SALTMARSH RESTORATION HANDBOOK

UK & IRELAND

NOVEMBER 2021

Editors: Rachel Hudson, Joe Kenworthy, Mike Best

Environment Agency

ACKNOWLEDGEMENTS AND FUNDING INFORMATION

This publication has received funding from the Environment Agency and from Defra. It has also been enabled by substantial in-kind support and contributions from the editors and authors' organisations. This publication reflects the authors' views only.

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Thanks to the steering committee:
Stewart Angus (NatureScot), Louise Denning (Natural England), Ben Green (Environment Agency), Nick Hardiman (Environment Agency), Mike Jones (Environment Agency), Janet Khan (Scottish Environment Protection Agency), Heather Lewis (Natural Resources Wales), Sue Rees (formally of Natural England), Christopher Sweeting (Marine Management Organisation), Robert Wilkes (Environmental Protection Agency), Nick Williams (Natural England), Claire Young (Department of Agriculture, Environment & Rural Affairs – DAERA).

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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.

Thanks to Toni Llobet for use of his images of marsh animals in Chapter 4.

Front cover image: Colne Point marsh, Essex. © Environment Agency

UNITED NATIONS DECADE ON ECOSYSTEM RESTORATION 2021-2030

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

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Suggested citation for publication:
Hudson, R., Kenworthy, J. and Best, M. (eds) (2021). *Saltmarsh Restoration Handbook:* UK and Ireland. Environment Agency, Bristol, UK.

Suggested citation for Chapters (for example):
Möller *et al.* (2021). Saltmarsh Restoration: An introduction. In: *Saltmarsh Restoration Handbook: UK and Ireland* (eds. R. Hudson, J. Kenworthy and M. Best), pp.1-16. Environment Agency, Bristol, UK.

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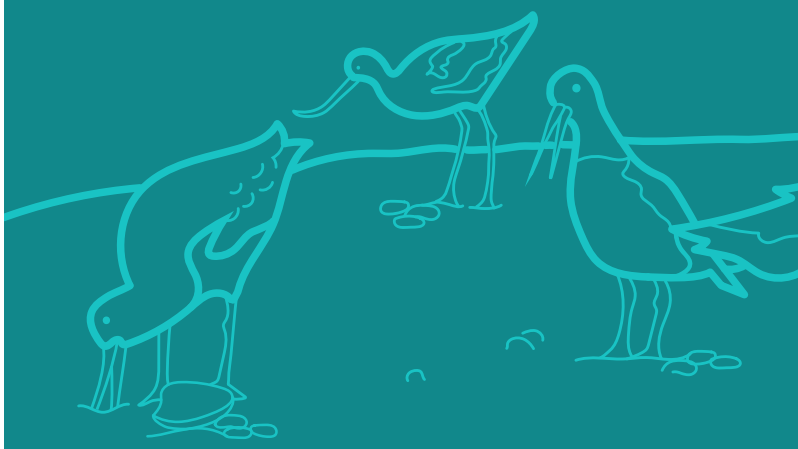


EXECUTIVE SUMMARY

This Saltmarsh Habitat Restoration Handbook aims to provide practical guidance on restoring and creating saltmarsh habitat across the UK and Ireland. It brings together advice on planning and implementing such schemes with selected case studies and lessons from previous examples.

The handbook includes: an introduction to what saltmarsh is, why it is important, the threats to saltmarsh habitat and the concept of restoring resilient and well-functioning saltmarsh (Chapter 1); information about starting a restoration project including choosing a site, project planning, choosing a design and calculating the benefits of restoring saltmarsh (Chapter 2); an overview of the consents and licences likely to be required and key organisations to contact about licensing (Chapter 3); an outline of how to effectively communicate a restoration project before, during and after changes are made (Chapter 4); a non-technical summary of the different approaches and methods to restoring saltmarsh habitat, and advice regarding monitoring and maintenance (Chapter 5).

Historically, saltmarshes were converted to agricultural and development land, especially during the 18th and 19th centuries. Reversing that trend and restoring saltmarsh habitat can help the UK and Ireland to deliver benefits for flood and coastal risk management, climate change mitigation, biodiversity recovery and promoting human wellbeing. As we enter the UN decade on 'Ecosystem Restoration' (https://www.decadeonrestoration.org/) and 'Ocean Science for Sustainable Development' 2021-2030, we recognise humanity's dependence on healthy, robust and functioning marine ecosystems. We need to protect and restore ecological systems that provide nature-based solutions (NBS) and resilience to the challenges we now face.

To restore saltmarsh habitat, with the many ecosystem services it provides, will require a diverse mix of approaches depending on the location, surrounding landscape and extent of degradation or loss. Overall, this handbook aims to support greater application of both small scale feasibility projects, as well as larger, more complex saltmarsh restoration efforts.

HANDBOOK CONTEXT

Marine habitat restoration

Over the past decade, the field of marine habitat restoration in Europe has grown significantly. This is due to increased awareness of the extent of the degradation of our valuable marine habitats, including saltmarshes, native oyster reefs, seagrasses and kelp, combined with our ability to identify the value that our marine habitats provide.

The UK Government's 25 Year Environment Plan commits to 'securing clean, healthy, productive and biologically diverse seas and oceans' and European directives (for example, Natura 2000) recognise saltmarsh as a priority habitat. There are two different approaches to restoring marine habitat; reducing pressure on systems and allowing natural recovery, or taking positive action to restore marine habitats and species. This handbook is focusing on the latter.

The production of this handbook was commissioned by the Environment Agency, as part of the cross-agency Restoring Meadow, Marsh and Reef (ReMeMaRe) initiative. The vision of the 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 in line with the Defra 25 Year Environment Plan time frame.

This handbook will be part of a quartet of restoration guidelines, along with those developed for native oyster reef habitat, seagrass habitats and for the beneficial use of dredged sediments.

Foreword
by Emma Howard Boyd, Chair of the Environment Agency.

Emma Howard Boyd

At the Environment Agency, we are planning for at least a 1 metre rise in sea level by 2100 in our flood and coastal risk management projects, but people do not want us to build infinitely high walls that cut off communities from the sea. Alongside new technology and advanced warning and informing systems we need to step up nature-based solutions.

Saltmarshes act as natural flood and coastal defences and have many other benefits too. They store carbon to mitigate against climate change, they protect water quality, they support biodiversity (such as nursery sites for commercial fish and shellfish, and feeding and nesting grounds for wading birds) and they provide cultural, wellbeing and recreational benefits to people working and visiting the marshes. In May 2021, the Green Alliance published a report, "Jobs for a Green Recovery", that said nature investments have a high cost-benefit ratio, with £1.30 back for every £1 invested in saltmarsh creation.

Over the last 150 years the loss of saltmarsh habitat across the UK & Ireland has been significant, but the multiple interlocking benefits listed above make a compelling case for investing in saltmarsh restoration. Notwithstanding fantastic work at existing sites such as Steart Marshes, Medmerry and Wallasea, we need more practical examples, which will support the country's ambition to achieve Net Zero.

In July 2021, a project led by the UK Centre for Ecology & Hydrology to develop a saltmarsh carbon code to support habitat restoration activities was one of the 27 schemes to benefit from the £10 million Natural Environment Investment Readiness Fund, created by Defra and the Environment Agency to drive private investment in nature. The project seeks to develop a rigorous and scientifically based voluntary certification standard for those that want to market the climate benefits of saltmarsh restoration, with assurances to voluntary carbon market buyers that the climate benefits are quantifiable, additional and permanent.

This handbook is for catchment and coastal partnerships, NGOs, landowners and community groups wanting to undertake their own saltmarsh restoration project. I hope it will inspire more people to get involved in delivering saltmarsh restoration in the UK and Ireland.

Thank you to all of the authors who have contributed to this handbook.

GLOSSARY

- **Abiotic (factors)** The non-living factors in an environment that will influence living organisms, such as sunlight, temperature, waves, tides and geology.
- **Accretion** Material deposited by sedimentation that increases land height/area.
- **Adaptive management** Management processes whereby project effects are continuously monitored and evaluated to determine the need for modification of project execution and monitoring effort. Adaptive management includes the implemented modifications.
- **Back barrier saltmarsh** Saltmarsh behind shingle or shell spit complexes.
- **Baseline** The existing conditions of the physical, chemical, biological and human environment before an activity starts.
- **Benthic** Connected with, or living near, the sea bottom; this includes the sediments within intertidal saltmarshes and mudflats.
- **Biodiversity** The variability among living organisms from all sources and the ecological complexes of which they are part.
- **Biomass** The mass or weight of living tissue/ organisms.
- **Biotic (factors)** The factors associated with, and interactions between, living organisms, for example, grazing and competition.
- **Blue carbon** Carbon stored in coastal and marine ecosystems. Coastal ecosystems such as tidal saltmarshes sequester and store more carbon per unit area than terrestrial forests and are now being recognised for their role in mitigating climate change.
- **Brushwood groynes** Double array of wooden stakes driven into the mudflat, with intervening space being filled with willow brushwood or similar material to reduce current velocities and wave heights.
- **Carbon sequestration** A biochemical process by which atmospheric carbon is absorbed by living organisms, including saltmarsh plants, and involving the storage of carbon in soils, with potential to reduce atmospheric carbon dioxide levels.
- **Carbon stock** The quantity of organic carbon held within carbon pools, which are systems that can store or release carbon (for example, below ground biomass).
- **Coastal squeeze** The loss of natural habitats, or deterioration of their quality, arising from human structures or actions, preventing the landward transgression of those 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.
- **Compensatory habitat** Habitat created to offset loss or damage to Special Areas of Conservation, Special Protection Areas and Marine Conservation Zones, to maintain the coherence of the natural networks.
- **Cost-benefit analysis** A decision tool that judges the desirability of projects by comparing their costs and benefits.
- **Cryptic habitat** Habitat that is effective at providing shelter/cover to fish species or other organisms.
- **Equilibrium (Ecological state of)** The state in which the action of multiple forces produces a steady balance, resulting in no change over time.
- **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.
- **Fringing saltmarsh** Saltmarsh lying seaward of sea embankments.
- **Geomorphology** The study of landforms and the processes that have made them.
- **Greenhouse gases** Gases that contribute to the greenhouse effect (hinder heat radiation from escaping through the atmosphere).
- **Halophyte/halophytic** Salt tolerant plants.
- **High marsh** Upper zone of the saltmarsh with infrequent tidal flooding.
- **Hinterland** This is the area of land landward of the coastline. It is normally outside the active coastal or estuarine processes, except in extreme circumstances.
- **Hydrodynamic** The circulation of sea water and fresh water, as well as the associated sediment transport, erosive and depositional process that contribute to shaping the coastal morphology.
- **Intertidal** Area between high and low water marks.

- **Intertidal recharge** Introducing sediments from elsewhere onto intertidal areas.
- **Land claim** The gain of land from the sea or other waterbodies. It may be achieved by draining saltmarshes and constructing new sea defences.
- **LiDAR** 'Light Detection and Ranging'; a remote-sensing technique used to measure relative distance (including height above sea level) speed or rotation from the sensor. It can be used to pick up solid surfaces or diffuse objects.
- **Low marsh** Lower zone of the saltmarsh always flooded during high tides.
- **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).
- **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.
- **Pioneer saltmarsh** Pioneer zone of the saltmarsh, covered by all high tides and typically on the lower edge of the marsh. Consists of species found in the early development saltmarsh.
- **Refuge** An area which provides shelter and protection.
- **Regulated tidal exchange** The regulated exchange of seawater to an area behind fixed sea defences, through engineered structures such as sluices, tide-gates or pipes, to create saline or brackish habitats.
- **Sediment recharge** See 'Intertidal recharge'.
- **Sedimentation polder** Intertidal area, enclosed by rectangularly arranged brushwood groynes to facilitate enhanced sediment deposition.
- **Sinuous** Having many curves and turns.
- **Spillway** A structure designed to allow the controlled overflow or release of water from a reservoir or flood storage area, or over flood defences.
- **Tidal prism** The amount of water that flows into and out of an estuary or bay with the flood and ebb of the tide, excluding any contribution from freshwater.
- **Transition zone** The areas of a saltmarsh nearest the 'dry' land; only coastal storms or extremely high tides result in tidal flooding of the area.
- **Zonation** The zones of plants in a saltmarsh; the zones are defined by the amount of tidal flooding, elevation, salinity and species interactions. Typically each zone is represented by specific plant communities.

Aerial photo of breach at Medmerry managed realignment, West Sussex, in 2013. Photo: Environment Agency

CHAPTER 1
SALTMARSH RESTORATION: AN INTRODUCTION

CHAPTER AUTHORS
Iris Möller, Tom Spencer, Mike Best, William Austin, Annette Burden.

KEY SUMMARY POINTS:

- **Saltmarsh habitats in the UK and Ireland have seen loss and damage over centuries. With this decline we have lost the ecosystem services and functions provided by the habitat.**
- **Active intervention is required to reverse the decline of saltmarsh habitats, and to successfully restore resilient and well-functioning saltmarsh.**
- **Saltmarsh restoration is a prime example of a 'nature-based solution', offering high potential to reduce flooding and coastal erosion, increase carbon sequestration, as well as a range of other ecosystem services.**

INTRODUCTION

Interest in coastal habitat (including saltmarsh) restoration has been steadily growing since the 1990s. In the European context, restoration was initially driven by the habitat regulatory framework, where the upper intertidal zone is recognised as being particularly important to biodiversity conservation and water quality regulation. Initially, restoration was primarily aimed at mitigating habitat loss and a great deal was completed as a by-product of flood defence improvement schemes. More recently, however, restoration has been motivated further by the recognition that 'nature-based solutions' can help to address the climate change.

It is also clear that saltmarshes are just one part of an interconnected coastal system. More often than not, their future is determined by past and present human modification of estuaries and embayments, such as hard flood and erosion defences that artificially constrain the area between mean sea level and the highest astronomical tide.

This introductory chapter provides information on the complexity of the saltmarsh system, the drivers for saltmarsh habitat restoration, and what it means to restore system resilience in such a way as to ensure maximum benefit and longevity of restoration schemes.

WHAT IS SALTMARSH?

Saltmarshes are near-horizontal platforms characterised by a largely continuous cover of salt-tolerant (halophytic) vascular plants (grasses, rushes and shrubs). At the lower (mudflat) transition zones, annual species may dominate the marsh canopy while the upper (terrestrial) saltmarsh areas are dominated by perennials (Figure 1.1). Invertebrates with highly specialised adaptations are often abundant on adjacent tidal flats. On the vegetated saltmarsh, invertebrate species richness is highly variable and sensitive to localised conditions. Saltmarshes are important habitats for breeding, feeding, and roosting birds, many of them migratory, as well as for fish and aquatic/marine invertebrate species.

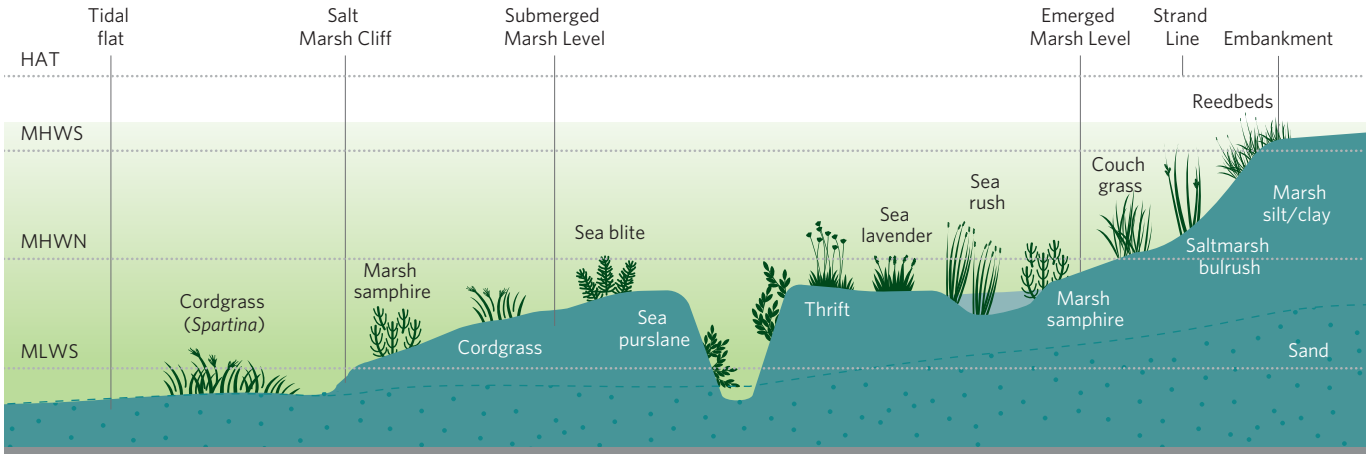


Figure 1.1: Schematic showing the profile of a saltmarsh and mudflat and their main physiographical features.

While often defined in ecological terms, the presence and functioning of saltmarsh systems is fundamentally determined by the interplay of ecological processes with hydrodynamic and sedimentary processes. These processes operate in an intertidal 'accommodation space', the area suitable for saltmarsh to develop. The vertical boundaries to this space are typically between mean high-water neap and highest astronomic tide (HAT). The seaward lateral boundary is a junction, either cliffed or ramped, with unvegetated intertidal and subtidal mudflats and sandflats on which seagrasses may (or may have once been) present. To landward, saltmarshes may be backed by brackish/freshwater marsh, vegetated shingle or sand dunes at the limit of tidal flooding. The disappearance of seagrass in many locations may be connected with changes in the type of transition between unvegetated tidal flats and the vegetated saltmarsh, and, in many locations, the marsh is artificially constrained from reaching this limit by sea defences or other infrastructure.

As part of the coastal zone, a wide range of saltmarsh settings are possible (Figure 1.2).

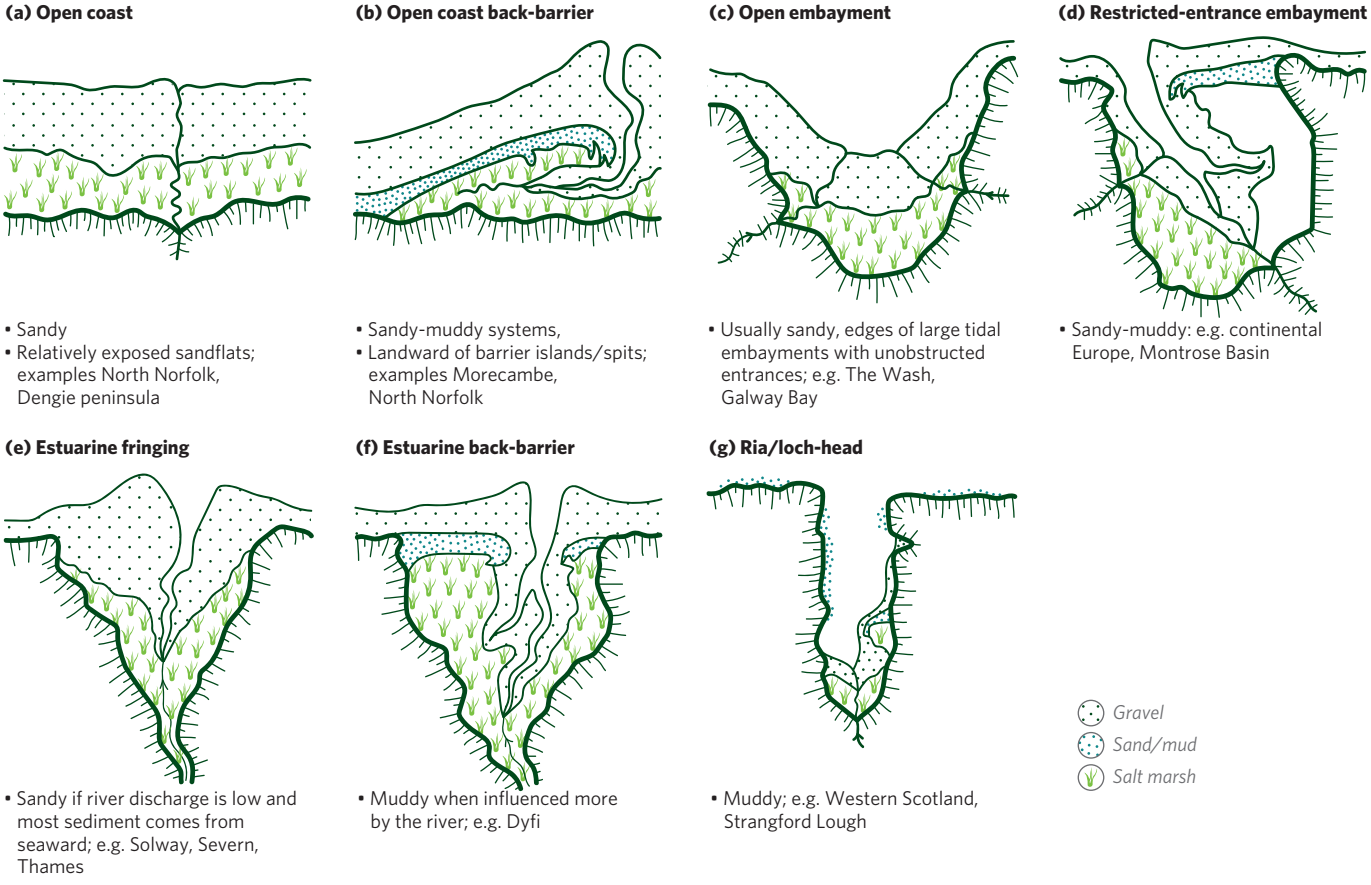


Figure 1.2: Seven distinct saltmarsh contexts identified by Allen (2000).

While these settings are generally protected from high wave energy, they are by no means 'low energy' settings when considering their exposure to tidal forces. For example, a 55ha back-barrier marsh on Scolt Head Island, North Norfolk, has 40 to 50cm of water over its marsh surfaces at high spring tides, and over a million cubic metres of water (and sediment) are exchanged over a 6-hour flood to ebb tidal cycle.

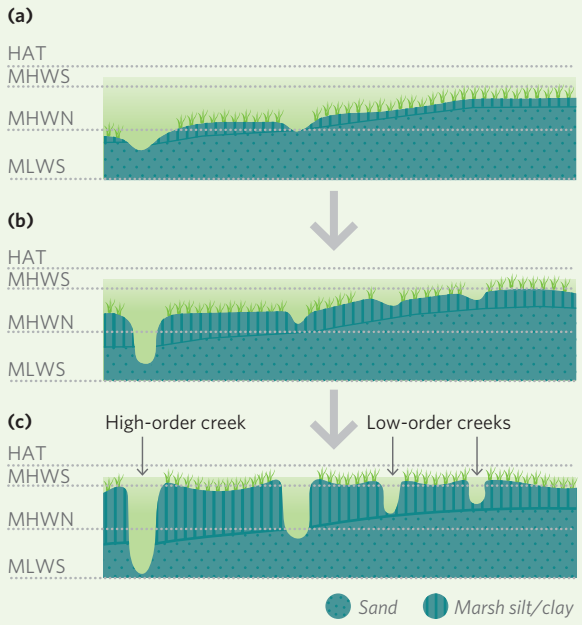
The degree to which the intertidal accommodation space is filled by saltmarsh depends upon: the amount of fine-grained sediment (fine sands, silts and clays) that is available to settle; the 'trap efficiency' of the intertidal surface to retain any sediment that does settle; and any possible processes, for example compaction, that convert sedimentation into long-term marsh accretion. The sediment that makes up the saltmarsh landform is delivered not only by the tides that flood the marsh but also by the vegetation canopy (in the form of plant matter) (Box 1.2).

BOX 1.1: SALTMARSH EVOLUTION FROM TIDAL FLATS

Where there is sufficient sediment supply, saltmarsh formation typically follows the development of shallow drainage on tidal flats, with pioneer plant colonisation on the higher surfaces subsequently allowing enhanced deposition through a positive bio-morphodynamic feedback. Over time, convex surfaces between the tidal creeks develop a concave cross section through preferential deposition of tidally imported sediment near creek banks as illustrated in Figure 1.3. This shows the progression from a 'young' marsh, low in the tidal frame (top) to a mature marsh platform (bottom). Once established, the saltmarsh system retains the various elements in its cross section, from the tidal channel or open coast to its landward limit, as shown in Figure 1.1.

The coastal zone exhibits a degree of 'self-organisation'. This means that a change in one area affects another and this affects the former. For example, physical and biological components of the saltmarsh both affect and are affected by the flow of water, nutrients, and sediment within, across/through, and around them. This is in addition to changes in external factors such as sea level, climate and sediment supply having an impact on the saltmarsh.

While unvegetated mudflats show phases of both erosion and accretion, and therefore variations in surface elevation, once saltmarsh vegetation becomes established surfaces become more resistant to erosion. Indeed, observations of vegetated saltmarsh surfaces after storm surge events and in true-to-scale large flume experiments have shown these surfaces to be remarkably stable even under high hydrodynamic forcing (Spencer *et al.*, 2015). The rate of infilling of the accommodation space is often initially rapid but then slows as surfaces rise, and tidal inundation frequency and sediment supply decline until equilibrium is reached.



(a) An early marsh low in the tidal frame, sloping seawards. (b) As marsh develops note the concave surfaces and higher density of creeks. (c) Mature marsh horizontal overall with concave surfaces, and a high density of well-developed creeks, some reaching deep into the tidal mud/sand flats.
HAT = highest astronomical tide. MHWS = mean high water spring tide level. MHWN = mean high water neap tide level. MTL = mean tide level.

Figure 1.3: French-Stoddart model of salt-marsh development.

BOX 1.2: ALLOCHTHONOUS VERSUS AUTHOCHTHONOUS SALTMARSHES

Marshes formed mainly through the accumulation of imported mineral sediments are referred to as 'allochthonous'. Those where the in situ accumulation of organic plant matter is the main contributor towards maintaining the marsh surface relative to sea level are referred to as 'autochthonous'.

Autochthonous marshes typically occur in micro-tidal settings (tidal range <2m), with the relative contribution of allochthonous sediments increasing with tidal range and connectivity to the river, tidal, or open coast sources of sediment.

Within the UK and Ireland, most marshes will experience a mixture of internal and imported sediment inputs depending on their local setting and context. The various processes that maintain saltmarsh surfaces are shown in Figure 1.4; an appreciation of these interacting dynamics is critical to saltmarsh restoration methodologies.

External sediment sources include contributions from riverine sediment discharge, coastal erosion along neighbouring coastlines, offshore sediment sources and atmospheric deposition. Restoration schemes may also transport and use external dredged sediment, this is discussed further in Chapter 5. Near shore sediment sources include sediment resuspension on tidal mudflats and erosion of marsh cliffs and tidal creeks.

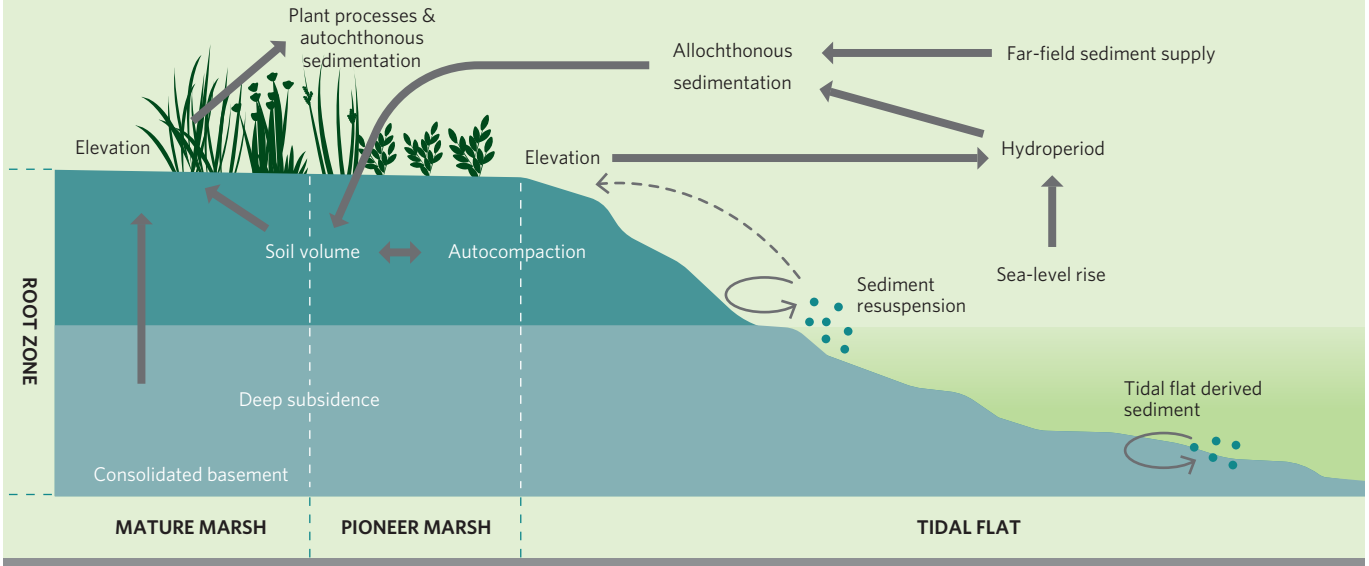


Figure 1.4: Key processes controlling the natural landform building process of saltmarshes through dynamic interactions between vegetation and marsh sedimentation and indicating external and proximal sources of sediment for pioneer and mature saltmarsh systems (after French (2006) and Schuerch *et al.* (2019)).

WHY IS SALTMARSH IMPORTANT?

Despite the long history of land claim and conversion to agricultural and other uses, there has been a fundamental shift over the last 30 years in how people view saltmarsh. Up until the mid-20th century, saltmarshes were widely viewed as being of little value to society, as land waiting to be 'reclaimed' as agricultural land, for human development, or as waste disposal sites. Since then, however, their high and unique biodiversity value and the range of functions they carry out has become increasingly recognised.

Biodiverse saltmarsh. Photo: Iris Möller.

BOX 1.3: NATURE-BASED SOLUTIONS

Nature-based Solutions (NBS) are 'actions addressing key societal challenges through the protection, sustainable management and restoration of both natural and modified ecosystems, benefiting both biodiversity and human well-being' (IUCN 2020). These ideas are gaining considerable traction, featuring in a range of international fora, including the UN Decade on Ecosystem restoration and within the scientific objectives for the 26th UN Climate Change Conference of the Parties (COP26), Glasgow 2021.

Restored saltmarshes have a high potential to reduce flooding and coastal erosion and are thus effective contributors to climate adaptation challenges. Restoration offers a long-term and cost-efficient response to global environmental change compared to traditional fixed hard structures and is, therefore, a prime example of NBS. When saltmarshes are used as a way of defending our coast, they can simultaneously create habitats for wildlife, protect carbon stores, be places for recreation and attract tourism to boost local economies. For example, Vieira da Silva *et al.* (2014) note that, although the primary drivers for creating Steart peninsula (England) saltmarsh realignment included habitat creation and management of coastal flooding, there are benefits for a significant number of other connected services including agriculture and fisheries, climate regulation, water purification and treatment, fisheries, recreation, tourism and education. They estimated a conservative net annual benefit range of £491,155 to £913,752.

Nature-based solutions can be categorised into:

- Fully natural solutions (existing ecosystems/ landforms that become recognised for the function they provide).
- Managed natural solutions (ecosystems/landforms that are actively managed through human intervention).
- Hybrid solutions (ecosystems/landforms that provide functions through their existence alongside engineered features).
- 'Environment-friendly' solutions (engineered solutions that contain added natural elements such as vegetated coastal protection structures).

When and where saltmarsh functions benefit people (for example by supporting fish stocks within an adjacent estuary or protecting the shore from flooding and erosion) they are referred to as 'ecosystem services'. Popularised by the Millennium Ecosystem Assessment (2005), ecosystem services generally fall into three broad categories:

- regulating services (including hazard regulation).
- provisioning services (materials directly extracted from the ecosystem and goods associated with it).
- cultural services (ranging from tourism and recreation to aesthetic and spiritual values).

All ecosystem services are sustained through a range of supporting services, such as pollination.

The Office for National Statistics have estimated that the UK marine natural capital assets (for which we can estimate a value) have an asset value of £211 billion (at 2018 values) (ONS, 2021). Saltmarshes make a significant contribution to this overall value through services including carbon sequestration and flood protection. The restoration of saltmarsh in any one location can be driven by considering any, or all, of the ecosystem services it provides, depending on the physical, ecological, political, and economic context within which the restoration is carried out (Figure 1.5). More information on each of these types of ecosystem services is provided in the sections below.

Hut Marsh, Scolt Head Island, North Norfolk. Photo: Tom Spencer

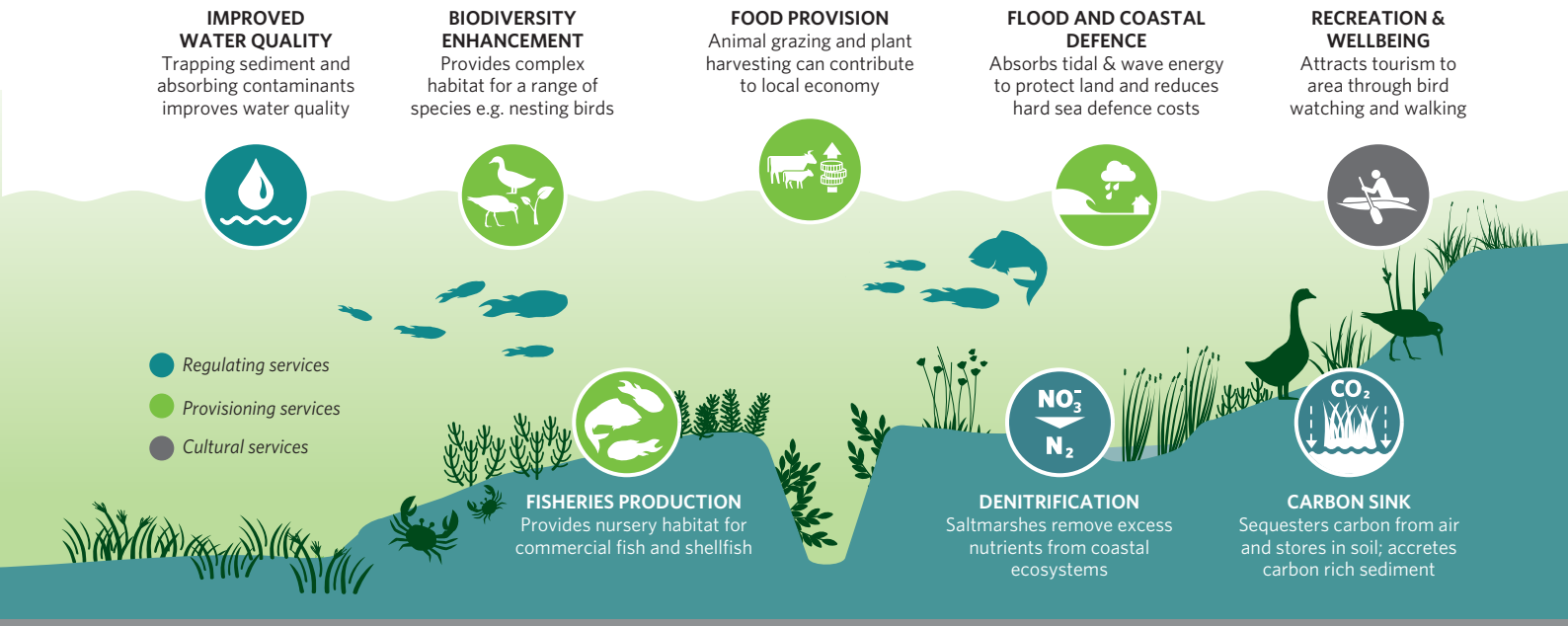


Figure 1.5: Ecosystem services provided by saltmarshes.

REGULATING SERVICES

Coastal protection by saltmarshes

Ecologically healthy and naturally functioning saltmarsh is a major contributor to flood and coastal erosion risk management (FCERM). In England, saltmarsh is thought to currently provide £1 billion of flood risk benefits, whilst research by Narayan *et al.* (2017) found that temperate coastal wetlands (including saltmarsh) saved >$625 million in flood damages in the north-eastern USA during Hurricane Sandy in 2012.

Saltmarsh reduces flood risk through:

- Wave attenuation: waves break in shallow coastal water, and in so doing expend energy which drives erosion and sediment transport. Consequently, in areas with wide intertidal flats such as healthy saltmarsh complexes, wave breaking and resulting erosion occurs away from critical flood defences and vulnerable receptors. By inducing breaking further offshore, saltmarsh also reduces the likelihood of waves and swash (the bore of turbulent water generated when they break) overtopping defences. The presence of healthy vegetation communities on saltmarsh surfaces increases friction. Over only a 40m distance, and when inundated to as much as 2m water depth, this reduces wave energy by an additional 60% when compared with unvegetated surfaces (Möller *et al.*, 2014).
- Surge attenuation: particularly extensive areas of saltmarsh can reduce the impact of storm surges (the increase in water level caused by low pressure storm systems) by increasing the friction acting on the surge as it propagates into an estuary. This mechanism is broadly similar to that which attenuates wave energy, albeit at a much larger scale. Restoration of saltmarsh via managed realignment or regulated tidal exchange in particular can reduce the impact of storm surges by reshaping the intertidal zone and creating space to accommodate larger volumes of water. This can have the effect of lowering peak water levels, reducing the risk of flooding.
- Sediment trapping: naturally functioning saltmarsh has an inbuilt capacity to trap and retain sediment in order to maintain an equilibrium elevation relative to the tidal frame (the vertical envelope between MHWS and MLWS). This makes it resilient to erosion, and capable of natural unaided recovery following erosive events such as storms.

Compared to engineered flood defences that fulfil only one function (flood protection), coastal ecosystems provide multiple ecosystem services, therefore allowing a much higher 'return on investment' than the construction of engineered defences alone.

Given their structural characteristics as relatively resistant landforms in the upper intertidal zone, saltmarshes have been shown to mitigate both high water levels and wave heights that occur during storm surge events.

As wave and tidal/storm induced flows pass over, or through, these morphologically complex ecosystems,

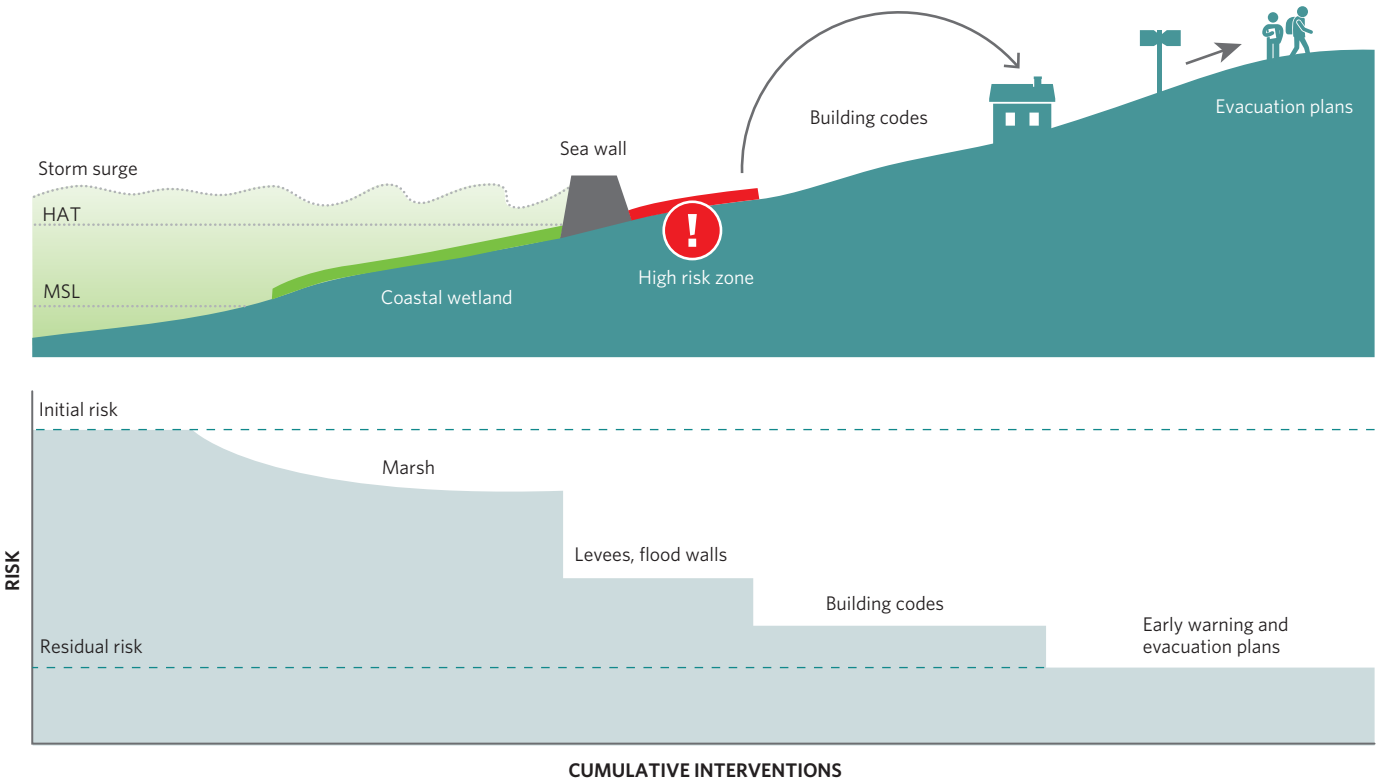


Figure 1.6: Coastal wetlands as the first of a potential range of flood risk reducing measures of coasts (MSL = 'mean sea level', HAT = 'highest astronomical tide') (adapted from Spalding *et al.* 2013).

they rapidly lose their energy through friction, drag and turbulence, particularly where the marsh platform may be dissected by branching creek systems, shallow unvegetated depressions and a dense and mature vegetation canopy (Figure 1.7).

Within the wider context of the coastal zone or estuary, these effects can result in significant changes to storm surge water levels and waves. When scaled up to an entire estuarine setting, for example, the expansion of intertidal areas can significantly lower both surge induced high water levels and wave energy.

Waves reduce rapidly in the first few metres of progressing over the marsh surface and dissipate less in deeper water depth (Figure 1.8). True-to-scale experiments in a large flume tank, have shown that natural saltmarsh can reduce the height of storm waves even under surge water depths, reducing wave heights by 18% over a distance of only 40m. Up to 60% of this reduction was attributed to the vegetation canopy alone, with the remainder due to topographic roughness (Spencer *et al.*, 2015).

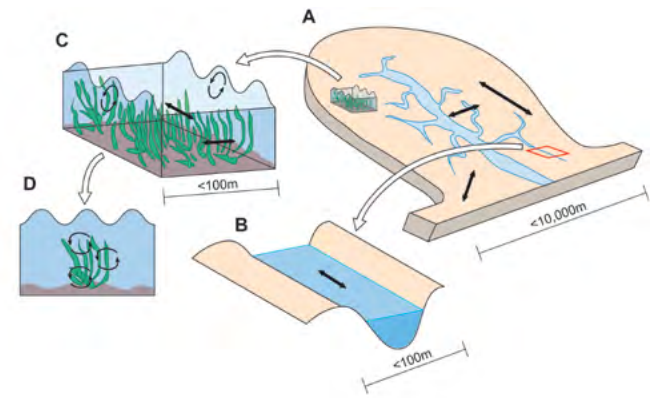
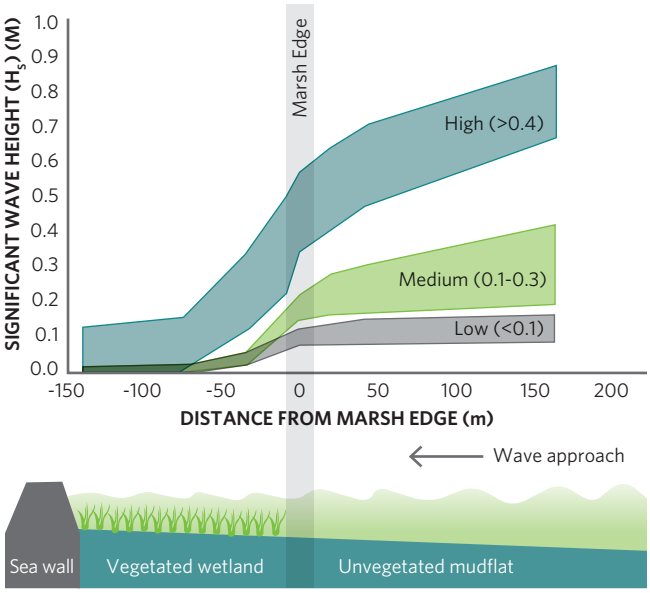


Figure 1.7: Different scales of 'roughness' and water flow through and over saltmarshes (Source: Möller and Christie, 2019).

The application of a wave dissipation model to a saltmarsh at Tillingham, Essex, UK has shown that the height of the defence embankment at this location would have to be raised by over a metre to prevent overtopping if the current saltmarsh, over 1km in width, was not present (http://www.fast-space-project.eu/). If a flood defence fails, having elevated and stable foreshore may also limit the dimensions of a breach. Research into the 1953 North Sea flood in the Netherlands concluded that the breach depth of dyke sections with stable marsh foreshores was restricted to the level of the marsh foreshore. In contrast, deep breaches developed in dykes behind bare tidal flats (Zhu *et al.*, 2020).

Faced with escalating building and maintenance costs of coastal engineered structures designed to prevent flooding, saltmarshes have been increasingly considered as alternative ways in which lives, livelihoods and habitats can be protected and sustained. A 'risk staircase' approach has been suggested, where coastal wetlands act as a nature-based first line of defence, used in combination with a range of other measures to reduce coastal flood and erosion risk (Figure 1.6). There is, however, always some 'residual risk'.



Note: the blue vertical band in the centre of the figure marks the transition to permanent vegetation on the marsh to its left; without the permanently vegetated marsh, wave heights would continue to reduce only at the rate with which waves reduce to the right of this transition.

Figure 1.8: Wave height reduction over a saltmarsh on the Essex coast, UK, for waves of 'high', 'medium', and 'low' height (approximate height given in metres in brackets) approaching the shore in different water depths (variation within the wave height bands).

Carbon uptake and storage by saltmarshes

Saltmarshes are the most widespread and important of the Blue Carbon (carbon stored in coastal and marine ecosystems) habitats outside of the tropics. They bury carbon at a greater rate, and store more carbon per unit area below-ground than their subtidal (for example, seagrass) and terrestrial (for example, forests) counterparts (Mcleod *et al.*, 2011); typical carbon sequestration rates in UK saltmarsh are 120-150gC m^{-2} yr^{-1} (Beaumont *et al.*, 2014). Saltmarshes, therefore, provide an important climate regulation service by sequestering carbon dioxide (CO_2) through burial and long-term storage of carbon (Duarte *et al.*, 2013).

Long-term carbon storage in saltmarshes is linked to:

(i) highly productive ecosystems.

(ii) depositional environments that trap carbon from both autochthonous (for example, host plant material) and allochthonous (terrestrial and/or marine) sources.

(iii) low oxygen concentrations in the sediments that promote the preservation of carbon-rich organic material.

Management interventions that protect and restore saltmarshes may therefore offer relatively cost-effective, sustainable options to halt the loss of carbon or increase carbon sequestration and long-term carbon storage. Appropriate management interventions can enhance saltmarsh carbon sinks and deliver new climate mitigation policies, while still yielding multiple ecosystem service benefits (McKinley *et al.*, 2020).

Little work has been done on the greenhouse gas fluxes from restored saltmarshes in the UK. Inland wetlands tend to undergo a process called methanogensis where high levels of methane are produced through microbial activity. High sulphur concentration in saltmarsh sediments tend to suppress methanogenesis, therefore avoiding the problem of methane emissions offsetting CO_2 sequestration. Burden *et al.* (2013) found almost no methane or nitrous oxide released from natural saltmarsh or managed realignments (neither at high or low elevations). However, Adams *et al.* (2012) found that both natural saltmarsh and managed realignments were small sources of methane and nitrous oxide, and that this was sufficient to reduce carbon sequestration rates by around 25%. The 'IPCC Wetland Supplement Tier 1 methodology' (see Box 1.4) sets methane emissions to zero for all coastal wetland sites with salinity >18psu. Updates to the 'Verra VM0007 REDD+ Methodology Framework' in late 2020, also highlight that Blue Carbon project activities can "increase salinity to reduce methane emissions" to derive verified carbon gains. Tidal inflow and resultant salinity fields could be factored in to site selection and project design with this >18psu target salinity to maximize the net blue carbon gains where appropriate.

BOX 1.4: POTENTIAL FOR INCLUDING SALTMARSH HABITATS IN THE UK GREENHOUSE GAS EMISSION INVENTORY

Anthropogenic greenhouse gas (GHG) emissions and removals resulting from saltmarsh management can be included in national emission accounting under the Land Use, Land Use Change and Forestry (LULUCF) sector. However, they are not included in the UK GHG inventory (GHGI) at this time due to a lack of robust data. The Intergovernmental Panel on Climate Change (IPCC) Wetland Supplement (IPCC, 2014) details expanded guidelines for the quantification and accounting of GHG emissions and removals associated with the management of different wetland types, including drainage, rewetting, revegetation and creation of tidal marsh and extraction from tidal marsh. Inclusion of the management of saltmarshes in the UK greenhouse gas emission inventory would reflect the impact of current efforts to protect and restore these long term carbon stores, allowing to account for their impact toward UK's climate change mitigation commitments under the Paris Agreement and the carbon budgets established under the UK's Climate Change Act. Further monitoring work will be required to establish UK specific emission factors for carbon sequestration from such restoration schemes and analyses of existing records to reflect the impact of other anthropogenic activities on tidal marshes since 1990.

Water quality impacts of saltmarshes

When occupying areas within sheltered water bodies, such as within estuaries, coastal embayments or backbarrier settings, saltmarshes can play a particularly important role in regulating water quality. For example, saltmarshes can reduce high nutrient levels as the ecosystem takes up inorganic nutrients such as phosphates and nitrates. However, elevated nutrient levels can also negatively affect and reduce future resilience of saltmarshes.

Saltmarshes can also significantly reduce faecal organism concentrations and absorb heavy metals such as mercury, cadmium and uranium from the water, thereby improving water quality.

PROVISIONING SERVICES OF SALTMARSHES

Saltmarshes are highly productive ecosystems supporting rich communities of salt tolerant (halophytic plants). They provide important resources and habitat structures needed for bird breeding, wintering and migratory staging, as well as important fish nursery grounds. Marine invertebrates are found in high abundances in these habitats, and in turn provide a food source for other species such as birds and fish. Even terrestrial species like voles and other small mammals will enter saltmarshes to forage.

One of the direct provisioning benefits derived from saltmarshes is that they often provide important grazing grounds for sheep and cattle. There is also a market for saltmarsh-grazed meat, referred to as saltmarsh beef or lamb, often marketed as naturally reared on local saltmarsh. In addition to being used for grazing, samphire (also known as glasswort or *Salicornia maritima*) is a saltmarsh plant that is often harvested, sold and eaten as a local delicacy. Samphire was also traditionally used as part of the glassmaking industry where, when burned, its ashes were an important source of sodium used in the glassmaking process. In harnessing these provisioning benefits, the functioning of saltmarshes themselves may be affected. It is important to bear this in mind when embarking on saltmarsh restoration. For example, overgrazing can be particularly impactful and affect other ecosystem services negatively by reducing sward height and carbon storage.

It is well recognised that intertidal marshes provide important nursery and rich feeding areas for young fish, such as sea bass and herring. In addition to fish, commercially important shellfish such as mussels and oysters may also make use of saltmarsh habitats. During the crucial early development stage, such habitats play an important role in early growth and survival of some species, and consequently an important role in the recruitment process. The water within a saltmarsh is often not deep enough for larger fish to risk entering, particularly during daylight, for risk of being stranded or preyed on by birds. Young fish, however, use the marsh as cover, foraging around the stems of plants. Large shoals of fry can be observed within sites moving with the tide, often on the edge of the tide/land interface.

Standing water at low tide, either in the form of old drainage channels or ponds, can contain large numbers of fish, acting as brackish lake systems, offering continuous refuge and food cover over each tidal cycle.

BOX 1.5: SURVEYS OF JUVENILE FISH USING SALTMARSHES

At Abbotts Hall, Blackwater Estuary, UK, Colclough *et al.* (2005) captured around 2,000 0+ year group herring (*Clupea harengus*) at low tide in one seine net haul from an old freshwater ditch. Similar results were found at Freiston Shore, UK, where the site acted as a nursery area for a range of different fish species, including economically important bass (*Dicentrarchus labrax*), sprat (*Sprattus sprattus*) and herring. Gut analysis of juvenile fish using Freiston Shore showed the site provided a nursery habitat throughout the entire tidal cycle, with the continuous utilisation of permanently flooded channels and food resources within these waterbodies. This study suggests that constructing additional areas of standing water within realignment sites would enhance the quality of this habitat for juvenile fish. Creating additional water bodies would increase available habitat beyond the period of spring tide inundation at a site, therefore decreasing competition for food resources and promoting enhanced growth rates and survival.

Figure 1.9: Fish monitoring using a seine net at Two Tree Island, Thames. Photo: Essex Wildlife Trust.

Saltmarsh systems are particularly important in supporting nationally and internationally important bird species, many of which are in decline. Saltmarsh habitats can provide important resources and habitat structures needed for bird breeding, wintering and migratory staging, sometimes supporting huge populations of wintering wildfowl.

The EBCC/BirdLife/RSPB/CSO (2017) report a decline in numbers of 45% since 1980 for at least six of the European lowland bird species found on saltmarshes. Saltmarsh is the primary breeding habitat for redshank (*Tringa tetanus*) in the UK, for example, with over 18% of the northwest European breeding population residing in Britain. Saltmarsh redshank populations have, however, declined by 53% between 1985 and 2011 at a rate of 1 pair per km^2 per year (Malpas *et al.*, 2013). Such decline may be due to a number of factors that do not necessarily relate to saltmarsh/intertidal area or condition, but it can be argued that the availability of intertidal habitat is an important necessary condition for the survival of important bird species.

Figure 1.10: Shelduck (*Tadorna*) feeding at Steart managed realignment, England. Photo: Hannah Mossman.

CULTURAL SERVICES

Recent work demonstrates a strong link between the natural environment and psychological well-being, including sense of self, perceived health, cognitive restoration, relief from stress and social relationships (Willis, 2015).

A clean environment, attractive countryside and biodiversity can also play a role in people's choice of where to live or spend their spare time.

Health and well being

Increasingly, the human health and well-being aspects of 'blue-green' spaces in general (naturally dynamic coastal landscapes) as well as saltmarshes in particular, are being explored. Evidence suggests that the health and well-being benefits of people's connections to saltmarshes are significant (McKinley *et al.*, 2018; Rendón *et al.*, 2019).

Human well-being refers to positive physical, social and mental conditions, not just the absence of disease. It is generally recognised that there are 7 aspects to human wellbeing:

- Health (for example, exercise, mental wellbeing).
- Connection to nature and 'sense of place'.
- Spiritual and cultural (historical connections, religious symbolism).
- Social cohesion (participation in recreational events, volunteering, wild food gathering).
- Life satisfaction and happiness.
- Living standards (for example, education).
- Safety and security (for example, flooding, climate change, military ranges).

The links between ecosystem services and human well-being can be complex, are often subtle, frequently understudied, and cut across other services. For instance, wild food can refer to local resident groups foraging for samphire (*Salicornia*), but also to commercial fisheries (for example, shellfish) that are sold locally or further afield. In this example, wild food foraging is linked to social cohesion with a low impact, while commercial fisheries are linked to living standards and may have a high impact.

On the aesthetic side, inspiration and stimulation have been identified including visual, aural, tactile, and olfactory; a sense of place or of wildness and wilderness. This provides an inspiration for art and artists; painting and photography, books and literature, poetry, song and dance performances. Some of these are done at a personal level (for example, sketching) or at a more transactional scale (for example, arts and crafts sold to tourists).

The spiritual and heritage aspects impact on human health in ways invoked from memories, peace, solitude, emotional healing, folklore, TV and radio and films. Cultural and natural heritage sometimes also requires an awareness of a site's importance or archaeology, which may be revealed through formal or informal education. Saltmarshes provide many educational resources at all academic levels and disciplines.

Tourism and recreation

Saltmarshes and mudflats predominantly attract visitors with an interest in natural history. A new nature reserve, created in 2002, provided public access to The Wash, attracting more than 50,000 visitors in its second year of opening, who spent an estimated £500,000 locally on food and services (Jones 2011). Activities, including bird (and other wildlife) watching, wildfowl hunting, fishing and water sports are particularly popular, in addition to walking and dog walking, angling, and just relaxing. The intertidal zone is rich in archaeology, including shipwrecks and settlements, which is well-preserved by sediments (eftec *et al.* 2006).

THE DECLINE OF SALTMARSHES

As saltmarshes are typical of low-lying coasts, they are often found adjacent to areas of intense human land-use. In these types of settings, the extent and value of saltmarshes are at risk, with land claim and drainage associated with conversion for development or intensive agriculture resulting in saltmarsh loss and habitat degradation. Some saltmarshes have also been damaged by inappropriate grazing, roads, paths and tracks, historical landfill activity, and cable lay and pipeline operations. Pressures on saltmarshes may be exacerbated in future by climate change, accelerated sea level rise, altered storm conditions and coastal squeeze (see Boxes 1.6 and 1.7). While estimates of the exact losses vary, one scenario predicts that as much as 4.5% of saltmarsh could be lost over a 20 year period due to sea level rise. These trends have been extrapolated in Table 1.1 which contains estimates of the extent of saltmarsh across the UK and provides a rough estimate of potential losses by 2060. Equivalent saltmarsh extent estimates have not been calculated for the Republic of Ireland at the time of writing. Instead, Table 1.2 contains a summary of changes to saltmarsh habitats between 2008 and 2018, showing that many saltmarsh habitats are under pressure with future losses predicted.

Table 1.1: Projected saltmarsh area loss for the UK, 2010-2060 (Office of National Statistics (ONS), 2016).

	AREA SALTMARSH (HECTARES)		PROJECTED LOSS (HECTARES)
	2010	**2060**	**2010 – 2060**
UK	46,631	41,369	5,262
ENGLAND	33,572	29,795	3,777
NORTHERN IRELAND	244	216	28
SCOTLAND	5,865	5,190	675
WALES	6,950	6,168	782

Note: Estimating saltmarsh area change over time is a challenging process as methods of assessment have changed over time; these estimates provide a very rough approximation of loss due to sea level rise and are based on simple extrapolation of short-term trends.

An image of the saltmarsh near Llandonna in bloom, Anglesey, May 2016. Photo: Nigel Pontee, Jacobs.

The status of saltmarshes in the UK and Ireland has been assessed in accordance with the Water Framework Regulations of each country and for Article 17 reporting under the Habitats Directive. Article 17 requires European Union Member States to report every 6 years about the progress made to implement the Habitats Directive (the UK will continue to monitor saltmarsh within National Site Networks and publish reports). The Article 17 Habitats Directive report for the UK in 2019 concluded that saltmarsh habitats, including *Salicornia* and Atlantic salt meadows, are in overall unfavourable conservation status, with decreasing or deteriorating short term trends. Article 17 assessment results for the Republic of Ireland are summarised in Table 1.2, and Perrin *et al.* (2020) report that the loss of saltmarsh in some estuaries, such as the Ballyteige Channels and Bridgetown Estuary in Ireland, has led to 'bad' Water Framework status classifications for saltmarsh area and a correspondingly low status overall for these estuaries.

Table 1.2: Summary of status of Habitats Directive Annex I saltmarsh habitats in the Republic of Ireland. For more detail see Brophy *et al.* (2019).

SALTMARSH ANNEX 1 HABITAT	LATEST CONSERVATION ASSESSMENT	CHANGE BETWEEN 2008 AND 2018 SURVEYS
1310 *Salicornia* mud	Favourable	Extent changes at some surveyed sites, but this is a naturally dynamic habitat expected to fluctuate from year to year.
1330 Atlantic salt meadows	Unfavourable-Inadequate	Overall assessment is unchanged, but the trend has changed from 'stable' to 'deteriorating'. This change in trend is due to losses in area, which are expected to continue into the future. Loss was noted at a number of sites, relating to infilling/reclamation, extraction of saltmarsh material for use in embankment repairs, and damage from over-grazing or the operation of vehicles.
1410 Mediterranean salt meadows	Unfavourable-Inadequate	Overall assessment is unchanged, but the trend has changed from 'stable' to 'deteriorating'. This change in trend is due to losses in area, which are expected to continue into the future. Losses mainly related to succession of habitat to swamp.
1420 Halophilous scrub	Unfavourable-Bad (deteriorating)	Overall assessment is unchanged. Loss of habitat recorded at one site and attributed to eutrophication and smothering by algal mats.

BOX 1.6: SEA LEVEL RISE AND COASTAL SQUEEZE

The term 'coastal squeeze' is commonly used to describe the loss of coastal habitats in front of sea defences. Coastal squeeze has not always been defined in a consistent way and there have been problems quantifying historic habitat loss and predicting future impacts of coastal squeeze. This is particularly relevant where there is a legal obligation to compensate for the impacts of maintaining coastal flood management infrastructure or management activities that could lead to coastal squeeze. Compensation in these cases has normally involved creating new habitat.

In this handbook we are using the following definition taken from the Environment Agency report: 'What is coastal squeeze?' published in 2021:

https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/what-is-coastal-squeeze

"Coastal squeeze is the loss of natural habitats or deterioration of their quality arising from anthropogenic structures or actions, preventing the landward transgression of those habitats that would otherwise naturally occur in response to sea level rise (SLR) in conjunction with other coastal processes. Coastal squeeze affects habitat on the seaward side of existing structures."

SLR can potentially bring about changes to saltmarsh in a number of ways, including:

- increased wave attack, leading to erosion of seaward edges of habitat.
- increased inundation of habitats, leading to changes in habitat zonation (including extent, position and type). This may result in high marsh communities being progressively replaced with lower marsh communities.

The behaviour of habitats in the coastal zone in response to SLR depends very much on the availability of sediment in relation to the driving forces such as SLR and wave activity. When investigating reasons for saltmarsh loss, there may be a number of contributory factors involved. It is important to consider whether observed changes in saltmarsh habitats are part of a progressive long-term trend or a shorter cycle. The width of the coastal zone and its component habitats can vary over time and between locations.

BOX 1.7: POSSIBLE ENVIRONMENTAL CHANGE CHALLENGES FOR RESTORING RESILIENT SALTMARSH SYSTEMS

(adapted from Natural England (2020) Climate Change Adaptation Manual – Coastal Saltmarsh)

CAUSE	CONSEQUENCE	POTENTIAL IMPACTS
SEA LEVEL RISE (SLR)	Altered coastal dynamics and sediment transport.	A rise in sea levels may cause loss or reduction of saltmarsh area unless: • rates of vertical accretion can keep pace with SLR. • there is space for inland migration of saltmarsh.
	Increased frequency of inundation and water-logging.	Increased area of exposed mud may lead to: • greater susceptibility to invasive plants and erosion. • impacts on soil processes and community composition.
	Wave heights may increase near the saltmarsh causing erosion.	Increased rates of lateral marsh erosion/erosion at the seaward edge. Increased fragmentation and internal dissection as creeks erode.
	Potential need for new or higher standard sea defences.	Defences may directly encroach on saltmarsh or impact marshes through changes to sediment dynamic.
HOTTER AND/OR DRIER SUMMERS	Increased evaporation. Drought.	Community composition may change as conditions become unsuitable for some marsh plant species but may promote others, for example, *Spartina*. Drought may cause vegetative dieback in upper zones of saltmarsh.
INCREASED STORM SURGE FREQUENCY/INTENSITY	Alter cycles of accretion and erosion.	May lead to long-term lateral erosion and loss of saltmarsh if the marsh does not have time to recover between storm events. Storms can also deliver large volumes of sediment to the saltmarsh.

HOW CAN WE RECREATE OR RESTORE SALTMARSHES?

Restoration and creation of saltmarsh habitat to replace that which is being lost and degraded is becoming increasingly important to increase the existing ecosystem's resilience and ability to adapt to environmental change.

BOX 1.8: WHAT DO WE MEAN BY RESTORATION AND CREATION?

It is important to distinguish between restoration and creation and also actions and interventions that are aimed at preventing loss (i.e. erosion prevention or management intervention to prevent ecosystem degradation).

Early policy literature largely refers to 'habitat creation'. Habitat creation brings with it the dangers of trying to establish saltmarsh where it has not been present historically. Creation may be possible in certain circumstances and with considerable effort (and cost), but there is usually a good reason for the absence of saltmarsh in areas where there is no record of it being previously. In these situations, surface elevation, sediment and hydro-dynamic conditions are unlikely to allow saltmarsh seeds to establish, grow and build a viable and resilient habitat.

Many low-lying coastal areas are the product of centuries of land claim, estuarine and intertidal zone modifications (Figure 1.11). Therefore many, perhaps the majority, of coastal management schemes on low-lying coasts are best described as 'habitat restoration' towards some prior state.

Three key points are important to consider in thinking about the 'prior state' that restoration efforts may aim to achieve:

(i) the context (sea level, tidal regime, sediment availability, climate) within which the lost or degraded ecosystem originally formed is likely to have changed.

(ii) coastal habitats both respond to fluctuations in waves, tides, sea level, and sediment washed onto them but also influence those very processes as they capture or release sediment themselves and occupy space around which tides and waves move as part of a feed-back loop.

(iii) restoration may only be implementable within current policy and societal contexts if particular restoration objectives are met (restoration actions may be determined by whether the aim is to restore for carbon mitigation, biodiversity, or coastal protection).

It is also imperative that interventions work towards achieving a future state of the coastal system that accommodates challenges such as climate change, sea level rise, and changing temperature/rainfall regimes as much as possible.

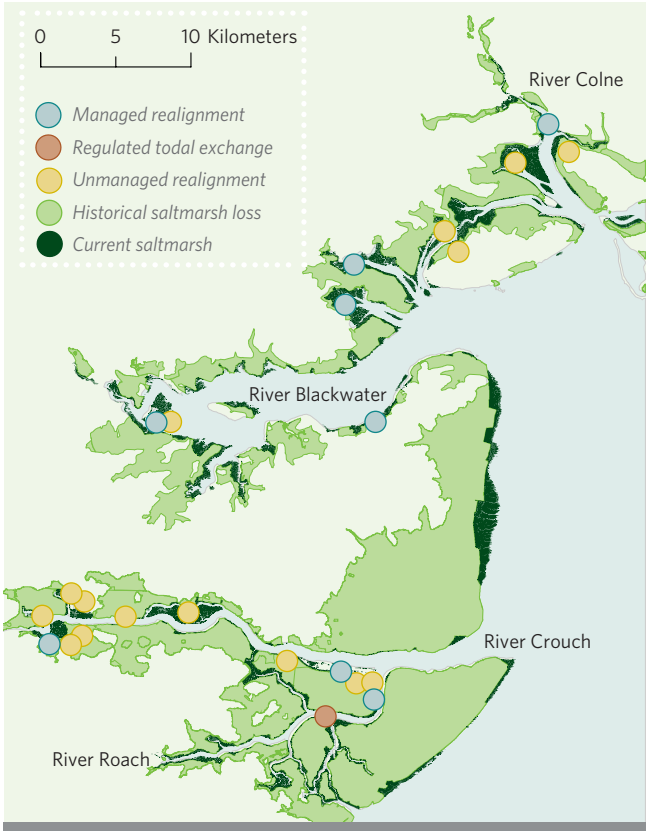


Figure 1.11: Land reclamation history and habitat restoration activities on the Essex coast, UK. *Managed realignment and regulated tidal exchange refer to active intervention procedures (See Chapter 5), unmanaged realignment indicates a scenario where an old sea wall or boundary has been overtopped and left to deteriorate.*

Sea level rise means that restoring saltmarsh landward of current coastal protection structures is most likely to lead to the emergence of a well-functioning wetland. This means, however, that land that is currently used for other purposes needs to be made available. To achieve such land use conversion, it is imperative to work with local communities and all stakeholders (see Chapter 4 'Communication and Engagement').

As schemes increase in size, their connectivity to adjacent tidal areas may raise concerns about the impact they are likely to have upon the larger-scale coastal system within which they sit. It is therefore essential that the wider physical, ecological, and human context, and the role of the 'to be restored' wetland are considered before any restoration plans are progressed.

RESTORING RESILIENCE

As saltmarshes are three-dimensional landforms formed by the interaction between biological, chemical and physical processes, their longevity depends on them maintaining (a) their vertical elevation within the intertidal zone and (b) their horizontal surface area.

To maintain the height of the saltmarsh surface relative to sea level rise, any sediment that deposits on the surface needs to form a thick enough layer when compacted so that the surface can 'keep pace' with relative sea level rise. Interpretation of a simple

sedimentation deficit or surplus measured over short (≤ annual) timescales as an indicator of vulnerability to sea level rise ignores the complexity of marsh response that arises over longer (> annual) timescales from the linkages represented in Figure 1.4.

To restore a fully functioning saltmarsh system, tidal and wave dynamics affecting the system at its most seaward or channel-ward limit must also be considered. Such information is not easily derived from distant wave or water level gauges, given the high level of modification of either within shallow water (Mossman *et al.*, 2011).

While marshes in many locations appear to have maintained their elevation relative to sea level vertically, they have suffered areal loss. This suggests that pressures at their seaward/estuarine channel restrict saltmarsh growth or are causing erosion. Such pressures may be imposed when external conditions change (for example, tidal channels migrate, tidal currents increase, or boat-generated waves become more frequent) or when marsh growth reaches inbuilt thresholds that prevent further growth (for example, encroachment onto a steeper foreshore with exposure of the marsh fringe to higher wave/tidal energy). Frequent 'channel switching' on the tidal flats in Morecambe Bay, UK, for example, has been associated with phases of saltmarsh advance and retreat, such as can be observed at Warton (Figure 1.12).

It is important to appreciate that the persistence of saltmarsh is not simply threatened by sea level rise but by a multitude of controls, including sediment supply, wave and tidal energy, and the dynamic coast around it that all determine the marsh's future. It is therefore, entirely possible that a saltmarsh is able to maintain its elevation relative to sea level but will be heavily eroded at the seaward margin or, if in a back-barrier setting, lost due to barrier 'roll over'. To restore resilient saltmarshes (Figure 1.13), all of these potential controls and any self-regulatory mechanisms, as well as all of the services they provide to society need to be considered.

Figure 1.12: Eroding marsh fringes in clay/silt rich marsh systems on the UK east coast (top) and the more sandy Morecambe Bay marshes (bottom). Photo: Iris Möller.

To date the majority of recreated saltmarsh habitat is found in the context of managed realignment (See Box 1.9 and Figure 1.14). However, there are a range of approaches for recreating/restoring marsh which are explored in more detail in Chapter 5.

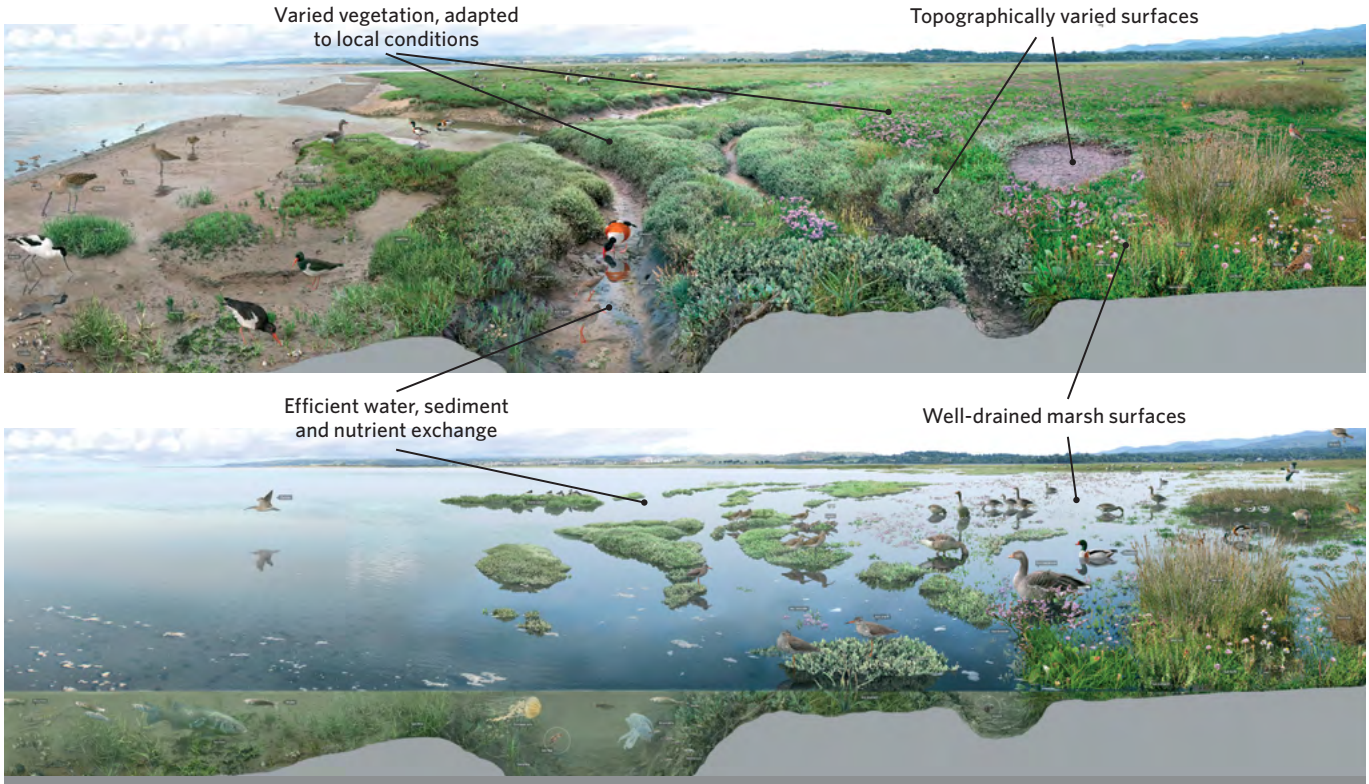


Figure 1.13: Key characteristics of resilient and well-functioning saltmarsh systems. Illustrations: Toni Llobet (@tonixllobet).

Table 1.3: Range of approaches for restoring saltmarsh.

HIGH LEVEL TARGET	POSSIBLE APPROACHES	EXAMPLE
Protecting and restoring existing habitats	Planting saltmarsh species Sediment trapping/fencing Wave protection Intertidal recharge	Eden Estuary, Scotland German and Dutch Wadden Sea Dengie Peninsular, England Allfleet's Marsh, England
Realigning defences	Managed realignment No active intervention and unplanned breaches Regulated tidal exchange Tidal flood storage	Medmerry, England Cwm Ivy, Wales Morecambe Bay, England Alkborough, England

BOX 1.9: MANAGED REALIGNMENT

Managed realignment refers to the breaching of existing coastal embankments originally constructed to allow saltmarsh to be converted to agricultural land. Much of the restoration in the UK and Ireland has so far been achieved by the re-introduction of tidal waters onto former intertidal areas lost due to historical land claim. By 2018, 50 managed realignment schemes had been completed in the UK (see Figure 1.14), creating almost 2500ha of habitat, of which 72 % can be classified as intertidal in nature (ABPmer, 2017). In addition, 24 regulated tidal exchange projects have been completed, creating a further 300ha of coastal habitat, as well as 18 restoration projects involving sediment recharge through the beneficial use of sediment routinely dredged from ports and harbours (ABPmer Online Marine Registry, 2014).

From the mid-2000s, schemes began to increase significantly in size. The three recent projects at Medmerry, Steart and Wallasea Island have created over 1,000ha of habitat alone, almost 40% of the total area of habitat that has been restored in the past three decades. Managed realignment in Ireland has been restricted to three sites totalling 48.5ha, but unintentional breaching of embankments around former saltmarsh areas has led to a number of unmanaged realignment sites (Perrin *et al.*, 2020).

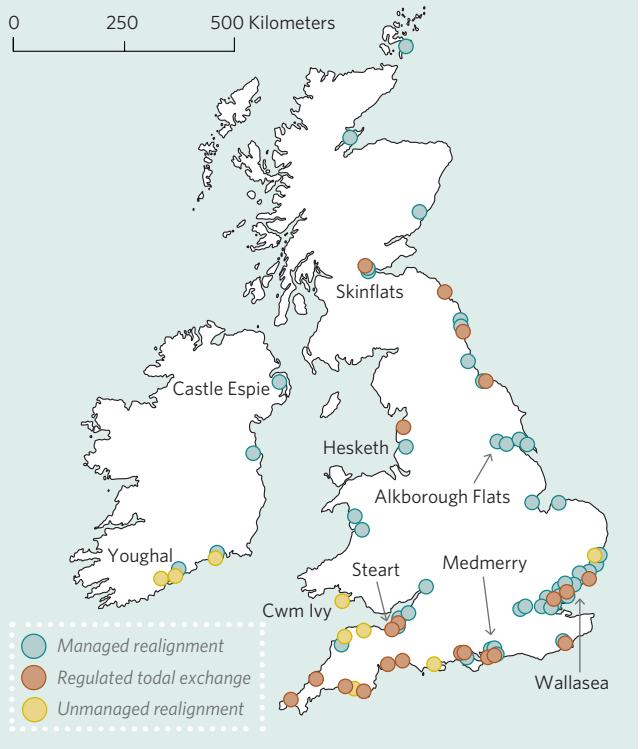


Figure 1.14: The distribution of managed and unmanaged realignment sites, regulated tidal exchange sites and sites receiving beneficial use of dredged sediments in the UK and Ireland. Sources: OMReg Habitat Creation Scheme Database – ABPmer and Perrin (2020).

FURTHER READING

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CHAPTER 2
GETTING STARTED

CHAPTER AUTHORS
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KEY SUMMARY POINTS:

- **Before starting a restoration project a comprehensive feasibility study and site selection process is recommended.**
- **Setting clear goals and targets for restoration projects enables success and progress to be measured, and the purpose of the project to be clearly communicated.**
- **Communicating the benefits of saltmarsh restoration can help to justify a project and apply for funding.**

INTRODUCTION

The project planning phase is critical for successful restoration schemes. This chapter provides a practical guide to starting a saltmarsh restoration project, from choosing a site to selecting design options that can best meet project targets, and potential funding streams.

Understanding what consents might be needed and who to engage are equally important to the project planning stage and guidance on these topics is provided in Chapter 3 and Chapter 4.

SETTING RESTORATION GOALS AND OBJECTIVES

Project goals and objectives will depend on the reason(s) for the project and may also depend on funding sources. It is helpful to define clear targets for the restored saltmarsh: for example, what size, species, habitat types and functions are the desired outcomes of the project? Within this process, it should be realised that:

- it takes time before the sedimentary processes, saltmarsh plants and animals become established.
- the area may not develop the same as a natural saltmarsh would.
- saltmarsh naturally undergoes succession, interim habitats are valuable too, but may not be aesthetically attractive to all stakeholders.

Clear and agreed targets will help to focus site selection and project planning, manage the expectations of stakeholders and provide a framework against which the success of the project can be measured and monitored.

BOX 2.1: DEFINING TARGETS, GOALS AND OBJECTIVES

Project Target: This describes the site and ecosystem to be restored and is broad, general and should be inspiring.

Goals: A project will normally have several goals, and these describe the level of recovery and outcomes desired, both in social and ecological terms. Goals are open, can be discussed and agreed upon with stakeholders.

Objectives: These are specific and discrete measurable outcomes or changes that are needed to achieve each goal. Objectives often relate to distinct aspects of the site or project time frame and are useful tools to assess progress and manage the restoration project.

CHOOSING A SITE

Selecting a site for restoration can be a complex and time consuming process, but it is critical in helping determine the success of the project. There is no single answer as to how to select the optimum site, but the following sections provide guidance on a number of key considerations and necessary processes to follow.

SITE SEARCH/IDENTIFICATION

When searching for potential sites, or assessing the suitability of a site, it is important to first consider baseline biological, physical and operational conditions. Some information will be available from the websites listed below. Where information is lacking, it will be necessary to carry out bespoke surveys to collect the data required to assess the suitability of a site.

Table 2.1: Data and information important to consider during the search for a site.

CHARACTERISTIC	CONSIDERATIONS	KEY SOURCES OF DATA AND INFORMATION
Existing habitats and species	The presence/absence, condition, extent and range of species present, including presence of non-native invasive species, can provide useful indicators of the suitability of conditions at a site for further restoration. Protected and rare species or habitats may be on site (or nearby), impacts on which would need to be considered (see also 'Environmental designations' below.	UK: National Biodiversity Network – https://nbn.org.uk/ Biodiversity record/data centres Defra's map portal MAGIC – https://magic.defra.gov.uk/ England: the CaBa Coastal Data Explorer Scotland: GOV.SCOT; Scotland's Environment Map Wales: the Welsh Government's geo-portal Northern Ireland: DAERA map viewers; Spatial NI Republic of Ireland: National Parks and Wildlife Service maps and data page
Known pressures impacting habitats	Where existing habitat is in poor or deteriorating condition, consider the reasons for this, for example, water quality/pollutants and erosion. This can help determine the optimum location and design for restoration. If a site is covered by an environmental designation, it is likely that this information may be available in the form of site condition assessments.	Condition assessments for designated sites may provide information on condition. England: Threats and pressures to designated sites are listed in, https://designatedsites.naturalengland.org.uk/ Where available, comparing historical and current saltmarsh maps can provide insights on rates of erosion; as can comparing different years of remote sensing data.

CHARACTERISTIC	CONSIDERATIONS	KEY SOURCES OF DATA AND INFORMATION
Coastal processes, geomorphology and natural constraints	It may prove difficult to effectively restore or create sustainable new saltmarsh in locations with: • insufficient supply of fine sediment. • lack of available accommodation space at suitable elevations high wave exposure (and therefore erosion of fine sediment). Check that physical characteristics are suitable for saltmarsh creation or restoration. Saltmarsh generally occurs between the MHWN and MHWS tidal datums in areas which are sheltered from wave action and receive an active supply of fine sediment. Sites up to the HAT tidal datum are often also considered 'transitional saltmarsh zones'. Remote sensing data (notably Light Detection and Ranging (LiDAR)) could be interrogated to gain insights into likely (or current) site zonation.	England: The MMO Saltmarsh Potential map (see Figure 2.1) identifies floodplain sites that could be physically suitable for saltmarsh creation, primarily through managed realignment or regulated tidal exchange techniques, available on the CaBa Coastal Data Explorer. Wales: A saltmarsh potential map has been produced but is not published at the time of writing. Armstrong *et al*. (Report 'in preparation'). Scotland: http://www.dynamiccoast.com Tide levels: Admiralty tide tables (UK). Very location specific. Find nearest station and convert chart to ordnance datum. LiDAR: Defra survey data platform (England); the Welsh Government's geo-portal; Scottish remote sensing portal; Open Data Northern Ireland; Ireland's Open Data Portal.
Environmental designations and heritage protection	Intertidal restoration projects may impact on adjacent, or on site, freshwater habitats/ species, which can lead to compensation or mitigation requirements. Look for both national and international designated sites, for example, Special Area of Conservation (SAC) or Special Protection Area (SPA). Ensure that restoration will not detrimentally effect the Water Environment status of the waterbody in question. Check if there are scheduled ancient monuments or other historic features to consider.	UK: Defra's map portal MAGIC Water Environment: country explorers (for example, Water Watch Wales, Catchment Data explorer, England). Republic of Ireland: National Parks and Wildlife Service maps and data page; EPA Maps (Protected areas & Water Environment). Historic England: https://historicengland.org.uk/listing/the-list Historic Monuments Scotland: https://www.historicenvironment.scot/ Wales: https://cadw.gov.wales/
Existing management regimes	Consult landowners and any local management plans or strategies to check whether restoration could conflict with existing activities. Check that land is not subject to existing agri-environment agreements or other agreements.	For England and Wales, consult the relevant Shoreline Management Plan and for all nations consider the wider landscape context.
Availability and cost of land	Where restoration requires the purchase of land (for example, for managed realignment projects), the availability and cost of land will invariably influence the site(s) being considered. It may sometimes be possible for landowners to secure payment for restoration activities through the Environmental Land Management Schemes.	Potential funding streams are discussed later in Chapter 2 in 'Funding streams.

CHARACTERISTIC	CONSIDERATIONS	KEY SOURCES OF DATA AND INFORMATION
Infrastructure constraints	Key infrastructure such as major roads and above or below ground utilities may restrict or prevent saltmarsh restoration in certain locations. Check if there is the potential for new or restored marsh to interact with public rights of way such as the England Coast Path.	Contact/consult websites of local councils and organisations responsible for highways, utilities and public rights of way.
Historical use of land	It is important to identify historical land uses of potential sites. Activities which may have polluted the soil are a particular issue, for example, historical landfills or sites used for the storage of hazardous materials. In some locations, industrial waste materials have even been used for the initial land claim itself (so may be present in the seawall). Unexploded ordnance may also be present/ buried.	Contact/consult local councils. Historical landfill sites in England, Scotland and Wales: https://data.gov.uk/
Societal attitudes	Where a change in land use is required to restore or recreate saltmarsh, for example through managed realignment, it is common to meet a certain amount of resistance among local people and it is important to identify and understand the root cause of these issues. Effectively communicating the multiple benefits saltmarsh provides, in particular its flood risk, socio-economic and climate resilience importance, can help to address negative perceptions. Community and stakeholder buy-in is critical for effective restoration, meaning communication with local people and businesses should be an ongoing component of restoration projects (and start as early as possible).	Chapter 4 contains further information.
Habitat connectivity	In heavily constrained locations, such as urbanised estuaries with extensive historical intertidal loss, all remaining fringing saltmarsh may be at risk of loss due to coastal squeeze under current sea level rise projections. In such scenarios, it can be tempting to focus on identifying the few remaining opportunities for large scale restoration or creation of new saltmarsh (for example, large managed realignment sites). However, where possible, it is advisable to aim for multiple pockets of restoration across the length of the estuary, rather than effectively relocating habitat into a single location. Spreading out restoration sites in this way improves the ecological connectivity of the system by creating corridors of habitat. This helps flora and fauna to migrate up- and downstream, for example, by providing shelter for fish during periods of high flows. In practice, the optimum approach in these situations is to realign defences and create accommodation space for marshes to migrate, but where this is not possible, you should consider connectivity as a parameter when selecting a site(s).	Estuary edges project website: https://www.estuaryedges.co.uk/ Chapter 5, 'Urban fringes'.

Figure 2.1: Map of locations in England potentially suitable for intertidal habitat creation using managed realignment and/or regulated tidal exchange techniques. Source: https://data.catchmentbasedapproach.org/datasets/432e71d9c0db44f6a3231cadfca30805_0?geometry=-22.788%2C50.667%2C19.026%2C55.291

Saltmarsh Fringe. Photo: Iris Möller.

PROJECT PLANNING

Once a site has been chosen, and land either purchased or secured, the project planning phase can commence. How this is approached depends on a number of factors, including who is carrying out the project, the reason(s) for the scheme, as well as the project size and location. However there are a number of typical steps, which are shown in Figure 2.2 and described in the sections below. The time needed for the project design and pre-restoration tasks should not be underestimated. These phases typically account for a significant proportion of the overall project time. This is especially true for some small-scale projects where the implementation stage may be relatively quick to complete once the earlier planning work has been carried out (Figure 2.3).

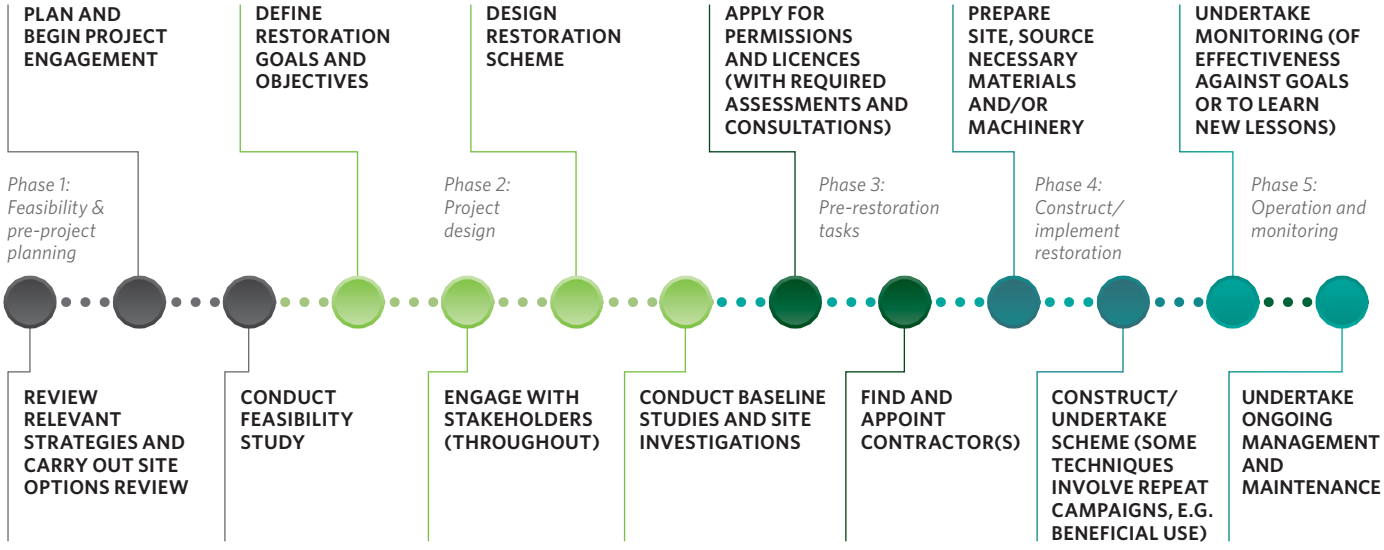

Figure 2.2: Typical saltmarsh project progression.

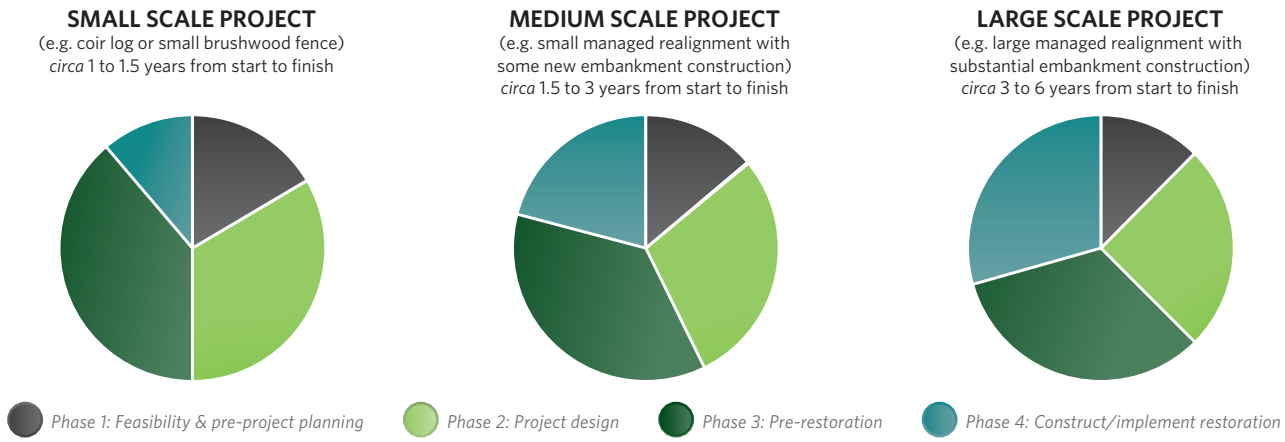

Figure 2.3: Saltmarsh project timeline wheels to show the relative proportion of time spent on phase 1 to 4 of saltmarsh restoration.

FEASIBILITY STUDY

Typically, a **feasibility** study would be carried out (before land is purchased or secured, where this is necessary), as follows:

1. Establish if saltmarsh creation/restoration is possible within the desired location(s). This typically involves applying expert judgement, while using readily available data. It would also serve to highlight, at a high level, if there are significant ecological, logistical, legislative or financial barriers to restoration (see earlier section on 'Choosing a site').
2. Develop initial ideas on possible design options/ concept designs which can work given the local conditions. Preliminary modelling can be beneficial, for example, where there is substantial concern that implementing a scheme in a given estuary may unduly impact existing habitats.
3. Identify knowledge and data gaps and highlight essential surveys and modelling for next phases.
4. Understand who should be involved in the project (in what context and at which stage) and what consents and assessments are likely to be required (see Chapter 3 for advice on organisations, consents and assessments).

Learning from other projects and similar sites, and ideally visiting these sites, can be invaluable during this stage and is highly recommended.

BUSINESS CASE

Once a decision has been made that a saltmarsh creation project is feasible in a given location, the **business case** process can commence. Again, how this is approached very much depends on the individual project and organisation involved. For example, many managed realignment schemes are carried out by flood risk management bodies such as the Environment Agency in England or Natural Resources Wales in Wales. These organisations follow detailed guidance/established procedures for such projects, see, for example, the (2019) Welsh Government business case guidance on Flood and Coastal Erosion Risk Management (FCERM). Broadly, the approach is to:

- understand the problem.
- screen a long list of options.
- appraise a short list of options.
- identify a preferred solution.

This appraisal process is typically carried out in an 'objective-led' manner, whereby the desired and required outcomes are defined and agreed at the start of the appraisal. The ultimate success of a project is measured on its achievement of these outcomes, and the benefits associated with these.

Significant, complex or contentious spending proposals would tend to go through a three-stage business case process, and simpler projects through a short form process (often referred to as 'Business Justification'). The more complex three-stage process typically consists of going through the following steps: Strategic Outline Case (SOC), Outline Business Case (OBC) and Full Business Case (FBC). A long list of options would normally be associated with the SOC, and a short list and the identification of the preferred option with the OBC. The final stage, the FBC, would contain the market prices obtained from the procurement exercise, final conditions of any legal agreements or consents, and a completed delivery and management plan.

When assessing options, at least one 'do nothing' (or 'walkaway') option and a 'do minimum' ('business as usual') option need to be considered, as well as considering 'do something' options. This will not only allow organisations to understand the implications of withdrawing investment, but also facilitate the comparison of other factors, notably benefits and opportunities.

Pools on the Dee estuary (natural). Photo: Hannah Mossman.

DETAILED DESIGN PHASE

Once a preferred option has been chosen, the **detailed design phase** can commence (see section on 'Choosing a design' below). This should draw on a wide range of expertise. Engagement with stakeholders, regulators and the public should ideally have begun before this stage (see Chapter 4), but must be extensive during the detailed design phase. The design process will again very much depend on the type of technique that is chosen (see Chapter 5 for more detail on techniques), as well as size and location.

Consider existing habitats and species

In most areas in the UK and the Republic of Ireland, a saltmarsh restoration site will either be immediately adjacent to a designated site/Marine Protected Area, or located within one. This carries with it an added level of scrutiny and required assessment, which needs to be taken into account during the detailed design process. For example, actions may need to be taken to avoid areas designated for their terrestrial interest features, or introduce measures to protect them from tidal inundation. With managed realignment, the location and number of breaches to allow tidal inundation may need be chosen carefully in order to minimise impacts on existing valuable saltmarshes and mudflats, as well as to achieve the desired habitats on site.

On-site protected species are also often encountered, requiring detailed mitigation measures, such as new freshwater wetlands to house displaced water voles and great crested newts at managed realignment sites. Numerous other constraints may also need to be factored into the design, such as the presence of above-ground or below-ground utility infrastructure, archaeological features, and site access.

Modelling

If not already carried out during earlier stages, hydrodynamic/numerical modelling is typically required during the detailed design phase, notably with managed realignment schemes and regulated tidal exchange schemes. This helps when developing designs and testing the validity of a chosen design. Model results inform habitat predictions and are also used to reassure implementers, regulators and the wider public that impacts on the adjacent estuary or coast are relatively benign, and flood risk is not increased. Modelling, or similar tools, are also used to underpin assessments that may be required to obtain permissions and licences for saltmarsh creation schemes (see Chapter 3, 'Permitting and licensing requirements' for more detail of what assessments may be required).

Implementing a scheme

Once a project has **gained the required permissions and licences, construction and implementation** can begin. The scale of this will again be very much project specific, and may be overseen by experienced engineering consultants, where appropriate. Licence and planning conditions must be adhered to during this stage and ongoing stakeholder engagement will be important. It is imperative to ensure that the ecological design is carried out as envisaged by the engineering consultants. Engineers' design drawings should be double checked against ecological designs to ensure consistency.

After a scheme is implemented

Restoration sites involving open tidal inundation do not necessarily need ongoing management. Schemes involving regulated tidal exchange will require a degree of management and maintenance, depending on the level of automation included in the scheme's design.

Embankments may also have been included in a given design, which will need to be regularly inspected, maintained, and upgraded as necessary. Repeat campaigns may be needed where beneficial use has been carried out.

Active management can be beneficial at saltmarsh sites to increase their value for both people and nature. For example, regular footpath maintenance may be needed and selective low-intensity grazing can improve plant diversity and encourage breeding by some wading birds.

Monitoring is an important activity after a scheme is implemented. Monitoring is discussed later in Chapter 2 in 'Pre-restoration/creation monitoring' and in Chapter 5, section 'Monitoring saltmarsh restoration sites'.

CHOOSING A DESIGN

Once a site (or short-list of sites) has been selected, it is necessary to consider options for the design of a project. There are many different methods for restoring saltmarsh, ranging from small-scale measures designed to remediate local pressures, to large-scale habitat re-creation projects. As with choosing a site, the process of designing a restoration project is complex but entirely necessary, and must be carried out properly to ensure the success of the scheme. Importantly, the optimum design for saltmarsh restoration must be determined in consultation with relevant specialists including ecologists, geomorphologists, engineers and flood risk managers.

In some circumstances, it may be that there is only one truly viable approach, whilst in others it will be necessary to develop a short-list of options to consider. For example, in locations where the intertidal area has been extensively converted to land and modern saltmarsh extent is negligible or absent entirely, managed realignment or regulated tidal exchange (RTE) techniques are likely to be required to generate the space necessary for saltmarsh to return. Conversely, in locations with extensive saltmarsh that is in poor or deteriorating condition, a greater range of design options is likely.

COMMON RESTORATION DESIGNS

These design options are discussed in more detail in Chapter 5. As explained in Chapter 1, Box 1.8, the term 'restoration' is used in this handbook to encompass coastal management schemes that aim to re-create saltmarsh on areas of low-lying coasts where saltmarsh has been lost, for example, due to historical land claim, as well as projects that aim to improve the state and resilience of existing saltmarsh.

Managed realignment

Coastal defences are realigned landwards (or removed entirely where safe to do so), creating new intertidal area for saltmarsh colonisation. The size (area) of potential managed realignment sites relative to the total intertidal area of an estuary/system in question is important to consider. Realignments which are particularly large relative to the existing intertidal area may increase the tidal prism of the estuary (the volume of water entering the estuary on a tide) sufficiently to change hydrology and sediment transport patterns. This, in turn, may affect geomorphology, ecology and risk management. This may be desirable in some situations (for example, to reduce peak water levels during high tides or surges, or to reduce maintenance dredging requirements at inlets), but, in others, it may be preferable to design more moderately scaled realignments. As noted above, designing such sites is often supported by hydrodynamic modelling (for example, to test breach sizes and locations, and to investigate whether extra channels need to be cut).

Regulated tidal exchange (RTE)

RTE enables controlled inundation of intertidal land via sluices and other engineered structures. As such, the exact extent to which RTE schemes will restore saltmarsh will depend heavily on the operational regime (for example, frequency of openings) and technical design (for example, elevation of sills at inlets). Compared with managed realignment, RTEs are generally less effective at restoring natural functioning (for example, uninhibited transfer of water, sediment and biota in and out of the intertidal), but can be effective at reducing peak water levels and aid in the creation of intertidal habitats that would not necessarily be able to form through managed realignment. This method can also be advantageous in limiting the impacts of the scheme on the wider estuary by limiting the amount of water entering the site. Many different control mechanisms are feasible with RTE, and design choices will depend on existing structures (existing freshwater drainage pipes are often repurposed), as well as desired habitats and water exchange frequency.

Figure 2.4: View of the breach made in the existing shingle bank at Medmerry managed realignment site. Medmerry, on the south east coast of England, is the largest managed realignment on the open coast in the UK and Ireland. The shingle bank defence was breached in 2013. Photo: Mark Schuerch.

Fencing/sediment trapping to restore degraded saltmarsh

Installing fences on degraded marshes can help trap sediment transported on the rising tide. This can reduce erosion pressures and increase the surface area of the marsh. Designers will need to balance the need to retain trapped sediment on the marsh surface with the requirement for water to enter and exit the marsh surface efficiently. Note that this approach is generally only suitable where approaches that work with natural processes are not viable. It is very important to consider the impact that any structures in the intertidal area may have on the natural movement of fish and other fauna onto the site.

Intertidal recharge

This approach involves directly adding sediment into the intertidal area to increase material available to create and maintain habitat. This may then be landscaped to create a desired form, or allowed to be transported by natural coastal processes. It is often possible to source sediment from nearby maintenance dredging operations (referred to as 'Beneficial Use of Dredged Sediment') as an alternative to disposal in licensed offshore sites. When considering intertidal recharge, it is important to assess the presence of any pollutants within the source material, and the range of particle sizes present. Saltmarsh requires mud and silt sized particles, whereas material with a high proportion of sand or gravel will be less suitable. Water depth influences how close vessels can approach a marsh and therefore is important to consider when assessing what recharge technique can be used.

Urban fringes

In heavily constrained systems (for example, embanked and urbanised estuaries or coastlines with little or no opportunity for realignment of defences), a more engineered approach to restoring saltmarsh may be necessary. For example, in locations where mudflat meets hard defences (namely walls or embankments) and no saltmarsh is present, it may be possible to construct terraces of suitable elevation (between MHWN and MHWS) to enable saltmarsh colonisation for example, see Cousins *et al*. (2017). As previously discussed, this type of fringe habitat creation can provide important habitat corridors within systems that have lost the majority of their historic natural saltmarsh extent. For further guidance and examples of restoration techniques in urbanised estuaries, see Estuary Edges.

ECOLOGICAL CONSIDERATIONS

Design may be further optimised for ecological considerations.

Fish/other fauna

Diversity of habitat can increase the value of managed realignment sites for fish and other animals. Benefits to fish and fisheries can be optimised by designing restoration that incorporates topographic variations and gentle slopes in the resulting saltmarsh habitat. See Chapter 5, section 'Incorporating fish habitat in intertidal landscape design' for more information.

Figure 2.5: Brushwood groyne – German Wadden Sea, August 2008 Photo: Mark Schuerch.

Vegetation

Varying elevations can promote colonisation by a greater range of plant species by providing transitions from lower to upper marsh conditions. Experience has shown that the landward realignment of coastal defences will quickly produce intertidal mudflats on low-lying agricultural land which are then colonised by saltmarsh plants (if elevations are high enough). However, there is often a lack of high marsh and transitional species. This absence is likely to be due to the restricted elevation of many sites, rarity in the species pool leading to limited dispersal opportunities, or biotic or abiotic constraints within sites. The majority of saltmarsh species do not form a persistent seed bank and in embanked areas the seed bank of former marshes is likely to decline rapidly. The regeneration of saltmarsh vegetation therefore relies on regular tidal inundation as the main way of dispersing plant seeds and propagules into a site. Other factors are considered in Chapter 5, section 'Vegetation Development on Restored Saltmarshes'.

For restoration projects, the presence of common cord-grass *Spartina anglica* needs to be carefully considered. This new species arose from a hybridisation between a native (small cord-grass *Spartina maritima*) and an introduced species (smooth cord-grass *Spartina alterniflora*). While this species is now currently accepted as a permanent fixture of the flora of European saltmarshes, its presence in the early stages of saltmarsh restoration may be less desirable. The sparsely vegetated mudflats that typify the early phases of saltmarsh development provide ideal conditions for its establishment. *Spartina anglica* can drastically alter

the sedimentary and drainage characteristics of its surroundings, leading to the creation of waterlogged and anoxic soils. Its establishment early in the development of saltmarsh gives the regenerating marshes a very different starting point to that of natural marshes, and may affect the eventual outcome of restoration efforts.

Soils and sediments

Where saltmarsh restoration is proposed in locations previously used for agriculture, it may be beneficial to manually turn over surface sediments to address historic soil compaction. Heavily compacted soils may restrict root penetration, and therefore vegetation density and diversity, as well as affecting drainage and sediment accumulation.

Major embankment of saltmarshes took place in north-west Europe between the 15th and 19th centuries, cutting off tidal inundation and subsequently sediment supply. Over many years, the structure and chemistry of the soil in these areas has become more terrestrial and dissimilar to the sediments that build up in a natural saltmarsh. The changes that occur during this process of desalination are many and varied, but the non-reversible changes are critical. These changes include the consolidation of the soil through irreversible drying and the loss of organic matter through oxidation. The effect of compaction and dewatering on embanked marsh sediments coupled with relative sea level rise has accentuated the differences between the embanked land and nearby saltmarshes. In many cases, there is a difference of 1.0 to 1.5 metres between the surface of the realignment site and nearby marshes. Therefore, unless the surface elevation of low-lying realignment sites is raised over time by natural sedimentary processes, or raised artificially using imported sediment, intertidal marshes are unlikely to re-establish initially at these very low-lying sites.

The main difference between saltmarsh creation through managed realignment and natural saltmarsh development is that managed realignment is based on soils. Although prolonged flooding will increase the moisture content, the soil will never return to its original state, leaving a distinct horizon forming a dense, hard layer which is very strong and highly resistant to erosion.

Figure 2.6: Rapid accretion at Steart (England) managed realignment. Photo: Hannah Mossman.

The rate of sedimentation within managed realignment sites can be extremely rapid in the early phases, depending on site elevation and turbidity. In estuaries with high suspended sediment loads (for example, Paull Holme Strays in the Humber Estuary, England), rates as high as 0.5 to 1 metre per year have been recorded over mudflat elevations (which are inundated more frequently with sediment laden waters) and saltmarsh can therefore quickly establish on sites that are initially only suitable for mudflats. In lower turbidity estuaries, accretion would be lower but can still lead to mudflats transitioning to saltmarshes in the medium term (for example, at Allfleet's Marsh, Crouch Estuary, England, this is starting to happen after 15 years). Initially high sedimentation

BOX 2.2: THE IMPORTANCE OF SITE ELEVATION – YOUGHAL, REPUBLIC OF IRELAND EXAMPLE

The Youghal Bypass, County Cork in the Republic of Ireland is an example of managed realignment that has not met its objectives for the creation of saltmarsh. The managed realignment scheme was implemented to compensate for saltmarsh and mudflat loss caused by a new road bridge over the Tourig Estuary (Perrin *et al.*, 2020).

The realignment objective was to create 1.7ha of compensatory intertidal habitat. The aim was for the majority of the intertidal habitat created to be saltmarsh. The plan was to build a new levee set back and remove the existing levee. A topographical survey showed that works would be required to raise the ground level to one at which saltmarsh can become established.

The proposed work programme, however, was not followed. Re-profiling was not carried out and at first the existing levee was not removed and the intervening area of about 2.5ha gradually flooded, forming a small brackish lake. An intentional breach in the older levee was subsequently made to rectify the situation, and a connecting channel was dug through a remnant area of saltmarsh. This allowed the lake area to drain and become intertidal. Since re-profiling works to adjust the topography of the newly created intertidal zone were not implemented, the area of managed retreat was too low for any saltmarsh to develop. When visited in August 2018, the compensatory habitat was still a tidal mudflat. Any accretion of sediment within this area has not been sufficient for any saltmarsh to develop in the time since construction.

This stands as a reminder of the importance of fully implementing the range of surveys and actions required to achieve a successful saltmarsh habitat creation project.

Figure 2.7: Formation of creeks at Steart managed realignment scheme. Photo: Hannah Mossman.

rates are short lived however, with low-lying areas building up sediment until an equilibrium profile is reached. Where sites are breached, the old embankment provides shelter for the new habitats from wave and tidal energy, and therefore helps with sedimentation.

Creeks

Creeks are an important and integral part of saltmarshes, distributing sediments to the interior of the marsh, allowing aquatic organisms access to habitat, and providing drainage following tidal inundation. Saltmarsh creek networks display a variety of morphological characteristics, parallel, meandering, braided and interconnecting, although they are most commonly dendritic (branching), with channels of varying sizes. Creeks develop through a variety of processes, including headwater retreat, downward cutting and lateral migration. Initial flow of water over intertidal flats occurs as sheet flow until subtle changes in topography focus water to depressions in the land surface, causing erosion and the formation of creeks.

Where saltmarsh restoration projects are carried out on land that was formerly saltmarsh prior to embankment, creek design has usually tried to replicate the original marsh drainage system (former creek patterns can be clearly seen from aerial photos and LiDAR data). The extent of excavation is usually limited and, in most cases, only a main creek dug, with perhaps one 'first order' tributary. There are several examples of 'accidental' realignments around the south-east coast of England where embankments have been breached during storm events and subsequently abandoned (see Figure 1.14 in Chapter 1 for locations of unmanaged realignment sites). As a result, saltmarsh has developed over the previously cultivated soils. One striking feature of a number of these sites is the persistence of old field drainage patterns. Some of these sites are over 100 years old, where the embankments were breached in a storm in 1897. The current creek network still resembles that of the field drains prior to the reinstatement of tidal flooding, with an orderly grid system of channels. This is with 1 to 2 metres of marine sediment overlying the old agricultural surface.

PRACTICAL CONSIDERATIONS

Given the variety of restoration approaches to choose from, design is likely to be influenced to some degree by practical considerations such as the amount of funding available and local stakeholder attitudes. We encourage ambitious restoration approaches, which seek to maximise the potential benefits that a project can provide, but equally it must be recognised that successful restoration at a system scale (across a whole estuary or coastline) will likely require a range of approaches at different scales and in different locations, from large and costly managed realignments or RTEs, through to smaller local enhancements such as urban fringe techniques.

PRE-RESTORATION/CREATION MONITORING

Before a scheme is implemented, a lot of data is required to:

- inform the business case and design phases.
- inform any assessments required when applying for permits and consents, for example an Environmental Impact Assessment (EIA) or Habitats Regulation Assessment (HRA).
- establish a baseline for success and impact (post-implementation) monitoring (some of these can overlap with the previous two categories).

The investigations required to inform site design may include LiDAR ground truthing, ground investigations, and collecting calibration data for hydrodynamic modelling.

For sites where saltmarsh creation is planned over land which is currently terrestrial, a wide array of available sources should be accessed first to gain a comprehensive understanding of what is currently present on site and the immediate area, and also what may be hidden underground. Some information sources will be freely accessible, whereas for others, a fee may need to be paid. Important aspects to investigate for initial site understanding are summarised in table 2.1 and include:

- existing on-site and adjacent designations – international, national and local.
- current land use and standard of protection for any embankments currently present.
- land use history, especially history of embankment.
- existing usage rights, land agreements/management, such as agri-environment payments.
- above and below ground utilities (for example, pylons, underground gas pipelines).
- unexploded ordnance (UXO).
- archaeology records.
- records on protected or notable species from biological records centres.

Figure 2.8: Installing an ALTUS system (a submersible altimeter), which can measure fluctuations in bed elevation every 15 minutes and can be left in place for several years. Photo: Heidi Burgess.

Figure 2.9: Installing a sonde (a type of transmitting sensor) to monitor conductivity, depth, salinity and turbidity in an intertidal channel. Photo: Heidi Burgess.

- topographical information (notably LiDAR) maps.
- public rights of way.

Investigations are also typically required to inform the site design, for example:

- ground investigations to determine suitability of materials for constructing embankments (where a new landward defence is needed) (these could be combined with archaeological trial pitting if this is required for an EIA).
- topographical ground-truthing to confirm LiDAR levels and check elevations of features that LiDAR can't capture, such as, the bottom levels of ditches and streams, reed beds, culvert dimensions and invert levels.
- calibration data for numerical models, such as, flow speed and water/tide levels.

For specific assessments, regulators, local councils and nature conservation bodies should be consulted early to help identify available data sources, and also likely survey requirements. Generally, best use of existing data should be made, supplemented by on-site data collection, where necessary. Collecting site-specific data can be expensive.

If an EIA or HRA is required, it is the responsibility of a project applicant to supply sufficiently high-quality information to allow the lead regulators to make a decision about environmental impact. Evidence and data used at any stage needs to be subject to quality assurance procedures. Dependent on the scale of the proposed project, experienced professionals may be needed to carry out relevant surveys to inform an EIA/HRA. The types of surveys that could be required include both habitats and species, dependent on the type of project or land/habitat to be developed. The key survey requirements that are typically associated with saltmarsh creation proposals are summarised in Chapter 5, section 'Monitoring saltmarsh restoration sites'. All surveys should be carried out at the appropriate time of year, using suitable methods for the species and the area. There may be a requirement for repeat surveys dependent on the features of interest and the timescales of the project.

Finally, **post-implementation monitoring** is generally carried out, both to verify impact and confirm site success. Detailed **baseline** surveys should be carried out before implementation to facilitate this; in other words, whatever is to be monitored after implementation will need to be investigated before changes to the site begin.

SALTMARSH RESTORATION: CALCULATING VALUE AND FUNDING OPPORTUNITIES

While saltmarshes have long been known to be very valuable habitats that provide a wide range of beneficial ecosystem services (see Chapter 1, section 'Why Is Saltmarsh Important?'), it will be important to clearly communicate these benefits to help justify a project proposal and to apply for funding.

It is difficult to apply an economic value to some benefits, such as contributions to recreation and well-being, yet they are of immense value to society. The social benefits of using saltmarsh as a nature-based solution should be emphasised when engaging with the local community, for example.

The section below gives advice on applying economic value to saltmarsh restoration projects. This can be a critical part of gaining approval and support for a project. However, it is equally important to communicate that there are also wider benefits for which there may currently not be enough data to include in an economic valuation.

CALCULATING STOCK AND SERVICES AND APPLYING ECONOMIC VALUE

The financial case for saltmarsh restoration is based on a straightforward presentation of the costs and benefits that will be directly associated with implementing the project. The economic case is more broad-based and should encompass costs and benefits for society as a whole. Therefore, it is recommended that, where possible, the ecosystem services of saltmarshes are valued. This can be done as part of a natural capital accounting exercise, or a cost benefit analysis (which is typically used to compare benefits of different options).

Monetising the benefits of saltmarshes as a natural capital asset can be complicated. This is not only because

Atriplex portulacoides. Photo: Hannah Mossman.

there is a range of frameworks and techniques that could be applied, but also because there are significant value gaps and uncertainties, and risks related to double counting. Furthermore, for some services, various values are discussed in the literature, not all of which are transferable between locations. These complexities mean that valuation may need to be carried out by someone with previous experience.

There is enough available data to allow at least a conservative estimate to be made. For example, many studies apply values derived from a review of European wetland valuations by Brander *et al.* (2006); this concluded that saltmarsh had a value of approximately £2,000 ha^{-1} yr^{-1} (in 2019 rates/prices) (across a range from £300 to £6,600 ha^{-1} yr^{-1}). This was based on default 'indicative economic values' for habitats providing ecosystem services such as water quality improvement, recreation, biodiversity and aesthetic amenity. It is, however, important to note that these values are dwarfed by larger estimates made by some authors for individual services; for example, Watson *et al.* (2020) estimated that the waste remediation value for saltmarshes of the Solent, England, was nearly £125,000 ha^{-1} yr^{-1} for nitrogen and phosphorus combined. In addition, fish related services have been valued very high elsewhere, notably in the United States. Such higher values could be applied in sensitivity tests.

Two other key services, which are frequently valued, are those associated with carbon sequestration and flood protection. Both of these are potentially important additional ecosystem service benefits provided by saltmarsh compared to mudflat. Healthy saltmarsh can sequester significant quantities of carbon, with typical figures in the range of 2.35 to 8.03 tonnes CO_2 ha^{-1} yr^{-1} (Beaumont *et al.*, 2014). Using the mid value (5.19 tonnes CO_2 ha^{-1} yr^{-1}) and based on the non-traded price of carbon of £68 per tonne (2019 prices from BEIS, 2019), this equates to a value of over £350 ha^{-1} yr^{-1}. Non-traded carbon prices are expected to increase significantly over time, therefore the economic value of carbon sequestration will also increase in the future. For example, the non-traded carbon price is projected to reach £230 per tonne of CO_2 by 2050 (BEIS, 2019).

Flood protection benefits associated with saltmarsh restoration can also be large. As saltmarshes erode, this will result in greater wave energy reaching the sea wall, exacerbating the decline in sea wall condition and advancing the need for repair/replacement. However, such benefits are very site specific. For many UK saltmarshes, the main benefit may relate to reduced maintenance costs for landward flood defences. For example, Shepherd *et al.* (2007) estimated that fronting saltmarsh provided a net saving of (in 2019 prices) just under £7,000km yr^{-1} in flood defence expenditure on the Blackwater Estuary (Essex, England).

Another service which could, and has been, frequently valued separately is the so-called 'non-use', or 'wider existence', value. This should ideally be derived by surveying the local public on how much they would be willing to pay (see Box 2.3) for having a particular area of saltmarsh restored or created, though values could also be transferred from earlier studies, provided due care is taken. For example, Luisetti *et al.* (2011) estimated a non-use benefit of just over £30 ha^{-1} yr^{-1} (2019 prices) for a hypothetical 81.6ha managed realignment project on the Blackwater Estuary (Essex, England).

Where valuation is carried out, a comparison with the current/before restoration situation needs to be done; in other words, the consequences of the change of habitat/land use needs to be taken into account. For managed realignment sites, this would typically involve a change from farming use to saltmarsh habitat situated in a nature reserve or designated site. The restored site may be lightly grazed and have various ecosystem services associated with it that farmland does not. With beneficial use of dredged sediment and other techniques where saltmarsh creation takes place over existing mudflat, then identifying added value can be more difficult.

From the above, it is evident that the creation or restoration of saltmarsh and mudflat habitats can provide significant ecosystem service benefits, but that the scale of the benefits can be quite site specific. In addition, the scale of intervention can also affect the per-hectare benefits, generally, there is a reduction in per-hectare benefits with increasing size of the intervention (Brander *et al.*, 2006; Luisetti *et al.*, 2011).

Several of the UK's existing saltmarsh creation sites have seen a full ecosystem services valuation exercise carried out, with high values generally derived. For example, Everard *et al.* (2009) valued the overall scheme gross benefit value of the 300ha Alkborough Flats scheme on the Humber Estuary, England, at just under £38 million (2019 prices) over 25 years. The Natural Capital for the 400ha Steart Marshes reserve, Somerset, England, has recently been valued at around £43.8 million yr^{-1} (Laver *et al.*, 2019). These valuations support the case for such schemes, as well as helping to communicate the wider benefits to stakeholders and the general public.

BOX 2.3: THE CULTURAL VALUES OF SALTMARSHES AND HOW THEY CAN BE CAPITALISED ON TO ENGAGE COMMUNITIES

Using ecosystem values is a compelling tool for illustrating the worth of saltmarshes, and conveying this to a broad audience. Cultural values are ecosystems' contributions to the non-material benefits that arise from human-ecosystem relationships. The non-materiality of cultural values means they are often hard to quantify or measure, and therefore end up being relegated or ignored.

Benefits and disbenefits, and associated values of saltmarsh, are a product of the active or passive interaction between humans and nature. They are influenced by factors such as acquired knowledge, personal values and agenda, and the overall political, economic and social settings at different scales and times (Rendón *et al.*, 2019). For instance, one person's aesthetically pleasing and biodiverse saltmarsh is another person's source of allergies and mud.

There is still a huge gap in our understanding of cultural values linked to social cohesion, happiness, and spiritual and cultural fulfilment.

Some values can be quantified by different approaches, from monetary to non-monetary. One approach is to compare people's willingness-to-pay for different options. Willingness-to-pay is the maximum amount a person is willing to pay for a product or service. For example, the results of a choice experiment of 1,553 respondents in Wales showed a preference for increasing saltmarsh, over hard defences, to reduce coastal flood risk. The willingness-to-pay to double the current area of Welsh saltmarsh is £6 per household per month, while it is -£2 for defences (Rendón, 2020).

Alternatively, Roberts *et al.* (2020) used narrative research (listening to the stories of people) to explore how people in 2 coastal communities in Wales experience and understand landscape change in relation to their sense of place and what this means for their wellbeing. This study highlights shifting relationships with saltmarshes, and how natural rhythms influence sense of place at coastal landscapes. The continuity of rhythmic change was often expressed through feelings of comfort (things always changing but staying the same) as well as a connectedness to nature. Disruptive changes (for example, changes that disturb natural rhythms and people-place relationships) on the other hand were perceived to impact the shared sense of place and generated feelings of loss. The question of how best to implement potentially disruptive environmental change (such as restoration) without exacerbating loss is inherently difficult. Therefore, it is crucial to recognise the diversity of values and concerns, at multiple scales.

Sea aster *Tripolium pannonicum* on a saltmarsh at high tide. Photo: Andrew Pearson.

FUNDING STREAMS

Saltmarsh restoration initiatives may receive funding from a variety of different sources, depending on factors like project rationale, design and benefits provided. The following table provides a number of examples of potential funding sources for projects. Most existing schemes have either been financed by government organisations, developers or environmental charities. Going forward, there may also be ways that saltmarshes can generate an economic return on investment, in addition to a natural capital value, for example, through carbon credit schemes or by combining saltmarsh restoration with bivalve aquaculture or other innovative ideas.

Table 2.2: Examples of potential funding sources for restoration projects.

FUNDING SOURCE/ TYPE	DESCRIPTION	EXISTING OR POTENTIAL FUTURE SOURCE?
Government/public funding		
A Local levy	Monies for local projects might be obtained through a council levy.	Potential future
Agri-environment/ sustainable farming schemes	These have, in the past, included saltmarsh management and creation options. Post-Brexit, particulars are still being established by the devolved administrations. For example, in Wales, a review is currently underway, and the anticipated sustainable farming scheme may provide opportunities for land stewardship that aim to encourage saltmarsh creation. In England, saltmarsh options are likely to be included under local nature recovery or landscape recovery schemes (from 2024).	Potential future
Carbon offsetting	Support and funding for saltmarsh restoration may be available through carbon offsetting initiatives. For example, the Environment Agency in England has committed to achieving Net Zero carbon emissions by 2030, with restoration of saltmarsh one of a suite of approaches being explored to help achieve this aim.	Potential future
Coastal Communities Fund (UK)	While currently closed for new applications, money from this UK Governmental fund went to projects which would lead to the regeneration and economic growth of coastal communities. Future rounds are anticipated.	Potential future
Water Environment Improvement Fund (England)	The WEIF scheme provides funding to improve the water environment in rural England, including enhancing protected areas and achieving Water Framework Regulations objectives.	Existing (England, where applicable)
Flood and coastal erosion protection funding (Grant in Aid)	If a scheme has flood defence potential, it may be eligible for funding through Flood & Coastal Erosion Risk Management Grant in Aid partnership funding. In England, funding is administered by the Environment Agency, based on contributions to outcome measures (saltmarsh is captured in OM4a). In Wales, if a project offers opportunities for multiple outcomes (including wellbeing, sustainable management of natural resources and provision/creation of new coastal habitats), Natural Resources Wales can potentially fund it based on a business appraisal and approval process.	Existing (where applicable)
Restoring Meadows, Marsh and Reef (ReMeMaRe) (England)	This (English) Environment Agency-led initiative aims to facilitate the coordinated restoration of 15% of England's priority saltmarsh, native oyster reef and seagrass habitats by 2043. A part of this initiative involves exploring different and innovative sources of funding for restoration.	Existing (England)
Community/developer funding		
Corporate (social responsibility) funding	A means for businesses to contribute to societal goals, including net zero and nature recovery (for example, Sky Ocean Rescue).	Some existing, plus potential future
Crowd Funding	A way of raising finance via the internet by asking a large number of individuals and organisations for small amounts of money. Tends to lead to some active involvement of/engagement with the local community.	Existing

FUNDING SOURCE/ TYPE	DESCRIPTION	EXISTING OR POTENTIAL FUTURE SOURCE?
Developer contributions to create compensatory habitat	Under the Habitats Regulations, developers (for example, ports and flood defence authorities) have to compensate for damage to designated sites. Damage could be direct (land claim, defence footprint) or indirect (for example, due to coastal squeeze caused by defences). Around half of the UK's existing managed realignment schemes were funded through developer contributions prompted by these regulations.	Existing (where applicable)
Developer contributions to deliver net gain	Net gain commitments are being considered by the relevant administrations in the UK and Ireland. Saltmarsh restoration may form part of a suite of measures.	Potential future
Heritage Lottery Fund (UK)	Supports a combination of projects, including nature conservation initiatives that protect and preserve historic and rural landscapes. Applicants have to ensure they have a clear plan and fulfil as many predefined 'outcomes' as possible.	Existing (UK)
Impact investment funds	Such funds aim to generate positive, measurable impacts as well as financial return (for example, on ecosystem services such as carbon sequestration or water quality improvements). Still in its infancy with regard to saltmarsh restoration in UK/Ireland.	Potential future
National Trust/National Trust for Scotland	The Trust may provide funding or land where this aligns with their coastal adaptation priorities ('Shifting Shores').	Existing (where applicable)
Nature conservation charities	Often drawing on member contributions, as well as various external funding sources, charities such as the RSPB, the Wildlife Trusts and the Wildfowl and Wetlands Trust, have been instrumental in implementing many existing saltmarsh restoration projects.	Existing (where applicable)
Network Rail (UK)	On certain sites, where their assets are facing coastal change, Network Rail may provide funding or undertake flood risk management measures, to support coastal adaptation and managed realignment (as is, for example, happening in Wales in partnership with Natural Resources Wales).	Existing (where applicable)
Philanthropic organisations	Private foundations or trusts may finance nature restoration projects for charitable reasons; these generally fund registered charities or organisations only.	Some existing, plus potential future

POLICY VIEW

This section introduces a number of legislative and policy drivers for the conservation and restoration of saltmarsh. Chapter 3 provides details of the environmental permits, licences and consents that are likely to be required for any saltmarsh restoration projects and proposals.

Legislative and policy drivers applicable to the UK and Republic of Ireland

Habitats Regulations/UK National Site Network sites: The European Habitats and Birds Directives for the Republic of Ireland, and the amendment of the Habitats Regulations by UK and Scottish Statutory Instruments, designate areas of particular conservation importance as Special Area of Conservation (SAC) or Special Protection Area (SPA) and Ramsar sites. In the UK and the Republic of Ireland, extensive areas of saltmarsh are subject to statutory protection and restoration obligations through SAC and SPA designations including the need to compensate in instances where protected habitats or species are detrimentally impacted by activities. These sites are still protected in the UK following the UK's exit from the EU.

Sites/Areas of Special Scientific Interest (SSSI/ASSI) and Natural Heritage Areas (NHA): SSSIs, ASSIs (Northern Ireland) and NHAs (Republic of Ireland) are national designations for sites of particular scientific importance in the UK and Ireland. Many saltmarshes are designated for ecological and geomorphological interests and are subject to statutory protection and restoration obligations.

Water Environment Regulations: The Water Framework Directive (WFD) originates from the EU but has been retained in UK law following the UK's exit from the EU

Loch Fyne. Photo: Bill Austin.

as the Water Environment Regulations. Saltmarsh is one of the biological indicators used to assess if a body of water is at good ecological status. If a saltmarsh is not achieving at least good status, plans to improve it may be included in the relevant River Basin Management Plan.

Climate change and falling biodiversity: The UK and Republic of Ireland governments, and the devolved administrations, are committed to addressing climate change and falling biodiversity, and have set carbon net neutrality targets and biodiversity action plans. Despite historical losses, the limited extent of the habitat and finite land areas suitable for restoration, saltmarsh is extremely effective at sequestering carbon. While the exact figures for uptake and storage rates vary depending on a number of conditions, it is generally acknowledged that healthy, naturally functioning saltmarsh sequester and store significant amounts of carbon from the atmosphere and ocean. Restoring and recreating saltmarsh habitats is therefore likely to play a future role in national efforts to offset carbon emissions. To qualify as a carbon offset, the reductions in greenhouse gas emissions need to be additional to what would have happened if the restoration project had not been carried out, and not canceled out by increased emissions elsewhere that are attributable to the project. The emission reductions would also need to be maintained over time, with robust monitoring required to verify that the emission reductions have been achieved (see Box 5.3 in chapter 5). The value of saltmarshes for wildlife is well recognised, with creeks and tidal marshes supporting a broad range of species, for example, by providing spawning and nursery areas for fish; and feeding, roosting and nesting areas for birds. Restoring degraded or lost saltmarsh can, therefore, also help counter falling biodiversity.

UK legislation and policy drivers

Marine Conservation Zones (MCZs): MCZs are protected areas designated under the Marine and Coastal Access Act 2009 and the Marine Act (Northern Ireland) 2013. They protect nationally important marine habitats, wildlife, geology and geomorphology. Saltmarsh is one of several habitat types included as MCZ features.

Environmental policies: The UK government's 25 Year Environment Plan commits the UK to restoring 75% of its surface waters (including estuaries and coasts to 1 nautical mile) to natural or near-natural condition, as well as outlining a requirement to deliver environmental net gain through capital works. The UK Marine Strategy aims to protect the marine environment, preventing its deterioration and restoring it where practical. England's Restoring Meadows, Marshes and Reefs (ReMeMaRe) initiative sets a target to restore or enhance 15% of England's priority saltmarsh, seagrass meadows and oyster reefs by 2043 to contribute towards the 25 Year Environment Plan targets.

Environmental Land Management Schemes: These schemes are designed to support the rural economy whilst helping achieve the goals of the 25 Year Environment Plan and other policy drivers by paying landowners for management of land which provides public goods. This can include payments for coastal habitat restoration (including saltmarsh).

Flood and coastal erosion risk management (FCERM) policies: Both the Department for Environment, Food and Rural Affairs (Defra) FCERM Policy Statement and the Environment Agency's National FCERM Strategy for England promote the Defra 25 Year Environment plan and have actions to take forward biodiversity and environmental net gain. There are also targets to offset carbon emissions through FCERM, as well as an enhanced focus on using natural and nature-based solutions to manage flood and erosion risk. Saltmarsh restoration is an established approach to delivering both FCERM and environmental outcomes. Additionally, there is a legal requirement to provide compensatory habitat if losses occur due to coastal squeeze in front of flood defences. The Environment Agency in England recently published new guidance on the definition of coastal squeeze and how to manage its past and future impacts (See also Chapter 1, Box 1.6).

BOX 2.4: SHORELINE MANAGEMENT PLANS (ENGLAND AND WALES)

Shoreline Management Plans (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 or the Republic of Ireland.

For England and Wales, each SMP proposes a management approach for discrete lengths of coastline (referred to as policy units, see Figure 2.11) within a wider plan area defined by regional sediment cells. 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 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, called the 'Shoreline Management Plan Refresh', to review all 20 of England's SMPs. The aim of the Refresh is to ensure the SMPs are prepared for impending policy transitions as we approach the end of Epoch 1, and provide guidance on incorporating the latest legislation, policies and evidence. This guidance (Environment Agency, 2020) outlines a key objective to ensure England's SMPs contribute towards environmental and climate resilience ambitions, including those outlined in the 25 Year Environment Plan (such as Biodiversity Net Gain and the Nature Recovery Network). The restoration and conservation of intertidal habitats will be central to efforts to ensure the resilience, sustainability and overall quality of SMPs.

Saltmarsh restoration is an established coastal management approach which can contribute to delivery of any of the three main policy approaches: HTL, MR and NAI (ATL policies are extremely rare, and would generally result in the loss of saltmarsh). Restoring saltmarsh can contribute towards HTL policies providing flood defence benefits, while MR and NAI policies may be drivers for saltmarsh restoration (for example, by creating space for marsh to develop). It is clear that there is likely to be a progressive and fundamental shift away from the 'Hold the line' policy in many areas in the future, and particularly from 2055 onwards (see Figure 2.10).

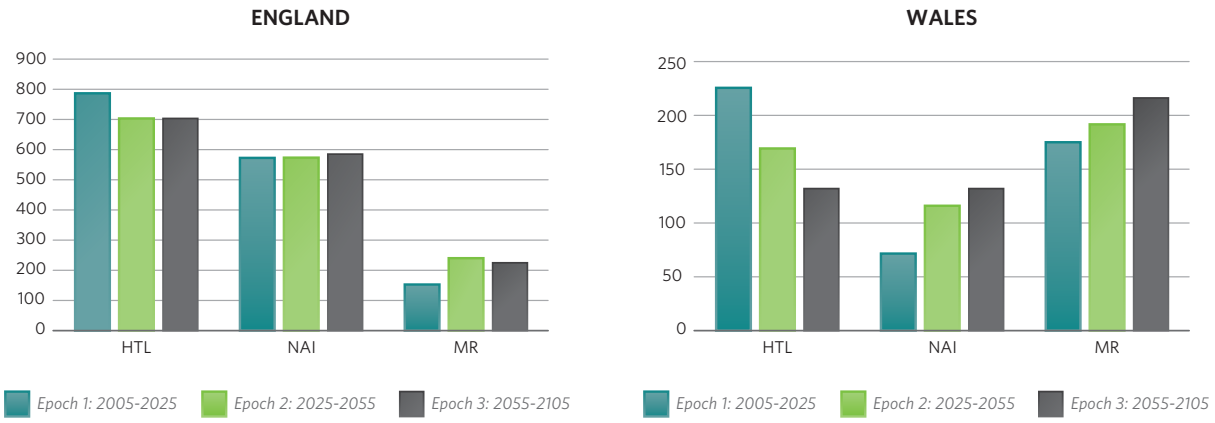

Figure 2.10: Summary of SMP policies over all three epochs in England and Wales.

Coastal and estuarine systems are made up of a variety of connected components, therefore successful restoration may require more than just implementing measures directly to a single area of marsh. Updrift management policies can significantly affect 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 over a year is known as updrift, while the direction that sediment generally moves to over a year is known as downdrift.) For example, holding the line (and preventing erosion) on extensive areas of coastline that would naturally supply sediment to an estuary, can reduce the ability of saltmarsh to warp up (accrete vertically) in response to sea level rise. 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.

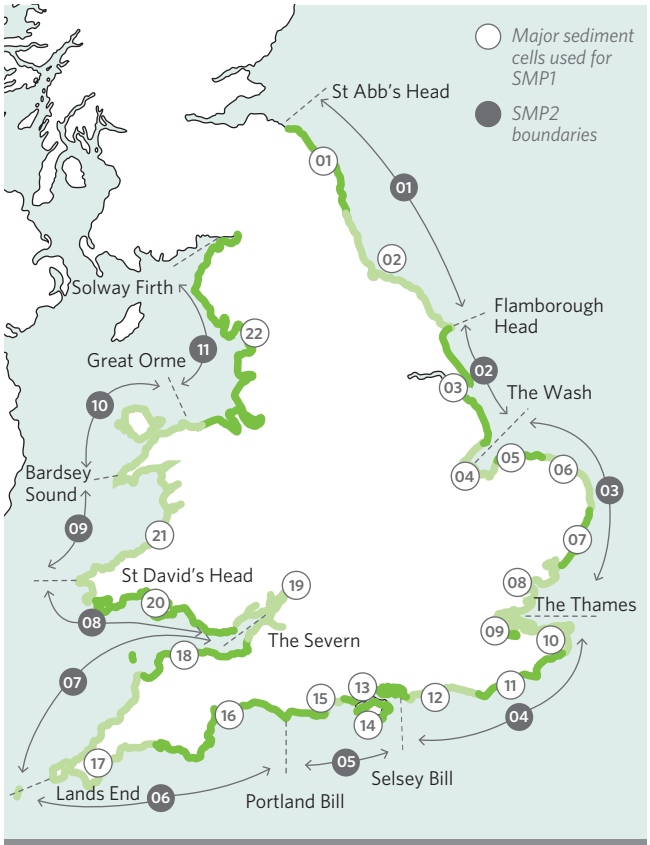

Figure 2.11: Map of Shoreline Management Plan areas. The SMP areas are based on sediment sub-cells (smaller interconnected spatial areas). Source: Ballinger and Dodds (2020).

Saltmarsh restoration in Essex, England. Photo: Kirk Markham.

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CHAPTER 3
LEGISLATION

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KEY SUMMARY POINTS:

- **Licence requirements for a project can require investment in time and resources. Early engagement with relevant organisations is recommended to identify what permissions will be required.**
- **Licence requirements will not only vary by nation, but can depend on exactly what is being proposed and what restrictions there are at a particular site. This chapter is intended to provide a general overview but you are advised to always refer to the latest advice for the area concerned by checking the relevant websites and contacting the relevant organisations.**
- **For projects in the Republic of Ireland, you should also check for changes resulting from the Marine Planning and Development Management Bill.**

INTRODUCTION

This chapter details the environmental permits, licences and consents that are likely to be required for any saltmarsh restoration projects and proposals across the UK (England, Wales, Scotland, Northern Ireland) and the Republic of Ireland.

Stakeholder engagement is key when considering saltmarsh habitat restoration proposals. As there are differences within the regulatory frameworks of the different countries considered within this handbook, so there are also different organisations that are responsible for key aspects of work that may be related to habitat restoration proposals.

Early engagement and developing a good, strong working relationship with the relevant stakeholders will be key to identifying the likely consents that need to be in place and any likely issues that may need to be addressed before securing these. It is likely that any habitat restoration proposals will require some form of permission/licensing, depending on which country and where within this country the project is located.

At the time of writing, the Republic of Ireland is developing a Marine Planning and Development Management (MPDM) Bill. The MPDM bill seeks to establish a new regime for the maritime area that will replace existing consent regimes. Once these changes are finalised, the details relating to planning and licensing in the republic of Ireland may have changed from the information provided in this chapter. Therefore, for projects in the Republic of Ireland you are advised to check the latest situation and what specific procedures are in place. More information on the MPDM bill is available on the government website: https://www.gov.ie/en/publication/91aab-the-marine-planning-and-development-management-bill/

LICENSING TOPICS

Key topics that different organisations are responsible for, that are likely to be at the forefront for saltmarsh habitat restoration proposals, are listed below:

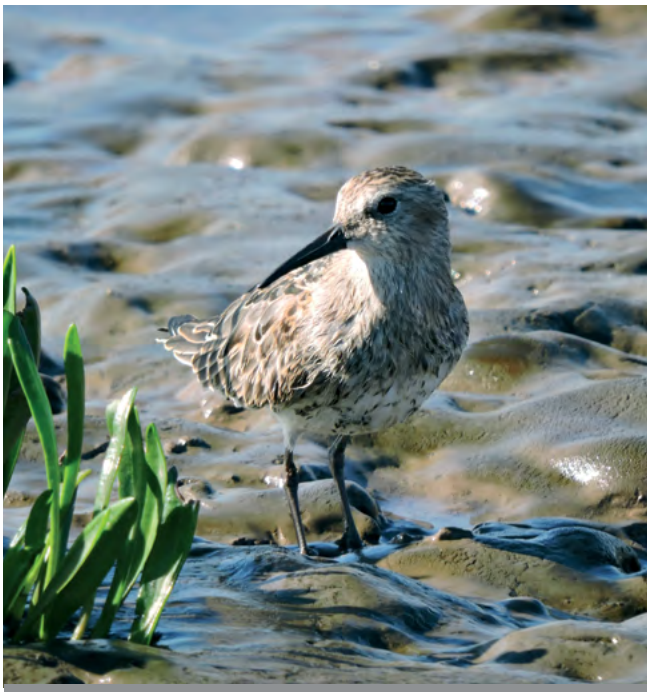
- **Marine licensing** – required for certain activities that take place within or on the sea, or on the seabed below Mean High Water Springs (MHWS) and any tidal river to the extent of tidal influence. Exemptions to a marine licence can apply in certain circumstances, although unlikely for saltmarsh habitat restoration proposals.
- **Planning permission** – required for any works above Mean Low Water (MLW). At times the jurisdiction of the local planning authority responsible for planning permission, and the jurisdiction of the marine licensing authority may overlap, in which case the relevant coastal concordat may be adopted, at the concerned authorities' discretion.
- **Foreshore and seabed leases/landowner permissions** – required to carry out works from the landowner or gain access to the works site. The landowner whose permission would be needed will be site and project specific. The Crown Estate (TCE) and The Crown Estate Scotland (TCES) own the majority of the UK seabed from MLW to the 12 nautical mile (22km) limit and more than half of the UK foreshore. Permission or a lease from TCE or TCES will be necessary if interacting with the seabed in this area. Permission from other private landowners affected by the proposed development will also be required.
- **Impacts on protected areas/features** – required to be determined and significances assessed if there is a potential for protected areas and/or features to be affected by the proposals. Potential for requiring protected species licences or specific consents depending on the features affected.
- **Impacts on water bodies (including to the biology, water and sediment quality)** – required to be assessed before the proposals are carried forward.
- **Impacts on flood and coastal protection** – required to be assessed if any changes are to be made to flood banks or sea walls or changes to potential flood regime, coastal defence structures or coastal processes.
- **Wildlife licensing** – generally required for activities that could possibly injure or disturb protected species, or their habitats.

KEY ORGANISATIONS

A summary of competent authorities responsible for key consents and licences in each country, is included in **Table 3.1**. A more detailed table of the key organisations responsible for granting permission, consent or licences within the marine environment across England, Wales, Scotland, Northern Ireland and the Republic of Ireland, related to the topics identified above, are identified in **Table 3.2**. The underpinning legislation and inshore relevant authorities are provided in **Figure 3.1**. The Marine Planning and Development Management Bill in the Republic of Ireland could lead to changes in the licensing bodies and application processes.

It is important to note that some regulators for particular topics will be statutory consultees for others, for example, Environment Agency (in England) and Statutory Nature Conservation Bodies (SNCB) are regulators in their own right for some consents, however at the same time they will also be statutory consultees to the Local Planning Authority for planning permission or statutory consultees to the Marine Management Organisation (MMO) (in England) (or equivalent for other countries) for the marine licence.

Similarly, in some instances, certain consents will need to be sought outright and in other instances they will be incorporated within other consents/permissions. In England, for example, if the scheme needs to apply for a planning permission and a marine licence, then issues pertaining to Sites of Special Scientific Interest (SSSI) consent/assent and Flood Risk Activity Permit (FRAP) will be covered by the planning permission and the marine licence, thereby not usually requiring a separate SSSI consent/assent and FRAP. However, this is usually best agreed and clarified through early engagement with the relevant stakeholders, and will be determined on a project by project basis.



Dunlin. Photo: Andrew Pearson.

Table 3.1: Competent authorities and advisory agencies for licensing and permissions in the UK and Republic of Ireland.

TOPIC	ENGLAND	SCOTLAND	WALES	NORTHERN IRELAND	REPUBLIC OF IRELAND
Marine management and marine licences	Marine Management Organisation (MMO)	Marine Scotland	Natural Resources Wales	Department of Agriculture, Environment and Rural Affairs (DAERA)	Relating to dredging and dumping at sea: ▪ Environmental Protection Agency. Related to activities not otherwise licensable by other bodies: ▪ National Parks and Wildlife Service (NPWS).
Planning permission	**Local planning authority**				
Foreshore and seabed leases/ owner permissions	The Crown Estate or private owners	The Crown Estate Scotland or private owners	The Crown Estate or private owners	The Crown Estate or private owners	Department of Housing, Planning and Local Government and Heritage or private owners
Impact assessments on Marine Protected Areas/SNCB	Natural England	NatureScot	Natural Resources Wales	Department of Agriculture, Environment and Rural Affairs, Marine and Fisheries Division	National Parks and Wildlife Service
Quality of the water environment	Environment Agency	Scottish Environment Protection Agency	Natural Resources Wales	Northern Ireland Environment Agency/DAERA	Environmental Protection Agency
Flood risk management	Environment Agency	Scottish Environment Protection Agency	Natural Resources Wales	The Department for Infrastructure Rivers	The Office of Public Works
Wildlife and protected species licensing	Natural England	NatureScot	Natural Resources Wales	Northern Ireland Environment Agency/DAERA	National Parks and Wildlife Service

Table 3.2: Key responsibilities of competent authorities in the UK.

	Marine management Marine licences	Planning permission	Foreshore and seabed leases	Nature conservation /SNCB	Water Environment Regulations Water quality	Flood protection	Wildlife licensing	Key responsibilities of relevance to saltmarsh restoration activities
UK/MORE THAN ONE NATION								
Local planning authority		X						Regulating the use of land within their jurisdiction and relevant planning. Managing and granting planning permissions.
The Crown Estate (England, Wales, Northern Ireland)			X					Management and licensing of the seabed and half of the foreshore around England, Wales and Northern Ireland and ensuring sustainable development of the seabed.
ENGLAND								
Environment Agency					X	X		Management and regulation of waste, water quality, water resources, contaminated land. Management of the risk of flooding from main rivers and estuaries.
MMO	X							Licensing, regulating and planning certain marine activities around the seas of England including dredging and disposal, depositing or removing substances from intertidal or subtidal areas.
Natural England				X			X	Provision of advice on nature conservation, designation of Areas of Outstanding Natural Beauty (AONBs) and Sites of Special Scientific Interest (SSSIs), management of certain national nature resources and enforcing associated regulations. Administration of grant schemes and frameworks that finance the development and conservation of the natural environment. Granting and management of wildlife and protected species licences. Assessment of Likely Significant Effects on Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites. Grants consents/ assents. Oversee the English Coast Path network which follows the alignment of sea defences in many locations.

	Marine management Marine licences	Planning permission	Foreshore and seabed leases	Nature conservation /SNCB	Water Environment Regulations Water quality	Flood protection	Wildlife licensing	Key responsibilities of relevance to saltmarsh restoration activities
WALES								
Natural Resources Wales	X			X	X	X	X	Responsible for providing advice on sustainable management of natural resources. Responsible for regulation, management and enforcement; including statutory protected sites and species, water quality, flood risk and waste. Land management, including National Nature Reserves and the Welsh Government Woodland Estate. Overseeing the Wales Coastal Path.
SCOTLAND								
Marine Scotland	X						X	Responsible for licensing, enforcement, sustainable management and compliance of marine renewables, fisheries and aquaculture industries. Licensing of marine protected species.
NatureScot				X			X	Scotland's nature agency; working to improve the natural environment in Scotland and inspire everyone to care more about it; providing advice to Scottish Ministers on matters relating to natural heritage. Responsible for granting wildlife and protected species licences.
Scottish Environment Protection Agency					X	X		Delivering Scotland's flood warning system. To help preserve and improve the water quality of lochs, rivers, estuaries, wetlands, groundwaters and coastal waters to ensure their sustainability. Monitoring and analysing samples from water sources. Providing advice and guidance to local authorities and developers in relation to planning applications and potential impacts on the water environment.
The Crown Estate Scotland			X					Management and licensing of the seabed, coastline and rural estates and supporting aquaculture, farming, forestry, tourism and offshore renewables through leasing and research.

	Marine management Marine licences	Planning permission	Foreshore and seabed leases	Nature conservation /SNCB	Water Environment Regulations Water quality	Flood protection	Wildlife licensing	Key responsibilities of relevance to saltmarsh restoration activities
NORTHERN IRELAND								
Department of Agriculture, Environment and Rural Affairs	X			X			X	Sustainable development of agri-food, environmental, fishing and forestry sectors of Northern Ireland, including marine management and issuing of marine and wildlife/protected species licences.
Northern Ireland Environment Agency					X			Regulate industry and ensure that the freshwater and marine environment is at good status.
The Department for Infrastructure Rivers (Northern Ireland)						X		Responsible for river and sea defence maintenance, the construction of flood alleviation schemes, the provision of flood maps and risk information. Their approval is required before carrying out works affecting flow in a watercourse.

Sea aster. Photo: Andrew Pearson.

Table 3.3: Key responsibilities of competent authorities in the Republic of Ireland.

	Marine management Marine licences	Planning permission	Foreshore and seabed leases	Nature conservation /SNCB	Water Framework Regulations Water quality	Flood protection	Wildlife licensing	Key responsibilities of relevance to saltmarsh restoration activities
Department of Housing, Planning and Local Government and Heritage			X					Regulating the use of the foreshore through a system of leasing and licensing.
Environmental Protection Agency	X				X	X		Licensing and regulating waste facilities, dredging and dumping at sea, waste water discharges and dumping at sea activities. Monitoring and reporting on the quality of rivers, lakes, transitional and coastal waters and groundwaters. Coordination and oversight of the technical aspects of the Water Framework Directive. Monitoring and reporting on bathing water quality.
Local planning authority		X						Regulating the use of land within their jurisdiction and relevant planning. Managing and granting planning permissions.
National Parks and Wildlife Service (NPWS)	X			X			X	Nature conservation through designation of sites and provision of advice to the government on the protection of habitats and species. Managing State-owned National parks and Nature Reserves. Licensing of certain activities not otherwise licensable by other bodies.
The Office of Public Works						X		The leading agency for flood risk management in Ireland, minimises the impacts of flooding through sustainable planning.

INSHORE MARINE LICENSING AND NATURE CONSERVATION AUTHORITIES

England

Marine Licensing:
The Marine Management Organisation regulate marine licensing under the Marine and Coastal Access Act 2009.

Nature conservation:
Natural England advise on the designation and management of marine protected areas in inshore waters.

Foreshore and seabed leases:
The Crown Estate manages and leases the seabed and half of the foreshore (under the Crown Estate Act 1961).

Water quality:
The Environment Agency monitor and work to protect the quality of estuaries and coastal waters. Relevant legislation includes the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017.

Northern Ireland

Marine Licensing:
Department of Agriculture, Environment and Rural Affairs (DAERA) regulate marine licensing under the Marine and Coastal Act 2009.

Nature conservation: DAERA designate and advise on the management of marine protected areas in inshore waters.

Foreshore and seabed leases:
The Crown Estate manages and leases the seabed and half of the foreshore under the Crown Estate Act 1961.

Water quality:
DAERA Marine and Fisheries Division monitor and work to protect the quality of estuaries and coastal waters. Relevant legislation includes the Water Environment (WFD) Regulations (Northern Ireland).

Scotland

Marine licensing:
Marine Scotland regulate marine licensing, on behalf of the Scottish Parliament, under the Marine (Scotland) Act 2010.

Nature Conservation:
NatureScot advise on the designation and management of marine protected areas in inshore waters.

Foreshore and seabed leases:
The Crown Estate Scotland manages and leases the seabed and half of the foreshore under the Crown Estate Act 1961 and Scotland Act 2016.

Water quality:
The Scottish Environment Protection Agency monitor and work to protect the quality of estuaries and coastal waters. Relevant legislation includes the Water Environment (Controlled Activites) (Scotland) Regulations.

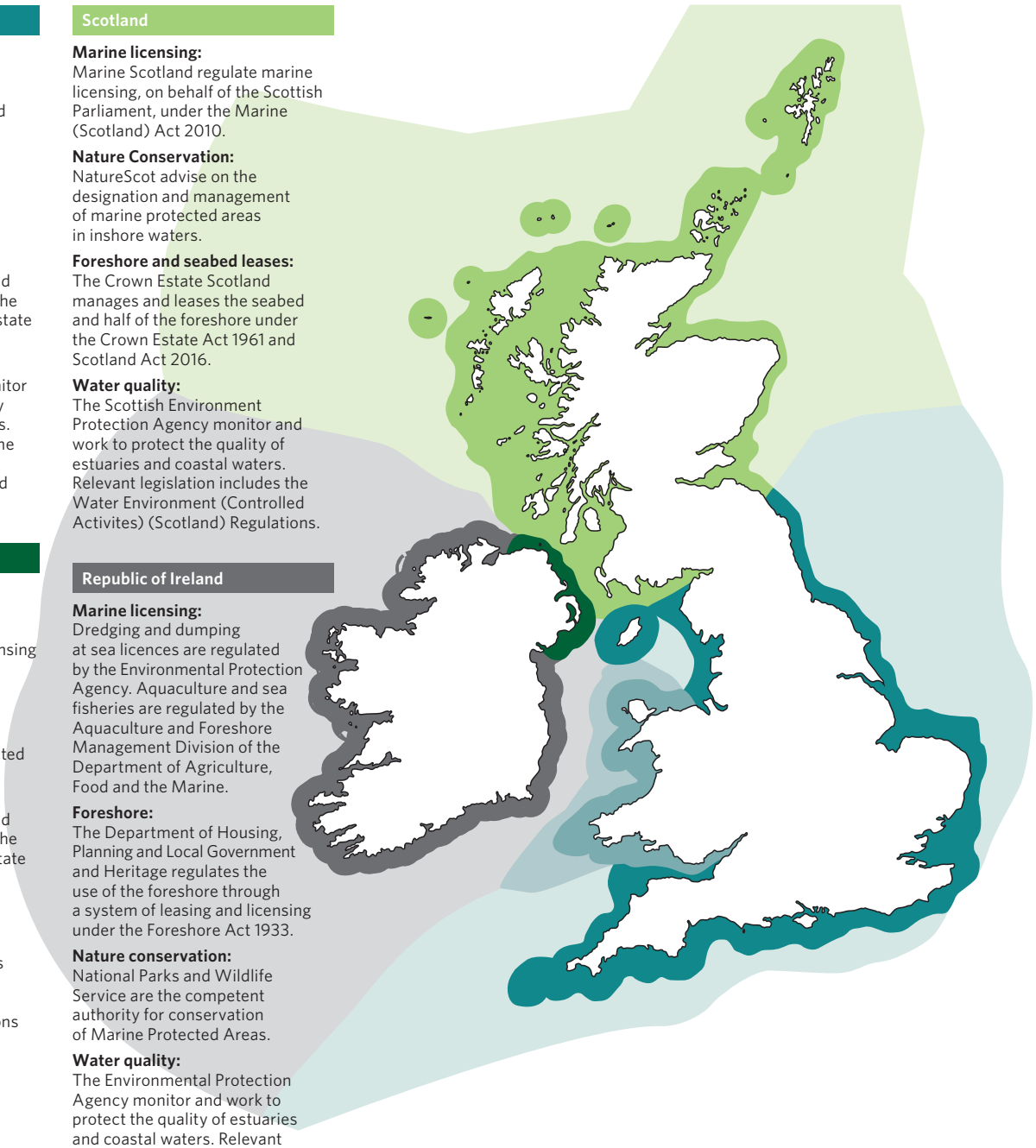
Republic of Ireland

Marine licensing:
Dredging and dumping at sea licences are regulated by the Environmental Protection Agency. Aquaculture and sea fisheries are regulated by the Aquaculture and Foreshore Management Division of the Department of Agriculture, Food and the Marine.

Foreshore:
The Department of Housing, Planning and Local Government and Heritage regulates the use of the foreshore through a system of leasing and licensing under the Foreshore Act 1933.

Nature conservation:
National Parks and Wildlife Service are the competent authority for conservation of Marine Protected Areas.

Water quality:
The Environmental Protection Agency monitor and work to protect the quality of estuaries and coastal waters. Relevant legislation includes the European Communities (Water Policy) Regulations 2003.



Wales

Marine licensing:
Natural Resources Wales (NRW) regulate marine licensing, on behalf of the Welsh Government, under the Marine and Coastal Access Act 2009.

Nature conservation:
NRW advise on the designation and management of marine protected areas in inshore waters.

Foreshore and seabed leases:
The Crown Estate manages and leases the seabed and half of the foreshore under the Crown Estate Act 1961.

Water quality:
NRW monitor and work to protect the quality of estuaries and coastal waters. Relevant legislation includes the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017.

Figure 3.1: Marine management, licensing and nature conservation authorities for coastal waters across the UK and the Republic of Ireland, with the underpinning legislation highlighted.

PERMITTING AND LICENSING REQUIREMENTS

This section sets out the likely permits and licences that may be needed for any saltmarsh habitat restoration proposals. As explained in the introduction to this chapter, if you are planning a project in the Republic of Ireland, you are advised to check for possible changes to the permits and licences that may be needed once the Marine Planning and Development Management (MPDM) Bill is finalised and implemented.

Consents, permits and licences that may be required for saltmarsh habitat restoration proposals are summarised in **Table 3.4**. Note that not all habitat restoration proposals will require all these listed permits and licences. Requirements will vary by the type of activities proposed, the scale of predicted change and the features of a chosen site for a saltmarsh habitat restoration project.

It is advised that licences and permissions required are researched during the project planning stage and that relevant stakeholders are consulted as early as possible during the planning stage. **Table 3.1**, in the previous section, sets out the relevant stakeholders in each country for each type of consent required.

A hypothetical case study is presented in **Box 3.2**. It should be noted that the purpose of this case study is only to provide an example and the likely thought process that saltmarsh restoration proposals would need to go through from a consenting perspective. The consents, licences and permissions needed will be specific to each individual project.

Table 3.4: Summary of the key consents and agreements that may be needed, depending on the scale, location and type of saltmarsh habitat restoration proposals.

CONSENT REQUIRED	WHERE NEEDED?	WHY NEEDED?
Landowner consent	If the area of proposed works overlaps with privately owned land.	Permission from the landowner will be needed.
Foreshore/seabed/ survey lease	UK: If the proposed works are in an area of foreshore or seabed owned by the Crown Estate and Crown Estate Scotland. RoI: Check with The Department of Housing, Planning and Local Government whether a lease is required to work in the foreshore.	To make sure you have permission from the owner of foreshore/seabed for any works proposed.
Planning permission	If the proposed works include construction on land (above mean low water).	For the local planning authority to regulate and manage plans and projects within its jurisdiction to ensure that plans fall within the overall plans for the area and do not have adverse effects on the environment or other users. Conditions may be imposed on a grant of planning permission, for example, relating to access details, public rights of way, archaeology, having a construction management plan.
Marine licence/ disposal at sea licence	If the proposed works in the intertidal or subtidal areas include activities such as construction, dredging, deposit or removal of any substance.	For the regulatory organisation to regulate and manage plans and projects within its jurisdiction, to have conditions in place for related environmental mitigation measures to minimise environmental impact, and associated monitoring.
Permission to carry out works on a river, flood defence or sea defence	Check with the relevant authority. A permit or written approval from the competent authority is likely to be required if the proposed works are near a watercourse. Flood Risk Activity Permit (FRAP) in England and Wales. Controlled Activities Regulations (CAR) authorisation (in Scotland)	To protect you and others from the risk of flooding and to ensure that the watercourse in the project area is not compromised by the habitat restoration proposals.

CONSENT REQUIRED	WHERE NEEDED?	WHY NEEDED?
Wildlife licence/ protected species licence	If you plan to remove or disturb wildlife, or damage habitats. If the habitat restoration proposals are likely to involve disturbing, trapping or handling protected species; or disturbing their habitats.	To ensure managed and minimised impacts on the relevant species/habitats.
SSSI/ASSI/NHA consent/assent [1]	If the proposed works could impact on a SSSI/ASSI/NHA.	To ensure minimisation of impacts on the SSSI/ASSI/NHA.
Harbour works licence	If the habitat restoration proposals are within the jurisdiction of a Harbour Authority.	Engagement and consultation with the Authority will be required, even if no extra consents or licences are needed.
Consider relevant Acts such as, The Countryside and Rights of Way Act 2000, NERC Act 2006, Highways Act 1980, Land Reform (Scotland) Act 2003	Likely to be considered as part of any planning application process. (See Box 3.1 for examples of planning permission outcomes where there were objections due to proposed changes to public rights of way.)	To mitigate impacts associated with any diversions or closures (temporary or permanent) of rights of way arising from the habitat restoration proposals.
Consent of coast protection authority	Check with the relevant authority.	Required for carrying out coast protection work, of which saltmarsh habitats form a part.
Discussion with the Inshore Fisheries and Conservation Authority (IFCA)	Relevant to England.	Engagement and consultation with the local IFCA is advised, even if no extra consents or licences are needed.

Table 3.5: Summary of assessments that may be required to support consent applications.

ASSESSMENTS THAT MAY BE REQUIRED TO SUPPORT	WHERE NEEDED?	WHY NEEDED?
Habitats Regulations Assessment	If the proposed works could impact part of the UK site network or a Natura 2000 site (RoI).	To assess the likelihood of significant effects on SACs, SPAs or Ramsar sites designated for their nature conservation interest.
MCZ Assessment	If the habitat restoration area is within or near an MCZ.	To ensure minimal impacts to the designated features of the MCZ.
Water Environment Assessment	If planning permission or another licence/ permit is required, you are likely to need to show that the proposals comply with relevant water environment regulations (the competent authority for the permission applied for will be able to advise you). Your assessment can be proportional to the scale of likely impacts.	To ensure that the status of bodies of water, including estuaries, coastal waters, lakes and lagoons, will not be degraded by the habitat restoration proposals.
Flood risk assessment	If the habitat restoration proposals are in an area with flood risk.	To ensure that the habitat restoration proposals do not compromise the flood risk in the area.
Environmental Impact Assessment	If projects are likely to have significant environmental effects.	To assess the likelihood and significance of any environmental impacts arising from the habitat restoration proposals.

1. An SSSI consent is issued by Natural England in response to a notice of proposal by owners and occupiers of an SSSI asking for permission to carry out works, which includes an activity listed on the Operations Likely to Damage (OLD) list.
An SSSI assent is issued by Natural England in response to a notice of proposal from public bodies while carrying out their functions such as the Secretary of State, government departments and agencies, local authorities and statutory undertakers requesting permission to carry out works on a site that includes an operation identified in the SSSI notification as likely to damage.

BOX 3.1: EXAMPLES OF PLANNING OUTCOMES FOR PROJECTS WITH RIGHT OF WAY OBJECTIONS

	Project gets delayed or rejected and managed realignment doesn't go ahead	Project goes ahead but without full community backing
Where	**Devereux Farm** Hamford Water, Essex.	**Donna Nook** North Lincolnshire.
Project proposal	To breach the current sea wall in two places, converting 30ha of agricultural land to saltmarsh habitat.	To breach 40 metres of sea defence to create 111ha of intertidal saltmarsh habitat and create a new sea defence about 500 metres inland.
Objections	The second breach would have required a public right of way to be closed and diverted as a condition attached to the planning permission. A public campaign to save the footpath led to a Public Inquiry in 2010.	The breach would remove 40 metres of Footpath 18 and the proposed solution was not seen as satisfactory. The objections led to a public inquiry in June 2018.
Outcome	The Planning Inspector submitted a decision in December 2010 declining the order by the Environment Agency, which meant the breach could not be constructed. In this instance, planning permission was granted but the Environment Agency did not construct the second breach due to being unable to fulfil the condition for closing and diverting the public right of way.	The Secretary of State approved the Environment Agency's application to close footpath 18 and the breach went ahead in 2019.

Clyde. Photo: Andrew Pearson.

BOX 3.2: A HYPOTHETICAL CASE STUDY FOR A SALTMARSH RESTORATION PROPOSAL.

Situation

A project proposing to use structures intended for saltmarsh restoration, within the intertidal zone in England, would have to go through several different licensing and jurisdictional permissions in order to legally proceed. Early engagement with the relevant organisations is recommended. Some will offer a pre-application advice service.

Marine licence

Firstly, visit the government MMO webpages to see whether a licence is required, or the work qualifies for an exemption (https://www.gov.uk/guidance/do-i-need-a-marine-licence). Information on different types of marine licences required in England and Northern Ireland can be found on this webpage, as well as an interactive assistance tool (https://marinelicensing.marinemanagement.org.uk/mmofox5/journey/self-service/start), which asks questions about the work and provides a conclusion as to whether or not a licence is required. For example, if work was to involve placing biodegradable structures onto the seabed, implemented on foot, a marine licence would likely not be required, and proof of an exemption would be acceptable to move forward with the process. However, the MMO may still need to be notified of the activities. This web page also provides links to various other consents which may be required by certain works. If a licence is required, the MMO will advise if any assessments are required in support of the licence application.

Landowner and local planning authority

Landowner permission is likely to be needed, whether the area of saltmarsh is on land owned by a private individual or an organisation (such as The Crown Estate).

Planning permission is also likely to be needed. This will require pre-application consultation with the local planning authority, who will be able to advise if any assessments are required in support of the planning application.

Conservation designations

Much of the saltmarsh habitat of the UK and Republic of Ireland is protected either in its own right or because it provides habitat for protected species such as migratory birds. Saltmarsh is also a priority habitat in the UK under the Biodiversity Action Plan. This means that often saltmarsh that is targeted for restoration, will fall under an SSSI/ASSI/NHA, as well as potentially SAC, SPA and Ramsar designations. Designations should be checked when proposals are being developed (see Chapter 2, Table 2.1 for links to useful maps and data). According to the outcome of this check, the relevant statutory nature conservation body (SNCB) (for example, Natural England) should be consulted to inform them of the saltmarsh restoration proposals, regardless of whether the proposals are exempt from a marine licence/planning permission or not. The SNCB will be able to advise on the potential impacts on any designated features, and the content of a Habitats Regulations Assessment (if needed to be produced) for SACs, SPAs and Ramsar sites or if an SSSI/ASSI/NHA consent needs to be applied for. For England, the form for this consent application is online (https://www.gov.uk/government/publications/request-permission-for-works-or-an-activity-on-an-sssi).

To inform a Habitats Regulation Assessment (HRA) or an SSSI consent application, in England, Natural England's designated sites system (https://designatedsites.naturalengland.org.uk/SiteSearch.aspx) can be searched for a specific site. This will reveal specific features of the site and will be useful for the assessments to follow. When completing an HRA, it is important to justify whether or not the work will have a significant impact on any qualifying features listed, or conservation objectives set. The objective is to prove that even if the restoration work is unsuccessful in what it aims to achieve, it will not have a significant negative impact on the rest of the site. Once the HRA has addressed impacts on all relevant features, it can be sent to Natural England to be signed off, at protectedsites@naturalengland.org.uk (unless it is being submitted as a shadow HRA with a licence application).

Water environment compliance assessment and flood risk

In England, the 'Clearing the Waters for All' guidance (https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters) can be followed when assessing a project for compliance with the Water Environment regulations. Contact the relevant authority, in other parts of the UK and Ireland (see Figure 3.1 or Table 3.1 for help identifying the relevant authority), for advice on carrying out a compliance assessment with the equivalent regulations there. The results of the compliance assessment will need to be submitted alongside other supporting documents to the relevant regulator(s) from which permission/consent is being sought.

If the area of interest is within or near a waterway, then the Environment Agency (in England) will need to be consulted, and a Flood Risk Activities Environmental Permit applied for accordingly.

Harbour Authority

If the proposals are within the jurisdiction of a Harbour Authority, then permission of the Harbour Authority will be needed. They will need to be made aware of any proposed restoration work that is going ahead. It will benefit the project to keep them updated throughout the duration of the project, even after the licensing is approved and the project is underway.

Sea aster with butterfly. Photo: Andrew Pearson.

LEGISLATION CONCERNING PUBLIC PARTICIPATION IN ENVIRONMENTAL DECISIONS

The 'Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters' (**the Aarhus Convention**), which was ratified by the UK in 2005 and by Ireland in 2012, requires public authorities to confer the following rights on the public regarding the environment:

1. the right to access environmental information that is held by public authorities.
2. the right to participate in environmental decision-making.
3. the right to access justice in environmental matters.

According to the Aarhus Convention, members of the public should have the right to participate in environmental decision-making. In this section, we outline the process map of public participation from two perspectives of relevance to many saltmarsh restoration projects: (1) environmental permits and (2) environmental impact assessment (EIA). Effective communication and engagement (discussed in Chapter 4) will help to avoid unexpected objections to restoration scheme proposals being raised during formal periods of public consultation.

(1) PUBLIC PARTICIPATION CONCERNING ENVIRONMENTAL PERMITS

When environmental permits are required for a saltmarsh restoration project, the responsible public authorities have a duty to consult the public. For example, according to the 'Environmental Permitting (England and Wales) Regulations 2016', public authorities must consult the public on:

(i) preparing new standard rules and revising existing rules for environmental permits

(ii) certain applications for environmental permits

(i) PUBLIC PARTICIPATION CONCERNING STANDARD RULES

In preparing and revising standard rules, the public authorities must consult those people it considers represent the interests of communities likely to be affected (for example, NGOs). The relevant organisation publishes a consultation paper for new standard rules on its website and the public can make representations. The consultation period for new standard rules is normally 12 weeks, and for revising existing rules normally a minimum of 28 days. After the consultation period, the organisation will review the comment, and then finalise and publish standard rules.

(ii) PUBLIC PARTICIPATION CONCERNING ENVIRONMENTAL PERMITS

If someone needs to apply for environmental permits but cannot meet any of the standard rules, then they need to apply for a bespoke permit. When the Environment Agency for England receives a valid bespoke permit application, for example, it will publicise the application within 30 working days. The Environment Agency then invites individuals and organisations to comment on the applications for normally 20 working days. After the consultation period, the Environment Agency will consider the comments and decide whether or not to grant a permit.

(2) PUBLIC PARTICIPATION CONCERNING ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment (EIA) is a systematic decision-making process to assess the possible environmental impacts of a project. The steps involved include public participation:

1. Screening: should project be subject to EIA?
2. Scoping: what impacts should be assessed?
3. Preparing an Environmental Statement: describe the project; identify and predict impacts and evaluate their significance; assess whether impacts can be mitigated.
4. **Public participation.**
5. Decision-making: decide whether proposed project should go ahead.

CHAPTER 4
COMMUNICATION AND ENGAGEMENT

CHAPTER AUTHORS

Hiromi Yamashita, Hannah Mossman (sub-lead), Tim McGrath (sub-lead) Contributing authors: Ellie Taylor, Akitomo Hayashi, William Austin, Clare Maynard.

KEY SUMMARY POINTS:

- **Consult with a wide range of stakeholders from the project conception to ensure local knowledge is incorporated into the project design and to increase stakeholder engagement and support.**
- **Community engagement brings about benefits to both the project and local communities.**
- **Consider a variety of approaches and styles of communication and consultations to engage effectively with different stakeholders.**

INTRODUCTION

It is no exaggeration to say that the success of saltmarsh restoration projects depends on the relationships you have with the local community.

Unlike other types of restoration projects, saltmarsh restoration, especially moving sea defences inland, creates dramatic changes to existing, familiar environments; for example, by introducing seawater onto local farmland. Enabling water to come closer to communities can trigger feelings of unease among the local community, with possible impacts on their livelihoods such as farming and fisheries.

Saltmarsh might also be an unfamiliar environment and regarded as unattractive, making it unpopular with some in the local community, particularly as they might not be the first to benefit from the project. These issues can create divisions within communities, and communication mechanisms that are inclusive and regarded as 'fair' are crucial in avoiding such problems.

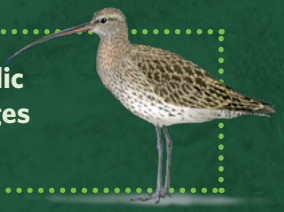
The aim of communication and engagement activities is to establish a long-lasting relationship with relevant groups and local communities, and not to push through a project that they do not want. Imposing a project on a local community could not only jeopardise it, but also sow seeds of resentment towards any future saltmarsh restoration projects in the area. A saltmarsh restoration project could bring opportunities for local towns and villages to revitalise their environment and livelihoods, as well as improve their resilience to future climate change. It helps to remain open-minded and learn from any 'difficult' comments, because they could provide valuable insights for improving the project and establishing a trusting relationship with key stakeholders for future effective collaborations.

This chapter covers the **Why, Who, What, How** and **When** of communication and engagement for saltmarsh restoration projects. It is written particularly for those who have an official role in liaising with the public in preparing for the different phases of a restoration project (**before** project approval, **during** construction and **after** project construction has 'ended'), but it is hoped that it will also be useful for others in related roles. **Direct quotes from 27 practitioners who have experienced** successes and difficulties in communication and engagement will be shared throughout the chapter. A "*Questionnaire on Your Experience of Communication with Public about Coastal Restoration and Flood Risk Management*" was sent to people who have experience of engaging with community members about coastal changes in the UK and Ireland, and whose job description requires them to communicate with the public.

"Public participation could cause project delays..."

"Personally, I do not know how best to communicate with the public."

"I feel hesitant in starting public participation in the early stages of a project."



"I am already too stretched in my work to handle anything else."

Let's now look at these concerns.

WHY? Benefits of good communication and engagement

IMPORTANCE OF COMMUNITY ENGAGEMENT IN RESTORATION DECISION MAKING

Q **"I am anxious that local ideas will ruin our project."**

A **"Learning from local knowledge enables a project, not hinders it."**

BOX 4.1: IS IT 'PUBLIC PARTICIPATION' OR 'STAKEHOLDER ENGAGEMENT' OR SOMETHING ELSE?

In the literature and guidance we often see terms such as: 'public participation', 'community engagement', or 'stakeholder engagement' and although they can be (and have been) used interchangeably, there are subtle technical differences in their meanings and the terms can mean different things in Australia, the US and the UK.

'Public' is one or more natural or legal persons, their associations, organisations or groups.

A **'stakeholder'** is an individual, group, or institution (including governments) that has a defined and recognised interest, or 'stake' in a decision-making process. That interest may be economical, cultural, recreational, religious or other, and the stakeholders will be affected by a decision or have some influence on its outcome.

The **'community'** is made up of people with a local common connection, usually geographical. Every **'community'** will be made up of a range of local stakeholder interests. These might include local residents, local groups and voluntary groups. Interested groups could be web based or virtual as well as groups that meet face to face.

Engagement is a generic English word, so you have to be aware of the context it is used in. In this context **'engagement'** means people '*doing*' rather than just *talking*.

Engagement is generally felt to be inclusive and often indicates that you're part of a long-term process, whereas the word **'participation'** creates a bit more distance, you can participate in something but have no influence on the process itself.

However it should be noted that these distinctions are not always made. For example, the International Association for Public Participation (IAP2) confirms that it uses the terms 'public participation' and 'community engagement' interchangeably. It defines public participation as:

"a process that involves the public in problem solving or decision making and uses public input to make decisions. It includes all aspects of identifying problems and opportunities, developing alternatives and making decisions. It uses tools and techniques that are common to a number of dispute resolution and communication fields." (IAP2, 2010, p. 20).

As explained in Chapter 3, public consultation forms part of permit application and environmental impact assessment processes. It can also bring about many benefits for saltmarsh restoration schemes including:

For projects

- providing an opportunity to co-design projects and schemes.
- identifying key stakeholders and local needs.
- establishing two-way information exchanges.
- exchanges could generate novel solutions.
- identifying local expertise, which otherwise may be overlooked.
- efficiency in knowing potential obstacles at an early stage.
- reducing misunderstandings and hostilities towards each other.
- encouraging active involvement for future volunteer work.
- obtaining negotiated consensus.

For citizens

- being given rights in decision-making.
- having a chance to make the project fit with public values and priorities.
- raised awareness of local coastal management.

For future relationships

- building trust between the local community and those involved with the project.
- ensuring transparency in decision-making.

DEALING WITH UNCERTAINTY: THE VALUE OF LOCAL KNOWLEDGE

Tacit and explicit knowledge

Tacit knowledge = experiential or local or traditional knowledge
Highly personal and hard to formalise, making it difficult to communicate or to share with others. **Insights, intuitions, long-term observations** and experiences

Explicit knowledge
something **formal and systematic** and can be expressed in words and numbers, and easily communicated and shared in the form of hard data

Saltmarsh restoration projects are carried out in a context of uncertainty. Assembling and accumulating multiple sources of knowledge help minimise this uncertainty. When making decisions, it is important to combine two different types of knowledge: tacit and explicit.

Explicit knowledge (such as sediment budgets and hydrology data) is often regarded as robust and quantitative and therefore 'useful' in the consultation process. This can lead to the mistaken belief that it is better than local or tacit knowledge, even though scientific knowledge can often only answer specific questions that might not capture the many configurations of the broader context.

In contrast, **tacit** or experiential knowledge is often built up over longer periods on multiple occasions (for example, fishermen sensing changes in current movement and sediment accumulation). Capturing the tacit knowledge that local communities, groups or experts may have built up from long-term observations of a saltmarsh, and combining this with explicit knowledge, will create a stronger decision-making data platform.

WHO? Identifying stakeholders and the community

Q **Would it be better if I make the stakeholder numbers as small as possible?**

A **No... Limiting opportunities to obtain local knowledge is not advisable in keeping a project healthy.**

The scale of consultation and the parties consulted will vary with the type of saltmarsh restoration project planned. Large-scale habitat creation schemes, such as managed realignment or flood storage schemes, will require full planning permission and consultation with a wide range of groups. For these sites, local community groups and (if the scheme results in diverted public rights of way) local walking groups will be very important. In contrast, smaller restoration schemes, such as those to protect existing saltmarsh, may require smaller-scale consultation.

Some suggested groups to consult are presented below. Identifying and understanding the level of consultation needed for each group is vital in order to effectively target engagement.

Reeds (*Phragmites*) in a brackish saltmarsh. Photo: Andrew Pearson.

(A) Statutory – planning law prescribes circumstances where local planning authorities are required to consult specified bodies before a decision about an application is made.

Examples include:

- governments and their agencies (for example, Environment Agency and Natural England, Natural Resources Wales, SEPA and NatureScot, Department of Agriculture, Environment and Rural Affairs, Environmental Protection Agency).
- local flood authority.
- local highways authority.
- Marine Management Organisation.
- Canal and River Trust.

(B) Non-Statutory – other consultees who, while not designated in law, are likely to have an interest in a proposed development.

Examples include:

- ramblers and other relevant public access groups.
- local farming organisations.
- representatives from local fisheries.
- local marina and harbour authorities.
- local wildlife groups.
- local wildfowler groups.
- rail network operators.

(C) Public – local planning authorities are required to carry out a formal period of public consultation before deciding on a planning application.

Examples include:

- Local councils, for example, parish or district councils.
- Neighbourhood forums.
- Local community groups.
- Land-owners and local farmers.

COASTAL COMMUNITIES AND ENGAGEMENT

Q **Are there differences between coastal and other communities?**

A **Yes. The more you understand the local context, the better you understand the public's comments.**

Coastal communities share properties with both rural and urban populations while also having unique characteristics of their own. Management schemes and policies, and citizen engagement schemes need to consider the characteristics and make-up of the coastal communities involved in order to implement successful strategies. Many coastal communities are characterised by ageing resident populations and/or high economic deprivation, but these are often supplemented with part-time, second home residents. The perceptions of, and value obtained from, the local environment are likely to differ between these types of residents, as might the willingness, confidence and ability to engage with consultations. As such, communication strategies should be targeted to ensure all types of residents are able to get their voices heard.

Saltmarsh at Brancaster, Norfolk. Photo: Mike Best.

Coastal communities vary across the UK and Ireland, but some of the following characteristics may be of relevance (adapted from Atterton, 2006, ONS, 2020):

Demographic:

- ageing population.
- little or no movement of young people into area.
- high movement out of area.
- high number of retired or benefit claimants.
- high number of second homes.

Seasonal employment:

- pressure on facilities in summer months.
- quiet winters.
- highly dependent on seasonal tourism.

Risks

- rising sea level.
- erosion.
- flooding.
- economic disadvantage.

Protected environment:

- designations to conserve nature, landscapes, geomorphology or natural heritage.
- unique habitat.
- endemic species.

Local communities may already have some mistrust in development schemes and be wary of any organisation approaching with new plans to change their landscape. Moreover, the issues in these communities need to be handled with sensitivity. In some areas, the risk of flooding or erosion brings with it the real threat of losing one's house or having to relocate.

DISCUSSION WITH LANDOWNERS AND FARMERS

Q **What should I consider before approaching landowners and farmers?**

A **Understanding individual situations and concerns is crucial.**

What are the points to consider in terms of communicating with local landowners and farmers, especially if a restoration project requires them to accept loss of existing landscapes and farmland? Our questionnaire suggested "investing *time in going to meet the landowners to listen to their concerns*" and "keeping *in regular contact with the landowners throughout the project, responding to any issues that* arise".

Case study: 4.1

WWT Steart Marshes, engagement with farmers and landowners

The Steart Peninsula was a large area of coastal grazing marsh that was mainly farmed for dairy and beef in the form of improved and semi-improved grazing land, with a cultivated area used for growing maize. In multiple private ownership, a large proportion of the land was tenanted to seasonal graziers. This land use had been the most dominant feature for many years, protected from the tides of the Severn Estuary by an earth embankment along the River Parrett. However, in 1981 the peninsula experienced catastrophic tidal flooding, there was a general acceptance that the current agricultural management regime might not be sustainable.

Open two-way communication between the project team and farmers and landowners was important to get to know their current situations and future hopes, as well as their thoughts in obtaining alternative land nearby. This was coupled with open dialogue between the Environment Agency and landowners, and culminated in all of the land being acquired through voluntary agreement. There was also agreement for the existing tenants to retain the option to carry on agricultural management until the scheme was complete, with a number continuing throughout the transformation to WWT Steart Marshes. (For more information see McGrath, 2022).

DISCUSSION WITH LOCAL FISHERMEN AND FISHERY ASSOCIATIONS

In communities where small, coastal fisheries are still active, local fishermen might want to know about saltmarsh and tidal flat restoration projects because of their important role as nursery grounds for local fish. In recent years, there have been many studies which reveal that fish living outside of restoration project sites use them for breeding (See Chapter 5, section 'Incorporating fish habitat in intertidal landscape design' for more information). However, at the same time some fishermen might also have concerns, for example, whether there would be impacts from any periods of increased turbidity from initial erosion or activities such as sediment recharge. It's helpful to identify and ask local fishery organisations to inform you of any negative and positive changes so they can be recorded for the project. Their information will help you to review options and refine the project design to avoid or mitigate possible impacts by, for example, carrying out work at a time of day/season to avoid a particular fishing activity.

WHAT AND HOW? Styles and methods of communication and engagement

WHAT DO WE MEAN BY PUBLIC 'PARTICIPATION'?

Q **I've met the public and told them about the project. So that's my job done, isn't it?**

A **That might not even be considered as public participation.**

Some forms of 'public participation' may be regarded as 'tokenistic', and can damage relationships. Real participation tries to ensure the local community is at least an equal partner. It empowers them and respects their decisions about their own environment, which they are going to live with and manage for the future. Avoid 'public participation' activities that make the local community feel they are ignored or that decisions have been forced on them. **Ask "how high can the project elevate public participation levels and empower local people?"** (see Figure 4.1)

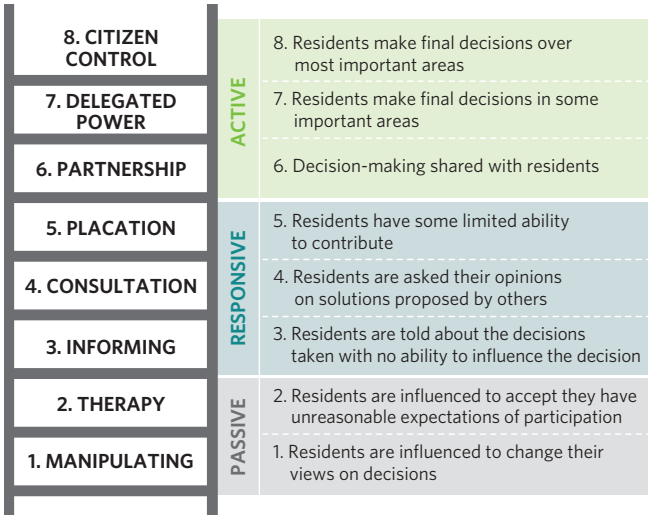


Figure 4.1: Ladder of participation (adapted from Arnstein, 1969). The approaches near the bottom of the ladder could be considered non-participation or tokenistic. Rising up the ladder, the approaches give local communities increased levels of decision-making power.

MODELS OF PUBLIC PARTICIPATION

Participation processes differ from community to community, and from project to project. However, there are models, or ways of thinking about public participations, that can be adopted. Experience tells us that a top down approach, such as the Decide-Announce-Defend (DAD) model, creates resentment, which affects trusting relationships with communities long into the future. At the beginning of the process, the public might seem to accept a proposal, but at the end, the lack of trust could cause delays and negative feedback. The Engage-Deliberate-Decide (EDD) model nurtures better relationships on the ground.

MODEL	ADVANTAGES	DISADVANTAGES
Engage-Deliberate-Decide (EDD) Encourages engagement and participation from all stakeholders from the start of the project. Takes a collaborative approach to finding solutions, and focuses on deliberation with all members, including the local community, before a decision is made. Creates two-way information exchanges, which can be useful throughout the project.	Any objections or doubts can be worked through in deliberative conversations. Consideration by diverse people with different perspectives can enhance mutual understanding, relationships and may result in better solutions. Can save time in the long run by gaining support from people and groups that will be needed for successful implementation.	It can take longer to get started. Requires a group of people/ stakeholders willing to give time to the project.
Decide-Announce-Defend (DAD) The decision-making process is conducted by the project leads and professionals to create the preferred solution. Efforts are then focused on how to defend and convince other stakeholders that this is the best solution when the plans are announced. Community engagement is limited and usually there is little flexibility to change the design of the plan.	Initially quicker and simpler because fewer people are involved. May be easier to make decisions. Uses professional expertise to come up with solutions.	Risk of delays or plans being unsuccessful if the project meets resistance at the 'defend' stage. Not well suited to projects requiring support/cooperation from others.

DIFFERENT STYLES OF COMMUNICATION AND CONSULTATIONS

Face-to-face communication is an effective way to provide information about a project and to interact with all stakeholders that have an interest. Face-to-face consultations allow for discussion and queries to be raised in a focussed environment with the right people there to give answers. Face-to-face interactions can be time and resource intensive. Large-scale, community-wide consultations may be more cost-effective than smaller scale, targeted communication. There are different forms of face-to-face consultation, tailored to be as formal or structured as required.

Getting the language right and respecting people's views is important to create a positive experience. Drop-in sessions are useful to capture an audience that cannot commit to a specific time of day.

Different styles of room setting create different atmospheres to suit the role of face-to-face meetings:

- conference style (to provide information to a large group).
- round table (to get to know each other).
- festival stall/workshop style (allows small groups of people to discuss and share ideas on particular topics).

One-way forms of remote communication, such as physical or online newspaper articles or adverts, leaflets and websites, can be useful to convey important information and key events to a wide range of people. They allow people to read and reflect on information in their own time, although they do not easily allow community responses. Online or social media distributed material may reach a larger audience but miss subsets of the community.

Simple maps and artist drawings of what the restoration site might look like, or more complex digital visualisations or virtual reality models, can really help people to visualise the future landscape and how they could interact with it. This may be particularly useful if the restoration scheme would change public access and rights of way.

Paper or online surveys and questionnaires can be used to capture opinions, shape future communication strategies and highlight aspects of community concern or misunderstanding. However, individual responses cannot be directly responded to.

Methods of two-way remote communication allow an individual's suggestions and concerns to be heard and potentially addressed. Online forums and communities can provide a platform for two-way discussion about a site. However, experienced, skilled mediators may need to be considered and two-way communication may be simpler in a face-to-face context.

Visits provide opportunities to share and experience the existing and possible future sites, and also to have informal chats with local people in more relaxed situations. A shared visit experience can create an important reference and shared resource for future meetings. Working with local schools can create and retain interest, especially if curriculum relevant resources are made available.

Whichever style of meeting or communication you choose, try to provide an atmosphere in which people feel ok to express their concerns and expectations fully. Be aware of your facial expressions not only when hearing support for your project but also negative comments.

Face-to-face communication methods include:
drop-in sessions
workshops
public meetings
focus group interviews
role play scenarios
conference and events
home visits
informal chats on site (for example, with dog walkers)
Remote communication methods include:
newsletters
digital visualisation (for example, digital modelling, virtual reality)
information boards
exhibitions/road-shows/pop-up stalls
social media
online forums
questionnaires
Visits could include:
organised site visits/walk-abouts
field trips to a restored site (online and off-line)

USEFUL LINKS AND RESOURCES

Community engagement toolkits
www.involve.org.uk/resources

WHEN? When to engage and typical concerns

BEFORE OBTAINING PERMISSIONS: THE PRECIOUS OPPORTUNITY TO MAKE THE PROJECT FIT FOR LOCAL NEEDS

The public often have a negative perception of 'public participation' and 'community engagement', sometimes based on poor past experiences. Therefore, the very beginning of the consultation process is often tough since they are quite rightly apprehensive.

What was the first impression you received from the community about the project?

Practitioners who responded to the questionnaire said they received various first impression responses from the public, with a similar proportion of negative and positive first impressions.

The first impression you get might not be positive, but there are many ways to work with this.

Typical complaints and worries about saltmarsh restoration projects

Local communities are often concerned about large-scale changes to landscapes that can arise from managed realignment, regulated tidal exchange and flood storage schemes. Restoration of urban fringe habitat or efforts to prevent further erosion of existing habitat may be less controversial because the changes they bring to the landscape are less dramatic. However, that does not mean that all parties will accept these schemes – for example, the natural spread of pioneer saltmarsh plants on a beach at Hoylake, Wirral in England, is controversial and there have been some public calls to remove them to preserve a sandy beach (mechanical raking and spraying of the beach to remove vegetation was stopped in 2019 and scientific studies and public consultations are being planned before deciding on future beach management). For more information visit https://haveyoursay.wirral.gov.uk/hoylake-beach-information.

The results of the questionnaire, sent to the people responsible for communication in previous saltmarsh restoration projects, show the following concerns, which are all relevant and need to be resolved with care through consultation.

Loss of rights of way	Anyone in the country can object to a planning application, so people who come from other areas to use public footpaths/rights of way can object. (See also Box 4.2 and case study 4.2).
Loss of land/food security	Some people are attached to the land, especially where the area is currently used for farming. Farmland, as opposed to saltmarsh, may be perceived as important and productive, for the local community and for the world. 'Giving land back to the sea' could be seen as admitting defeat and a lack of governmental efforts to protect land. There is also the potential issue around the relocation of farming areas.
Landscape change	People are very attached to the familiar scenery around them. What constitutes beauty differs from person to person, and the possible loss of an existing view may sometimes raise concerns.
Increased number of tourists	Coastal towns can be sensitive to seasonal changes and tourism, and might need to have facilities available to accommodate change. Some welcome, while others do not welcome, the visitors close to their communities. Some benefits from having visitors tend to be concentrated on certain businesses.
Loss of local habitat	Some people value existing habitat that they are used to. Some might have concerns over different wildlife, and perceived threat of avian influenza.
Others concerns	Loss of existing sea defence, damage to property, increasing flood risk, mess during construction, loss of fishing rights, increased road traffic, loss of parking, "wasting tax payers" money.

How have projects responded to or accommodated concerns of local communities in the past?

The following are answers from people who completed our questionnaire, sharing examples of how they have successfully addressed concerns in past projects.

Listen and share local concern

- We had been briefed on the pre-project concerns of the local communities and **so could design workshops** which directly addressed these concerns.
- We try to understand their concerns and consider how the project **could address those concerns and meet their expectations where possible**, while still delivering the objectives of the scheme.
- **We showed where we had taken local concerns** on-board and addressed them. We **shared information** as soon as we had it.
- We listened to the local issues and concerns that were raised and responded within **an agreed timescale and with balanced** reasons why it was considered that such changes were required.

Visualise the project

- A 3D model and photomontages/visualisations helped to explain what the project will look like and how their interests will be affected.
- We showed live modelling of a do-nothing scenario.
- We took them to visit similar sites that were already established.

Flexible designs

- We asked them to input into the design and litigation measures.
- We were able to change the design to address their concerns.
- We dropped a component of the project that would have led to the closure of a section of public highway.
- We devised a resilience strategy.

Explain about funding

- We explained about the funding mechanism for flood and coastal erosion risk management projects, what could and couldn't be funded by grant-in-aid and why other funding sources/community contributions would be required to deliver broader outcomes.
- No compulsory purchases were made where schemes were on purchased land; at site meetings it was incorrectly thought that land owners had to sell.

Continuous engagement

- We introduced site managers early on in the project and the contractors met with the community as soon as they were on-board. They engaged with the community at an early stage, addressing concerns and establishing trust.
- We encouraged the community to have the channel to voice their opinions.
- We continued to try to engage with the community although they were very unreceptive as **they perceived authorities as 'not listening to them' if the authorities do not do what they want them to do**.
- We used community focus groups led by community.
- We used a mixture of communication approaches (for example, having an engagement officer, using social media and site notices).
- It took a lot of time to contact landowners.
- We had regular meetings with all stakeholders via estuary partnerships. The specific engagement was therefore part of a larger engagement programme.
- We **facilitated access to other communities** who had experienced similar issues and concerns.

Photo: Mike Best.

BOX 4.2: PUBLIC ACCESS AND RESTORATION SCHEMES

The termination and replacement of footpaths can be controversial, and careful consultation and consideration of the options is needed. Artist impressions might be helpful at the planning stage both to illustrate why an access route might need to be diverted and to gain public support for the proposed new route. Important points to consider in terms of footpaths when designing and implementing a restoration scheme include:

- **Investigating if the path absolutely needs to be re-routed:** For example, it may sometimes be feasible to provide a bridge.
- **Ensuring connectivity of the new landward footpath to existing footpaths and routes:** Footpaths that do not really lead anywhere are more likely to result in objections.
- **Considering the length of the new footpath:** If the new connected route is much longer than the previous one there is more likely to be resentment or people may opt to leave the official route and create their own shortcut, potentially causing erosion/damage. Can other sections of footpaths elsewhere be used to create shortcuts or shorter circular routes?
- **Ensuring connection to nature alongside public access:** New routes with views, or varied sections can increase connection to nature and are more likely to be considered favourably. A good question to ask is, have you considered the best way to connect to nature along the public access in your scheme?
- **Providing the feeling of connection to the sea:** Diversions of access routes inland may be perceived as being further from the sea and result in resentment. Saltmarsh, although intertidal, may be perceived as terrestrial. Maintaining partial access to the original route may be beneficial.
- **Considering Shoreline Management Plans:** Any proposals to reroute public access or install bridges in England or Wales will need to consider the relevant Shoreline Management Plan.

Case study: 4.2

How the Steart project, Somerset, came to a consensus on a walking route

During the detailed design stage of the Steart Coastal Management Project (now WWT Steart Marshes), the village community of Steart was consulted about the proposed footprint of the new embankment and the position of the new public footpath. The villagers were presented with three options regarding the possible bank location, with proposed slope profile and landscaping.

Following consultation, a final position was agreed and confirmed. Over this location the position of the new footpath was agreed, which wound its way from the top of the bank at a viewing point down to a series of newly created freshwater wetlands, giving visitors a variety of different wetlands to see and experience. This effect, with landscaping in the form of new native hedge planting, reduced the impact that visitors would have had on the village to an acceptable level.

DURING THE CONSTRUCTION WORK: MANAGING COMPLAINTS AND EXPECTATIONS

Creating opportunities for further consultation

Q **We've got planning permission! So, our work with the public is done?**

A **No – Now is the great time to strengthen your relationships with the community.**

The construction phase provides another opportunity for you to really get to know the community and their expectations and concerns. What kinds of communication and community engagement activities could be meaningful during this period, both for the community and for the project?

Ways to understand the community's continuing concerns include:

- meeting at a time and in a place that is convenient to the community.
- adopting an open-door policy at the site office.
- advertising public meetings in advance and through key stakeholders.
- maintaining clear and up to date information exchange via local newsletters and/or dedicated social media account.
- ensuring there is a key point of communication contact within the local parish and village communities.

Particular areas which need the local community's cooperation include:

SUPPORTING FARMERS	MANAGING DUST	MANAGING NOISE
• Offer previous land managers first option on agricultural land management. • Work with farmers with skills to carry out small-scale engineering works such as hedge cutting, ditching works and pond construction. • Work with farmers to harvest the grass or carry out grazing where it benefits construction activities.	• Restrict construction vehicle access on road through village. • Inform and regularly update community on construction programme. • Reduce ground compaction during haulage of excavated material. • Arrange for periodic cleaning of the access road into the village following construction traffic use.	• Restrict construction vehicle access on road through village. • Restrict construction hours when working in close proximity to the village. • Inform and regularly update community on construction programme. • Restrict working hours during the weekend.

Managing public expectations with limited resources

When the construction starts, more local people become aware of your project including those who did not come to the consultation meetings. Some might start asking you to make changes to the project plan or give you good ideas to solve existing issues. Of course, it is not possible to respond to all the suggestions, but there are ways you can carefully manage the financial and delivery plans to accommodate some needs. When your project can respond to concrete local needs, trust in the project rises. Local people will cherish the site more in the future. Local support is crucial when nature restoration projects need long-term support from communities for them to be truly meaningful.

Examples of changes made to previous project plans to respond to local needs (these are from answers to our questionnaire)

CONCERN/REQUEST	CHANGES TO PROJECT PLAN
Concerns over a proposed orchard planting scheme and public viewing screen	• Scheme amended to maintain valued views of landscape. • Public viewing screen removed to reduce impact of visitors.
Request to construct an improved manure storage unit with contracted farm wetland	• A constructed treatment wetland was added to the project to improve the water quality of any run-off and compensate for the loss of chicken manure storage.
Concerns over the increased visitor traffic in the village	• Car parking and toilet block facilities were built into the design to create a focal point of visitation and reduce community concerns over visitor pressure and its effect on community life. • Traffic passing places were constructed at regular points along the approach road. • A second car park was constructed near the village to reduce visitor traffic into the village.
Slight worries about not knowing how the environment changes	• Funding was found to enable local people to visit other local managed and unmanaged realignment sites, giving an opportunity to meet other communities who had experienced coastal change.
Archaeological site was found on the project site	• A themed engagement project, working with the local school, was created to celebrate the archaeological value of the landscape and offer an insight into how historical coastal processes affected the local community of the time.

AFTER 'COMPLETION': KEEPING COMMUNICATION CHANNELS OPEN

As the site evolves, so do the community perceptions towards the project. To keep the links between the project and the community close, there are various attempts you can now concentrate and work on.

Q **Is it time to say goodbye to the locals?**

A **Now is the time to provide opportunities for locals to get close to the site.**

There are various ways to keep communication channels open, such as recruiting a site manager and communications officer, providing information boards for contacts, having regular meetings with locals (even once a year), inviting schools to visit sites and opening a community forum, post-construction, supported by the local or parish councils.

Education and awareness raising activities at a restored saltmarsh

Various organisations and websites provide information on the ecosystem services of saltmarshes and education materials (for example, see Box 4.3). Different methods of communication capture different groups of people in the community. Empowering children and local people as part of a restoration team is one way. While the benefits are substantial, working with public groups in poor weather and muddy, tidal environments, with difficult access over rough terrain poses challenges. Co-ordination of large numbers of volunteers can also be time-consuming, so consideration could be given to engaging a dedicated volunteer co-ordinator. Training volunteers to coordinate others can also be a promising approach.

BOX 4.3: EXAMPLES OF EDUCATIONAL RESOURCES

Ramsar Convention on Wetlands: Provide fact sheets of wetlands, as well as materials for the World Wetland Day under different themes annually http://www.ramsar.org

Wetland Link International (WLI): The network of wetland centres across the world, with open resources for delivery of communication, education, participation and education (CEPA) activities.

https://www.wwt.org.uk/our-work/projects/wetlands-link-international-wli/

Case study: 4.3

Saltmarsh blue carbon citizen science project

The UKRI C-SIDE (UK Research and Innovation Carbon Storage in Intertidal Environments) project focuses on understanding carbon stocks in saltmarsh habitats and has incorporated a highly successful citizen science contribution to the collection of soil samples across the United Kingdom, through a project called 'CarbonQuest'. On Monday 2 December 2019, the project organised a launch event for 'Blue Carbon Quest' with primary school-age children from St Margaret's Primary School at the Montrose Basin, Scotland. The Scottish Minister for Rural Affairs and the Natural Environment (Mairi Gougeon MSP) and the Scottish Wildlife Trust joined in too. The children collected soil samples (their data is now part of the national inventory) and they learnt about the value of the site, which is home to over 80,000 migratory birds.

'Blue Carbon Quest' launch at the Montrose Basin, Scotland, with pupils from St Margaret's RC Primary School, Montrose. Photo: William Austen.

Case study: 4.4

Green shores project, active participation in restoration

There is a growing body of evidence demonstrating the value of actively involving local communities in the restoration process. It increases community ecological knowledge and improves connections between local communities and restoration sites, and the natural environment more generally.

The Green Shores project, led by Dr Clare Maynard of St Andrews University, aimed to create saltmarsh by propagating and planting plugs to establish natural flood defences in the Tay and Eden Estuaries, and the Dornoch Firth in Scotland. Over 300 volunteers from schools, community groups and even playgroups were involved in the propagation, on-site planting, on-going maintenance and monitoring of the outcomes during the three-year project. The volunteer help during the project totalled over 9,000-person hours.

St Leonards pupils planting Shelly Shore.
Photo: Green Shores, University of St Andrews.

Community gardeners at the Tayport site.
Photo: Green Shores, University of St Andrews.

Volunteers planting along a rubble shore in the Eden Estuary in 2010. Photo: Leuchars Station.

Case study: 4.5

Monitoring, research and continued engagement at WWT Steart Marshes

Volunteers have been annually monitoring the establishment of saltmarsh vegetation on the managed realignment since the first summer after restoration. Dr Hannah Mossman of Manchester Metropolitan University modified existing surveying techniques so that they could be used by multiple volunteers with varying levels of prior knowledge. Training on plant identification and survey techniques is run each year, and over 6,000 data points on plant community composition have been collected. Over 30 people have been trained and conducted at least one survey, with ten who have been involved in every survey and are now sufficiently skilled to carry out surveys independently. Volunteers report that the surveying is particularly exciting because it allows them to explore parts of the site that are normally inaccessible.

Community open days are also held at Steart Marshes, when people can come and chat with scientists to discover more about the saltmarsh and the ecosystem services it provides. Past academic literature indicates that citizens lack understanding of the importance of wetlands and their ecosystem services. However, the results of a questionnaire given to households in the stakeholder villages of the Steart Marshes restoration project revealed that **most respondents showed understanding of the benefits of saltmarshes and had very positive opinions about the restoration project**. In the questionnaire, the research project listed all of the main ecosystem services provided by coastal wetlands, and asked people to choose all the ecosystem services they thought relate to wetlands. Most people seemed to be very much aware of the regulating and supporting services of saltmarshes (for example, reducing damage from storms and flooding, preventing coastal erosion, providing areas for birds to rest or feed, providing space for animals to graze). However, the functions of purifying seawater through the food chain, reducing CO_2 emissions and providing services for fisheries were not well recognised (Yamashita, 2022).

View of Steart Marshes. Photo: Sacha Dench, WWT.

CHECKLIST FOR COMMUNICATION AND COMMUNITY ENGAGEMENT

LISTEN and LISTEN

- You are there to listen, not just talk. You will learn stuff you need to know.
- Take on board feedback within the development of the project.

EARLY ENGAGEMENT

- Engage with the local community early on. Listen to and address their concerns as soon as possible. If there are aspects you can't change, explain clearly why this is the case. Be clear, transparent and manage their expectations but where there are things you can change, do it.
- Proactively engage with key stakeholders, rather than expect them to attend drop-in sessions. This can save the project money.
- Put out as much detail as possible in advance and make use of visual aids to explain the project and potential options, and accept the fact that there'll be objections.
- Have open workshops to bring together interested parties. Those who you feel should be on your side are not always positive. Keep engaging.

EMPOWER PEOPLE TO BE A PART OF THE SOLUTION

- It's important to be timely in communicating, and spend time to take concerns and comments into account when planning a project. Ideally, empower citizens to shape the direction of study.
- Invite them to be part of the solution.
- Make sure there's a clear route for communities to input into design plans and that these are considered. Often scheme design is incentivised to force efficiencies and a consultant gaining a bonus should not overrule a benefit identified by a local stakeholder.

ESTABLISH STRONG COMMUNICATION CHANNELS

- Spend longer in the community.
- Establish strong communication routes to engage with the community and prevent misinformation.
- Have someone as the point of contact and inform them that this is a big role and will require a lot of time.
- Outline exactly what the communities can expect through the consultation and how they will receive reasoned responses.

BE HONEST

- Be honest – even if the message is difficult.
- People are going to ask you about the negative impacts you don't want to talk about anyway, but if you raise them proactively you can talk about them on your terms, and the response is often more favourable than if you wait for these issues to be raised by others.
- Have a succinct and easily understood summary of what you are trying to achieve. Be honest about impacts and the mitigations to be implemented.

BE FRIENDLY

- Be friendly and enthusiastic – it's infectious. Speak in easy, colloquial terms. Don't patronise the public and listen to local tales and anecdotes. It all counts.

USE MORE SOCIAL MEDIA

- Use more social media. Local groups often tell us to use it to target their own social media groups and pages.
- Use social media to raise awareness of the drop-in sessions to boost public attendance.

SUFFICIENT BUDGET and TIME

- It's not a 9-5 job! Ensure there is suitable budget to use and make sure that community needs/ideas aren't ruled out by contracted financial incentives alone.
- Make sure you have sufficient budget and time to engage very early, before the project gains any momentum.
- Reach out to as many people as possible.
- Explain the problem, and that it is their problem that you can help with.

EXISTING GUIDELINES ON PUBLIC PARTICIPATION

2003 Community and public participation: risk communication and improving decision making in flood and coastal defence (EA and DEFRA, RandD Technical report FD2007/TR).

"Review the effectiveness of consultation and communication procedures and practices used in flood and coastal defence in England and Wales and, from this, to put forward suggestions for best practice methodologies to enable the public and stakeholder groups to better appreciate flood and coastal defence issues."

2006 Improving community and citizen engagement in flood risk management decision making, delivery and flood response (Environment Agency).

"The majority of people interviewed felt that the Environment Agency needs to play a proactive role in terms of community and citizen engagement. It is in a unique position to promote social capital and has already moved towards this goal."

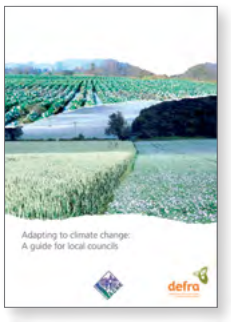
2009 Understanding the process for community adaptation planning and engagement (CAPE) on the coast (DEFRA).

"CAPE is a long-term, community centred planning process which aims to involve those most affected by the risks and opportunities presented by coastal change."

2010 The coastal handbook: A guide for all those working on the coast (Environment Agency).

"The Handbook is intended to act as a reference point so each chapter starts with a short summary and three key 'must remember' points to help the reader."

2010 Adapting to climate change: A guide for local councils (Defra).



"This guide aims to provide local councils and community groups, wanting to take action to adapt to climate change, with information on some of the future risks and opportunities."

2015 Well-being of Future Generations (Wales) Act 2015.

"Everyone engaged with or operating within the planning system in Wales must embrace the concept of placemaking in both plan making and development management decisions in order to achieve the creation of sustainable places and improve the well-being of communities."

2019 Community engagement on climate adaptation: An evidence review (Environment Agency).

"The project aims to produce new learning about, and enhanced guidance for, community engagement practice in situations where engagement might be particularly challenging."

CHAPTER 5
SALTMARSH RESTORATION METHODS

CHAPTER AUTHORS

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KEY SUMMARY POINTS:

- **Saltmarsh habitats can be created or restored in a number of ways, by (i) reducing wave energy and placing or encouraging sedimentation on existing marshes and mudflats, (ii) creating new intertidal areas landward of existing defence lines (iii) enhancing estuary edges in urban areas.**
- **One of the most important design considerations for saltmarsh restoration involving realigned defences or urban fringes is achieving the correct ground elevation relative to the local tidal frame – typically mean high water neap (MHWN) to highest astronomical tide (HAT).**
- **In areas close to existing saltmarshes, vegetation in restored areas will develop naturally within a few years. Planting may be appropriate to encourage rarer species or in areas that are more removed from natural supplies of seeds and propagules.**
- **Scheme designs need to consider creating successful conditions for saltmarsh within the scheme itself as well as avoiding adverse impacts on surrounding areas.**

INTRODUCTION

This chapter describes the various methods that can be used to protect, restore and recreate saltmarsh habitats. The rest of the chapter is split into 6 main sections:

Vegetation

Key factors involved in vegetation development on restored saltmarshes that need to be considered in the design and construction process.

Fish

How the design of wetland habitats can be enhanced for fish usage.

Sediment/wave manipulators

Potential techniques for protecting and restoring existing and newly developing saltmarsh by sediment trapping, intertidal recharge and increasing shelter.

Realigning defences

How new habitats can be created by realigning defences. Includes non-engineered approaches, managed realignment, regulated tidal exchange, flood storage techniques.

Urban fringes

How intertidal habitats can be created within heavily urbanised estuaries where there are extensive lengths of vertical defences and limited space.

Monitoring

Drivers that dictate the monitoring requirements, potential procurement routes and the monitoring methods themselves.

Each section gives a general description, outlines where the approach is appropriate, summarises some of the key design considerations and maintenance/monitoring requirements. A number of case studies and further information sources are also given.

VEGETATION DEVELOPMENT ON RESTORED SALTMARSHES

This section describes the main factors controlling the development of vegetation on restored saltmarshes, and the management actions that may influence this. In addition to the predominantly abiotic (non-living) factors described below, secondary factors such as grazing or local species pool may influence vegetation. Assessments should therefore be site-specific using local reference conditions.

Frequency and duration of tidal inundation

Plant colonisation on saltmarshes depends primarily on the frequency and duration of tidal inundation. On restored saltmarshes, these factors are determined by the elevation of the site, local tidal regime and the extent to which site design allows tidal exchange. Lower elevations have more frequent and longer inundations. Saltmarsh plants can generally occur from mean high water of neap tides (MHWN) up to the level of the highest astronomical tides (HAT). The elevations above Ordnance Datum (OD) of MHWN and HAT will vary locally, so to assess the likelihood of vegetation colonising at a restored site or to predict the likely vegetation communities, the tidal regime should be assessed as close to the site as possible. Sites that regulate tidal exchange (for example, flood storage sites or controlled tidal exchange sites) may experience different tidal regimes to managed realignment sites with many large open breaches that allow relatively unhindered flow of tidal waters.

Exposure to waves and currents

At the lowest elevations, where pioneer vegetation first colonises, physical disturbance from wave or current velocity exposure may shift the seaward saltmarsh edge to higher elevations. New establishment at exposed sites can be unpredictable and be most successful during calm periods and neap tides. Wave exposure can limit vegetation from establishing at estuary fringes in particular. Temporary reduction of wave energy to enhance pioneer vegetation establishment is possible using biodegradable materials, but managers should be aware that:

- this will not alter the overall boundary conditions.
- this is likely to impact sediment availability elsewhere.
- tidal flat habitat will be lost.

In restoration schemes where the seaward defence remains largely intact (for example, managed realignment), wave energy will generally be lower than open sites, due to the protection provided by the sea defence, and additional structures to encourage vegetation should not be needed. At sheltered locations, appropriate site drainage will improve establishment success – see below.

Drainage and water content of sediments

Frequent and prolonged inundation results in waterlogged sediments, constraining the species that can occur. However, other factors can also influence the degree of waterlogging.

Some sites by their design will retain tidal waters for longer, for example, where managed in a regulated tidal exchange, where sea walls are lowered (such as at Devereaux Farm managed realignment in Essex, England, to establish a saline lagoon in part of the site) or where pipes are used rather than breaches being constructed (for example, Brancaster regulated tidal exchange in Norfolk, England). Sediment waterlogging results in vegetation communities that are characteristic of lower elevations, and can prevent vegetation from establishing.

Within a site, sediment waterlogging is affected by local topography, with raised features draining more freely. Restored saltmarshes are often flat and so are comparably more waterlogged than natural marshes, resulting in vegetation that is characteristic of lower saltmarshes and not very diverse. The creation of topographic features such as pools and humps can increase the diversity of vegetation. Construction of this topography can be done prior to restoration of tidal inundation, but where there is high sediment availability such features may not persist. Enhancement of topography after restoration is feasible, and has

Figure 5.1: Topographic features created 12 years after initial restoration at RSPB Freiston Shore. The structures increased the environmental diversity of the site and increased plant diversity locally. Density of breeding common redshank (*Tringa tetanus*) also increased following topographic manipulation. Photo: John Badley, RSPB.

been successfully carried out by the RSPB at Freiston Shore managed realignment in Lincolnshire, England (Figure 5.1).

Initial creation and later natural development of creek networks should improve sediment drainage, but the less dense creek networks in restored saltmarshes (compared to natural marshes) potentially limit this. The creation of sloping gradients down to artificial creeks will likely increase the speed of natural creek development and so increase creek density.

Sandier sediments tend to drain quicker than finer, muddier sediments. However, saltmarsh establishes on a wide range of sediment types and so vegetation is unlikely to be the primary factor when selecting sediment for recharge schemes. Other factors, such as availability and stability, will be more important.

Plant seed and propagule availability

Provided suitable sources of seeds or other propagules are available from nearby marshes, saltmarsh plants rapidly colonise new sites at elevations above MHWN. For example, managed realignments typically attain similar proportions of the local species pools to natural marshes within five years, and rapidly attain cover of vegetation at suitable elevations. This is partly because most managed realignment sites have seed sources within a few kilometres, and so in these circumstances, seeding and planting are not needed. Other restored sites, particularly urban fringe environments, may not have suitable sources of propagules nearby, so planting or seeding may be required.

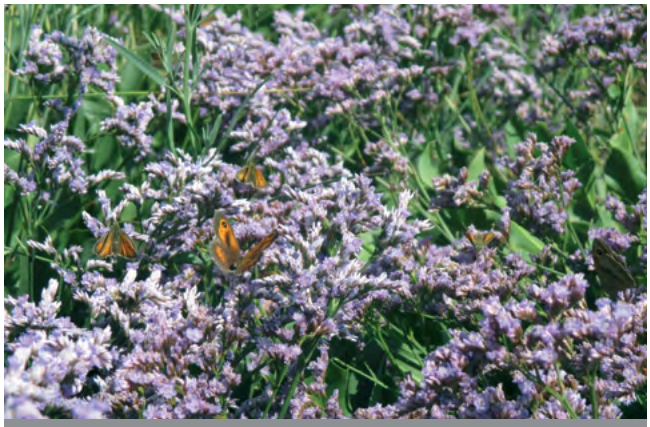

Figure 5.2: Sea lavender (*Limonium vulgare*) and gatekeeper butterflies. Photo: Hannah Mossman.

Figure 5.3: Plugs ready for planting. Photo: Hannah Mossman.

Some differences in community composition are evident between natural and restored marshes, with some species such as sea lavender (*Limonium vulgare*, Figure 5.2), sea plantain (*Plantago maritima*) and sea pink/sea thrift (*Armeria maritima*) tending to be rare on restored marshes. These differences remain even after decades of development, so if these species are desirable then planting will be necessary (Figure 5.3). Survival of planted plugs of these species is high in appropriate conditions, despite the lack of natural establishment at the same locations (on average 60% survival after four years, Mossman *et al.* 2020), so planting for these species may be an effective solution.

Planting might also be appropriate to help establish vegetation in estuary fringing habitat where conditions prevent seedling establishment. Adult transplanted plants can survive in a broader range of conditions than seedlings and, once forming a continuous sward, can modify the environment to be more favourable for further seedlings to establish. For example, the Green Shores project on the east coast of Scotland created around 2,750m^2 of estuarine fringing saltmarsh through direct transplantation. In this project, large plugs of saltmarsh were dug from adjacent natural marshes and split into smaller transplant units for planting into degraded and unvegetated upper mudflats. However, care must be taken not to cause irreparable damage to donor sites and, although using clonal propagation is an efficient way of generating large volumes of plant material for transplantation, it can result in low genetic diversity and so some seed propagation and subsequent transplantation would be beneficial to increase genetic diversity.

Before attempting any seeding or planting, assess whether seed availability is indeed limited or whether disturbance by waves and currents prevents colonisation on mudflats. In the case of the latter, carefully consider if a soft-engineered solution, including transplanting, can attain the desired restoration outcome, particularly in the long term (Figure 5.4).

Salinity

The salinity of tidal and other waters flowing into the restored site (for example, run off, inflow) will determine the types of communities that will develop. Species characteristic of lower salinities include sea club-rush (*Bolboschoenus maritimus*), grey club-rush (*Schoenoplectus tabernaemontani*) and common reed (*Phragmites australis*). Common reed is a native and a natural dominant of brackish saltmarshes in Britain and Ireland (Packer *et al.* 2017), but it may be undesirable over large areas at sites where the aim is to provide compensatory saltmarsh. Control is challenging without herbicide use (see Hazelton *et al.* 2014 for a review of control methods), so limiting freshwater inputs and maintaining water salinities of greater than 15psu is likely to be most effective in limiting reed growth.

Figure 5.4: Bio-degradable biorolls in situ protecting 'new' transplants of *Bolboschoenus maritimus* from wave energy in the Tay Estuary, Scotland. Control plots with and without biorolls and/or planting are visible in the background. Note the biorolls have sunk into the sediment and have been colonised by algae. Photo: Clare Maynard, Green Shores, University of St Andrews, 2020.

Figure 5.5: Evidence of mullet (*Mugilidae*) feeding, observed during a low-tide walk over at Cwm Ivy, September 2020. The two lines are made by teeth scraping off the algae to feed on. Photo: Heidi Burgess.

Water quality and sediment contamination

Restored sites using sediments from urban or industrialised areas may contain a range of contaminants. There is strong variability in the uptake of these pollutants by saltmarsh plants, and very little evidence that heavy metals and polycyclic aromatic hydrocarbons have negative impacts on them. However, eutrophication (excessive nutrient loading) has been shown to decrease root growth in some circumstances in saltmarsh plants, reducing sediment stability and increasing erosion (Deegan *et al.*, 2012). Restored sites in such areas may benefit from techniques to retain sediment.

INCORPORATING FISH HABITAT IN INTERTIDAL LANDSCAPE DESIGN

Fish are an important part of intertidal habitats. These habitats are also fundamentally important for fish, providing the optimal locations for critical early life stages. It is highly likely that large-scale destruction of these habitats in Europe over centuries has added significantly to the decline in commercial fish stocks.

Fish will use the intertidal and nearshore sites for a variety of reasons including:

- **Feeding**. Invertebrate production in intertidal habitats is twice that in subtidal ones. Larger fish feed on smaller ones as they drift out on the ebbing tide.
- **Nursery**, early phase of life cycle. Warm shallow cryptic habitats provide abundant food and shelter from predators, particularly in and around stands of vegetation.
- **Whole life cycles**. Some fish do not move far from where they are spawned.

Incorporating fish use into an intertidal design is generally not expensive, should only mean minimal adaptions to construction plans, and should be incorporated into the design at an early stage. Successful design needs to reflect how fish use these habitats.

Fish keep energy consumption to a minimum using selective tidal stream transport. They move into the habitat on the front edge of the rising tide, maximising feeding time during the period of tidal inundation. They often swim near the surface, therefore across-channel structures should be removed if they could potentially impede fish passage. After high water, they move out again, following the drainage patterns, keeping close to the bed. Very small species, such as the common goby (*Pomatoschistus microps*), can remain in small pools continuously, but most fish are only present during the upper half of the tidal cycle. Some may remain throughout if they can find at least 50cm of standing water with accompanying shelter. Fish movements across the site are directed by the tidal flows but moderated by the balance between the profusion of food and the risks of predation. Fish are making dynamic risk assessments throughout their use of the site.

Before inundating or restoring a site, it is important to understand:

- what is already living in the site, and if there are brackish areas.
- what species are present outside of the proposed site.

Table 5.1: Design features beneficial for fish.

ASPECT	ADVANTAGES
Tidal gates that allow passage for migration	Provide passage for migratory fish. Leaky gates provide a brackish environment, which allows for a wider variety of species to thrive.
Gentle gradients	Channels that are present, or to be constructed, should have banks that have gentle gradients to allow easy access/egress to feeding areas as the tide changes. The gradient of the land either side of the channels should also be gentle to prevent fish becoming stranded and reduce severe bird predation.
'Lumps and bumps'	It is beneficial to have a 'natural', sinuous dendritic (branching) structure of shallow gently sloping channels, which will extend right to the back of the marsh, already present in the land to be inundated as part of saltmarsh creation. This can be achieved by the inundation of 'rough pasture' which can benefit from the persisting 'lumps and bumps'. Flat fields should be roughened before inundation to introduce 'lumps and bumps'.
Non-uniform channel shape	Sinuosity and unconformities in channel shape are important as this will result in cross-stream current variations. Different species uses water flow in different ways. For example, strong swimmers such as sand smelt and grey mullet will feed as they retreat on the ebbing tide. In a sinuous channel form they can move into the current to intercept food items and then retreat behind the cover. At the same time, they are progressively moving down and out. This very efficient feeding behaviour is not possible in a straight channel form.
Unvegetated areas of mud/sand flat	Provide important feeding grounds.
Deep pools, with shallow sloping sides	Provide low-tide refuges.
Gentle flow patterns	It is good practice to emulate the gentle flow patterns seen across natural intertidal habitats. Fast currents at choke points tend to limit fish utilisation. Therefore DO NOT dig one big drainage channel and a couple of side branches that will lead to fast water flows with abrupt changes in seabed level, as this is the exact opposite of what fish need.
Drainage pattern continuity	Ensuring continuity between the drainage pattern on the site and that on the subtidal foreshore on the seaward side of the previous barrier is essential. Since fish use the deeper water in the drainage system during egress on the ebb, lack of continuity can cause stranding and bird predation just outside a breach. This has been observed in the early stage of some realignment sites. The need for fish to be able to move freely into and out of intertidal areas with the tides should also be considered when introducing new structures as part of a restoration project, such as when using sediment trapping techniques. If fish are excluded or delayed entry on rising tides they can lose valuable feeding time. If they are impeded in moving off intertidal areas, as water levels fall, they can become subject to severe bird predation or become stranded.

WAVE PROTECTION AND SEDIMENT RETENTION FEATURES

Options for existing saltmarsh or realignment situations

Description

Offshore and intertidal structures can be used within realignment schemes, or when restoring existing saltmarshes, to provide conditions that encourage sediment deposition and subsequent accretion. They can also be used to protect saltmarsh edges from erosion by reducing wave energy. Potential approaches include breakwaters, sedimentation fields or sediment retention enhancement devices (SREDs). Sedimentation fields are described separately in the section below. These methods aim to reduce the hydrodynamic energy of the system, by slowing fluvial and tidal flows or reducing wave energy. A variety of techniques and materials are available, ranging from potentially high cost permanent breakwater structures to relatively low cost structures, such as coir roll or BESE (Biodegradable Elements for Starting Ecosystems).

Breakwaters can be used to moderate inshore wave action, dissipating wave energy and helping prevent erosion or resuspension. Finer sediments are deposited inshore of breakwater structures, which helps to promote the development of a stable saltmarsh or mudflat.

Breakwaters are generally placed offshore and either create a hard barrier to prevent wave action or reduce water depths, causing waves to break before reaching the shore. Hard structures, such as rock or rubble mounds, have been used as a breakwater. Biogenic structures (structures produced by living organisms), such as oyster reefs, can also function effectively as breakwaters as well as providing other ecosystem services such as habitat for fish and invertebrates. Seagrass meadows can also reduce hydrodynamic energy at the seaward face of saltmarshes. Breakwaters can be used in combination with other sediment retention features (for example, see case study 5.2, Dengie Peninsula).

Various types of revetment (structures that protect against erosion) can also be strategically placed to disperse wave energy and act as a sediment trap so that, in time, saltmarsh plants may colonise the sediment. Brushwood structures, as described in the section below on sedimentation fields, is one option. Rock rolls (tubes of strong mesh filled with stones) or rock mattresses can form a more permanent option, and coir rolls or BESE elements are biodegradable options that can also encourage saltmarsh vegetation to settle and colonise. Coir is made from the husk of coconut shells (Figure 5.7). BESE elements are made from potato starch (Figure 5.6), formed to make a 3D lattice grid, which can be clipped together to form larger sheets. These are laid and fixed across the ground with wooden or metal stakes. The framework is used to capture and hold sediment, raising sediment height and increasing drainage and oxygen levels, to help saltmarsh growth. These products can encourage vegetation hummocks to form in the centre of the lattice. This mimics what would naturally happen around individual saltmarsh plants. It also reduces drag on the developing saltmarsh plants so they are able to increase root density early in their development. The product is estimated to disintegrate in around 10 to 15 years (depending on temperature and light levels), at which time it is expected that saltmarsh plants will have become sufficiently established to continue binding the sediments and colonise any remaining unvegetated areas.

Using structures to stabilise eroding saltmarsh edges can be combined with other options such as vegetation planting or sediment recharge techniques.

Where appropriate

Approaches that manipulate natural processes might help to restore eroding saltmarsh at sites where natural recovery after erosion is limited because periods of calm conditions are not long enough for seeds to germinate and plants to establish. It is essential to determine the cause of the erosion problem to assess if intervention would be beneficial, and select the most appropriate management action. Temporary structures can also be used within realignment schemes, and combined with planting techniques or sediment recharge campaigns. Small-scale trials could be designed at first to investigate if temporary biodegradable structures could be effective options to facilitate or speed up restoration in a particular site.

Figure 5.6: Biodegradable Ecosystem Engineering Elements (BESE®) are 3D structures made out of potato starch. They help stabilise sediments and allow vegetation to colonise or establish in areas of high wave energy or current velocity.
Photo: Ralph Temmink, NIOZ.

Breakwaters are generally located some distance offshore in more exposed situations, usually in parallel to the shoreline, for example, lighter barges were sunk off the Dengie Peninsula (see Case Study 5.2). Breakwaters can also be used within managed realignment schemes to protect against internally generated waves. For example, excavated material from seawall breaches was deposited on site at a realignment site at Orplands, Essex, to provide protection during the early stages of development.

Design considerations

In all cases, but particularly in the case of 'hard' interventions such as breakwaters or hard structures along the saltmarsh edge, care must be taken to ensure the structures don't disrupt coastal ecosystems, impact on the continued functioning of the wider coastal or estuarine system or damage the 'integrity' of any important nature conservation sites (for example, by reducing the area of mudflats accessible to feeding birds in a Special Protection Area). Structures can interfere with sediment transport pathways, and there is a risk of scour and localised erosion around the structures themselves. Also, there is a risk that linear structures may exacerbate current-induced erosion by channelling flows, and wave refraction and diffraction could put other areas of the shore at risk.

It is essential to understand the local sediment dynamics and budgets, and model the impacts of structures when planning and designing projects that modify natural processes. Modelling the wave climate, tidal currents and sediment transport will help you to assess if wave protection structures are appropriate, which engineering option would be most effective, and how to orientate and space structures.

If you are considering the benefits of restoring oyster reefs or seagrass to act as a breakwater in front of saltmarsh habitat, please see the separate handbooks for advice on design considerations https://nativeoysternetwork.org/resources/

Table 5.2: Aid to scheme selection: structures that manipulate natural processes.

FEATURE/ STRUCTURE	ADVANTAGES	DISADVANTAGES
Permanent breakwater	Can dampen wave action, helping to enhance stability of mudflat and saltmarsh.	High cost option. May exacerbate current induced erosion by channelling flows. Obstacle to sediment transport and potential impacts to wider environment.
Rock/shingle/clay barrier	Can combat wave induced erosion. Lower cost than permanent breakwater. Contribute fines onto the system to feed the marshes as they degrade.	Obstacle to sediment transport and potential impacts to wider environment.
Biogenic reef, for example, shellfish beds	Can absorb wave energy providing protection from erosion. Reefs can grow with sea level rise and are low maintenance. Also provide additional ecosystem services.	Shellfish need more frequent tidal inundation than saltmarsh for best growth. Ecological constraints on reef development may limit how close to a saltmarsh a reef can develop and the coastal protection benefits.
Polder fences	Can enhance accretion and help create saltmarsh habitat where policy is to hold the line or help to retain recharge sediment.	The structure will degrade and require maintenance. Potential impacts on fish and invertebrates unless safe entry and exit points are designed in. Would require early discussions with appropriate nature conservation organisation if being considered.
Rock rolls and mattresses	More resilient in higher energy environments than biodegradable options. Relatively easy to handle and install.	Can sink into sediment. Potential obstacle to fish and invertebrate movements.
Coir and geotextiles	Suited to small-scale projects. Relatively easy to handle and install.	Can sink into sediment. Potential obstacle to fish and invertebrate movements. Geotextiles brings risk of releasing microplastics into the environment.
BESE elements	Suited to small-scale projects. Relatively easy to handle and install. Biodegradable structures.	Can sink into sediment.

Case study: 5.1

Colne Estuary, Essex, England

Essex Wildlife Trust and the Environment Agency began a collaborative saltmarsh restoration pilot project on the Colne Estuary, Essex in 2018.

The project aims to:

- restore eroded saltmarsh in low energy creeks at the back of existing saltmarsh.
- protect coastal defences immediately behind the restored saltmarsh from erosion at the toe of the sea wall.

Relatively low cost coir rolls were trialled in various locations across channels at the back of the saltmarsh to encourage sediment to accrete and saltmarsh plants to colonise once sufficient levels of sediment build up. Wooden stakes and hessian rope hold the coir rolls in position in structures of 3 or 6 rolls depending on the depth of the channel. In total 30 coir roll structures were installed at 3 sites over 3 days in November 2018. One structure was in a very high energy channel and needed repairing in June 2019. The project team found that changing the layout of the coir rolls to a wider, flatter structure made it more resilient to the energy level of the site.

The project team visited the sites every few months to monitor the condition of the structures and measure any accreted sediment. Photographic records were taken at fixed points. The team planned to use notches made in the stakes to help measure sediment accretion but found that the stakes were not in a stable position and accretion and erosion of the structures was localised so that a measurement of one stake was often not representative of the overall state of the structure. Looking forward, the team plans to continue the fixed point photography and is also exploring ways to collect complementary data in a more formalised way in collaboration with the University of Essex. LiDAR and drone surveys are also planned to help the team assess accretion and the wider impacts of the structures on surrounding and connecting creeks.

Pioneer plant species became established during the first summer after structures were installed. The project will continue and expand the monitoring of the pilot project structures over the next few years to validate and explore their success. There is also potential to expand the project by experimenting with new structures and combining more than one approach.

Key lessons are that vegetation has established best:

- in shallower channels where structures were close to the height of existing vegetation.
- in channels with lower energy.
- where multiple structures were concentrated, for example in a U shape.

Figure 5.7: Installation of one of the coir roll structures in November 2018 (left) and example coir structure in summer 2019, by when plants had begun to grow (right). Photo: Essex Wildlife Trust.

Sedimentation fields (potential hold the line option)

Description

Sedimentation fields (fenced areas) are designed to help increase the size or space for saltmarsh habitat by extending a marsh seawards. This method uses structures designed to slow the passage of water, in an attempt to enhance sediment deposition on intertidal mudflats, to increase their elevation and support the establishment of saltmarsh vegetation. Artificial or natural materials are introduced into intertidal mudflats to reduce hydrodynamic energy and enhance sediment settling during slack water periods. Designs significantly vary, but traditionally sedimentation fields use polders (these are often brushwood fences) erected to enclose a width of mature marsh with a seaward extent of mudflat (Figure 5.8 and 5.9). The polders are often combined with internal earth groynes and artificial drainage networks. Over the past centuries, sedimentation fields have widely been used in the Netherlands and Germany to actively claim land from the sea, and to a limited extent in the UK to revert the loss of saltmarshes.

Where appropriate

Sedimentation fields are used to facilitate seaward expansion of saltmarshes, therefore this approach may be most appropriate where saltmarshes are affected by coastal squeeze and/or marsh edge erosion. While managed realignment approaches involve abandoning agricultural land, sedimentation fields do not require a realignment of the current defence line or the loss of terrestrial areas. Therefore, sedimentation fields, may be an alternative management approach to managed realignment and can be used in sites with 'Hold the Line' management strategies. In contrast to intertidal recharge approaches (described below), where dredged materials are used to elevate intertidal mudflats, sedimentation fields use the readily available sediment and encourage increased sedimentation. The resulting elevation increase is considerably slower than with intertidal recharge; this may be favourable, particularly where a target is to preserve infaunal communities (animals that live in the substrate/soft sediment).

Sites with existing (extensive) intertidal mudflat areas where sufficient sediment is available may be appropriate. Small-scale projects of sedimentation fields, notably implemented in the 1980s in Essex, have yielded mixed successes (French, 2001). In the Dutch and German Wadden Sea, however, sedimentation fields have successfully been used to counteract marsh edge erosion (Esselink *et al.*, 2017). In sediment depleted areas, sedimentation fields may be combined with sediment recharging operations. Increased sedimentation rates may help saltmarshes to establish in foreshores where intertidal elevations are too low to support vegetation growth. Examples from the German and Dutch Wadden Sea suggest sedimentation rates three times higher than for neighbouring natural saltmarshes (Esselink *et al.*, 2017). There, artificial seaward expansion has widely been used to protect sea defences from wave erosion. About 50% of all saltmarshes on the Dutch/German/Danish Wadden Sea coast are artificially created through sedimentation fields and artificial drainage networks. However, increasingly, new sedimentation fields are limited to areas where existing saltmarsh is under threat of erosion, and artificial drainage networks are avoided where possible.

It may not be appropriate to introduce sedimentation fields to create saltmarsh by replacing or changing mudflat habitats in designated sites for nature conservation, or in sites with local constraints or objectives that conflict with a sedimentation fields approach. Early engagement with the appropriate organisations is advisable in all cases.

Figure 5.8: Sedimentation field in the German Wadden Sea, August 2008. Photo: Mark Schuerch.

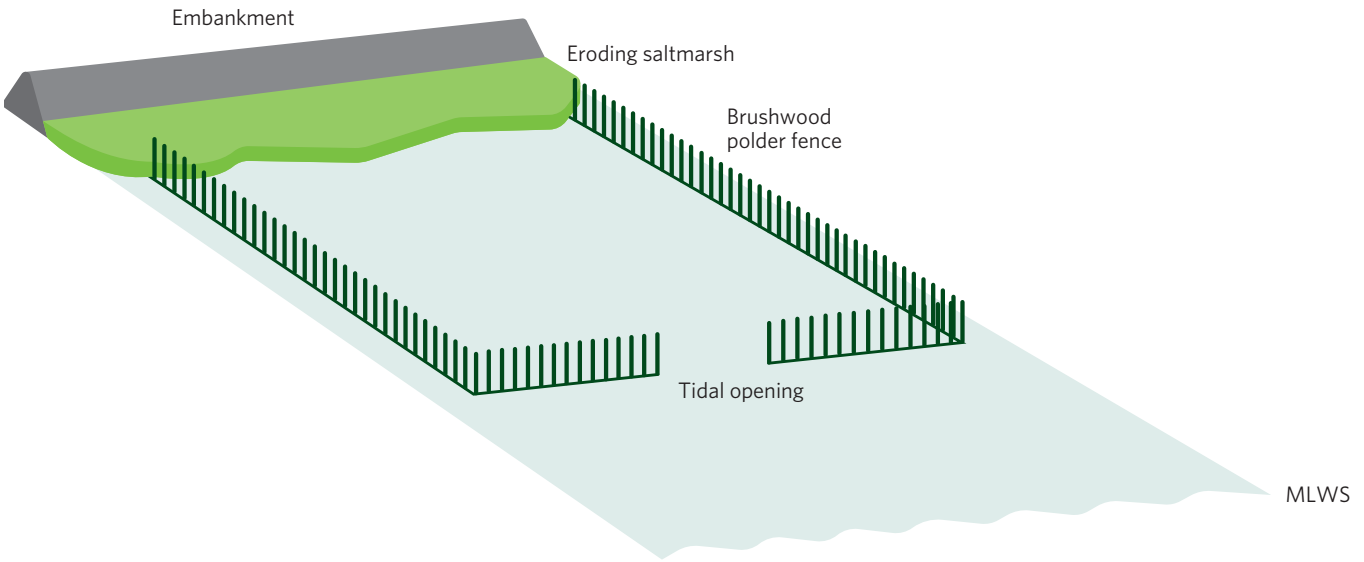

Figure 5.9: Basic setup of a single sedimentation field (also referred to as sedimentation polder) consisting of brushwood groynes inserted in the mudflat to form an enclosure with a tidal inlet (adapted from Colenutt, 2001).

Design considerations

Sedimentation fields should be carefully planned. Numerical modelling (for example, using modelling packages such as Delft3D, MIKE, Telemac) can be used to predict the effects of local scheme design on volumetric change to the saltmarsh, the intertidal mudflat and the marsh edge. The changes to the three morphological units can be variable, therefore it is important to clearly define the targets for the planned management intervention.

Wave and wind exposure

Effective scheme designs are highly site specific and are particularly sensitive to wave exposure and dominant wind/wave directions. Scheme designs must take into account the local hydrodynamic environment to ensure an efficient reduction in local wave energy for sedimentation fields to be efficient. This may be achieved by strategically placing additional wave breakers around the sedimentation fields (French, 2001; Siemes *et al.*, 2020). New marsh edges may need additional protection to prevent lateral erosion. If expanding into marine environments with too high tidal flow velocities, sedimentation fields may be ineffective.

Polders/groynes

Dimensions of sedimentation polders and/or spacing of brushwood groynes should be adjusted to local environments, but typically range between 100 and 400 metres. Gaps in the fencing along the seaward line of each enclosure allow the tide to flow into a series of channels within the area.

Inlets and drainage

The spacing and size of the tidal inlets, connecting the drainage network to the open sea must be carefully considered not only to increase the sedimentological effectiveness of the scheme but also to avoid negative impacts on the ability of fish and invertebrates to migrate shore-perpendicular with the incoming/outgoing tide.

Creek networks are important in influencing the flooding and drainage within saltmarsh systems. An artificially constructed sedimentation field may require an artificial drainage network to produce adequate circulation. If dredged sediments from the drainage network are used to artificially nourish the areas within the sedimentation polder, there is a risk that benthic intertidal communities (those living on or in the sediment) could be negatively impacted by rapid accretion of sediment.

Sedimentation fields, where brushwood groynes are arranged perpendicular to each other, can be used to create fully enclosed areas of intertidal mudflat to facilitate sedimentation through their ponding effect. In these instances, negative ecological effects associated with dredging and maintenance of drainage ditches are somewhat reduced since drainage ditches are introduced at a later stage during the marsh building process. However, negative impacts on biological connectivity may be more pronounced. Sedimentation polders without artificial drainage networks may also be far less effective at increasing intertidal mudflat elevations.

Figure 5.10: Fully developed saltmarsh in the German Wadden Sea, created through the combined use of sedimentation polders and drainage networks. Photo: Mark Schuerch, University of Lincoln.

Appearance

While sedimentation fields, often implemented alongside extensive artificial drainage networks, can be effective in restoring or creating saltmarshes, the created marshes may strongly differ in appearance from natural saltmarshes (Figure 5.10), including a reduced topographic complexity, a higher number of rectangularly arranged drainage channels, and a reduced biodiversity (Esselink *et al.*, 2017).

The wider estuary/coastal environment

The artificial seaward expansion of saltmarshes will change conditions in the broader intertidal environment, such as the estuary or tidal basin. Artificial conversion of intertidal mudflats to vegetated saltmarsh may increase sediment import, reduce the tidal prism and cause estuarine infilling. The overall effect of increased saltmarsh areas on the wider estuarine/tidal basin environment would need further investigation.

Maintenance and management

The long-term management of the site, and the monitoring strategy, relies heavily on the pre-defined targets for the scheme (for example, habitat creation/restoration, coastal protection).

If using brushwood groynes to establish sedimentation fields, scouring around the structures may occur as a consequence of increased flow velocities, particularly at the tidal inlets of sedimentation polders. Moreover, the brushwood filling the space between the double array of wooden stacks may be washed away over time. Therefore, regular maintenance of the structures is necessary to maintain their effectiveness to reduce tidal flow velocities. Failure to adequately maintain brushwood groynes will lead to a reduced sedimentation promotion and/or increased erosion and may trigger an undesired release of the captured sediment with potentially negative consequences for neighbouring coastal ecosystems.

Intertidal recharge

Description

One approach for restoring coastal and estuarine habitats, including saltmarsh, is to use some of the large quantities of sediment that are dredged every year for the purposes of maintaining ports, harbours and navigation channels, to provide the morphology and physical conditions suitable for successful restoration.

The potential for using dredged sediments in saltmarsh restoration projects is briefly described in this section but you can find more detail on the different ways that dredged sediment can be used to support habitat restoration projects, and advice on planning, design, and regulations, in the 'Restoring Coastal Habitats with Dredged Sediments' handbook.

Intertidal recharge can be used alone or in combination with one of the other methods described in this chapter. For example, dredged sediment can be used to:

- support raising or landscaping the hinterland before creating a managed realignment breach or regulated tidal exchange.
- nourish a saltmarsh at regular intervals to help it to grow and protect it from further or future degradation.
- maintain sediment budget to increase future resilience of a saltmarsh.
- help to restore lost saltmarsh habitat.
- protect existing sediments (for example, limit erosion of mudflat fronting a saltmarsh).
- provide a barrier against wave energy.

Case study: 5.2

Dengie Peninsula

In the 1980s, a series of sedimentation fields were made on the open coast of the Dengie Peninsula, namely at Sales Point, Marsh House Farm and Deal Hall, Essex (French, 2001). At Marsh House Farm (middle of Dengie peninsula) and Sales Point (northern Dengie Peninsula) the sedimentation fields were constructed in 1984 and 1986 respectively, by sunken lighter barges placed shore-normally over 500 metres and 200 metres respectively from the sea defence, to act as seaward breakwaters (Figure 5.11 a-d). In 1989, the breakwaters were complemented by shore-perpendicular brushwood groynes to enclose sedimentation fields about 600 metres in width.

In contrast, the sedimentation fields at Deal Hall (southern Dengie Peninsula) were designed as sedimentation polders (400 by 400 metres each), with an internal earth groyne system and a dense network of primary and secondary drainage ditches. Two initial sedimentation fields were established in 1980 (Figure 5.11e-f). These were later complemented by a third sedimentation polder without internal earth groynes and drainage ditches in 1989.

Most of these schemes were deemed successful in promoting sediment accretion and/or reducing intertidal elevation loss after 12 to 17 years. However, the positive effects on intertidal sediment accretion has not always led to the expansion or creation of saltmarsh. For example, intertidal elevations initially increased by about 10 to 35cm within the sedimentation field at Sales Point, but elevations have stabilised since 2010 and saltmarsh has not established (Environment Agency, 2020). This may, in part, be because the brushwood groynes enclosing the sedimentation field sideways have not been maintained and appear to have degraded over time. In contrast to Sales Point, new saltmarsh has established at Marsh House Farm where elevations of the intertidal mudflat have increased to allow for the establishment of pioneer vegetation (French, 2001) and the previously narrow saltmarsh in front of the sea defence has expanded (Figure5.11 c-d).

While the sedimentation fields with earth groynes and drainage ditches at Deal Hall were deemed successful by French (2001), due to initial elevation gains, more recent elevation data reveal significant elevation loss within the sedimentation fields after about 2000. The sedimentation field without earth groynes and drainage ditches has not had any significant impact on intertidal mudflat elevations, and has not been able to halt the lateral erosion of the saltmarsh (Environment Agency, 2008).

In conclusion, the sedimentation fields established along the Dengie Peninsula have not achieved the project target to increase the area of saltmarsh, despite some initial positive effects on intertidal elevations. The performance of the sedimentation fields appears to have reduced after about 10 to 15 years, which may be connected to the continued degradation of the brushwood groynes and the drainage network. In contrast, significant areas of new saltmarsh have successfully established within sedimentation fields in large parts of the Netherlands and Germany, even where saltmarsh had eroded before the management intervention (Esselink *et al.*, 2009).

Lessons learnt are:

- that both the brushwood groynes and the drainage network are crucial elements for successful sedimentation fields.
- coastal managers should establish a long-term plan to maintain sedimentation fields and design a targeted monitoring system for intertidal elevations and marsh edge dynamics.

Figure 5.11: Sedimentations on Dengie Peninsula. Aerial photographs from Sales Point (a-b), Marsh House Farm (c-d) and Deal Hall (e-f) from the years 1987 (a, c, e) and 2020 (b, d, f). Note that brushwood groynes in Sales Point were implemented in 1989, therefore they are not visible in panel a. The 2020 images show that the area of saltmarsh has not increased at Sales Point or Deal Hall, despite some of the structures still being visible. Saltmarsh has expanded at Marsh House Farm. Image sources: All images from 1987 are from Cambridge University Collection of Aerial Photography © copyright reserved (www.cambridgeairphotos.com). All images from 2020 are from the Environment Agency (Environment Agency, 2021).

BOX 5.1: BENEFICIAL USE OF DREDGED SEDIMENT

Beneficial use of dredged material means to use dredged material in a way that will benefit society and the natural environment. The restoration and establishment of saltmarsh is recognised as an important benefit to the natural environment.

Where dredging causes a loss of sediment or reduction in regional sediment supply, this can cause coastal habitats, including intertidal flats and saltmarsh, to erode and/or limit their ability to accrete and keep pace with sea level rise. Removing sediment from the system can therefore inhibit saltmarsh growth and restoration. Conversely, beneficially using dredged material in proximity to the marshes and working with natural processes to redistribute this sediment, can support their restoration and resilience.

There are a number of different methods to dredge, transport and dispose of sediment at the beneficial use site. The methods used during dredging, transportation and disposal play an important role in determining the physical characteristics of the arising dredged material, with subsequent implications for designing the best disposal strategy to suit a habitat restoration scheme and its objectives.

Where appropriate

Potential beneficial use sites can range in size from small scale, feasibility projects, to larger, more ambitious and more complex restoration projects.

There are many factors to consider when assessing the potential for making use of sediment recharge at a site. These include:

- the aims of the restoration project.
- availability of suitable sediment – the location of existing or potential dredge and disposal activities, the volume being dredged and the composition and characteristics of that material.
- the wider environmental conditions.
- logistical constraints such as accessibility.
- the potential impact of the works themselves.

Design considerations

If feasibility studies show that beneficial use is a viable option for a site, it is important to quantify *what material* and *how much* of it will be required. Clearly defined success criteria are essential to ensure the project is cost effective, has minimised negative environmental impacts and maximised positive environmental impacts.

Factors to consider when designing a project include, but are not limited to, the:

- navigable access and constraints.
- proximity of dredging relative to the restoration site.
- local environmental conditions (for example, tidal velocities, tidal range, wave climate).
- physical characteristics of the dredged material.
- sediment quality and compatibility.
- need for retaining structures.
- potential impacts and sensitive receptor.

Further, beneficial use methods often depend on a range of environmental, technical and economic factors that will constrain the options available.

Maintenance and management

As for other types of methods, management will depend on the scale, complexity and objectives of the project.

For complex projects, or where more than a single sediment recharge campaign is planned, it is advisable to apply an adaptive management approach. Adaptive management is a decision framework that facilitates flexible decision making that can be refined in response to uncertainties and as outcomes from current and future management actions become better understood. The adaptive management cycle consists of iterations of targeted monitoring, impact assessment and management actions, either continuously or on a regular basis during project delivery and following completion (where appropriate), to support overall management of the project and any associated risk and potential impacts identified. The approach requires early involvement and open dialogue with all stakeholders throughout the project.

Dredged material being excavated from a hopper barge and hydraulically pumped via pipeline, in order to recharge an eroding marsh. Photo: Suave Air Photos, taken March 2012.

Examples

Table 5.3: Examples of UK beneficial use projects over the last 25 years. (From the Restoring Coastal Habitats with Dredged Sediments.)

DREDGE AND DISPOSAL APPROACH	BENEFICIAL DISPOSAL SITE	YEAR(S)	APPROXIMATE VOLUMES
Mechanical excavation and mechanical disposal	Maldon Saltings and Northey Island, Blackwater Estuary	Annually since 1990s"	2,000 to 3,000 m^3 yr^{-1}
	Loder's Cut Island, Deben Estuary	2015, 2017 and 2018	1,725 m^3 over three campaigns
Mechanical excavation and bottom placement	Boiler Marsh, Lymington Estuary/Solent	Annually since 2014	6,000 m^3 yr^{-1}
Hydraulic dredge and bottom placement	Port of Harlingen, Wadden Sea Netherlands	2017 and 2018	600,000 m^3 over two campaigns
Mechanical excavation transported for hydraulic (pipe) disposal	Boiler Marsh, Lymington Estuary/Solent	2012 and 2013	4,500 m^3 over two campaigns
Hydraulic dredge and direct hydraulic (pipe) disposal	St Osyth Borrow Pits, Brightlingsea, Colne Estuary	2017 – 2020	20,000 m^3 over two campaigns
	Suffolk Yacht Haven, Levington, Orwell Estuary	Annually since 1997	10,000 m^3 yr^{-1}
Hydraulic dredge transported for hydraulic (pipe) disposal	Horsey Island, Hamford Water	1998 to 2006	108,000 m^3 over four campaigns
	Shotley (North), Orwell Estuary	1997	22,000 m^3 behind a retaining gravel bund
	Allfleet's Marsh Managed Realignment, Crouch Estuary	2006	550,000 m^3 over one campaign
Hydraulic dredge transported for hydraulic (rainbow) disposal	Horsey Island, Hamford Water	Early 1990s	148,000 m^3 over a few campaigns

REALIGNING DEFENCES

There are four approaches for creating new intertidal areas landwards of existing defences lines.

- Non-engineered realignment sites.
- Managed realignment.
- Regulated tidal exchange.
- Tidal flood storage.

This section deals with each of the 4 techniques separately, but schemes can combine a number of techniques, for example, managed realignment with regulated tidal exchange lagoons.

A number of design elements/features are common to all types of engineered realignments:

- design of new flood embankments to protect low-lying areas further landwards.
- rerouting/reconstruction of existing freshwater outfalls.
- infilling of existing field drains to break the linear drainage system.
- addition of sediment to raise bed levels (for example, to promote saltmarsh vegetation).
- removal of sediment to create channels, lagoons and scrape features.
- provision of compensatory habitat to replace any losses from within the scheme.

These elements are described within the section on managed realignment.

Realignment schemes represent significant developments (and can cover up to several hundred hectares) which effect many stakeholders. Stakeholder consultation during all stages of project development is therefore very important. Affected parties/issues include landowners,

particularly farmers, footpath users, wildfowlers, navigational users and local fisheries. Some schemes can encounter local opposition due to reasons such as perceived increase in flood risk, losses of agricultural land and changes to public rights of way. These aspects are explored in more detail in Chapter 4.

Non-engineered realignment sites

Description

Non-engineered realignment, also known as unmanaged realignment, occurs where flood defence structures are breached naturally by tidal waters, often following storm events and/or sluice failure. Sites are often backed by secondary flood defences and/or naturally rising ground.

While there may be little or no preparation (for example, no construction of a new counter wall and no deliberate opening of the sea walls), this does not mean that the risk of flooding was not recognised in advance. The intent to let sites evolve is regularly identified within shoreline management plans in England and Wales, and it is sometimes the case that decisions were made in advance to allow this natural evolution to occur through no active intervention. Once created in this 'non-deliberate' manner, the site is then left to evolve into coastal habitat. A decision to not intervene is likely to be taken based on the flood risk to hinterland communities and the role that the site plays in the coastal ecosystem. There are also historical examples of unplanned realignment sites that have developed after defences were breached during extreme events, with repairing the defences deemed either not viable or beneficial.

These sites do not have any landscaping or engineered changes in morphology carried out before site breaching. As a result, these sites do not have any deliberate topographic variations constructed to use specific elevational niches in order to support a targeted habitat type, reduce hydrodynamic energy or to create flood storage capabilities.

Figure 5.12: The colonising saltmarsh with mudflat in the foreground within the Cwm Ivy Marsh site.

The main benefit of non-engineered restoration is that, when successful, it allows for the creation of intertidal habitat without the expenditure on extensive designing and landscaping. Defunct sea walls with small areas of bare ground provide useful habitat for rare and scarce invertebrates. For example, around The Wash such areas support populations of the sea aster mining bee (*Colletes halophilus*).

Examples of non-engineered sites include the planned site at Cwm Ivy Marsh on the Gower Peninsula, Wales (see case study 5.3), and historical unplanned breaches caused by storm events such as Pagham Harbour, West Sussex (breached in 1910) or Porlock Bay, Somerset (breached in 1996). Significant areas of non-engineered realignment are also found on the East Coast of England, for example, there are more unmanaged realignment sites than managed realignment sites on the Crouch Estuary (see Figure 1.11 in Chapter 1). Porlock Bay is one of the largest unmanaged realignment sites in the UK and Ireland (about 75ha) but this is a fraction of the size of some of the largest managed realignment sites, for example, the Medmerry managed realignment site in Sussex is over 300ha.

Where appropriate

If the proposed restoration area contains no infrastructure, and is backed by higher land or remnant flood defence, then non-engineered restoration is a potential approach. This approach is particularly appropriate for previous land claim sites that have retained their morphological signature, in particular the relic dendritic (branching) creek networks or an alternative artificial drainage ditch system. The presence of these features is likely to accelerate post-breach site development, with an established creek network fundamental to the physical functioning of the restored intertidal marsh. However, sites with a history of intensive agricultural activity could have experienced irreversible changes to the soil structure and are subsequently susceptible to waterlogging, potentially limiting the ecological development of the site and making them less suitable for non-engineered restoration.

The non-engineering approach is suitable when creating specific habitats is not a project aim. If particular habitats are targeted then an assessment of the variations in elevation within the site will be required. A comparison of the elevation of the external intertidal environment, the breach area and the proposed site will also be required, as these topographic differences control the fluctuations of water in and out of the site, and subsequently the site's hydro-period. Future elevation changes resulting from the erosion and accretion of sediment need to be considered, taking into account a prediction of the future sediment supply. The tidal prism of the new site would also need assessing to ensure that there would be no adverse impacts on the estuary as a whole caused by changes in the hydrodynamics.

Planning considerations

As with other restoration schemes, consideration of any scientific and ecological designations and public opinion will still be essential. As part of the planning process, public rights of way will need to be maintained. If possible, it is good practice to have the alternatives in place and established in good time before any potential breach, and local bylaws altered to allow for the emergency re-routing as a breach becomes inevitable. If a site is breached accidentally then some of this work will have to be carried out retrospectively.

Maintenance and management

Monitoring may be carried out even at non-engineered realignments in order to see how habitats are developing, particularly if the site is being used to provide compensatory habitat.

For non-engineered realignments maintenance requirements are likely to relate to inspection and repair of any flood defence assets around the rear of the site. This might, for example, include ensuring that embankments and sluices continue to operate correctly and provide the appropriate standard of service.

Site management is likely to depend on the reasons for undertaking the scheme. At Cwm Ivy (see case study 5.3) the site is managed for nature conservation with pony grazing.

Managed realignment

Description

Managed realignment involves removing short lengths of an existing flood defence to create breaches, or in some instances, removing the entire defence, in order to allow the re-introduction of tidal regimes to areas of previously claimed low-lying land. If there is high land further landward and no assets at risk, then the realigned area may extend to this and take the opportunity to create a gradation of habitats from marine through to terrestrial. However, in many instances high land lies a considerable distance inland and there are numerous assets that need to be protected from flooding (for example, roads, railways, industrial and residential properties). In such cases new flood protection structures need to be created further inland, in order to prevent the uncontrolled flooding of areas further landwards.

The majority of schemes that have been carried out to date in the UK have been driven primarily by the need to create compensatory habitat following the loss of intertidal through, for example, port development, coastal squeeze or coastal defence works. However, they have taken advantage of this need to provide improved flood defences (for example, larger defences). A smaller number of schemes have been driven primarily by flood defence needs, for example to reduce flood defence costs by shortening/removing the line of defence.

Managed realignment is most commonly used to create a combination of intertidal mudflat and saltmarsh habitat, although a range of other habitats may also be created around the higher parts of the site and in separate compartments within or adjacent to the managed realignment area.

Case study: 5.3

Cwm Ivy Marsh

Cwm Ivy Marsh is located on the Loughor Estuary, Gower Peninsula, Wales. Prior to realignment the site was an area of land claim used predominantly for grazing. The land claim occurred in three stages, with the legacy of these still present in the form of earth embankments within the site. The 38.3ha site (Figure 5.12) was allowed to breach following the decision by Natural Resources Wales to stop maintaining the defensive sea wall in order to restore the intertidal habitat and compensate for losses elsewhere. The site is surrounded by hills and areas of higher elevation, with freshwater draining prior to site breaching through both artificial channels and the former dendritic creek network. The site was breached during a storm in August 2014, with no landscaping or design works carried out prior to breaching. Subsequently, sediment accreted at between 30 to 75 mm/year. However, as in engineered restoration sites, areas of bare ground have been identified within the colonised area.

Cwm Ivy Marsh is progressing well towards becoming a functioning, biodiverse saltmarsh. An intricate network of brackish pools and creeks is developing, which includes the original drainage ditches and land drains, along with newly-formed channels and the re-emergence of paleo-channels of the historical saltmarsh (Benbow, 2017).

The majority of the site is now made up of saltmarsh or transitional habitats. Saltmarsh grass (*Puccinellia maritima*) is abundant, together with pioneer species including glassworts/samphire (*Salicornia species*) and a range of mid marsh species such as thrift (*Armeria maritima*), sea purslane (*Halimione portulacoides*) and sea lavenders (*Limonium* species) have also colonised (Benbow, 2017).

Elements potentially contributing to the success of this non-engineered site may have included the varied topography, the presence of paleo-channels and existing drainage. The site is also managed for nature conservation with pony grazing. Currently there is only one breach in the sea wall. If further breaches occur as predicted, and in line with the 'do minimum' policy at this site, this would improve natural functioning and tidal exchange, and better integrate Cwm Ivy Marsh with the estuary.

Where appropriate

Given that managed realignment schemes are usually carried out to create intertidal habitat, then a key requirement is the site elevation relative to the local tidal frame. The sites typically need to have large areas lying below the level of mean high water spring tides to make them suitable. Sites also need to be free from significant amounts of infrastructure (for example, roads, railways, buildings) and contaminated land.

To date, most UK schemes have been located in low-lying areas within estuaries or embayments, where land has previously been claimed from the sea. Managed realignment schemes are less common on the open coast, but the Medmerry scheme on the south coast is one example where a gravel barrier that fronted a low-lying coastal flood plain has been breached. In the Republic of Ireland, only been a very small number of managed realignment projects have been carried out to date.

The location of managed realignment schemes within estuaries is an important factor in determining the impact on estuary water levels and the form of the connection with the wider estuary. Large schemes within inner reaches of estuaries can reduce water levels (see section 'Tidal flood storage' below), while large schemes in the outer reaches of estuaries can raise water levels (Pontee, 2015). Numerical modelling work has also shown that the numbers of breaches, their location and their sill levels can also influence the impact (Pontee, 2015).

Design considerations

Site elevation

The level of tidal inundation within schemes can be estimated using simple GIS approaches, but, for larger schemes, hydrodynamic modelling is commonly used since it more accurately assesses how water will flow onto the site. A range of computer modelling packages exist and a range of engineering and specialist companies provides these services. Well-known products include MIKE21, Delft3D and Telemac.

It is possible to modify elevations within schemes, although this adds to the overall cost of the scheme. Sediment can be added to raise bed levels and promote the development of saltmarsh vegetation. Elevations can also be lowered either over wider areas to promote mudflat development, or in more discrete areas to create a range of channels and lagoon features.

Siltation

If managed realignment is being carried out to create a specific habitat type then the design process needs to consider the long-term development of the site. A key factor here is the degree of siltation that occurs in the site. Siltation within sites can raise bed levels from those suitable for mudflat development to those where saltmarsh vegetation can develop.

Breach design

The type of connection with the wider estuary/coast requires careful consideration. Aspects include the number and configuration of breaches, whether or not the breach will be armoured or will be left to adjust naturally, and the requirement for wholesale removal of existing embankments – see Table 5.4.

It is common practice to try and optimise the size of the breach during the design process to create an opening that is stable but not excessively wide. Hydrodynamic models or the empirical approach proposed by Townend (2008) may be used for this purpose. Hydrodynamic models are also used to investigate the flooding and drainage characteristics of the site under different breach/bank removal options.

Contaminated land

Although the site selection process generally rules out heavily contaminated sites, there may still be parts of the site that contain contaminated land, for example, the edges of old landfill or industrial spoil tips. Contaminated sediments can be removed to disposal sites but this is an expensive operation in terms of excavation, haulage and disposal fees. Some types of contamination can be dealt with in situ by capping the areas with sediment and ensuring that the edges are protected from erosion. As well as the release of solid contaminants through erosion, consideration needs to be given to the potential for the release of material in solution. Specialist surveys are required to assess the type of contamination and necessary remediation activities.

Creek systems and former ditches

Most schemes are created on land that was formerly used for agriculture. These areas often contain extensive ditch and watercourse systems which need to be rerouted and connected to new outfalls. Freshwater inputs to sites can be used to enhance the variety of habitats, but siltation rates and the potential for freshwater sluices to become blocked need to be considered. Typical site works also include infilling the existing field drain and borrow dyke system on the site to break the linear drainage system and help a 'natural' creek network to become reinstated. Where sites are low in the tidal frame and sedimentation rates are high, new creeks would be expected to arise naturally. Conversely, where sites are higher in the tidal frame and sedimentation rates are lower, or where sediments have been compacted by former land use, an artificial creek system may need to be constructed. Artificially constructed creek networks should look to maximise flooding and draining of the site while mimicking the channel and network properties of natural marshes. Deeper pools can be created within creek channels to provide refuges for fish during low water (see section 'Incorporating fish habitat in intertidal landscape design' above).

Flood embankments

The design of new embankments within the scheme needs to consider the desired standard of protection and design life, source of material (from within site or imported) and the incident conditions (predicted water levels and wave heights). The front slopes of embankments can be reduced to create a broader area for terrestrial or transitional habitats. Using earth cut from within a site for new embankments, rather than bringing material in, can reduce environmental impacts and financial costs. Borrow pits can be used to create tidal creeks, lagoons or shallow depressions within the site to enhance the variety of habitats.

Table 5.4: Breach design considerations

ASPECT	ADVANTAGES	DISADVANTAGE	EXAMPLE
Undersized breaches	• Reduced construction time/cost. • Breach can erode to stable size.	• Site may not fully flood or drain until breach has eroded.	Wash Banks
Large breaches	• Allows site to fully flood or drain. • Can be used to reduce risk of erosion in breach.	• Increased construction time/cost.	Wallasea Island
Non armoured breach	• Reduced construction time/cost. • Breach can erode to stable size. • Suitable for uncontaminated embankments and sites where eroded sediment unlikely to impact on sensitive receptors.	• Not suitable where erosion would create problems – contaminants, footbridges over the breach, sensitive receptors.	Steart Hesketh Out Marsh East
Armoured breach	• Suitable for sites where breach size needs to be fixed, for example, where bridges are required, where embankments contain contaminants, and sites where eroded sediment might negatively impact on sensitive receptors.	• Increased construction materials/time/cost.	Saltern Wetlands
Single breach	• Reduced construction time/cost. • Can reduce impacts on water levels in wider estuary (in some settings).	• May restrict maximise inundation and drainage of site (depending on size). • Can increase the erosion of the fronting intertidal.	Steart
Multiple breaches	• Helps lessen the erosion of the fronting intertidal habitats at each breach. • Can increase the impacts on water levels in wider estuary (in some settings).	• Helps maximise inundation and drainage of site. • Increased construction time/cost.	Hesketh Out Marsh West, Hesketh Out Marsh East
Whole bank removal	• Helps lessen the erosion of the fronting intertidal habitats. • Increased area of intertidal habitats (from defence removal).	• Increased construction time/cost. • Maximises inundation and drainage of site.	Welwick (Humber Estuary)

Hybrid schemes/sub-compartments

Regulated tidal exchange (RTE) compartments can be created within managed realignment schemes to create specific habitats (see section on 'Regulated tidal exchange' below). The creation of habitats, in addition to saltmarsh, can be an objective of some schemes to compensate for existing protected habitats that would be displaced from within the realignment area. A range of freshwater habitats can be created either in separate compartments with the regulated exchange of tidal or freshwater (for example, see case study 5.6: Wallasea), landward of the retired flood embankments or at higher elevations within the site. The new embankments within schemes offer opportunities for transitional or terrestrial vegetation to develop, and wildflower grass mixes are commonly used in these areas.

Impacts on wider estuary

A key consideration in the design of managed realignment schemes is to avoid adverse impacts on the surrounding estuary area. Realignment schemes have the potential to impact water levels, flow speeds and resulting geomorphological processes in surrounding areas. The impacts of the schemes depend on the location within the estuary, the size of the intertidal area created, the elevation of the site and the form of the connection with the estuary. Hydrodynamic models are commonly used to assess the impacts of different designs before selecting the final design. For example, at the Steart Marshes site in the Parrett Estuary, modelling led to the selection of a single breach arrangement rather than multiple breaches because this design had less impact on water levels with the wider estuary (Pontee, 2015).

In terms of flow speeds, managed realignments lead to an increase in flows near to their entrance and downstream of the site in the main estuary, particularly during the ebb tide. The impact of these changes on other estuary users need to be carefully considered. For example, whether the erosion of channels across the fronting intertidal, potential changes in low water channel and bank position and the effects on currents (speeds/direction) could impact on commercial and recreational navigation. The fate of any sediment eroded from the fronting intertidal also needs to be carefully considered, especially where there is a risk of it being deposited on commercial shellfish beds.

Maintenance and management

Maintenance requirements are likely to relate to inspection and repair of any flood defence assets such as embankments and sluices around the rear of the site. If armoured breaches have been created then periodic inspection of these is likely to be needed to ensure they have remained stable. Inspection and maintenance of others aspects, such as fencing, footpaths and access tracks and bridges is also required.

Site management typically involves managing grazing regimes and visitors. Additional management activities may also be required for saline lagoon features.

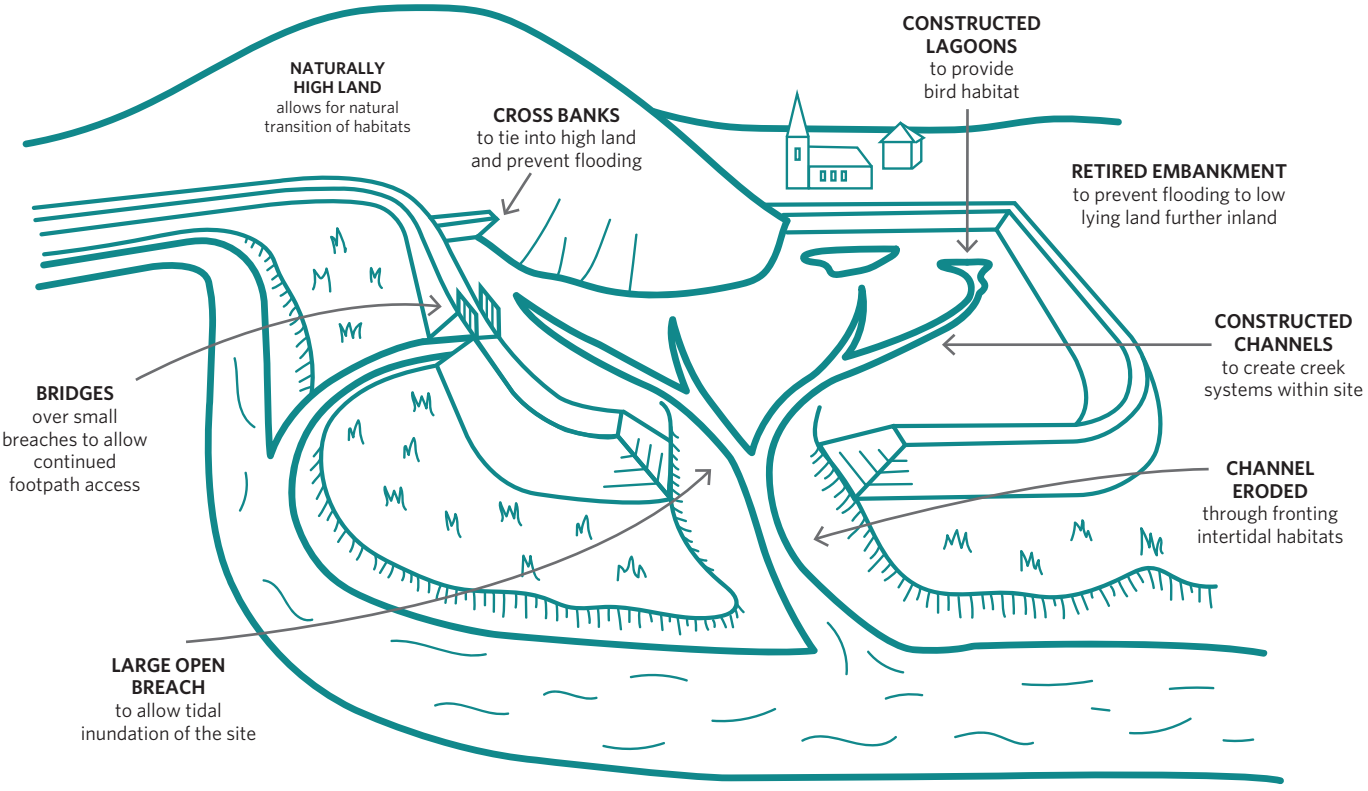

Figure 5.13: Aspects of a theoretical managed realignment project.

Case study: 5.4

Hesketh Out Marsh (west and east) (large 322ha project)

The Hesketh Out Marsh site lies in the middle part of the Ribble Estuary on the north west coast of England, near the confluence of the Rivers Ribble and Douglas and River Ouse. The site was claimed from the estuary in the 1980s and was used for agriculture. The scheme was carried out by a partnership between the RSPB, Natural England and the Environment Agency, to provide compensatory habitat, create a range of intertidal habitats and improve flood protection. New intertidal habitats were needed to:

- compensate for direct losses of habitat at Morecambe (60km north of the site) incurred as part of a flood alleviation scheme there.
- offset historical and ongoing losses elsewhere in the Ribble Estuary.
- contribute towards meeting targets contained in the national and Lancashire Biodiversity Action Plans.

The restored saltmarsh habitat, combined with raised embankments constructed as part of the scheme, provide a 1 in 200 year standard of flood protection to over 140 residential properties and 300ha of prime agricultural land. 'One in 200 years' refers to a flood height that has a long-term likelihood of occurring once in every 200 years (also called a '200-year recurrence interval').

Initial work to identify realignment sites in the Ribble took place between 2003 and 2004, with the scheme subsequently delivered in 2 phases:

Combined, the 2 phases of the scheme have created over 300ha of saltmarsh habitat. Numerous breaches were designed into the scheme to connect creeks in the fronting intertidal marsh with remnants of the former creek network. Shallow lagoons towards the rear of the site were also excavated to create a range of dynamic bird habitats.

One of the interesting lessons from the Hesketh Out Marsh West scheme was that the tidal lagoons created at the head of the excavated creek network underwent significant changes. Although raised sills were included to retain water, the tidal flows eroded these, leading to the lagoons draining down. This lesson led to an alternative lagoon design being used within Hesketh Out Marsh East – here a number of lagoons were created without connection to the tidal creek system. The plan shape and bathymetry of the lagoons were also further optimised for wading bird use. The combined site is now managed as a coastal reserve, managed by the RSPB.

Further information on this scheme and the lessons learned can be found here:
https://www.therrc.co.uk/sites/default/files/projects/49_hesketh.pdf

	PHASE 1: HESKETH OUT MARSH WEST	PHASE 2: HESKETH OUT MARSH EAST
Design	2004 to 2006	2012 to 2015
Construction	2007 to 2008	2014 to 2017
Project summary	180ha of saltmarsh, mudflat and lagoon habitats have been created. Construction work included excavating and reinstating the historical creek network (about 15km of creeks), infilling boundary ditches and creating 4 breaches in the sea defence.	160ha of saltmarsh, mudflat and lagoon habitats have been created. Construction work included strengthening inner banks, excavating creeks and lagoons and breaching the seawall.

Figure 5.14: Hesketh Out Marsh West in the Ribble Estuary during the construction phase. The light brown linear features within the site are channels being excavated along the line of former tidal creeks which existed prior to land claim. A number of shallow lagoons can be seen at the head of the creeks. Photo: RSPB.

Case study: 5.5

Devereux Farm (small 15ha project)

The Devereux Farm site lies in Hamford Water in Essex, England, and demonstrates what can be achieved on a relatively small scale. This scheme has created 15ha of new intertidal habitat, including saltmarsh, islands, mudflats, saline lagoon and transitional grassland and was completed in 2011 by a partnership between the Environment Agency and the private landowner.

The purpose of the scheme was to recreate a mosaic of intertidal habitats, including habitat for breeding avocets, to help compensate for historical and predicted losses in the wider Essex and South Suffolk SMP area.

Prior to flooding, the realignment site was contoured to create islands to enhance the site for avocets. A breach 200m long was created in the sea wall, and the site was flooded in October 2010. One short counter wall was constructed at the eastern side of the site with locally sourced material to ensure that farmland was not flooded.

Since the site breached, saltmarsh has developed well over the parts of the site where the elevation is suitable. A range of saltmarsh types are present, from pioneer saltmarsh at lower levels to upper saltmarsh. The mixture of habitats present within the site is attractive to a wide range of wildfowl and waders. There is a thriving colony of avocets nesting on the islands that were created specifically for them, and up to 450 black-tailed godwits have been recorded in autumn and winter. A typical range of saltmarsh invertebrates have colonised the site from surrounding areas of intertidal marsh.

Regulated tidal exchange

Description

This approach is similar to managed realignment except that instead of breaches/bank removal, structures are used to control the ingress and egress of water into and out of the site. Regulated tidal exchange (RTE) can be used to create a range of intertidal or brackish habitats.

Compared with managed realignments, the use of structures in RTE schemes is likely to limit the total amount of water that can enter the site (since the cross sectional area of the structures is typically smaller than a managed realignment breach). This can be advantageous in limiting the impacts of the scheme on the wider estuary or the degree of flooding further landwards, but may also restrict the amount of intertidal habitat that can be created. For example at Wallasea, Phase 4 of the works implemented RTE to create nearly 300ha of intertidal habitat by including separate inlet and outlet structures set at different heights. This limited volumes of water entering the scheme on the flood tide and ensured that the scheme fully drained on the ebb.

Where appropriate

Regulated tidal exchange schemes are likely to be located in similar locations to managed realignments, that is, low-lying flood plains in estuarine and coastal areas. The Environment Agency and RSPB (2003) reported that RTE sites need to be at least 0.1m lower than high tide level, have a tidal range of at least 3m and have gradients of between 1 and 3%. They also recommended that the sites needed to be underlain by impermeable geology, which was not prone to erosion or aquifer contamination.

RTE sites require a permanent sea defence to remain in place to allow the construction of a tidal exchange structure within it. RTE schemes may be feasible at a greater range of sites than managed realignment schemes for several reasons. Firstly, such schemes can be more easily developed landwards of existing infrastructure such as roads or railways, since the use of culverts can allow the existing infrastructure to remain in place (which is typically not possible with breaches). Secondly, the ability to control water levels may allow sites with a wider range of elevations to be chosen.

In the correct circumstance RTE can be implemented without the need for a new primary defence line. Regulated tidal exchange compartments can be created within larger managed realignments to create specific habitats.

Design considerations

Inundation frequency and duration

The frequency and duration of tidal inundation control the type of intertidal habitats that can develop within sites. Unlike managed realignment schemes, where inundation is dictated by the design of the breaches and the elevation of the site relative to the local tidal frame, within RTE schemes, the control structures themselves can modulate tidal inundation and therefore be designed to create targeted conditions for the development of specific habitats. RTE designs also need to ensure that there is sufficient tidal exchange to prevent the occurrence of hypersaline or low oxygen conditions and ensure a minimum accretion rate across the site.

RTE may be used to create saltmarsh at lower elevations than would naturally occur under conditions of unrestricted tidal exchange by restricting the degree of tidal inundation. Conversely, RTE may be used to create mudflat at higher elevations than would naturally occur in a site with unrestricted tidal exchange by retaining water within schemes to generate extended inundation periods (for example, Teesmouth National Nature Reserve). The Environment Agency and RSPB (2003) stated that mudflat formation was best achieved by ensuring that the sites are subject to 450 to 600 tidal inundations per year, while saltmarsh would develop on sites with fewer than 450 to 500 inundations per year, with one inundation not lasting for much longer than a few diurnal tidal cycles. Lower saltmarsh habitats develop where there are between 500 and 30 inundations per year and upper saltmarsh where there are fewer than 30 inundations per year. Both saltmarsh and mudflat habitats are encouraged by ensuring that sites are allowed to flood rapidly but drain slowly and that one inundation does not last more than a few tides.

Freshwater inputs can also impact Inundation frequency and duration, which can affect vegetation development. For example at South Efford Marsh, the development of saltmarsh vegetation was temporally set back by long wet periods around 2013 to 2015, which increased the inundation durations within the site.

Exchange structures

The choice of exchange structures requires careful consideration especially with regards to future site operation and maintenance (see Table 5.5). Like managed realignment schemes, the potential for erosion seawards of the exchange structures and the requirement for scour protection should be considered.

Table 5.5: Structures used in RTE schemes.

TYPE OF STRUCTURE	DESCRIPTION	ADVANTAGES	DISADVANTAGE	EXAMPLE
Basic culverts (with no tidal flap)	• Flows in and out of site determined by level and size of culvert. • Flows in and out of site can be adjusted by stop boards on the landward side to retain different levels of water within the site.	• Can be adapted from existing drainage culverts. • No onsite personnel needed to operate. • Lowest cost.	• Degree of inundation and drainage limited by size of culvert. • Can lead to ponding within site due to slow drainage rates. • May require additional culverts to allow site to drain down on each tide and avoid ponding.	Gwent Levels Tees Estuary
Manually operated sluices (for example, penstock valve)	• Flows in and out of site determined by level and size of culvert. • Flows in and out of site adjusted by manually operated valves.	• Can be used to adjust the tidal inundation and drainage of the site to limit or extend inundation extent and frequency to encourage specific habitats to develop. • Can be closed on extreme events to avoid flooding to properties further landwards. • Low cost.	• Requires onsite personnel to operate.	Wallasea
Self-regulated tidal gates	• Flows in and out of site determined by level and size of culvert. • Flows in and out of site adjusted by adjustable float system, which allows the gate to automatically close at a certain stage on the flood tide and open at a certain stage on the ebb tide.	• Can be used to adjust the tidal inundation and drainage of the site to limit or extend inundation extent and frequency to encourage specific habitats to develop. • Can be closed on extreme event to avoid flooding to properties further landwards Automated operation (no onsite personnel required for operation).	• Increased costs compared to basic tidal flap valve. • More complex structure requiring greater maintenance. • Care needs to be taken that structures do not become blocked by debris or siltation.	Goosemoore Black Hole Marsh
Electronically operated tide valve	• Flows in and out of site determined by level and size of culvert. • Flows in and out of site adjusted by electronic sensors depending on water levels outside and inside the schemes.	• Can be used to adjust the tidal inundation and drainage of the site to limit or extend inundation extent and frequency to encourage specific habitats to develop. • Can be closed on extreme event to avoid flooding to properties further landwards Automated operation (no onsite personnel required for operation).	• Higher capital costs especially for large structures. • More complex structure requiring greater maintenance. • Needs a power supply.	

TYPE OF STRUCTURE	DESCRIPTION	ADVANTAGES	DISADVANTAGE	EXAMPLE
Spillways/ high level sluices	• A spillway is a lowered portion of an embankment that allows sea water to enter and leave the site at a relatively high elevation. • Flows into and out of the site are controlled by the level and length of the spillway.	• Can be used to adjust the tidal inundation of the site. • Can be used to retain water reduces the volume of water entering. • Moderate capital cost (but depends on scale of structures). • No onsite personnel needed to operate.	• Cannot be closed on extreme events. • Doesn't allow low level drainage – requires a separate drainage outfall. • Likely to require erosion prevention measures on the landward side due to high velocities.	Saltram Wallasea

Capital and maintenance costs

RTE schemes have the potential to have higher capital costs than comparably sized managed realignments due to the requirement for structures rather than breaches. RTE schemes may also have higher maintenance requirements than managed realignments arising from both the maintenance of the fronting embankments and the RTE structures. Larger structures add significantly to the cost of schemes.

However, small RTE schemes involving the opening of existing sluices to allow marine waters to inundate relatively small areas of land can be low cost.

Phased schemes

Regulated tidal exchange schemes may be used as a forerunner to undertaking full managed realignment. This can be advantageous in encouraging siltation in low lying areas, kick-starting the development of intertidal habitats, or in getting stakeholders on board with the concept of intertidal habitat creation.

Hybrid schemes

Regulated tidal exchange compartments can be created within larger managed realignments to create specific habitats. This approach can be used to create lagoons that permanently retain water and have different salinities to the wider site. Such features can be beneficial for bird usage.

The design of saline lagoons needs to ensure their salinity remains within a suitable range (see Wallasea Island case study). Management of inflows and outflows can be used to maintain salinities within a target range, while also providing suitable water depths and exposing mud. Lowering water levels in spring exposes bare areas for birds such as avocets (*Recurvirostra avosetta*) to nest on. Falling water levels from spring through to autumn increases the accessibility of invertebrates and fish for feeding birds, while also providing mixtures of bare and sparsely vegetated mud and shoreline detritus that can support a rich invertebrate fauna. Raising water levels in autumn suspends plant seeds and thereby makes them available to feeding wildfowl. Creating islands in lagoons can greatly increase their value for nesting birds and provide safe high tide roosts.

Impacts on wider estuary

The hydrodynamic impacts of RTE on the wider estuary are likely to be less than for managed realignment schemes due to the smaller volumes of water involved. High flow speeds are likely to occur near the RTE structures themselves and lead to the formation of channels across the fronting intertidal. Larger schemes may require the use of hydrodynamic models to assess the impacts on the wider estuary.

A number of RTE design considerations are similar to those of managed realignments and these are listed above at the start of the section on realigning defences.

Maintenance and management

Requirements for maintenance and management are likely to be similar to managed realignments (see above). RTEs are likely to have additional maintenance requirements related to maintaining the fronting embankments and the tidal exchange structures, especially where these involve moving parts such as valves or gates.

Case study: 5.6

Creation of saline lagoons at Wallasea Island

The Wallasea Island Wild Coast Project in Essex, England, has created about 700ha of coastal wetland on ex-arable land. This wetland includes around 160ha of managed realignment known as Jubilee Marsh, together with wet grassland, saline lagoons, and a large number of islands. These non-tidal habitats greatly increase the overall value of the site for coastal wildlife. This case study focusses on the saline lagoons created within the larger scheme, some of which were created using RTE so that water levels and salinity can be carefully managed.

The project is being led by the RSPB in partnership with Crossrail, Defra, the Environment Agency and Natural England.

In total in the Wallasea Island Wild Coast Project, 170ha of saline lagoons have been created. In Jubilee Marsh land levels were raised prior to introducing tidal flooding using inert material excavated during the construction of Crossrail's twin-bore railway tunnel beneath London. This has been used to create higher areas that are developing into upper saltmarsh, and which contain a series of saline lagoons. The lagoons have been designed so they are topped up with sea water on high spring tides, but the islands in them remain unflooded during the bird breeding season.

Saline lagoons have also been created outside of Jubilee Marsh, either by excavation or by impounding water above ground level. Water levels and salinities in these lagoons are managed using RTE structures to provide optimal conditions for wildlife. In particular, it is important to prevent the lagoons from becoming hypersaline, as this would kill the invertebrates and fish in them. Site management aims to maintain the salinity of these lagoons between about 15 and 45 parts per thousand.

RTE structures were selected to enable the salinity design criteria to be met. There is a variety of structures, but most are simple, manually operated drop board sluices.

Having simple sluices that the RSPB can effectively open or close, and change the level of as required, provides the most flexibility. Inputs of saline water are needed during late spring and summer to prevent the lagoons from becoming hypersaline. This is especially tricky in the very shallow lagoons, where salinity can rise very rapidly due to evaporation, therefore using sluices to rewater the lagoons can resolve this. However, if water levels fluctuate too much at that time of year, the water may become too deep to provide good feeding habitat for birds. Some species (especially avocets (*Recurvirostra avosetta*)) nest very close to the shoreline, and may be vulnerable to getting their nests flooded if water levels go up, therefore drying out of the lagoons would be required. Having simple, manually operated structures also means that the RSPB can periodically dry out individual lagoons to allow them to be colonised by annual plants (and also provide good marginal invertebrate habitat), and then re-flood these areas to suspend the seed of these annual plants to make them available to feeding wildfowl. This also adds organic matter to the lagoon, which should increase invertebrate biomass.

The plan is for the complex of lagoons in the top left of the photograph (Figure 5.15) to be periodically dried out and re-flooded on rotation (water levels were very low in these lagoons when the photograph was taken). One group of saline lagoons is surrounded by a predator-exclusion fence to protect nesting birds from ground predators.

The first lagoons were flooded with saline water in winter 2015/16 and have already (by 2020) been colonised by a range of typical saline lagoon invertebrate species, including the spire-snail (*Ventrosia ventrosa*), lagoon cockle (*Cerastoderma glaucum*), the isopod *Idotea chelipes*, and lagoon sand shrimp (*Gammarus insensibilis*). The lagoon margins are also developing a valuable insect fauna which contains, for example, the nationally scarce shore-bugs *Halosalda lateralis* and *Saldula pilosella* and nationally scarce ground-beetles *Tachys scutellaris* and *Pogonus littoralis*. The margins of the lagoons have also been colonised by the suite of nationally scarce annual plants already present at the site. These include stiff saltmarsh-grass (*Puccinellia rupestris*), sea barley (*Hordeum marinum*) and annual beard-grass (*Polypogon monspeliensis*).

The saline lagoons and islands provide important nesting habitat for avocets, gulls and terns, together with areas for waterbirds to roost and feed at high tide. In 2019, the first year following completion of groundworks at the site, all of Wallasea Island's breeding avocets (146 pairs), common terns (56 pairs), black-headed gulls (1,928 pairs) and Mediterranean gulls (4 pairs) nested on islands in the lagoons. In 2020, small numbers of black-headed gulls also nested on the shore of a lagoon that is protected by the predator-exclusion fence. During mid-winter (December 2019 to January 2020) high tide counts, the 170ha of saline lagoons supported a mean of 13,400 wildfowl and waders.

Tidal flood storage

Description

Tidal flood storage schemes are schemes designed to reduce tidal water levels in estuaries. They incorporate breaches, spillways (lowered embankments) and sluices to allow the site to flood and drain. The schemes work by removing large volumes of water from the estuary towards high tide during extreme events. Flood storage areas can be used to create new areas of intertidal habitat and schemes may combine elements of both managed realignment and RTE to achieve their function. Regulated tidal exchange compartments can be created within flood storage schemes to create specific habitats. Like RTE schemes, flood storage sites require a permanent sea defence to remain in place to allow the construction of a tidal exchange structure within it. The requirement to maintain the existing defences and construct a number of large structures, such as spillways or sluices, means that flood storage schemes are likely to be more costly than comparably sized managed realignment schemes.

Where appropriate

The correct siting of the scheme within the estuary is critical if the scheme is to generate water level reductions. Hydrodynamic modelling has predicted that large realignments in the outer estuary can produce increases in water levels (making such locations unsuited

Figure 5.15: An aerial photograph of RSPB Wallasea Island taken in July 2019 (see case study 5.6). Jubilee Marsh is at the bottom of the photograph. Photo: RSPB.

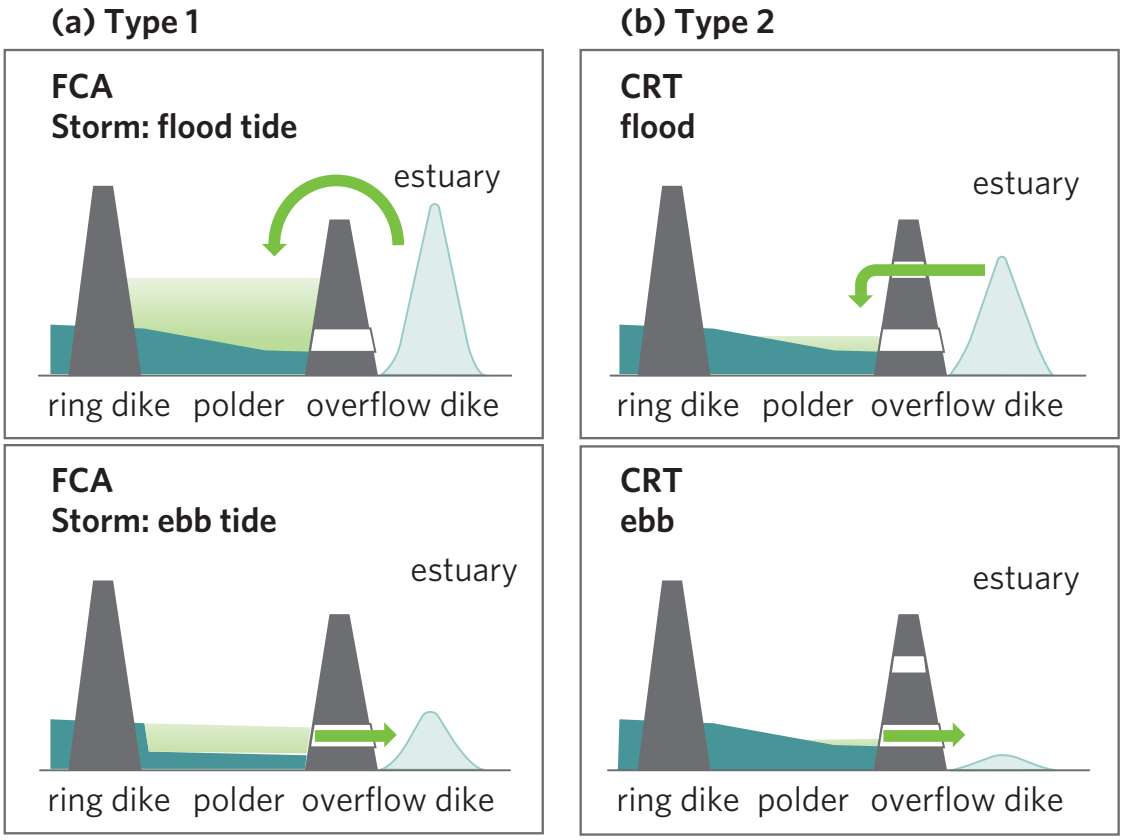

Figure 5.16: Flood control areas (FCA) in the Scheldt estuary, Netherlands. (a) Type 1 – Flood control area designed with a flood safety function: during high storm tides the water overtops the fronting embankment and flows into the flood control area. Water drains back to the estuary via outlet sluices on the ebb tide. Intertidal wetlands are unlikely to develop because the area may only flood a few times a year. (b) Type 2 – Flood control area with controlled reduced tide (CRT) designed with a safety function but, with a sluice system, also to restore a restricted tidal regime, allowing intertidal habitats to develop: during high tides water enters the site through inlet sluices. Water drains back to the estuary via outlet sluices on the ebb tide. Modified from Meire *et al.* 2014.

for flood storage schemes), while large realignments in the inner parts of estuaries can produce reductions in water levels (making such locations potentially well suited for flood storage schemes). Several estuaries have been modelled, including the Thames and the Humber in England, and the Alkborough flood storage scheme has been developed in the Humber, near the confluence of the Ouse and Trent, approximately 60km upstream of the estuary mouth. In the Netherlands, Meire *et al.* (2014) noted that if schemes were too close to the mouth, their impact will be small, if they are situated too far upstream, their impact will be negligible in more downstream parts. In the Scheldt estuary, the first flood control area is situated about 100km from the mouth of the estuary.

Design considerations

Design types

The type of habitats that develop within flood storage sites is dependent on the type of scheme. Flood storage areas (also known as Flood Control Areas in the Netherlands), have been broadly categorised under two categories. These categories have been derived from how they are deployed along the Flemish part of the Scheldt estuary.

- Type 1: Only inundate under extreme events and are unlikely to create intertidal habitats. These schemes have stretches of lowered existing flood embayments (spillways) to allow water to spill into the site under extreme events and low level sluices to allow water to flow back to the estuary (Figure 5.16).

Figure 5.17: The Alkborough Flats Flood storage scheme located near the confluence of the River Trent and River Ouse. Photo: @petersmith.com

- Type 2: Inundate under extreme events and regular tides and can create intertidal habitats. These schemes use sluices to control both the inflow and the outflow of water under normal tidal conditions to create intertidal habitats, while also allowing the site to function as a flood control area by over-spilling under extreme events. The tidal regime in the site is much reduced compared to the wide estuary since the sluices limit the exchange of water.

In designing Type 2 schemes it is important to consider the trade-off between maximising daily tidal exchange to create intertidal habitats versus limiting daily tidal exchange to maximise the flood storage capacity.

In the UK the only estuarine flood storage area to date is Alkborough in the Humber Estuary (see Case Study 5.7). This is a Type 2 scheme based on the above classification. The scheme is located in the inner estuary and combines a spillway, to allow the scheme to flood rapidly under extreme events, with a small breach to allow the scheme to flood under normal tides. The regular tidal inundation results in the creation of a range of intertidal habitats. The breach also allows the site to drain down after flood events.

Flood defence performance

The flood defence performance of tidal flood storage schemes (degree of water level reduction) is complex and requires the use of hydrodynamic models. As noted above, the performance of schemes critically depends on the location of the scheme within the estuary. Performance is also dependent on a number of other design aspects including the size of the scheme and the way it is connected to the wider estuary. Numerical models (such as MIKE21, Delft3D, Telemac) need to be used to assess the performance of schemes and optimise designs. Larger schemes have larger impacts on water levels. Sites flood earlier in the flood tide if sills are lower and later in the flood tide if sill heights are higher. Generally, sites that flood later are better at reducing water levels. The performance of flood storage schemes can also depend on the crest elevation of defences elsewhere in the estuary, since this governs how much water spills out of the main estuary channel in a flood event versus how much water propagates up the estuary.

Maintenance and management

Requirements for maintenance and management are likely to be similar to those described for managed realignment sites. Flood storage areas are likely to have additional maintenance requirements related to maintaining the fronting embankments and the tidal exchange structures such as spillways, valves and gates.

Case study: 5.7

Alkborough

The Alkborough Flats site lies in the inner part of the Humber Estuary near the confluence of the Rivers Trent and River Ouse (Figure 5.17). The site was formerly claimed from the estuary and was used for agriculture. Completed in 2006, the scheme covers 440ha (of which about 170ha are intertidal areas) and cost £11.1 million to deliver.

The purpose of the scheme was to:

- provide flood storage to reduce peak tide levels in the estuary during extreme events, providing a saving of approximately £12 million by deferring works to improve the existing tidal defences elsewhere in the estuary.
- contribute to habitat creation requirements by creating 170ha of new inter-tidal habitat and 200ha of other natural habitats such as grazing marsh, saline pools, wet and dry reed bed habitats, a freshwater area, hedgerows and areas of grassland/scrub.

The scheme achieves its flood storage function by virtue of its location in the inner estuary together with the provision of a 1,500 metre long spillway created by lowering and armouring the former fronting flood embankment. This allows the scheme to fill rapidly towards high tide during extreme events. By removing a large volume of water from the estuary, the flood storage area reduces water levels over a wide area of the Humber (For a flood event with a 0.5 percent chance of happening in any year (1 in 200) the scheme at Alkborough will reduce extreme water levels by more than 150 mm).

The scheme also has a 20 metre wide armoured breach to allow the site to function as a conventional managed realignment site under normal conditions. This has led to the creation of a range of intertidal habitats. Given the position in the inner part of the Humber Estuary, a significant portion of the intertidal habitat area has been colonised by reed bed.

An important lesson from this schemes is that high flow speeds on high tides were caused by the narrow size of the single armoured breach relative to the large site area. The high flow speeds rapidly eroded the fronting intertidal in the first few weeks after the breach was made. The breach is fronted by a rock apron to prevent the structure becoming undermined.

In common with other realignment sites on the Humber, the intertidal area has undergone high rates of siltation. In the context of a flood storage scheme, such siltation has the impact of reducing the flood storage capacity of the scheme over time. Long-term siltation rates and flood storage performance need to be considered at design stages in order to inform the business case for such schemes.

Further details on this case study and the lesson learned can be found here:

https://www.therrc.co.uk/sites/default/files/projects/54_alkborough.pdf

URBAN FRINGES

Description

Past land claim and narrowing of estuaries, known as encroachment, typically increases tidal flow speeds (Winterwerp and Wang, 2013) making a more hostile environment for flora and fauna. Furthermore, such sections of estuary often do not have any tidal marsh remaining along their fringes (for example, the Rother in East Sussex (Environment Agency, 2015)) thereby removing the localised ecosystem services available and fragmenting 'ecological corridors'. A good example of the benefit of these ecological corridors is to migratory fish, which use the incoming tide to move up estuaries. These fish will have greater chance of success in their inland migration with the presence of marshes where they are known to actively feed (Fonseca *et al.*, 2011). Without these marshes, there will be both less food for this inland migration and less refugia (safe havens).

There is good reason to restore fringes of marsh (saltmarsh in lower estuaries or reedbed in upper stretches) along estuaries but restoration to date has tended to focus on the creation of more isolated large schemes. The greatest need for these fringing marshes is in urban areas where the environment is the most hostile, for example, with frequent vessel movements and vertical walls in most places. Conversely, this also means that clever engineering is required both to squeeze them into the limited space available and also to make them last.

Although there are examples of urban fringing marsh creation worldwide (for example, Mishima *et al.* 2019), the widest range of examples that avoid the pitfall of encroaching onto the existing mud and gravel foreshore to create the marsh, is believed to be on the Thames Estuary. The Estuary Edges project (Thames Estuary Partnership, 2020) has collated and analysed the benefits of the differing designs (referred to as 'features') in order to promote their use to developers.

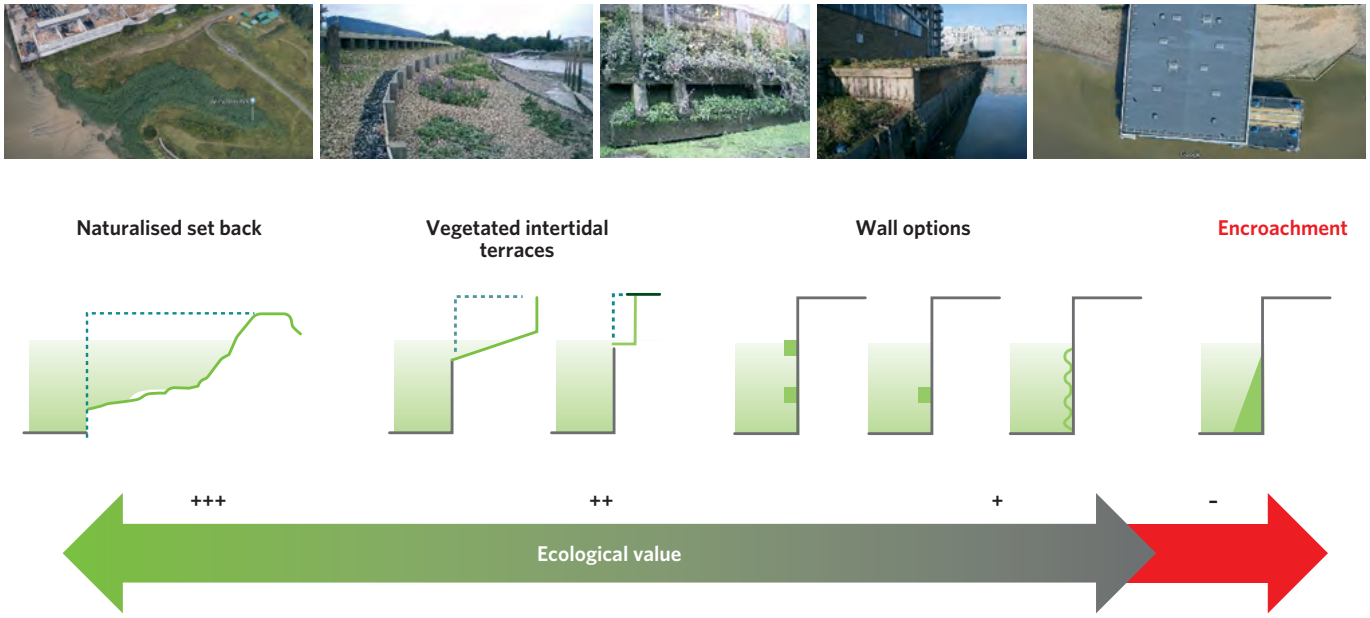

Figure 5.18: The 3 classifications of urban fringing feature and their ecological value. Source: Estuary Edges, 2020.

There are 3 classifications of feature, in order of ecological value (Figure 5.18):

1. Naturalised setback – a mini managed realignment typically including a creek feature and helped to accrete with brushwood.
2. Vegetated intertidal terraces – engineered set back using retaining walls to hold and accrete sediment at different elevations.
3. Wall options – rebuilding an existing wall to include (or bolting on) timber where vegetation can take hold, horizontal surfaces to encourage sediment accretion and different sediment types such as shingle (options where set back is very difficult or impossible).

Where appropriate

Urban fringe features are recommended for stretches of estuary where past encroachment has caused mudflat or saltmarsh to be completely lost or where intertidal loss is predicted to occur as sea levels rise. They are particularly important where all intertidal (of any form) has been lost or where no marsh remains on a long length of estuary (a rule of thumb of 1km is suggested).

Avoid building over existing intertidal or subtidal areas unless there are extenuating circumstances (for example, land contamination, significant infrastructure) because it replaces one habitat with another and, worse still, risks increasing flow speeds further.

Rebuilding a flood defence, typically as part of a redevelopment, is often an ideal opportunity to introduce urban fringe features into the new design. Many urban fringe features will have a lower whole life cost than replacing the existing wall like for like (Naylor *et al.*, 2017) because the engineering required to build them can be conducted in the dry behind the existing flood defence and, generally, less engineering is required.

Design considerations

Urban fringe features rely on sediment accretion that high currents and large or high frequency waves can prevent. Planting pre-grown saline tolerant plants (many developers will prefer this for instant 'wow'), and using protective rock armour, matting or groynes can help mitigate, but if the energy really is too high, a cobble, gravel or bare timber substrate may be the only design achievable. High energy conditions are likely, for example, on the outside of a meander bend, opposite a long fetch aligned with the prevailing wind direction, particularly if the foreshore has been lost through past encroachment.

Daylight is increasingly diminished in high density urban developments but some is still required for vegetation to succeed, even amongst saltmarsh which are excellent at competing in harsh conditions (Silvetri *et al.*, 2004). There is likely to be very limited light, for example, on a north facing bank with high flood walls or buildings to the south, west and east. Unvegetated mud still has ecological value but is not the main missing habitat in these environments.

Naturalised set back options have the most ecological value and the least engineering (engineered aspects will require maintenance) so should always be considered first. If set back is not possible, intertidal vegetated terraces and wall options should be considered in that order.

Bottom dwelling fish, such as flounder (*Platichthys flesus*) and common goby (*Pomatoschistus microps*), have been found to avoid passing up and over walls/sharp edges (Colclough *et al.*, 2005). Therefore, the best features have a continuum from the foreshore that can be achieved in

small spaces, through either construction of 'zig zags' or slopes running parallel to the channel.

Consideration should be given in the design to local heritage, education/signage for the public, aesthetics and risk to navigation, particularly for schemes located within an urban environment.

Maintenance and management

Urban fringe features may require a little more maintenance than managed realignments due to their potentially engineered nature and the number of pressures, including:

- scour from vessel wakes.
- greater risk of invasive non-native species arriving, for example, spread from local gardens or shipping (invasive species could have a significant impact on the ecological value of such a small site).
- replacement of timbers, used either as a biodiversity enhancement or as a retaining structure.
- litter.

A development will typically include a defect liability period of up to 10 years, although most of the problems associated with a feature are likely to be discovered within the first 5 years. The defect period should be used to monitor sediment accretion and plant establishment/invasion, but contracts should remain in place beyond this time, at least to remove litter and to replace biodegraded timbers.

Minor washout of sediment can be combated with the mitigations listed above (see 'Design considerations'). Plant species should be expected to change with time as the feature evolves (Cousins *et al.*, 2017), especially if they were planted.

Case study: 5.8

Greenwich Peninsula, London

The Greenwich Peninsula is located in the middle to lower Thames Estuary where saltmarsh plants are increasingly common (for example, Sea club rush (*Bolboschoenus maritimus*) and Sea Aster (*Aster tripolium*) are present). Three differing designs of intertidal vegetated terrace (Figure 5.19) were created as part of the Millennium redevelopment in the late 1990s, replacing over 1,300m of steel sheet piling. One of the three designs was intentionally connected to the foreshore, whereas gravel washing over one of the others has accidentally created a continuum. Both terraces are used extensively by the bottom dwelling fish flounder (*Platichthys flesus*) and common goby (*Pomatoschistus microps*) as well as bass (*Dicentrarchus labrax*) and other species (Colclough *et al.*, 2018).

Pre-grown plants with erosion matting were used and some were lost due to wave energy lifting the matting. Replanting during the defect liability period without the matting was found to work well. In more recent years, an increase in erosion close to the passenger ferry dock suggests an increase in vessel wake.

Invasive non-native species should be removed for as long as possible, and a long-term performance assessment after the initial 10-year period should be considered, as has been carried out by the Estuary Edges project (Thames Estuary Partnership, 2020).

Drone survey of saltmarsh at Cwm Ivy, Wales. Photo: Heidi Burgess.

MONITORING SALTMARSH RESTORATION SITES

Monitoring saltmarsh restoration sites is important before, during and after project implementation in order to:

- assess any potential impacts of a site.
- establish if the project is developing as intended and meeting its objectives.
- inform adaptive management approaches and maintenance programmes.
- inform the design and development of future projects.

Monitoring plan objectives

The reasons for monitoring the restoration scheme are varied and should inform what is monitored, when and for how long, within the constraints of the budget available for monitoring. Aspects that may need to be monitored include:

- **Progress against specific project objectives.** All restoration projects should have clear specific, measurable targets/objectives to which site development can be compared, and these should form the basis of the monitoring scheme design. Such targets might be related to specific species (for example, the provision of a specified area of suitable habitat or a specified number of breeding pairs), to human visitor numbers or volunteering opportunities, or to the provision of another ecosystem service (for example, amount of carbon stored). Project objectives are likely to cover any monitoring needed to meet **requirements of funding sources**.
- **Compliance with statutory requirements.** For example, if restored saltmarshes are created as compensatory habitat, monitoring the restored area to establish if it has similar characteristics to natural marshes is required. This typically relates to vegetation development and bird usage of the site. If there is a potential impact on the water quality of an aquifer or surface waters, then water quality monitoring may need to be carried out to ensure compliance with the relevant water environment regulations.
- **Protected species.** Monitoring of protected species for which the scheme will have a significant direct effect (often, but not exclusively, great crested newts, water vole and badgers) will be required.
- **Potential risks identified in the environmental statement.** Such risks will be project specific, but monitoring is often required to assess subtidal and intertidal effects in the wider estuary, including changes to shell fisheries and navigation channels, and erosion or movement of breach and exit channels.
- **Compliance with conditions of planning consent.** There may be conditions of planning consent that require additional monitoring during project implementation, for example, traffic in local roads during construction, or archaeological finds.
- **Impacts on the wider system.** Changing the coastline may have an impact on a wide variety of factors, for example, flood risk, local marine life or number of visitors to an area. In order to understand and model potential impacts, baseline studies need to be carried out long before the scheme is implemented.
- **Research topics to inform future restoration practice.** Research into restored saltmarshes can inform future site design and management, and inform our understanding of their value/economic benefits. Research is most valuable when conducted at several sites, allowing general patterns to be identified.

Carrying out monitoring

Ideally, monitoring should be a balance of measuring the outcomes of the project aims, while also collecting new data to inform future projects. Budget limitations may mean that monitoring is focussed on that which is essential for statutory and planning requirements. But there are different ways in which monitoring can be carried out, for example, through universities, citizen science, charitable organisations, volunteer groups, existing monitoring programmes or using other sources of funding.

Engaging with stakeholders early to discuss monitoring can result in joined up thinking, which may enable monitoring for more than one area for little extra expense and effort. This also means that results can be analysed across disciplines more easily, allowing a more thorough understanding of a system. This is particularly important where methods are labour intensive, involve expensive equipment or where access to a site is difficult or restricted.

Consider at the planning stage what level of accuracy (how close to reality) and precision (repeatability) of data is required, as this will guide which monitoring methods are suitable, as well as which temporal and spatial balance to apply.

BOX 5.2: ROLE OF PROFESSIONAL INSTITUTES AND CITIZEN SCIENCE IN MONITORING

The knowledge on how fish use saltmarshes and restored sites is relatively new. The Institute of Fisheries Management (IFM) have developed technical support and training for individuals and bodies (for example, IFCAs and wildlife trusts) who want to engage in estuarine/saltmarsh/fish sampling. There is large and growing demand for citizen science in this field and the IFM can provide training to citizen science volunteers.

Other examples of using citizen science to monitor restoration projects are given in Chapter 4, 'After completion: communication and education activities with the public'.

'Temporal balance' refers to the frequency of collection versus the duration of the monitoring campaign. For example, would you want to collect data once a month for 10 years or every 15 minutes for 1 year? Typical sampling takes place either quarterly, twice yearly or annually. It is sensible, if resources permit, to start monitoring at a high frequency, for example, quarterly, and then reassess if this frequency is needed so it can then be increased or decreased. Many managed realignment schemes have been carried out to provide compensatory habitats and monitoring is needed to demonstrate that the appropriate habitats are forming within the site and that the anticipated fauna are using the site. While earlier managed realignment schemes in England had 10 years of monitoring, more recent schemes in the last 6 years or so tend to have 5-year campaigns.

'Spatial balance' describes the area covered by the measuring techniques, from point measurements up to whole landscape capture. It is possible to apply a range of spatial and temporal techniques, which, by complementing each other, provide a fuller picture of the processes occurring.

Some variables can be assessed either in the field or by taking samples back to a laboratory for analyses. The availability of facilities, specialists, equipment and site access, along with man hours, will determine which is feasible and appropriate for a project, along with the accuracy and precision needed.

Whichever monitoring techniques are used, data protocols need to be established at the outset of a project. This will allow for long-term storage and access of data.

Methods for monitoring

There is a wide range of variables that could be monitored and a vast array of methods that could be used to assess the baseline and development of newly restored intertidal area. Below, we describe some of the typical things to monitor at a site before, during and after the restoration, with some suggested methods. It is not a definitive list and monitoring regimes should be carefully tailored to site objectives. Furthermore, new techniques are regularly being developed. The methods are not restricted by restoration type (realignments, regulated tidal exchange, using fencing or BESE techniques) but choice will depend on site size, location within the tidal frame, accessibility of both workers and general public and, of course, funding.

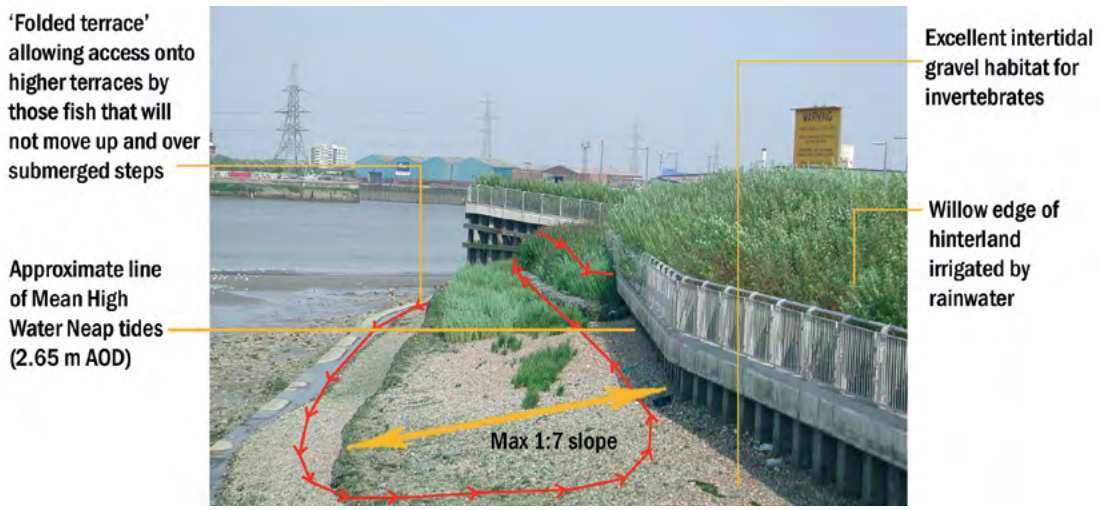

Figure 5.19: Designs of intertidal vegetated terrace created at Greenwich Peninsula, including the accidental 'zig zag' so helpful to bottom dwelling fish. Top left photo: Clearwater Photography. Bottom photo: Thames Estuary Partnership. Right photo: Estuary Edges.

Case study: 5.9

Greatham, Tees Estuary, England, realignment monitoring programme

Saltmarsh habitat has been restored to the north and south of the Tees Estuary at Greatham. This scheme created 23ha of new intertidal habitat at Greatham North by breaching flood defences to the north of the Tees Estuary in 2014, and restored a further 30ha at Greatham South by breaching flood defences south of the estuary in 2018.

The Environment Agency carried out remote surveys in 2019 using CASI (Compact Airborne Spectrographic Imager) and LiDAR (Light Detection and Ranging). They have used the collected data to create a Digital Terrain Model (DTM) of the area and a modelled habitat zonation map (Figure 5.20). There is a good correlation between ground truth survey quadrat data from Greatham North and the habitat zonation map, except for narrow bands of upper marsh that weren't picked up from the aerial survey data.

The correlation was less good for the more recently inundated intertidal habitats at Greatham South. The habitat map, derived from aerial survey data, includes several areas of mid low marsh, whereas ground survey quadrat data found the majority of the site to be pioneer marsh. This difference is likely due to the presence of terrestrial plants on site, which on aerial imagery were miss-classified as low mid-marsh.

The DTM has helped the Environment Agency to easily identify areas with the greatest variation in gradient, and, in turn, to focus quadrat surveys on areas where the greatest saltmarsh succession was likely to occur based on elevation change.

Lessons learned:

- Ground-truthing of remote surveys is very important, especially for newly created/restored habitats that have a transition phase.
- Digital Terrain Model data can be invaluable for informing where to position future ground survey transects.
- Based on monitoring carried out to date, the areas of best zonation at Greatham appear to be where inundated areas have a gradual incline, and the flood bank behind them is not too steep/abrupt.

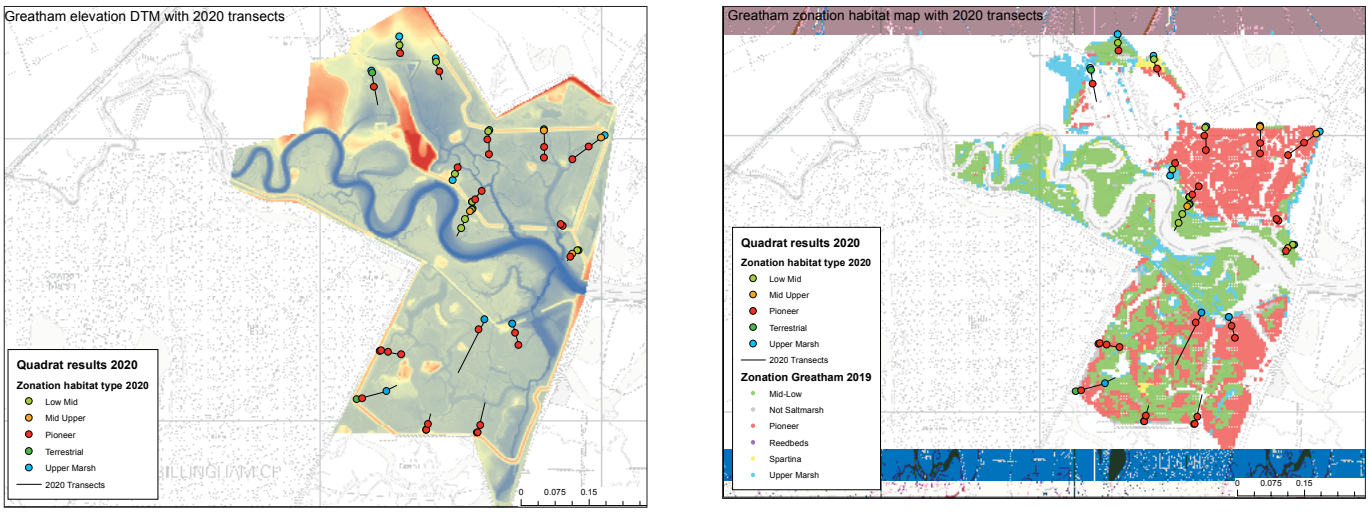

Figure 5.20: Use of remote survey data at Greatham (see case study 5.9) to create a digital terrain model (left) and habitat zonation map (right).

Table 5.6 provides examples of monitoring methods, broken down by discipline and from where the physical monitoring will take place. Methods for the different disciplines may overlap and, with simple adaptions to protocol or method, may therefore serve more than one purpose. More detailed description of the methods associated with each discipline are available as technical guidance sheets in an appendix (Appendix Technical Guidance Sheets for Monitoring).

Table 5.6: Examples of monitoring methods by topic.

	REMOTE SENSING – AERIAL	WATER COLUMN AND SUBMERGED BED	TERRESTRIAL SURFACE	SUB-SURFACE (TERRESTRIAL)
Hydrology	• Satellite imagery. • LiDAR. • sUAV (small Unmanned Aerial Vehicle – drone).	**Hydroperiod (Depth):** • Tidal gauges and buoys. • Benchmark indicator – by eye and hand recording. • Static photography. • Pressure sensors. **Waves:** • Off-shore wave buoys. • Acoustic Doppler Velocimeter (ADV). • Inexpensive and open-source tools – 'mini buoys'. **Freshwater input:** • Bottled samples – lab or on-site analyses. • Installed salinity sensors. **Velocity and currents:** • Spot measurements – biodegradable floating objects. • Acoustic Doppler Current Profiler (ADCP) . • ADV can be adjusted for shallow water velocity and current measuring or low-cost 'mini-buoys' constructed in-house. **Surface water quality:** • Bottled samples – laboratory. • Spot samples – hand held meters. • Sondes – specific probes for longer more regular sampling. • Existing estuary/coastal monitoring.	• Rain and wind gauges. • Water features survey. • Walkover survey.	• Groundwater – aquifer deep borehole. • Groundwater – borehole water extraction points. • Groundwater fluctuations – Piezometers. • Pore water – shallow tube well sampling points.
Geomorphology and sediment processes	• Satellite imagery. • LiDAR. • sUAV (drone). • Structure-from-Motion (SfM) elevation models.	**Suspended Particle Matter (SPM):** • Bottled samples. • Gravimetric analyses. • Turbidity probes. • ADCP.	• Sediment pins. • Elevation plates or tables. • Submersible Altimeters (ALTUS systems). • Fixed-point photography. • Differential Global Positioning Systems (DGPS). • 3D laser scanning. • Shear vane. • Cohesive Strength Meter (CSM).	**Sediment cores for:** • Visual inspection – structure. • Laboratory analyses – geochemistry (XRF, XRD, ICP-OES/ ITRAX, TOC) – structure (CT scans) – physiochemical properties (bulk density, grain size, Eh/pH, porosity). • Pore water – – centrifugal extraction – rhizon technology. • Ground Penetrating Radar (GPR) – sub-surface water features.

	REMOTE SENSING – AERIAL	WATER COLUMN AND SUBMERGED BED	TERRESTRIAL SURFACE	SUB-SURFACE (TERRESTRIAL)
Flora and microbes	**Flora:** • Satellite. • sUAV – drone combinations of CASI and near infrared images.	**Bacteria and fungi:** • DNA extraction of samples from soil.	**Flora:** • Permanent quadrats – NVC. • Other quadrat and vegetation surveys.	**Flora:** • Root structure – CT Scanning. **Bacteria and fungi:** • DNA extraction of samples from soil.
Fauna	• sUAV – drone for fish habitat.	**Fish:** • Fyke nets, block nets, seine nets. • Small light weight dredges. • Acoustic monitoring. • Gut content. • Underwater video monitoring. **Key species:** • eDNA from water samples.	**Birds:** • Wader and wildfowl counts. • Breeding bird surveys. **Invertebrates:** • Pitfall traps, sweep netting, suction sampling. • Pollinator transects, pan traps.	**Benthic invertebrates:** • Sediment cores.
Cultural heritage (Archaeology)	• Satellite. • LiDAR. • sUAV – Drone. • Photogrammetry.	• Bathymetric surveys.	• Walk over surveys. **Geo-physical surveys:** • Resistivity. • Palaeomagnetism. • Ground Penetrating Radar.	• Test pits, including. hand dug. • Cable percussion boreholes. • Windows sample cores. • Hand augurs. • Palaeoenvironmental assessment dating – carbon-14, optically stimulated luminance.
Carbon stock and Sequestration (see also Box 5.3)	• Satellite imagery (NDVI). • LiDAR. • sUAV – Drone.	• Non-available at time of print.	• Ground-truthing of erosion and accretion (see methods under Geomorphology and Sediment). • Above-ground plant biomass. **Greenhouse gas fluxes:** • portable greenhouse gas analyser and lab analyses.	• Cores – analysed for elemental analyses, isotopes, biomarkers (for example, XRF, XRD, ICP-OES/ITRAX, TOC). • Below-ground plant biomass.

BOX 5.3: METHODS FOR ASSESSING CARBON STOCKS AND EMISSION FACTORS IN SALTMARSHES

Tracking carbon stocks (total amount of carbon stored in an area) and changes in greenhouse gas emissions over time, are important monitoring aims for projects with a target/funding linked to carbon sequestration. This monitoring would be useful at the local level to quantify the effectiveness of the project in meeting its objectives, and would also be valuable at a wider scale, providing data that can be compared across sites, to help us better understand the climate change mitigation potential of saltmarsh restoration/creation.

The detail of the monitoring work needed will be dependent on the specific monitoring objectives. For example, for blue carbon interventions aiming for accreditation on the voluntary carbon market, the level of detail required will be outlined by the certifying body. Standardised methods for field measurements and analysis of stocks and fluxes should be followed. There is good guidance in the 'Blue Carbon Manual' produced by the 'Blue Carbon Initiative' (Howard *et al.*, 2014). Guidance for monitoring saltmarsh is also covered by guidelines produced by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2014). The IPCC wetlands supplement to IPCC guidelines for national greenhouse gas inventories provides countries with best practice, widely applicable default methodologies to assist countries in compiling national inventories of greenhouse gases. It is recommended that IPCC guidelines and standards be followed for the assessment of blue carbon outcomes; meeting these international standards will both help serve the integration of these habitats into national greenhouse gas accounting and, in turn, provide acceptable targets for voluntary carbon markets/carbon financing.

Carbon stocks are calculated by adding all relevant carbon pools (reservoirs of carbon) within the site that store and release carbon. Relevant blue carbon pools include the biomass of living saltmarsh plants (above ground and also that of the roots and rhizomes below ground), organisms such as algae that live on those plants, the biomass of dead detritus/plant tissues and soil organic matter.

The IPCC guidelines provide guidance at different levels of detail from tier 1 (a method that uses default values) to tier 3 (the most detailed method) allowing carbon stock to be estimated where site specific data has not been collected. However, estimates calculated using default values will have a high degree of uncertainty. Table 5.7 contains a summary of tier 1 and 2 guidance for data on carbon pools and emissions needed from saltmarsh restoration or creation sites. Many of the monitoring methods for tier 1 assessments are straight-forward, the main requirements being to:

- monitor soil carbon contents when revegetated surfaces reach 10% or more plant-cover.
- determine if the salinity of the tidal waters on rewetting exceeds 18psu before no non-CO_2 emissions can be assumed.

Tier 2 assessments are less straight-forward and cost-effective to carry out, and may require specialist analytical or technical support.

Post-restoration sediment accumulation in an extended golf-hole cutter core (10cm diameter) recovered from RSPB Nigg Bay nature reserve (Cromarty Firth). Marine sands and silts, which accumulated rapidly after the realignment, are overlain by organic-rich saltmarsh soils – highlighting active and ongoing soil carbon burial at this site Nigg Bay was Scotland's first coastal realignment project, implemented in February 2003. Photo: William Austin, May 2021.

Table 5.7: Data needed to estimate carbon stock and emissions from rewetting, revegetation, and creation of saltmarsh.

	TIER 1	TIER 2
Biomass	No data needed. Assumes no change in biomass stock as a result of rewetting.	Annual above-ground increase due to biomass growth Annual above-ground decrease due to biomass losses Carbon content of dry biomass Proportion of woody and herbaceous biomass
Dead Organic Matter (DOM)	No data needed. Assumes no change in DOM as a result of rewetting	Address dead wood and litter pools separately Average annual transfer of biomass into and decay out of each pool due to processes and disturbances Carbon fraction of each pool
Soil Carbon	Estimate of when 10% of the overall area is colonised by vegetation	UK-specific emission factor disaggregating organic and mineral soil type
Non-CO_2 emissions	Assumes no non-CO_2 emissions as a result of rewetting if the salinity is greater than 18psu	Assumes no non-CO_2 emissions as a result of rewetting if salinity is greater than 18psu UK-specific methane (CH_4) emission factor based on water salinity if less than 18psu

Monitoring for blue carbon should be designed to meet the requirements of the IPCC criteria (Table 5.7) and carried out in 4 stages:

1. **Before-intervention:** set a monitoring baseline (ideally monitor for at least 12 months before the proposed intervention to characterise all seasonal variation). Where possible, identify an adjacent representative natural site to help track progress towards 'natural' conditions and representative soil carbon contents.
2. **Intervention:** record all measures taken to restore the saltmarsh, such as, site re-profiling, sediment enhancement/use of dredged material and potentially vegetation planting, so that this information can be taken into account in the planning process for any long-term monitoring programme.
3. **After-intervention:** agree long-term monitoring sites within the first 12 months. These sampling sites will form the framework for repeat monitoring, ideally coinciding with times of peak plant biomass. Measure the accretion rate every month for the first 12 months because it is likely to change rapidly.
4. **Transitional period:** track progress after the initial intervention. Aim to monitor progress towards as close to a natural habitat as is possible. Repeat measurements at 12-month intervals are ideal, however, continue to measure the accretion rate more regularly (at least every 6 months) for 2 to 5 years following restoration.

Several types of survey can be useful for monitoring blue carbon:

1. **Elevation ground survey:** to underpin any spatial analysis of the intertidal zonation of the saltmarsh as it establishes and responds to ongoing sediment accretion.
2. **Vegetation and soil surveys:** to monitor changes in saltmarsh plant communities and above-ground plant biomass. Collect soil samples (using small diameter push-corers or longer gouge-corers) of fixed volume and depth (10cm) in parallel with the vegetation survey data.
3. **Accretion rate surveys:** you can use surface elevation tables to measure changes in saltmarsh surface elevation and infer accretion rate changes.
4. **Greenhouse gas flux surveys:** these are beyond the scope for many restoration projects and the IPCC tier 1 and 2 approaches allow emission factors to be applied without the need to collect direct measurements. However, these surveys can provide important information on net greenhouse gas fluxes in or out of the saltmarsh. Seek specialist advice to establish a reliable GHG flux monitoring programme. Partnering with an academic institute would provide this support and advice.
5. **Long-term remote surveys:** these methods can be particularly helpful in large-scale assessments, where upscaling from limited ground survey data are essential. Mapping habitat for the whole area of restoration sites helps to inform more accurate emissions estimates. Remote sensing can provide the opportunity to up-scale from plot-scale measurements and estimate the total area of each habitat (transitional grassland, mudflat, saltmarsh zone and/or NVC community) for separate emissions reporting.

Examples of potential techniques that could be used in these surveys are given in Table 5.6, with more detail provided in the technical guidance sheet on carbon sequestration in the appendix.

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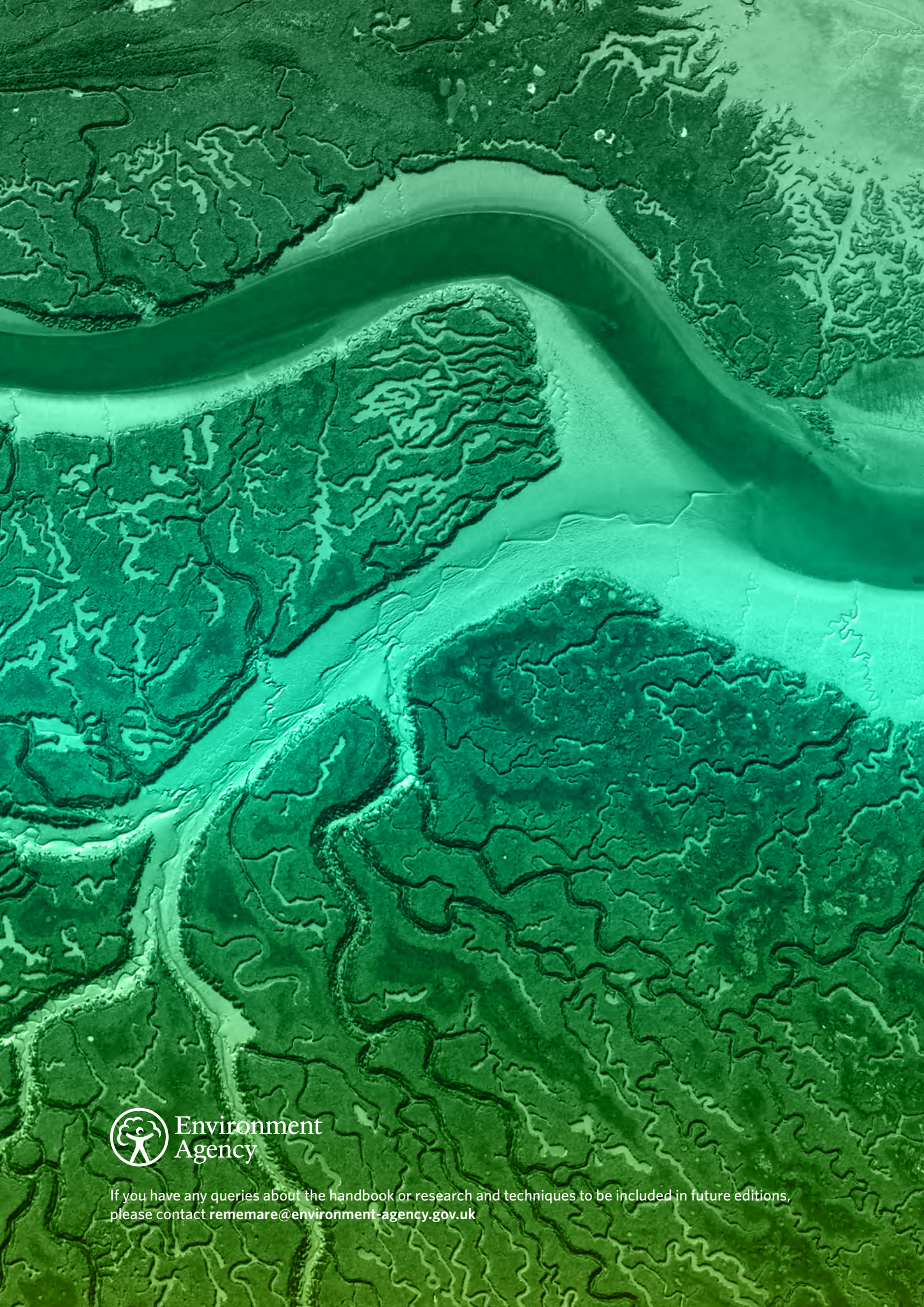

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