or qualifying features
- Evidence base

The management objectives described for each site can be used to help establish a need and design for the restoration project to create the greatest environmental benefit.

The conservation advice packages must form the basis of any MPA related assessments carried out by the competent authority. Applicants must provide all of the information that the authority will need to carry out these assessments. It is important that applicants structure their assessment of potential impacts around the features, attributes and pressures outlined in the conservation advice packages.

The role of the SNCBs is to advise the marine licensing authority and the applicants as to whether there is sufficient evidence within these assessments, whether the right features and pressures have been assessed and whether any conclusions drawn, are reasonable and demonstrate beyond reasonable scientific doubt, that there will be no adverse effects on site integrity and qualifying features.

Water quality

A deterioration in water quality, over the short term during dredging or disposal, is typically considered one of the more likely impacts associated with a beneficial use project. The main impact pathways are:

- The generation of sediment plumes
- The relocation and/or remobilisation of any contaminants present within the material being dredged
- If carried out at a sufficiently large scale, potential changes to hydromorphology and associated coastal and physical processes

The Water Environment (Water Framework Directive (WFD)) (England and Wales) Regulations 2017 aim for all water bodies up to 1 nautical mile out to sea to achieve "good ecological status" and "good chemical status" out to 12 nautical miles. An alternative objective of "good ecological potential" may be set if there are grounds for time limited deterioration. For example, where pressures preclude the achievement of good status (e.g., navigation or coastal defence) in heavily modified water bodies (HMWBs). In Scotland, similar provisions are implemented through the Water Environment and Water Services (Scotland) Act 2003 out to 3 nautical miles.

In all nations, applicants must be able to show that the project will not cause or contribute to a deterioration in status or jeopardise the water body achieving good status. To do this, consideration must be given as to whether the use of dredged material to restore habitats will impact on the physical, chemical or ecological status of the estuarine or coastal waterbody in question. In England, Wales and Northern Ireland, applicants should carry out a Water Environment Assessment (previously known as a WFD compliance assessment) as part of their application.

This includes an appraisal of impacts on six receptors: hydromorphology, habitats, fish, water quality, protected areas (including SACs and SPAs, shellfish waters, bathing waters and nutrient sensitive zones) and invasive non-native species (INNS). In Scotland, the applicant must provide sufficient evidence for the regulator to make the assessment.

A *Zostera marina* meadow, growing in sandy substrate on the Isles of Scilly (Fiona Crouch, Natural England).

Monitoring

If we are to upscale our restoration efforts and support ocean recovery, it is important that lessons learned and experiences gained through practical application and associated monitoring are shared. This allows practices, regulations and their application to evolve and develop as new information becomes available through this collaborative and iterative process.

Monitoring will form a key component of a beneficial use project, but the purpose, objective and scope of the monitoring will depend on the stage of the project at which it is implemented and again, will be both project and site specific (Box 3.6).

At the site investigation and baseline monitoring stages, for regional beneficial use networks or large to landscape scale work, a holistic understanding of the system will be key for the design, monitoring and management of the project(s). For smaller scale projects considered low risk and where similar case study examples have been carried out and any associated impacts are well understood, less extensive monitoring may be appropriate. **From a regulatory perspective, surveillance and compliance monitoring should be objective driven and proportional to the risk posed by the activity.**

Monitoring should also not be simply viewed as an activity required to achieve compliance. It is a chance for our collective learning and development. With a view towards a collaborative future in habitat restoration and sediment management, sharing the learning outcomes of beneficial use (successes, failures and costs) will support future application and upscaling of projects, by contributing to the evidence base and reducing uncertainty in methods, results and impacts. In addition to the various websites provided in this handbook that host case study examples for this purpose, as well as potentially being hosted alongside the SMF following future development as previously discussed, this outreach can be achieved at many levels. For example, stakeholder engagement across local and regional partnerships, through publication of scientific papers in peer reviewed journals, presentations at relevant conferences, workshops and webinars, or in articles hosted by regular industry publications (e.g., Terra et Aqua).

It is widely recognised that monitoring can represent a significant proportion of the overall project cost. Additional sources of monitoring support may be obtained through stakeholder engagement. Those with a particular interest in the project outputs may be willing to support financially or provide supporting actions if there are clear benefits in doing so. Academic institutes may have a detailed scientific knowledge and interest in particular aspects of the project and importantly, may have access to additional sources of funding otherwise unavailable to project partners. Designed and managed well, citizen science initiatives can also provide useful monitoring data, not least regarding the socio-economic impacts of a project. Such initiatives can also help foster lasting relationships between project partners and local communities, with associated benefits relating to project acceptance, trust and long term management of the site.

BOX 3.6: DATA COLLECTION AND MONITORING PHASES

Site investigation

Early project data collection, to understand the conditions at the project site and used to facilitate feasibility studies and the project design process.

Baseline monitoring

Data collection during the design phase, used to characterise natural baseline conditions and their associated variability at the site and within the surrounding area (e.g., natural variations in suspended loads over the tidal cycle or due to storm events, or tidal current velocities over the spring neap cycle).

Data is also used:

- To identify sensitive receptors and support the project impact assessment
- As input and to calibrate numerical modelling studies (if used)
- To support further development of the project design
- To provide a baseline against which surveillance and compliance monitoring can be used to implement adaptive management measures and assess changes as a result of the works

Surveillance monitoring

Environmental measurements made during the construction phase (e.g., suspended loads downstream of the works), to assess changes resulting from the works and decide whether any changes observed are acceptable, or if trigger thresholds (described below) have been exceeded that require adaptive management action.

Compliance monitoring

Monitoring undertaken to ensure that environmental change and subsequent recovery is in line with any regulatory conditions stipulated in the licence(s) for the works and that the works have been completed to the agreed contractual scope.

Aerial monitoring of a breeding seabird colony nesting on saltmarsh, vegetated and unvegetated sand and gravel at the Langstone Harbour nature reserve, Hampshire (Wez Smith, RSPB).

Future marine management structures and sustainable financing options will also likely require some form of monitoring. For example, BNG will require all developments (above the MLW mark) to compensate for any loss of biodiversity and create an additional 10% biodiversity uplift, calculated using the biodiversity metric. Achieving the required BNG may be supported through beneficial use projects. The projects may therefore require monitoring to ensure that they are achieving the desired habitats and objectives, as well as to inform any management measures. Similar targeted monitoring requirements may be needed to provide evidence of compliance with other innovative funding sources such as carbon market models (Box 3.7).

Habitat and species specific monitoring guidelines should be followed where available, such as those provided in this habitat restoration series. Below, a brief summary of some of the main monitoring methods more pertinent to beneficial use are provided. It should be noted that these cover a range of potential scenarios and it is reiterated that monitoring should be objective driven and proportionate. In addition to the parameter(s) being monitored, this includes factors such as the duration and/or frequency of the monitoring itself. For example, if monitoring natural variations in tidal currents and suspended loads, a minimum of 1 month is typical in order to capture variations over lunar and associated spring-neap cycles. However, this may not capture natural events such as storms, it will not provide a description of seasonality and it may need to be extended over greater time scales for larger projects using the monitoring data to inform an adaptive management strategy during the works. Details of the monitoring requirements for particle size and sediment quality have been discussed previously.

BOX 3.7: BLUE CARBON MONITORING

To help deliver more and ideally, more ambitious habitat restoration projects in the future, it is increasingly understood that sustainable financing options will be important. For example, carbon market models will require the collection of carbon measurements to help determine the magnitude of creditable offsets that can be claimed to finance future blue carbon habitat restoration projects. However, there are challenges around creating a sufficiently robust carbon market based on the available data, which need to be addressed through monitoring.

Where blue carbon is being monitored, the standardised methods for field measurements and analysis of stocks and fluxes in coastal ecosystems should be followed, as outlined by the Blue Carbon Initiative. 'Coastal blue carbon' (Howard *et al.*,2014), provides an outline of the rationale and project design for measuring blue carbon in the field, as well as approaches for data analysis and reporting. It is consistent with international standards, Intergovernmental Panel on Climate Change (IPCC) guidelines and other relevant texts.

The detail of the monitoring work needed to assess the benefits will be dependent on the importance and reliance that is placed on them. The IPCC guidance for the inclusion of coastal wetlands in national GHG inventories breaks down the monitoring and evidence requirements into three tiers, depending on the resolution of the data. It may not be possible or necessary to pursue detailed and costly (Tier 3) levels of monitoring for each project (even though that is the aspirational ideal) and instead, it may be more appropriate to rely on indicative (Tier 1) levels of evidence while also recognising the uncertainty associated with this. For blue carbon interventions aiming for accreditation on the voluntary carbon market, the level of detail required will be outlined by the certifying body.

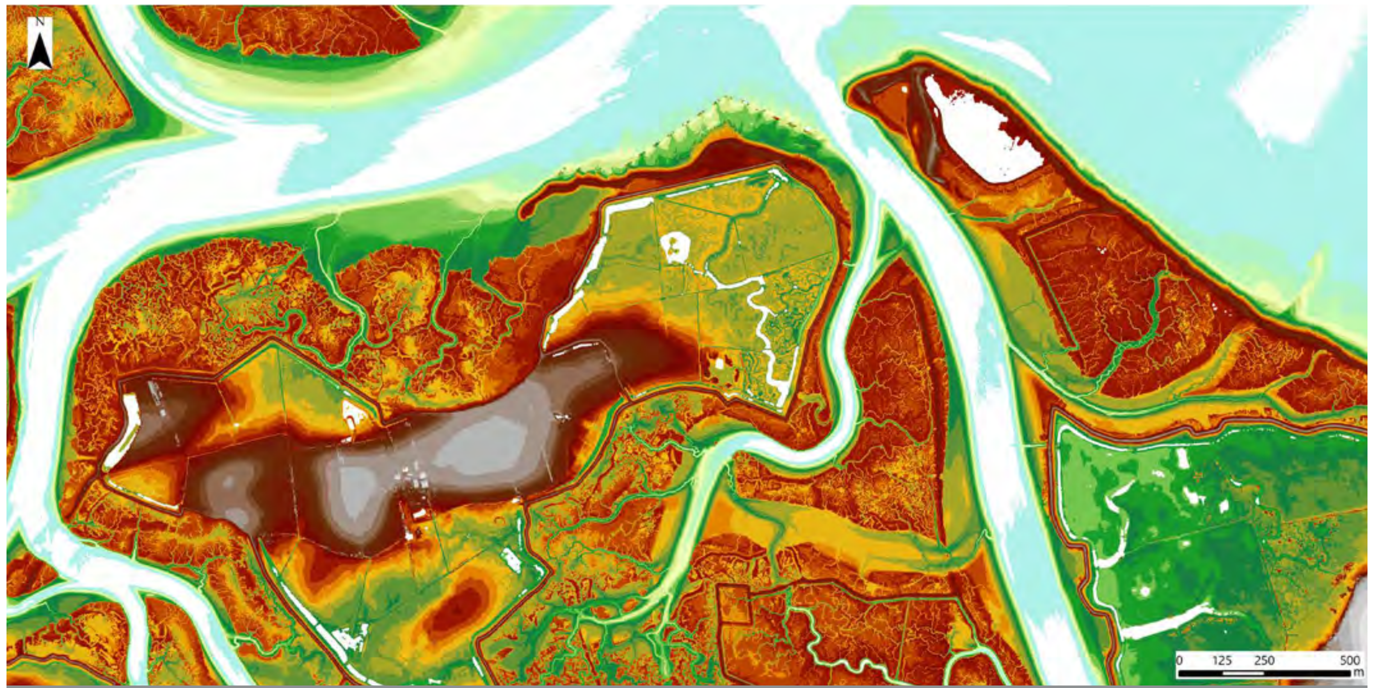


Figure 3.6: Example of a LiDAR DSM, Horsey Island and Walton Naze (ABPmer)[1].

Bathymetry, topography and disposal volumes

The measurement of bathymetric (below sea level) and topographic (above sea level) elevations are fundamental in the project design. This includes confirmation of achieving the TDD, matching the dredge and disposal volumes required to meet the design specification and may also be used to support the disposal returns process described.

Methods may range from simple manual measurements in the field that allow volumes to be approximated for smaller projects, to single or multibeam bathymetric surveys. In some instances, dual echosounders may be used to quantify any fluid mud layers that may be present above a more consolidated bed and relevant to dredge and disposal activities.

Technological developments such as unmanned aerial vehicles (UAV) (i.e., drones) allow the generation of digital elevation models (DEMs) (bare earth models) over large areas of the intertidal and terrestrial environment. When meshed with bathymetric datasets across areas of overlap in the intertidal, the result can further facilitate mapping and matching of volumes of dredged material with the storage capacity of the beneficial use site. Care must be taken however, for example, where models include the canopy height of vegetated surfaces or other structures (digital surface models (DSMs)). This can mask the actual bed level and thereby reduce the accuracy of volume calculations (Figure 3.6).

Physical processes

Understanding the hydrodynamic environment will play a role in the project design, impact assessment and may also contribute to planning the works themselves, such as operational windows, if the site or equipment to be used is likely to be constrained by tidal access or weather.

Acoustic doppler current profilers (ADCPs) are a common method that may be used for measuring variations in tidal velocities through the water column, tidal elevations, wave parameters and where an acoustic backscatter sensor (ABS) is available, may also provide a measure of total suspended solids (TSS) or suspended sediment concentrations (SSC) (TSS and SSC are described in the next section).

ADCPs will require accurate calibration and regular servicing, but can be deployed over long periods to provide temporal data series. They can be bed mounted, upward looking to provide measurements from a fixed point, or vessel mounted, thereby allowing characterisation over a large area and where TSS and tidal velocity profile data are collected simultaneously, can also allow sediment flux calculations if needed to support a project or strategy.

Measurements of meteorological conditions such as barometric pressure, wind speed and direction may also support or be important to planning and understanding coastal and physical processes and operational windows.

[1] LiDAR data © Environment Agency copyright and/or database right 2021. All rights reserved.

Sediment plumes

For projects considered low risk and where only a visual assessment or basic measure is of interest, water samples can be simply collected and allowed to settle, thereby providing a low cost, visual and easy method for assessing suspended loads against baseline levels.

As sediment plumes are one of the primary impact pathways, increasingly sophisticated monitoring of suspended loads may be required as project risk increases. Optical sensors measuring turbidity are commonly used and are often integrated into multiparameter sondes, able to concurrently measure other parameters of interest, such as water temperature, salinity and dissolved oxygen (DO) levels.

Turbidity is a measure of the 'cloudiness' of the water, created by the presence of material suspended in the water column causing light attenuation. SSC is the dry mass of non-dissolved sediment in suspension, whilst TSS includes both non dissolved sediment and organic material.

Although SSC and TSS are often referred to interchangeably, differentiation can be important where high levels of organic matter are present. To convert turbidity measurements to TSS or SSC, an accurate calibration of the sensor's response to a range of suspended loads likely to be encountered in the field is required and should be carried out by experienced personnel.

Sondes may be deployed over long periods to provide temporal data series. Providing data in real time during dredging and disposal activities, they also allow an adaptive management strategy for higher risk projects through the use of trigger thresholds (Box 3.8). Although many sensors have self-cleaning mechanisms, regular servicing may be required to remove biofouling of the sensor and maintain accurate measurements.

The location of sampling and monitoring stations should also be carefully considered. This is to ensure that the resultant data is fit for purpose and where used, allows meaningful adaptive management actions to be implemented before a negative impact occurs.

BOX 3.8: TRIGGER (THRESHOLD) LEVELS

Trigger levels are site specific 'thresholds' that indicate the potential for causing a negative impact on a receptor, in this example, due to high suspended loads. They are generally only required for projects considered to be of higher risk.

If required, trigger levels should:

- Be set based on an understanding of baseline environmental conditions and their natural variations (e.g., over the tidal cycle and due to storm events)
- Account for natural variations occurring during dredge and disposal operations
- Be specific to the receptor's sensitivity to the pressure

In the absence of detailed knowledge of local sensitivities, a common approach is to derive trigger levels statistically, such as using percentiles calculated using baseline monitoring datasets.

Two trigger levels are typically used, providing a 'caution' level (e.g., reduction in disposal rate) and a 'stop' level (e.g., stop disposal). Near real-time surveillance monitoring is required to allow adjustments to the work schedule to be made in response to exceedances of the trigger levels and to manage suspended loads at acceptable levels (Figure 3.7).

When defining and implementing trigger levels, it is also important to consider the locations of the monitoring stations, differentiating between real and erroneous data (e.g., due to fouling of the sensor) and the frequency and duration of the trigger levels used.

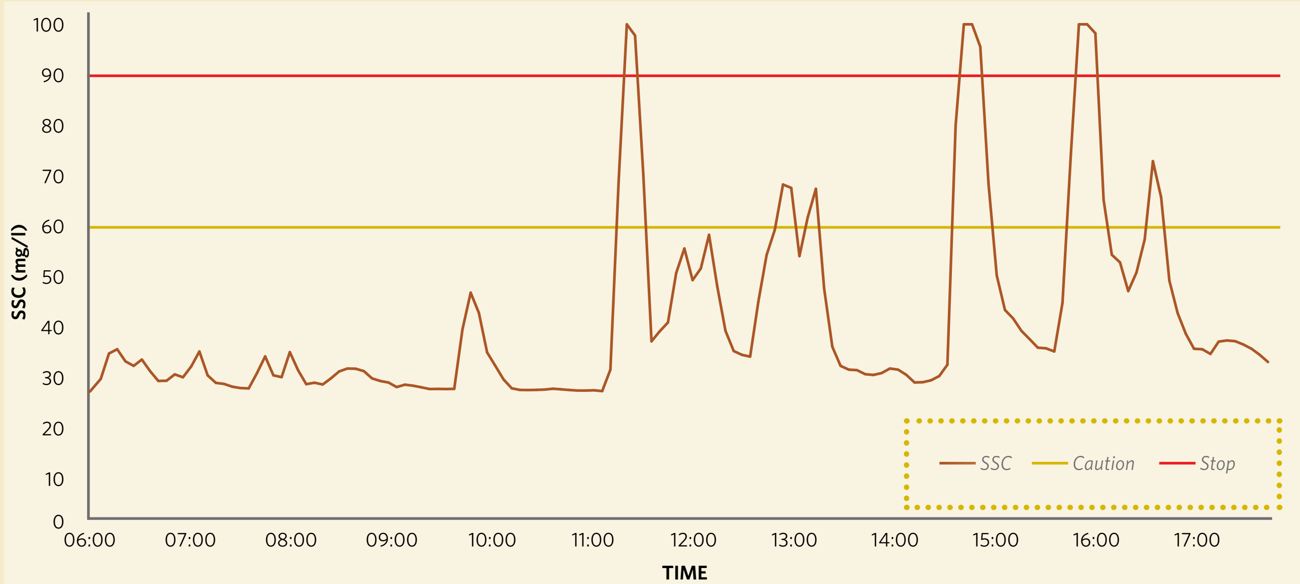


Figure 3.7: Example of SSC measurements and associated caution and stop trigger thresholds.

Biological features

Although habitat restoration projects target environmental benefits, biological communities may be sensitive receptors affected by the restoration works themselves. They may therefore require monitoring for large projects or in sensitive locations that have been identified as high risk (e.g., close proximity to native oysters or seagrass beds).

The impact, monitoring and management of sediment plumes have been described above.

Disturbance or changes in the behaviour of birds, marine mammals and terrestrial or riparian species may result due to a number of reasons, such as the simple presence and operation of the vessels and plant used on the project. For example, birds are often drawn to the disposal site to feed on what would otherwise be an inaccessible food source. Visual observations by trained ornithologists, marine mammal observers and ecologists are the most common method of monitoring these receptors.

The primary method for monitoring changes in benthic community structure is through sediment sampling, with subsequent identification and quantification carried out by specialist laboratories. If required, this is often undertaken alongside the sediment sampling carried out to assess sediment quality, thereby providing useful information on environmental parameters that influence community structure (e.g., PSD). In some instances, drop-down video and camera with subsequent visual identification may also be applicable and have the added benefit of providing material to support stakeholder engagement and outreach.

Detecting meaningful or statistical changes in biological community structure requires careful design of the monitoring plan, including the consideration of factors such as the appropriate number of sample stations and replicates, as well as the timing and frequency of surveys. If monitoring of biological impacts is warranted, existing guidance on the provision of appropriate marine ecology survey methods and design should be used to develop and agree a monitoring plan specific to the project with the relevant stakeholders and regulatory authorities.

Mitigation

Where potential negative effects are identified, they should be to removed or their significance reduced as far as reasonably practical through changes to the project design or by including appropriate mitigation, monitoring and adaptive management strategies. A few examples of potential mitigation measures for beneficial use projects are provided in Table 3.13.

Table 3.13: Example mitigation measures.

POTENTIAL IMPACT	MITIGATION
Sediment plumes	Adjust rate of dredge and disposal activities.
	Disposal in the intertidal during periods of emergence (i.e., when sub-aerial).
	Disposal during a specific period of the tidal cycle to disrupt a potential impact pathway.
	Use of dredged material or structures to construct bunds or settlement ponds within which to retain material.
	Use of silt or bubble curtains to provide a physical barrier around potential points of plume generation (e.g., around the dredger or at the point of disposal).
	Use of an underwater diffuser during disposal via pipeline.
Sensitive species and habitats	Seasonal, phased or zoned working to avoid sensitive species (e.g., migratory birds and fish, or marine mammals) or sensitive habitats (e.g., high tide roosts and fish spawning grounds), ensuring non-impacted areas are available locally for temporary relocation or impact avoidance, if necessary.
Trapping or barriers	Provide entry, exit or passing points in any retaining structures that may trap or provide a barrier to the movement of fauna.
Morphology and functioning	Micro-siting beneficial use sites to avoid the blocking or fixing of dynamic geomorphic features, such as rills and channels, which play a key role in habitat functioning and their use by fauna.
Relatively higher contaminant loading	Where dredged material is deemed suitable for use as part of a habitat restoration project, but contaminant loadings are relatively higher in material dredged from a particular area, this may be capped using cleaner material during disposal.

Evidence base

The evidence base required to support an application should be proportionate to the activity. In an effort to guide applicants and help regulators assess the timeliness of the evidence base supporting the an application, Table 3.14 provides a summary 'checklist' of potential evidence or data that may support or be required during the design, planning, licensing, implementation and/or monitoring of a beneficial use project.

It is not expected that all of the information listed will be available, especially during the early stages of the licensing process (e.g., when submitting sample plan requests), nor will all of the information necessarily be required in order to adequately assess or complete all projects. However, it is recommended that applicants provide as much information as possible at the earliest opportunity.

Table 3.14: Extensive but non-exhaustive list of information, evidence and data sources that may support a beneficial use application.

ITEM	DESCRIPTION
Rationale for project	A clear and consistent description of the project will be required and should be communicated throughout the consenting, marine licensing and permitting process.
Dredge location(s)	Location map and co-ordinates (e.g., polygon nodes).
Type of dredge	Capital or maintenance dredge.
Dredge method(s)	Proposed dredge method(s).
Dredge depth	Depth of sediment to be removed.
Dredge volume	Total dredge volume. Preferably, a breakdown of volumes per size fraction and schedules.
Sediment quality	Sediment sample analysis in accordance with the agreed sampling plan and associated assessment of the sediment quality within both the dredge and disposal sites, including any potential issues or considerations.
Previous sediment quality assessment data	Previous sediment sample analysis, typically collected within the last 3 years and analysed by a validated laboratory, subject to agreement with the relevant authority.
Proximity to potential sources of contamination	Distance from dredge or disposal areas to potential sources of pollution (e.g., vessel bunkering or combined sewer overflows (CSOs)). Information is used as a weight of evidence approach.
Historical uses of the area	Historical uses of the area (e.g., ship building and other industry). Information is used as a weight of evidence approach and is related to the above.
Disposal site location(s)	Location map and co-ordinates (e.g., polygon nodes).
Disposal rate	The expected or actual disposal rate and frequency within the disposal site.
Distance between dredge and disposal site locations	Transit distance of the vessel(s) responsible for transportation of the dredged material between the dredge and potential disposal sites.
Disposal method(s)	Proposed disposal method. The disposal method does not need to be well defined at the pre-application sampling plan stage, but an indication is useful (e.g., mechanical or hydraulic).
Specific gravity of the sediment	Derived by measurement or using the conversion factors provided in Table 3.6.
Proximity to sensitive infrastructure	The locations of, proximity to and potential impact pathway between dredge and disposal operations and potentially sensitive infrastructure (e.g., sluice gates).
Details of previous or existing dredging or disposal activities in proximity to the site	Previous or existing dredging and beneficial use activity (e.g., previous sediment sampling results (as above) or as part of a cumulative or in combination impact assessment). Information is used as a weight of evidence approach.

ITEM	DESCRIPTION
Tidal and fluvial currents	Tidal levels and natural variations and patterns in current velocities (e.g., tidal diamonds on admiralty charts and river flow data).
Wave climatology	Description of the local to regional wave climate and natural variations and patterns in wave statistics (e.g., Cefas Wavenet).
Natural sedimentary processes	Descriptions of local geomorphological features, changes and natural sedimentary processes based on knowledge of geology and hydrodynamics (e.g., National Network of Regional Coastal Monitoring Programmes).
Bathymetric and topographic data	Accurate elevations of the site to support project design and visualisation (e.g., EA LiDAR data, UK Hydrographic Office (UKHO) bathymetry data).
Model results	The results of any numerical predictive modelling used in the project design or impact assessment. Models should be appropriately calibrated.
MPAs and qualifying features	Locations of, proximity to and potential impact pathways between dredge and disposal operations, MPAs and their respective qualifying features, including information on status and management objectives (e.g., Defra Magic Map and conservation advice packages).
Navigation access	Locations of shipping channels and navigational markers to support logistical planning and minimise risk to safe navigation as a result of the works (e.g., Admiralty charts).
Photographs of the surrounding area	Photographic imagery of the project site and any associated features of interest, to convey a sense of scale and feel for the site, as well as providing visual evidence to support assessments made in the application.
Historical habitat extents	Can help identify potential restoration sites and show historical changes and trends in geomorphology at the site and the extent of relevant habitats (e.g., aerial imagery from national archives).
Restoration potential maps	Can help identify potential restoration sites and contribute towards established strategic aims such as Nature Recovery Networks (NRNs) (e.g., Coastal Data Explorer data hub).
Protected wreck sites	Identify and describe potential or protected wrecks and wreckage of historical, archaeological or artistic importance (e.g., national archives).
Distribution of INNS	Identify potential biosecurity risks or issues associated with dredge and disposal activity (e.g., OneBenthic online tool).

Marshes targeted by the disposal of around 470,000 m^3 of fine material arising from the Port of Harlingen over two winter seasons, as part of the Mud Motor project, Netherlands (Martin Baptist, EcoShape).

CHAPTER 4
RECOMMENDATIONS AND MOVING FORWARD

FINAL OVERVIEW

As estuarine and coastal habitats in the UK continue to face extensive declines and both current and future threats, it will be increasingly important to manage marine sediment as a resource, beneficially using dredged material to support the necessary physical conditions that facilitate restoration and enhance or protect existing habitats wherever possible. Doing so will help delay their loss or even reverse their decline, also allowing time to deliver other sustainable adaptations and solutions to the longer term pressures faced.

We have the technical ability to implement beneficial use projects and achieve societal benefits, that is not in doubt. Several techniques have already been successfully undertaken across multiple sites in the UK and internationally. The potential also exists to do more and to carry out larger scale projects in the future.

In many locations around the UK, however, carrying out beneficial use projects to achieve habitat restoration remains an aspiration rather than an active practice. This is because delivering them generally requires a substantial change to existing practices and ways of thinking and many barriers to delivery exist that need to be overcome (as discussed in Chapter 1).

The aim for the future is to change the established way of doing things and to achieve more projects by building on the collective experience and knowledge available. To achieve a material change and enable more and ideally larger projects to be implemented in the future, then the following thoughts and recommendations should be carefully considered by the relevant parties.

GREATER STRATEGIC PLANNING

To deliver more projects in the future and to translate national objectives for habitat restoration into practical delivery, greater strategic and partnership-based planning at the local to regional scale is needed. Such approaches will provide a better understanding of what projects can be done and where, the associated sediment supply and demand, whilst building collaborative partnerships that can deliver future projects.

In recent years, high-level strategic maps have been produced that describe areas where potential habitat restoration could be achieved. These can be used to help identify networks of potential beneficial use sites that would benefit from additional sediment. This may also provide opportunities for beneficial use to support more integrated multi-habitat restoration projects. For example, the restoration of complementay habitats may have additional benefits beyond the individual ecosystem services that each provides (e.g., habitat connectivity) and where the functioning of one habitat can support the development and health of another (e.g., wave attenuation or improving water quality). In the future though, more detailed analysis and mapping will be needed to ensure that local opportunities are identified based on site specific considerations and objectives. This localised opportunity mapping work can be undertaken as an integral part of future local nature recovery strategies, biodiversity net gain initiatives and Government net zero targets.

A local and regional strategic approach is also important for building partnerships. It will be vital to have active collaboration and the involvement of key stakeholders and beneficiaries (including local communities, regulators, conservation bodies, business and industry).

Evaluating and tailoring opportunities and recognising the benefits to stakeholders at both local and regional scales will help provide integrated, place-based delivery. An exemplar of this is the Solent Beneficial Use of Dredged Sediments project, which is being progressed by the Solent Forum coastal partnership and there are numerous other partnerships following similar approaches across many of the UK's estuaries and coasts already.

The main goal of these strategic and partnership based approaches should be to acquire the necessary marine licences and permissions for beneficial use habitat restoration sites in advance of dredge material becoming available. This would create a pipeline of projects that are ready to receive sediment as and when it becomes available and would represent a major change to existing practices that could significantly increase the potential for beneficial use of dredged material. This pipeline could then inform ongoing logistical planning of the works over the short and long term and in turn, reduce uncertainty, cost and the potential for missed opportunities.

STRONG COMMUNICATION & ENGAGEMENT

Having clear communication and robust stakeholder engagement processes is fundamental for the delivery of beneficial use projects for habitat restoration, not just for strategic planning. General perceptions of dredged material and a lack of understanding around natural processes and environmental impacts, such as contaminated sediments or the use of fine sediment, have historically led to concerns that have impeded the progress of beneficial use.

It will be important to have regular and transparent discussions (within partnerships) about the objectives, technical issues, costs and benefits. A consensus agreement as to what success looks like when it comes to habitat restoration is also critical. These aspects help participants to have confidence in the process and ensure that concerns are taken on board.

It will also be important for lessons learned and experiences gained through practical application and associated monitoring, to be shared externally via accessible platforms. For example, on websites that are already hosting case study examples, or, by tying this information to other databases, such as the potential habitat restoration maps and sediment management framework currently under development.

This needs to include information regarding the successes, failures and costs. Numerous schemes have already been completed from which data and evidence is available. However, information sharing has been incomplete and inconsistent over the years. Improving this situation is required to help address concerns or issues encountered at individual project sites and it would greatly assist with future projects, by ensuring that lessons from one site can feed across to other initiatives elsewhere.

Finally, beneficial use also needs to be communicated effectively to wider society and translated appropriately to reflect the audience's needs. Generally speaking, it is more difficult to draw an emotive response and connection when discussing mud, sand and gravel in comparison to discussions around the more evocative seascapes of swaying seagrass meadows, thriving saltmarshes or the hustle and bustle of a native oyster reef. Educational programmes that connect the underlying physical environment to these habitats is key, whilst normalising the process of beneficially using dredged material would help with understanding, support and recognition of sediment as a resource.

CLARITY ABOUT THE COSTS, BENEFITS & BENEFICIARIES

The upfront resource and effort required to support the recommended creation of a pipeline of projects with all of the necessary marine licences and permissions is recognised and must be addressed.

As part of this, greater clarity regarding the costs, benefits and beneficiaries involved in restoration activity, including a reflection of the value provided, is also required, so that they are made more obvious and central to the argument. It is recommended therefore that strategic planning and site selection initiatives are benefits-led and supported by natural capital accounting approaches.

Traditionally, the costs of using dredged material have been judged against the costs of disposal in financial terms only. For the added benefits of using dredged material to be fully realised, it is essential to consider all of the costs and benefits to society, both short and long term.

This will help establish fairer mechanisms for funding projects and as a result, support the practical implementation of habitat restoration and realisation of the benefits. To achieve this, partners and collaborators need to be involved at the onset of any project(s) in order to integrate the interests and benefits of the various stakeholders into the management of the project.

The above would all support future planning, feasibility studies and project delivery, whilst helping practices, regulations and their application to evolve and develop as new information becomes available through this collaborative and iterative process.

BUILDING ON A SUPPORTIVE REGULATORY PROCESS

Recognising that there will always be a need for regulation to manage and protect people and the environment, one way to achieve more in the future would be to adjust and simplify the regulatory process to support the use of sediment. This may happen gradually, as new and supportive environmental legislation comes into force in the UK, but it is likely to require active promotion also.

Where there are gaps in existing policy, the integration of beneficial use networks into spatial planning frameworks, such as shoreline management plans, would support beneficial use becoming an integral part of the UKs coastal adaptation programme in response to climate change and biodiversity loss. In this sense, it is hoped that the regulatory process will move away from a situation where each new dredging activity and each new licensing arrangement for that activity is considered individually and in isolation. Instead, moving to a systems-based model where the dredged sediment resource in each region of the country is viewed strategically and that management and licensing supports the strategic priorities accordingly.

In the short term, it is hoped that this document will help support beneficial use applications and avoid unnecessary project delays that can significantly increase time and costs. The more projects carried out, the more opportunities there are for case studies to be collated and shared. Licensing and permitting case officers within all relevant regulatory or advisory organisations would also benefit from such case studies, along with appropriate training to help better understand the concept of beneficial use, what is expected and what is generally considered to be best practice.

What is clear, is that more practical examples of collaborative beneficial use projects supporting estuarine and coastal habitat restoration are needed, from small, to land- and seascape scales, in order to drive changes to the established ways of working and thinking.

Beneficial use is a versatile tool, which can provide the geomorphological and physical conditions to support the restoration of many important estuarine and coastal habitats, such as native oyster reefs, seagrass meadows and saltmarshes, from small to land- and seascape scales.

FURTHER READING

ABPmer. 2017. **Using dredge sediment for habitat creation and restoration: A cost benefit review. A summary of the techniques, costs and benefits associated with using fine dredge sediment to 'recharge' intertidal habitat.** ABPmer Internal White Paper. Report No. R.2865.

ABPmer. 2018. **Beneficial Use of Dredge Sediment in the Solent (BUDS), Phase 1 Project Scoping and Partnership Building,** ABPmer Report No. R.2845. A report produced by ABPmer for Solent Forum, March 2018.

ABPmer. 2020. **Beneficial Use of Dredge Sediment in the Solent (BUDS) Phase 2, Feasibility Review for Sediment Recharge Project(s) on the West Solent Saltmarshes,** ABPmer Report No. R.3155. A report produced by ABPmer for Solent Forum, February 2020.

Ausden, M., Dixon, M., Lock, L., Miles, R., Richardson, N. and Scott. C. 2018. **Precipitating a SEA Change in the Beneficial Use of Dredged Sediment (SEABUDS).** RSPB Technical Report.

Bolam, S.G., Barry, J., Bolam, T., Mason, C., Rumney, H.S., Thain, J.E. and Law, R.J. 2011. **Impacts of maintenance dredged material disposal on macrobenthic structure and secondary productivity**. Marine Pollution Bulletin. 62, 2230 - 2245.

Bridges, T.S., King, J.K., Simm, J.D., Beck, M.W, Collins, G., Lodder, Q. and Mohan, R.K. (Eds.). 2021. **International Guidelines on NAtural and NAture-Based Features for Flood Risk Management**. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Central Dredging Association (CEDA). 2015. **Integrating Adaptive Environmental Management into Dredging Projects.** A CEDA position paper. Central Dredging Association (CEDA) and International Association of Dredging Companies (IADC) (Eds.). 2018. **Dredging for Sustainable Infrastructure.** CEDA and IADC, The Hague, The Netherlands.

Central Dredging Association (CEDA). 2019a. **Assessing the benefits of using contaminated sediments.** A CEDA position paper.

Central Dredging Association (CEDA). 2019b. **Sustainable management of the beneficial use of sediments – A case studies review.** A CEDA Information Paper.

Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. 2016. **Nature based solutions to address global societal challenges.** DOI: 10.2305/IUCN.CH.2016.13.en.

Howard, J., Hoyt, S., Isensee, K., Pidgeon, E. and Telszewski, M. (eds.). 2014. **Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows.** Conservation International, Intergovernmental Oceanographic Commission of UNESCO, International Union for Conservation of Nature. Arlington, Virginia, USA.

International Maritime Organization (IMO). 2014. **Waste Assessment Guidelines Under the London Convention and Protocol.** London 2014. 978-92-801-1613-7.

Lonsdale, J.A., Blake, S. and Griffith. A. 2021. **A novel systematic, risk based approach to support the designation of aquatic disposal sites.** Marine Pollution Bulletin. 162.

Marine Management Organisation (MMO). 2019. **Identifying sites suitable for marine habitat restoration or creation.** A report produced for the Marine Management Organisation by ABPmer and AER, MMO Project No: 1135, February 2019, 93pp.

Mason, C., Lonsdale, J.A., Vivian, C., Griffith, A., Warford, L., Hynes, C., Barber, J., Sheahan, D., Bersuder, P. and Bakir, A. 2020. **Review of Action Levels used for assessing dredging and disposal marine licences.** Report ME5226/C7590 for the Department of the Environment, Food and Rural Affairs. 113 pp.

Oslo Paris Commission (OSPAR). 2014. **OSPAR Guidelines for the Management of Dredged Material at Sea.** Agreement 2014-06.

Parker, R., Benson, L., Graves, C., Kröger, S. and Vieira R. 2021. **Carbon stocks and accumulation analysis for Secretary of State (SoS) region: (2021) Cefas Project Report for Defra**, 40 pp.

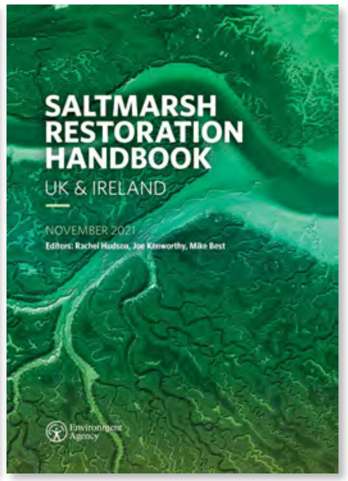
The World Association for Waterborne Transport Infrastructure (PIANC). 2009. **Dredged material as a resource: Options and constraints.** Report Number 104.

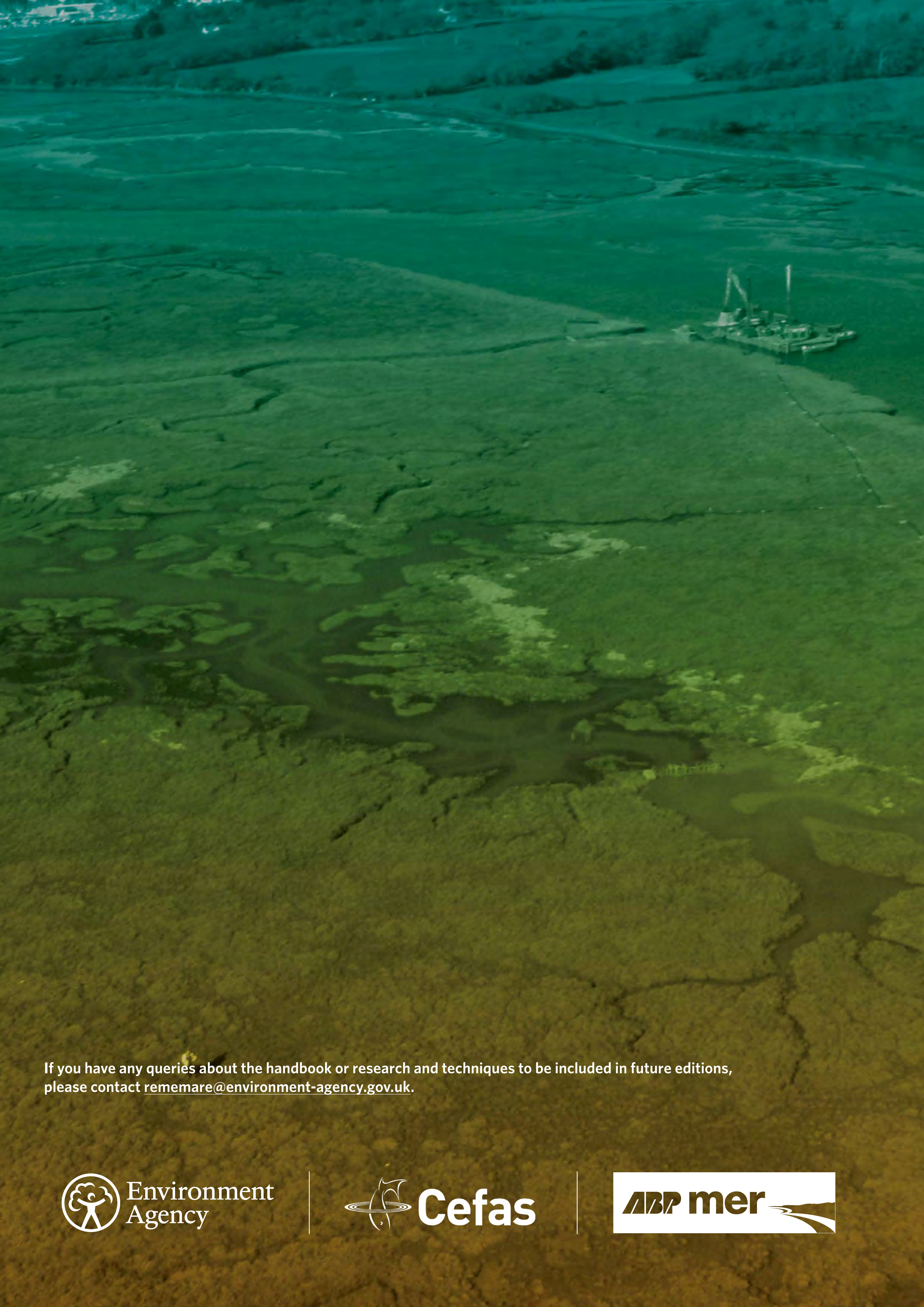
The World Association for Waterborne Transport Infrastructure (PIANC). In press. **Advocating Beneficial Use for Waterborne Transport Infrastructure Projects**. Report Number 214-2022.

Turner, K., Schaafsma, M., Elliott, M., Burdon, D., Atkins, J., Jickells, T., Tett, P., Mee, L., van Leeuwen, S., Barnard, S., Luisetti, T., Paltriguera, L., Palmieri, G. and Andrews, J. 2014. **UK National Ecosystem Assessment Follow-on. Work Package Report 4: Coastal and marine ecosystem services: principles and practice.** UNEP-WCMC, LWEC, UK.

US Army Corp of Engineers (USACE). 2021. **Engineering with Nature: An Atlas (Volumes I and II).**

NOTES





If you have any queries about the handbook or research and techniques to be included in future editions, please contact rememare@environment-agency.gov.uk.