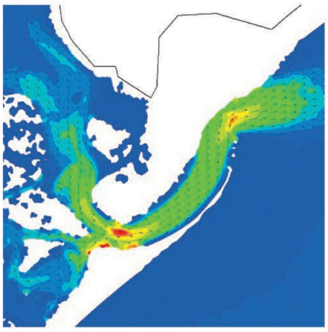
Solent Forum

Beneficial Use of Dredge Sediment in the Solent (BUDS) Phase 2

Feasibility Review for Sediment Recharge Project(s) on the West Solent Saltmarshes

February 2020




Innovative Thinking - Sustainable Solutions

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A report for the Solent Forum

February 2020

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	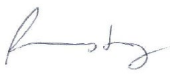	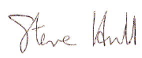

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Non-Technical Summary

Project background

This report reviews the work undertaken for Phase 2 of the Solent Forum's 'Beneficial Use of Dredge Sediment in the Solent' (BUDS) project. This second phase of the BUDS project involved investigating the feasibility, and value, of conducting a major new beneficial use project (or multiple projects) on the West Solent saltmarshes along the Hurst Spit to Lymington frontage (see Image NTS1).

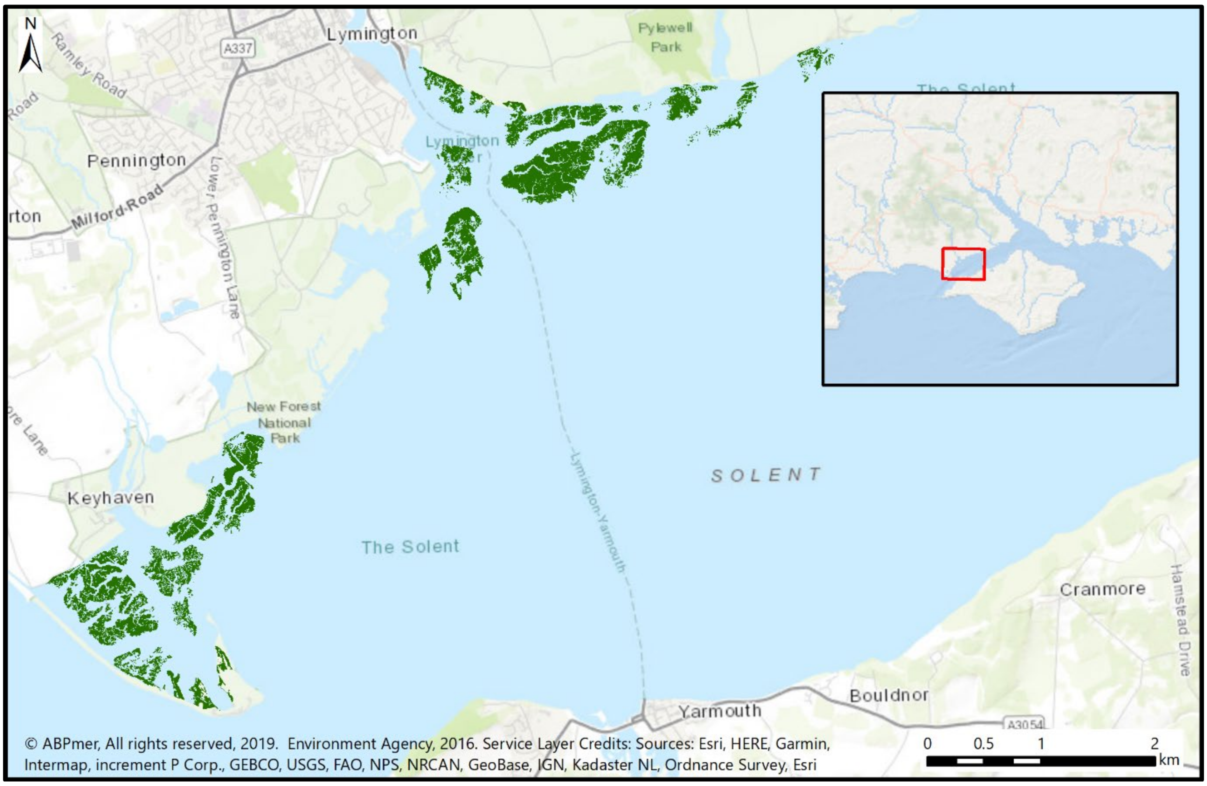

Image NTS1. Location of the West Solent marshes

The Solent Forum started the BUDS project in 2017, following requests from its members who were keen to see more of the region's dredged sediment used to restore and protect its deteriorating intertidal habitats. Phase 1 of the BUDS project involved a high-level review of the Solent region to identify sites that would gain most from a beneficial use campaign. These were sites where dredge arisings (silts mainly) could be used to 'recharge' deteriorating habitats and achieve a range of environmental, social and economic objectives (especially increased coastal flood protection). Alongside this strategic review, a key aim of this initial stage was to begin developing collaborative partnerships with those willing to support one or more recharge initiatives, especially at a large scale.

The Phase 1 strategic review was completed in March 2018. It recommended that the next phase should involve actively progressing one or more project(s) while also working with regulatory bodies to help develop guidance and provide oversight. It was envisaged that this oversight would then help identify major new projects which stakeholder partnerships could support as well as smaller-scale schemes that individual operators and harbour authorities would like to progress.

The Phase 1 review also concluded that a 'stand out' candidate site for recharge work was along the Hurst Spit, Keyhaven, and Lymington frontages. In this area, the marshes are rapidly eroding and they play a key role in coastal and harbour protection as well as being of high conservation value. Therefore, a recharge project pursued along this frontage could achieve substantial and multiple benefits. The Phase 1 work further showed that there was a great deal of willingness, across a wide range of stakeholders, for such projects to be realised.

Phase 2 Objectives

To progress the recommendations from Phase 1, this second stage of the BUDS project involved investigating the 'real world' feasibility of conducting valuable beneficial use project(s) on the West Solent saltmarshes. Key objectives for this phase were to:

- Clarify how, and where, dredge sediments can be beneficially placed on these marshes;
- Understand the costs and benefits of possible initiatives on a more site-specific basis; and
- Recommend how practical projects can be pursued in BUDS Phase 3 and further define the roles that different stakeholders might play in future initiatives.

The results obtained from this review are designed not only to determine how and whether a project might go ahead in the West Solent, but also to provide information to help guide other projects in the Solent and, it is hoped, more widely in the UK and internationally. This second stage was made possible by an Environment Agency grant, and is being overseen by the BUDS Technical Group, which includes technical specialists and representatives from a range of stakeholder groups. Further details and all products from the BUDS project can also be found on the Solent Forum website[1].

Phase 2 Methods

To progress the BUDS Phase 2 study, a number of different tasks were carried out. These were progressed through the following four-stages:

- **Stage 1 Baseline Conditions and Background Review:** To provide a contextual foundation for this review, existing conditions in the West Solent were reviewed through analyses of:
  - The condition of the marshes and the rate at which they are declining;
  - The local distribution of breeding and overwintering bird populations;
  - The existing dredging activities in the West Solent;
  - The (ecosystem service) benefits of the West Solent saltmarshes[2]; and
  - The main consenting/licensing issues.
- **Stage 2 Technical Options Review:** As the second stage in the process, possible locations and approaches for a recharge campaign (or campaigns) across the area were identified and evaluated. Four possible recharge 'Project Examples' were then selected for further review;
- **Stage 3 Cost and Benefits Analysis**: The anticipated costs and benefits of the four Project Examples were then assessed. This task was important because, as noted in Phase 1, understanding about the costs and benefits of recharge projects is currently very poor; and
- **Stage 4 Review of funding opportunities:** A brief review of possible future funding sources and mechanisms was undertaken based on existing literature and stakeholder consultation.

1 http://www.solentforum.org/services/Current_Projects/buds/

2 The benefits of the West Solent marshes were also mapped/illustrated to inform this review and future engagements with possible partners and the public.

Throughout this process, regular consultations and meetings were held with partners, stakeholders and dredging specialists. In response to this work, recommendations were then made for implementing a project or projects in Phase 3. These were placed in context of the background to, and aims of, the BUDS project and are to be agreed and developed with project partners.

Phase 2 Results

Stage 1 Baseline Conditions and Background Review

It is now very well established that the West Solent marshes are rapidly declining. The baseline review of **marsh extent and condition** carried out for this study, quantifies the losses at around 2% of vegetated marsh area and 2% of the marsh volume each year. If there is no active intervention, it is likely that this proportionate rate of loss will increase over time as the marshes decrease in size and fracture and also respond to the effects of sea level rise. Therefore, the vegetated marshes will probably be gone by around 2045-2050. These findings have built on, and confirmed, earlier work and were supported by a detailed analysis of shoreline elevation data as well as aerial imagery derived from a project-specific drone survey.

Saltmarshes are important **'natural capital' assets** which provide many valuable **ecosystem services**. They have inherent ecological value in their own right but also: have a nature watching/amenity function; act as fish nurseries and foraging grounds; bury carbon; and act as 'wave breaks'. In the West Solent, the latter function is especially important given there are several harbours and marinas, hundreds of boat moorings, and long lengths of seawall benefiting from the wave protection the marshes provide. It is important to note though, that the **future coastal defence** priorities for this shoreline are currently being reviewed by the Environment Agency and the New Forest District Council (NFDC). Consultations on this work are to begin in 2020 and therefore it is unclear at this time how future beneficial use projects will precisely fit into local coastal defence planning and, therefore, how valuable recharge work will be for flood risk management.

Aside from having this important coastal protection function, as these marshes disappear (at around 2% each year, for now) this is costing society at least £50,000 per annum in lost carbon and saltmarsh habitat value alone. The West Solent marshes have a high nature conservation value and provide an important function by supporting many **overwintering and nesting birds** every year, some of them in internationally important numbers. The value of the marshes for birds is, though, increasingly being compromised due to marsh lowering and edge erosion. As a result, several of the West Solent marshes that were important to breeding birds are now too low, or too small, for birds to nest on.

A **review of licensed dredged resources** from other West Solent locations, and their existing disposal practices, showed that opportunities exist for depositing sediments materials from other harbours and marinas along the Hurst to Lymington frontage. In theory, over 600,000 m^3 of maintenance dredge materials are available annually from nearby sources. The majority is excavated in Southampton Water using large dredgers which could not easily discharge their materials at the West Solent marshes due to their size and the need for both specialist discharge equipment and substantial sediment-retaining infrastructure at the receptor site(s). Dredge arisings from smaller harbours/marinas such as Beaulieu, Yarmouth and the Hamble could be used more easily, due to the barges/dredging method employed and because many of them send at least some of their materials to the nearby Hurst offshore dredge disposal ground anyway. It is thought that realistically each year, in the short term, some 15,000 to 30,000 m^3 of muddy sediment could be available for beneficial use from nearby harbours, in addition to approximately 20,000 m^3 from Lymington itself. There may also be beneficial use opportunities closer to these harbours which may represent a better disposal location than the West Solent marshes.

To provide a brief **overview of issues around the marine licensing** beneficial use projects, a meeting was held with the Marine Management Organisation (MMO) and the Centre for Environment Fisheries and Aquaculture Science (Cefas) during Phase 2. This confirmed a substantial willingness to support beneficial use projects within the confines of their regulatory roles. Sediment (testing) requirements were also highlighted during this meeting, and bunding, monitoring and assessment recommendations made.

Other national and international initiatives are currently underway which further indicate a widespread willingness to support such projects. These initiatives are reviewing regulatory frameworks and seeking ways in which beneficial use projects can be facilitated. Any regulatory change will be slow however, and therefore the emphasis in the short-term needs to be on adopting strategic and partner-led approaches to actively select sites for future recharge work and, in doing so, to identify projects where the regulatory process is made as procedurally simple and cost-efficient as possible. That is what the BUDS project is seeking to do.

It is hoped that BUDS will be an exemplar of how to work with the regulations while also guiding how those regulations might adapt over time. The expectation also is that BUDS will support recharge projects that will, in turn, provide further lessons and evidence (i.e. 'learning by going') on top of established experiences, leading to increasingly ambitious and widespread projects over time.

Stage 2 Technical Options Review

There are several ways that recharge projects could technically be carried out and also multiple locations where these might be applied. There are also many variations and different strategies that could be pursued for each technical approach and these could range from small-scale trials to larger scale initiatives. There are, furthermore, varying levels of certainty associated with the different techniques, not least because very few major/ambitious marsh recharge projects have been done before.

Recognising this complexity and the spectrum of possible opportunities, a three-step process was adopted to identify and compare the different ways in which beneficial use could be conducted in the West Solent. These steps were as follows:

- **Step 1**: informed by the baseline/background review, an **initial high-level review** was undertaken to identify all the sites where a recharge could technically be carried out;
- **Step 2**: A **site selection process** was undertaken that involved reviewing these sites based on a range of factors, and ranking them into High, Medium and Low priority options; and
- **Step 3**: Finally, different indicative **technical approaches were identified** for carrying out recharge work at the preferred locations.

At Step 1, a total of 15 possible recharge locations were identified. At Step 2, four were chosen as high priority sites (Stoney Point Hawker's Marsh, Boiler/Pylewell and Pennington). Then, for Step 3, four indicative and illustrative approaches (Options 1 to 4) were selected. These increase in their scale, technical complexity, cost and the levels of benefit achieved and are outlined as follows.

- **Option 1 - Extended bottom placement**: This would involve extending an approach which the Lymington Harbour Commissioners (LHC) have been adopting for some of their dredged materials over the past few years. LHC are 'bottom placing' sediment at the edge of one of the big marsh complexes, Boiler Marsh. This involves contractors manoeuvring split bottom barges over low mudflat locations, and then opening the barges and releasing the dredged materials. This approach is proving to be effective in retaining a good proportion of deposited sediment which forms a raised mudflat area that then shelters the marshes behind. There are several locations elsewhere along the Hurst to Lymington frontage where both LHC and others could place substantial volumes of sediments beneficially in this manner. This offers an opportunity (at low or no extra cost) to add or retain sediment in the local system and can create sacrificial bunds to help slow marsh decay and fracturing. Such increased bottom placement alone will only partially slow the erosion rate (possibly at an undetectable scale) and the marshes will still continue to progressively disappear. This approach also cannot be used to create/restore saltmarsh habitat. This is because it is not possible to directly place sediment high enough in the tidal frame (given the small local tidal range and the relatively large clearance required in relation to ship draught).

- **Option 2 - Introduce a mobile sediment transfer station**: This would involve setting up a 'transfer station'/platform with associated pumping equipment that can be placed at marsh-edge locations. Barges would be able to moor up to these, and a proportion of the annual dredged sediment volume would be pumped directly onto the marshes and around their margins via pipelines. This would enhance the habitats and slow their decline. The platform would be moveable so this could be done at various locations. This approach offers an opportunity to raise bed levels on the marshes (perhaps as gradual 'thin-layer placements') and restore the quality of the habitat, though it may only slightly delay the loss of marshes. This would require double handling of materials, which is more costly and time-consuming than placement directly from a dredger or hopper barge[3].
- **Option 3 - Create erosion protection fencing with recharge**: In order to more substantially delay, or even halt, marsh retreat, this would involve the installation of relatively substantial erosion protection fences along the exposed outer marshes edges, and then recharging behind those fences. Trials are recommended for this approach, as it is largely untried in the UK, particularly at exposed locations.
- **Option 4 - Carry out a large-scale (one off) recharge scheme and bunding**: While the preceding options offer an opportunity to stall ongoing losses of marsh habitat, much larger-scale projects could aid in facilitating the reversal of losses and providing substantial benefits for coastal protection. This option would involve recharge of sediment alongside the introduction of substantial retaining bund structures (probably constructed using coarser shingle materials).

In summary the anticipated costs and benefits of these approaches are as follows:

- **Option 1**. Could increase the volumes of sediment deposited from harbours/marinas intertidally rather than offshore. This may achieve cost savings for some of them and there would be a net increase in sediment delivery directly to the West Solent. The benefits to coastal protection, harbour protection, carbon sequestration and nature conservation will be modest;
- **Options 2 and 3**. Each of these approaches would cost more than extending bottom placement, but would provide greater benefits for coastal protection, harbour protection, carbon sequestration and nature conservation. Both the costs and the benefits would be larger for Option 3 than for Option 2;
- **Option 4.** This would be the most expensive option, but it would deliver the largest amount of habitat and potentially also the largest benefits for coastal protection, harbour protection, carbon sequestration and nature conservation. This could be a compensation measure linked to coastal development, but there would also need to be certainty of net habitat improvement.

Each of these four options represents an advancement of the current situation because they each offer an opportunity to deliver more sediment onto and around the marshes in order to enhance them, slow their decline and achieve other benefits. They also offer valuable opportunities for learning new lessons about the practical approaches and costs of marsh protection and restoration.

[3] Many variations to this approach were identified in this study (see Section 4.4.2 of the main report)

Stage 3 Cost Benefit Analysis

For Stage 3, a Cost:Benefit Analysis (CBA) of beneficial use options in the West Solent was undertaken. To enable this CBA to be carried out, it was necessary to develop site-specific 'Project Examples' that would then be reviewed and compared. For this analysis, four such 'Project Examples' were derived by taking three of the high priority locations (identified in Steps 1 and 2 of Stage 2) and applying each of the four technical approaches (identified in Step 3 of Stage 2). These Project Examples are illustrated in Image NTS2 and can be summarised as follows:

- **Project Example 1**: Bottom placement at Stoney Point;
- **Project Example 2**: Moveable transfer station for thin layer placement at Boiler/Pylewell;
- **Project Example 3**: Erosion protection and recharge at Boiler/Pylewell; and
- **Project Example 4**: Large scale bund and recharge at Pennington.

To undertake the CBA of these four Projects Examples, several assumptions were made in relation to:

- The costs of the beneficial use options;
- The consequences of doing nothing (e.g. likely future rates of marsh decline and timing of new capital flood defence and harbour protection works);
- The effects of the beneficial use options in reducing rates of marsh erosion and deterioration and in deferring capital investment in flood defence and harbour protection works; and
- The monetary values of these benefits.

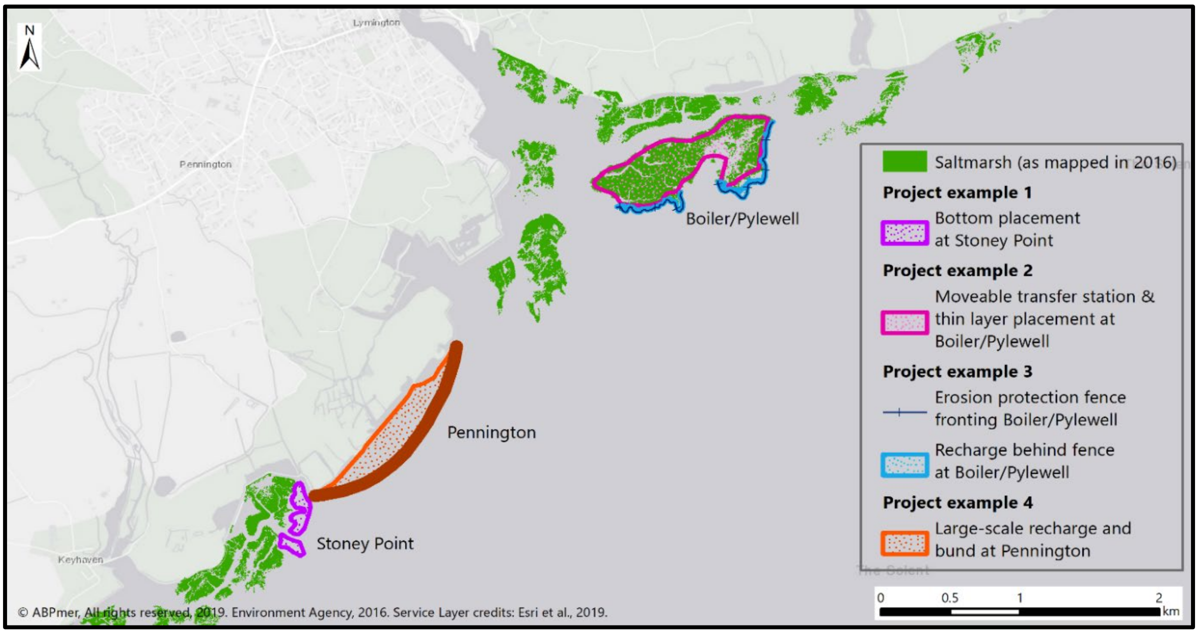

Image NTS2. Location of the cost benefit analysis case study sites

These assumptions were informed by evidence from the baseline and background reviews. In particular, the quality of evidence on historic and current rates of marsh erosion and deterioration in the West Solent is good and provides a reasonable basis for projecting future change. Similarly, emerging lessons from beneficial use schemes at Lymington and elsewhere provide evidence for evaluating the effectiveness of different interventions in reducing marsh deterioration and some useful detail (from the Lymington work especially) about project costs.

The CBA compared differences in the costs and benefits between a 'No Intervention' (business as usual) and an 'Intervention' case for each of the four project examples. The assessments were completed in line with HM Treasury Green Book guidance using a time period to 2100. For the benefits, 'bundled values'[4] were adopted to value the benefits of holding on to/creating saltmarsh and mudflat. Carbon burial and flood risk benefits were also valued. The Net Present Values of 'No Intervention' and 'Intervention' were calculated for each project example to understand the impact of each 'Intervention'.

The results are shown in Table NTS1. Based on the assumptions used, the CBAs for Project Examples 1, 2 and 3 all had benefits outweighing costs (by a Benefit:Cost ratios of around 2) when compared to 'No Intervention' or 'business as usual' options. The more costly and large-scale Project Example 4 had higher net costs compared to the 'No Intervention' option (with a Benefit:Cost ratio of 0.5).

Table NTS1. Summary of Cost Benefit Analysis

Project Example	No Intervention Net Cost £m (discounted value to 2100 at 2019 prices)	Intervention Net Cost £m (discounted value to 2100 at 2019 prices)	Benefit: Cost Ratio
Project Example 1: Bottom placement at Stoney Marsh	1.8	1.7	2.1
Project Example 2: Movable transfer station/thin layer placement at Boiler Marsh	13.5	11.5	2.4
Project Example 3: Erosion protection (and behind- fence recharge) at Boiler Marsh	14.8	11.6	1.9
Project Example 4: Large scale shingle and mud recharge at Pennington	6.4	8.8	0.5
Cells coloured green indicate net benefit to society; Cell coloured orange indicates net cost (in this case due to high projected up-front project fee)			

For Project Examples 1 to 3, the beneficial effects were mainly down to the assumption that marshes would erode less quickly, and that this would in turn lead to the costs of seawall re-construction, or the building of harbour wall extensions, being deferred to a later time. The monetary benefits of deferring such capital expenditure (by 5 to 15 years) more than offset any additional costs associated with beneficial use. For Project Examples 2 and 3, significant additional benefits were estimated to accrue from the anticipated large reduction in marsh erosion and deterioration.

For Project Example 4, the estimated capital cost of the sediment recharge was a large upfront cost, especially given that relatively conservative per-cubic metre costs of £15 were applied. Based on the assumptions used, in order for this example to provide an overall reduction in net cost, the cost of the sediment recharge would need to reduce from £15 m^{-3} down to around £8 m^{-3}. The key conclusions from the CBA work are therefore:

- Relatively low-cost interventions which defer capital expenditure on flood or harbour protection works are likely to be cost effective;
- Where interventions significantly reduce rates of erosion of existing marshes, or create new saltmarsh, this can also provide substantial benefits; and
- While there are uncertainties concerning the monetary values of some of the ecosystem service benefits associated with (West Solent) saltmarshes, these uncertainties do not appear to be material to overall decision-making which is more influenced by assumptions on the timing of capital investment and loss of sequestered carbon.

[4] The 'bundled values' are derived from previous research and amount to £1,400 ha^{-1} yr^{-1}. This generic valuation covers the multiple benefits marshes provides of improved water quality, recreation, biodiversity and aesthetic amenity.

It should be noted that the projects assessed in these CBA are examples and, while they are sensible projects in their own rights, the CBA findings are not intended to direct specific actions, but instead inform the development of a strategy for the West Solent as a whole.

Stage 4 Funding Opportunities

As a final analysis, project funding options were reviewed. This included examination of 'traditional' mechanisms such as funding by Government, Non- Governmental Organisations (NGOs) or developers, as well as more recent approaches such as crowd funding, blended finance and Net Gain related approaches. In order to facilitate the increased application of beneficial use in the West Solent, a combination of sources is likely to be required.

Recommendations for Phase 3

The recommendations for Phase 3 are summarised below by considering firstly, the background context (including the BUDS project's aspirations and funding considerations) and then, by proposing the next steps. These recommended next steps will need to be further developed and agreed with project partners and funders, as any future project inherently needs to be tailored to their requirements.

Background Context

Carrying out dredge reuse projects has always been subject to major, and often seemingly intractable, challenges. This is not just in the UK but internationally. While a lot of thinking has gone into identifying the problems and debating how they might be overcome, relatively little forward progress has been made towards resolving the issues and achieving practical solutions. The main reasons for this inertia include the absence of strategic planning/oversight and the lack of any clear societal agreement about where, and how, sediment can be beneficially used.

To address these challenges, there is a need to shift from a reactive and fragmented approach, in which each new dredging activity operates largely in isolation, towards a more proactive approach where well-defined and collaboratively-supported beneficial use solutions are strategically identified in advance. With the BUDS Project, the Solent Forum is pressing towards delivering just such a 'benefits and solutions-led' strategic approach by identifying valuable marsh restoration opportunities and developing collaborative partnerships that can support them.

Phase 2 of BUDS has concentrated on the West Solent marshes as the most obvious, though not only, location to start delivering in practice. It has shown that there is a need to advance more substantial beneficial use measures in this area at the earliest opportunity. It has also indicated that this work can achieve a net cost benefit (as was the situation for Project Examples 1 to 3 in this study) so there is a societal case for proceeding with them. However, for this to happen, a level of external funding (perhaps from several stakeholders) may be required to facilitate the project(s), as it is generally the case that those bearing the additional costs of a project (typically harbour authorities) may not be the main or only beneficiary from a project, and therefore may lack the incentive to incur additional costs.

A range of funding sources are available that could be used to fund projects in the West Solent. However, some of these sources have specific funding criteria which may be difficult for some types of beneficial use project to meet. Given that flood protection authorities are potentially a significant beneficiary from beneficial use projects, further exploration of the applicability of Flood Defence Grant-in-Aid funding is needed where projects protect existing marsh rather than create new habitat.

Larger projects like (Project Example 4) are expected to result in an overall increase in the net cost for society (unless the project's cost, including the fees for sourcing materials, can be reduced). This should however not exclude such schemes from consideration, as they may still be of interest to some stakeholders where substantial external funding can be accessed. For example, it is entirely feasible, (based on established guidance and case law) for a large project to be carried out to deliver compensatory habitat which offsets the impacts from important coastal developments. However, under existing legislation, such compensatory measures would also need to have certainty of outcome which will be a key consideration.

Recommendations

Based on this context, and the findings from the Phase 2 review, it is recommended that the next stage(s) of the BUDS project should include the following tasks, with direction from the BUDS Technical Group (which includes most of the key local stakeholders):

- **Doing more bottom placement in the first instance**. The very next step should be to adopt variants of Option 1 (bottom placement) in several locations. This should be at the earliest opportunity and will include work already envisaged by the LHC, as well as other possible initiatives (using locations identified in this study);
- **Progressing quickly to marsh edge protection and thin layer placement:** In the very near future, trial projects should be pursued to halt marsh edge erosion and improve the marsh quality and resilience by raising the bed levels. This would involve combination of the Option 2 (transfer station) and Option 3 (protective fencing) approaches. This should probably begin at the exposed Boiler/Pylewell Marsh, but then, if successful, be developed throughout the wider marsh complex over time; and
- **Ensuring that there is ongoing lesson learning and advocacy.** There will be many useful lessons that emerge out of the next stages and it will be important that these are communicated regionally, nationally and internationally. This is to inform and direct external initiatives (whether these are practical projects or regulatory developments) and also to help ensure ongoing buy-in to the BUDS programme.

In pursuing these tasks, a general aim should also be to avoid focussing on a single technique but instead apply and test **multiple techniques** across different locations (as well as combinations of techniques at specific locations) to maximise benefits. It is also recommended/expected that BUDS is progressed in an adaptive and strategic manner that allows for progressive 'scaling up' such that projects are progressed (relatively rapidly) as increasingly ambitious initiatives over time with each providing the lessons and confidence to move on to the next stage(s). Adopting this '**scaling-up over time**' approach will allow for the monitoring and communication of findings clearly across partners, funders and the local community. This will also help with building partnerships, verifying the effectiveness of the techniques used, providing reassurances they deliver with requisite certainty, where needed, and improving overall understanding about costs and benefits.

As part of the lesson learning and costs and benefits, it will be also be vital to improve understanding about the value that can be placed on these specific marshes, rather than having to rely only on generic valuations. This should include **determining the particular value that is placed on these habitats by those who live nearby and visit this site**. This value (referred to as 'non-use') was not included in the CBA for this project and could be very high given the location and history of these marshes. The process of obtaining such as a local valuation would not only help clarify the project rationale but could also help facilitate the active involvement of local people in the decision making about the valuable resource on their doorstep.

The approach taken will also need to **integrate with, and learn from, the flood defence review being conducted by the Environment Agency and NFDC**, as well as **the ongoing/extended bottom placement work that LHC are pursuing already**. A business case for developing an Option 2/3 fencing and recharge concept will need to be progressed and detailed procurement exercises undertaken, as well as funding opportunities explored.

Next Steps

To deliver these principles and recommendations, the tasks over the next few years should involve:

- **Spring 2020 to Spring 2021**: Key tasks are as follows:
    - Seek funding and in-kind supporting roles across partners, regulators and advisors;
    - Discuss further with all the relevant harbours and marinas to agree and develop a strategic plan for future recharge work. This should include clarifying the annual dredge volume contributions that they would be able to make to: Option 1 (bottom placement), and/or Option 2/3 (fencing and recharge);
    - Engage with, and actively involve, the local community, and carry out a non-use local community valuation study (perhaps in tandem with the Environment Agency and NFDC's consultation on flood defence priorities);
    - Seek permission (starting with a sampling plan) to licence more local deposit grounds for bottom placement work, including all/most Option 1 sites;
    - Carry out Option 1 extension work during the 2020/21 winter period;
    - Promote lesson learning and advocate for policy clarifications and changes (e.g. clarity of relevant issues such as compensation, mitigation, conservation management and FCERM/Outcome Measure funding) through regional, national and international forums;
    - Continue full-Solent oversight though work of the Solent Forum and maintenance of the BUDS online map;
    - Agree, among partners, the detail and the timing of an Option 2/3 approach;
    - Develop project detail and a business case/plan and then begin procurement work for an Option 2/3 approach to be done in late 2021 or early 2022;
- **Spring 2021 to Spring 2022**: Most above actions are ongoing and will need to continue. The key tasks for this year to include
    - Carry out monitoring and continue engagement work (including lessons from Option 1);
    - Apply for consents for an initial Option 2/3 approach;
    - Start the first trials of an initial Option 2/3 approach; and
- **Spring 2022 and beyond**: On an annual basis, continue all of the above and expand the scale of the work and/or the number of locations where it is carried out in response to findings.

From the consultations held during the review, there is expected to be a relatively broad consensus for the increased application of beneficial use across the parties. It is therefore hoped that this programme of work will be strongly supported.

As a final consideration it is worth again placing a high level of emphasis on the application of strategically-driven lesson learning, communication and monitoring (including possible citizen science approaches) to inform future projects. Phases 1 and 2 of the Solent Forum BUDS work have proven to be good examples of these principles, and exemplars of strategic planning. The BUDS project is demonstrating how broad regional policies for beneficial use (e.g. those set out in the MMO's South Coast Marine Plan) need to be proactively investigated at progressively more local levels in order to crystallise them into more distinct and deliverable projects that have the potential to attract investment and engender stakeholder participation.

This process needs to continue in the West Solent to engage and involve the local community and deliver projects. As part of this strategic oversight, it will also be important that completed projects provide a clear audit of the costs incurred as this will greatly help to inform planning of local recharge projects as well as other proposals for the rest of the Solent and other parts of the UK.

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1 Introduction

1.1 Project background

This report reviews the work undertaken for Phase 2 of the Solent Forum's 'Beneficial Use of Dredge Sediment in the Solent' (BUDS) project. This second phase of the BUDS project involved investigating the feasibility, and value, of conducting a major new beneficial use project (or multiple projects) on the West Solent saltmarshes along the Hurst Spit to Lymington frontage (see Image 1).

The Solent Forum started the BUDS project in 2017 following requests from its members who were keen to see more of the region's dredged sediment used to restore and protect its deteriorating intertidal habitats. As clarified during the first phase of the BUDS work, in total, over 1 million m^3 of fine sediment is typically excavated through maintenance dredging in the Solent each year (ABPmer, 2018). However, no more than around 0.02% of this (at the very most) is used beneficially to help protect and restore saltmarshes and mudflats within the Solent. This is despite the fact that the Solent's marshes have been progressively deteriorating and eroding over several decades. Therefore, there has been an ongoing loss of the important ecological and socio-economic functions that these habitats provide.

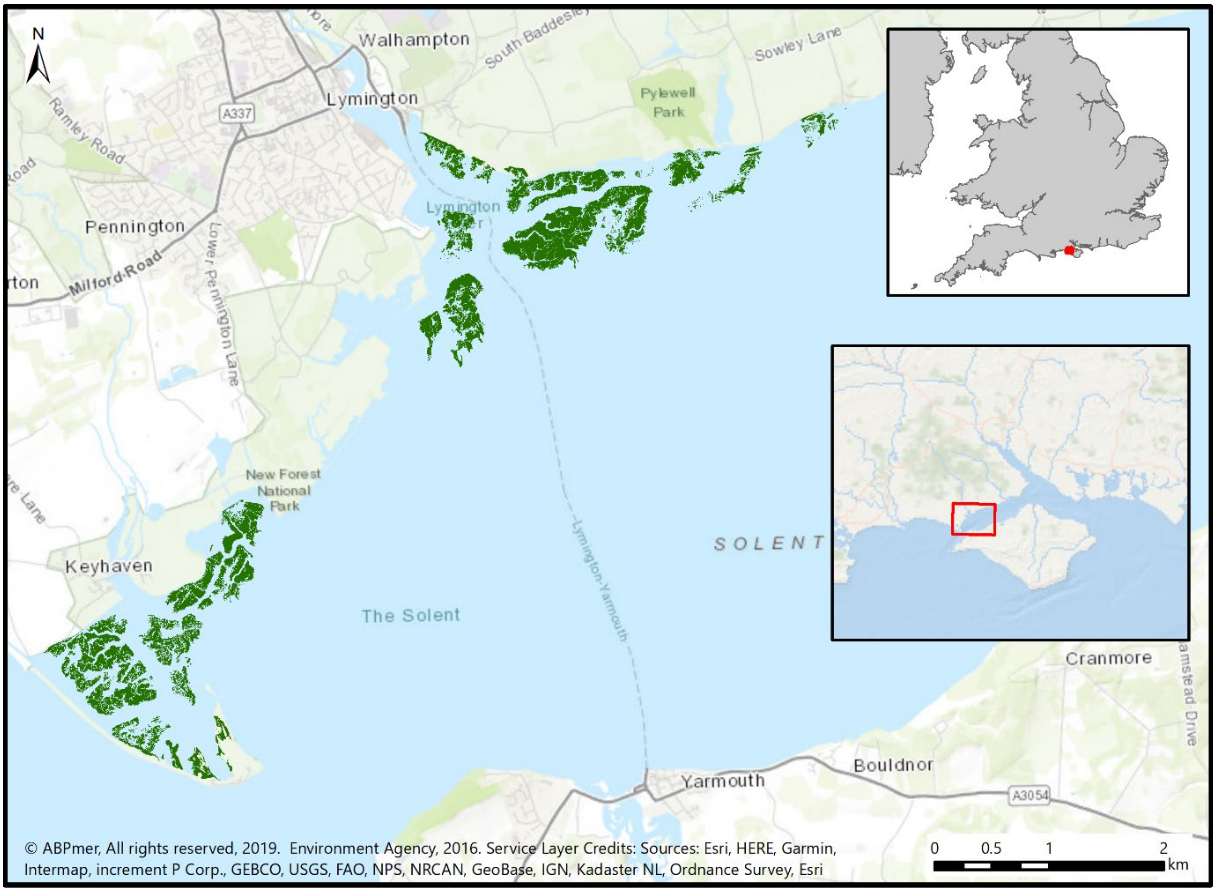


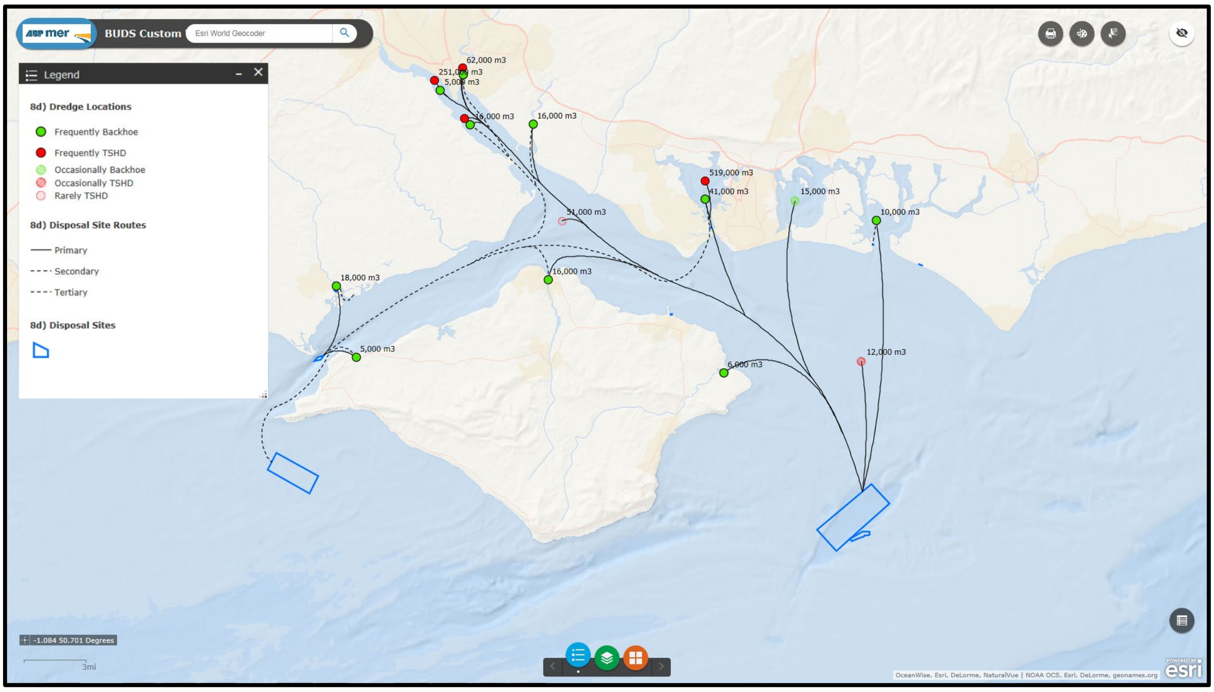
Image 1. Location of the West Solent marshes

The BUDS project is being overseen by a Technical Group that includes representatives from the Solent Forum; Natural England (NE); the Environment Agency; Lymington Technical Services; River Hamble Harbour Authority (RHHA); New Forest Distinct Council (NFDC); and Associated British Ports (ABP). Phase 1 of the BUDS project (undertaken in 2017 and 2018) involved a high-level review of the Solent region to identify sites that would gain most from a beneficial use campaign. These were sites where dredge arisings (silts mainly) could be used to 'recharge' deteriorating habitats and achieve a range of environmental, social and economic objectives (especially increased coastal flood protection). Alongside this strategic review, a key aim of this initial stage was to begin developing collaborative partnerships with those willing to support one or more recharge initiatives, especially at a scale which will have material benefits.

Phase 1 was completed in March 2018, and the following three key deliverables were produced:

- **A stand-alone cost benefit analysis** to better understand the socio-economic rationale for beneficial use projects and to help select potential sites (ABPmer, 2017);
- **An online mapping product** to aid coastal management decision making and the selection of beneficial use sites in the Solent; and
- **The final report,** with key recommendations (ABPmer, 2018)

These Phase 1 products and all other outputs from the BUDS project can be found on the Solent Forum website[5] and the BUDS mapping tool can be found at this link[6]. Image 2 shows a schematic representation of dredging activities in the Solent (one of the layers in the mapping tool).



Source: BUDS Webapp; Cefas and ABPmer data-layers

Image 2. Dredging and disposal activities in the Solent (Layer 8d of BUDS Map)

The Phase 1 strategic review verified that there are societal benefits from carrying out beneficial use work, especially in coastal areas that are vulnerable to tidal flooding either now or in the future. It was recommended, therefore, that the next project phase should involve actively progressing one or more project(s) while also working with regulatory bodies to help develop guidance and provide oversight. It was envisaged that this oversight would then help identify larger-scale projects which partnerships could support and smaller-scale schemes that individual operators and harbour authorities would like to progress.

5 http://www.solentforum.org/services/Current_Projects/buds/
6 https://abpmer.maps.arcgis.com/apps/webappviewer/index.html?id=84f75915f4d64d3f84d82e7b8923e9ba

The Phase 1 review also concluded that a 'stand out' candidate site for recharge work was in the West Solent along the Hurst Spit, Keyhaven, and Lymington frontages. In this area, the marshes are rapidly eroding and they play a key role in coastal and harbour protection as well as being of high conservation value. Therefore, a recharge project pursued along this frontage could achieve substantial and multiple benefits.

The Phase 1 work also demonstrated that there is a great deal of willingness across a wide range of stakeholders for such projects to be realised. It is noteworthy that there were also recommendations to explore two other possible beneficial use sites in the eastern Solent as part of the Phase 1 work. However, the West Solent was seen as a primary location, and an excellent 'proving ground' for a major recharge initiative for several reasons that are reviewed further in Section 3.

Further details about the aims of this Phase 2 study, and the structure and content of this report are set out in Sections 1.2 and 1.3 respectively.

1.2 Project objectives

Phase 2 of the BUDS work was carried out in 2019. It involved taking forward the following key recommendations from the Phase 1 work:

- Investigate the 'real world' feasibility of conducting major beneficial use project(s) on the West Solent marshes along the Hurst Spit to Lymington frontages (see Image 1);
- Work with regulatory bodies and key stakeholders to build partnerships, develop regional guidance, and identify responsibilities and funding mechanisms to assist with future beneficial use initiatives; and
- Maintain and populate the online BUDS map so that it can remain a useful resource for ongoing decision making.

Key objectives for this phase were to:

- Clarify how and where dredge sediments can be beneficially placed on the West Solent marshes,
- Understand the costs and benefits of such an initiative on a more site-specific basis; and
- Recommend how practical projects can be pursued in BUDS Phase 3 and further define the roles that different stakeholders might play in future initiatives.

The results obtained from this Phase 2 review are designed not only to determine how and whether a project might go ahead in the West Solent, but also to provide information that helps guide other projects in the Solent region and, it is hoped, more widely in the UK and internationally.

This second phase was funded by a grant from the Environment Agency and it is valuable that this has been done in a relatively short space of time following the completion of the Phase 1. This is because preserving the momentum that the Solent Forum has built up with a large number of stakeholders during the first stage is likely to be important for the BUDS project in general and also for any practical project to be realised in the future. Past initiatives in this field have faltered, in the Solent and elsewhere, where momentum was not maintained and this has meant that the practicalities, costs and benefits associated with possible initiatives are often not explored.

1.3 Report structure

This Phase 2 BUDS report is structured as follows:

- **Introduction** (Section 1): Summary of the project background and the aims of Phase 2;
- **Methods** (Section 2): Details of the approach taken for this project;
- **Baseline Conditions and Background Review** (Section 3): Review of existing conditions on the West Solent marshes and other pertinent background information (including wider marsh benefits, dredged sediment sources and marine licensing expectations);
- **Technical Options Review** (Section 4): Consideration of the technical options/approaches for carrying out beneficial use work;
- **Cost and Benefit Analysis** (Section 5): Review of the costs and benefits associated with carrying out different techniques (four very different 'project example' scenarios tested);
- **Funding Options** (Section 6): Review of potential funding sources for beneficial use projects; and
- **Conclusions and Next Steps** (Section 7): An overview of the findings with recommendations for task to be carried out in BUDS Phase 3

The report also includes the following appendices:

- **Appendix A - Marsh change analysis using Light Detection and Ranging (LiDAR) data**: Analyses of Environment Agency LiDAR data from 2007 to 2018, showing intertidal elevation changes over time along 24 transects across the Lymington to Hurst frontage;
- **Appendix B - Review of beneficial use projects**: An updated overview of the general issues and latest initiatives associated with using sediments beneficially to restore saltmarsh habitats. The Phase 1 BUDS report (ABPmer, 2018) included a more detailed analysis of this subject and therefore this appendix focuses only on recent developments and relevant new case examples; and
- **Appendix C – Review of beneficial use project costs**: An updated tabular review of the costs associated with using sediments beneficially to restore saltmarsh habitats. A previous review was carried out by ABPmer in 2017, which underpinned Phase 1 of BUDS and this appendix adds recent developments and relevant new case example information.

2 Methods

2.1 Introduction

To progress the BUDS Phase 2 study, a number of different tasks were carried out, including survey work, data/literature exercises and consultations with specialists. These tasks were essentially progressed as a four-stage sequence as follows:

- First, the baseline and background conditions across the West Solent marshes were described in terms of historic and ongoing changes in marsh extent and condition, the benefits provided by marshes and issues around marine licensing of beneficial use projects.
- Second, informed by the 'baseline review', possible locations and approaches for a recharge campaign (or campaigns) across the area were identified and assessed and a final selection made of four possible recharge strategies.
- Third, following the options selection process, a cost benefit analysis was carried out for four example projects which applied the options at specific locations.
- Fourthly, possible funding opportunities were reviewed.

Based on the findings of the review, specific recommendations have been made for Phase 3 of the BUDS project. Summaries of the work undertaken for each of these stages are presented in Sections 2.2 to 2.4 and details about the key meetings and consultations that were held to inform this work are included in Section 2.6.

2.2 Stage 1 Baseline conditions and background review

To provide an initial technical and contextual foundation for this review, a high-level analysis was carried out of the existing environmental conditions on the West Solent marshes along the Hurst Spit to Lymington frontage. This was done to understand the value of the habitats and to indicate where and why recharge work could most usefully be carried out, before then considering how that might be achieved. Furthermore, other pertinent background information was reviewed to inform later analysis.

For this 'baseline conditions and background review, which is presented in Section 3, existing survey data and recent studies were examined to describe aspects such as:

- The quantitative decline of the marshes (i.e. the **rates of physical erosion**);
- The **qualitative condition** of the marshes and main areas of poor quality due to die back (as indicated particularly by the plant coverage); and
- The breeding and overwintering **bird populations** of these marshes;
- The **main areas of dredging in the West Solent and nearby**;
- The **status of the coastal defences** along the West Solent frontage;
- The **ecosystem services** and wider socio-economic **benefits** provided by saltmarshes in general, and those of the West Solent in particular; and
- Issues around **marine licensing** of beneficial use projects.

To further support this baseline review, a bespoke five-day unmanned aerial vehicle (UAV) survey was undertaken to help review the existing status, and health, of the marshes. This was carried out during the week commencing 11 February 2019 and involved collecting a comprehensive, contemporaneous and high-resolution photographic record of the marsh plant coverage in the area under review. It encompassed all of the West Solent marshes, stretching from those in the lee of Hurst Spit to Pitt's Deep Lane (see Image 3).

Initially, it was considered that some brief *in situ* field surveys of the site would also be helpful for describing the baseline environment. However, this was subsequently deemed to be unnecessary at this stage because the aerial imagery provided by the UAV survey was of such a high resolution. It was also thought that such visits might, at the time of year when this work was principally being carried out, cause unnecessary disturbance to overwintering or breeding birds.

The data obtained during the Phase 2 baseline review was also collated and presented in the BUDS mapping product that was developed during Phase 1 (see the link in Footnote 6 on Page 2) and sent to the Channel Coastal Observatory (CCO). The findings from this review are presented in Section 3.

Image 3. Aerial imagery of North-West Solent marshes from the February 2019 UAV survey

2.3 Stage 2 Technical options review

As a second stage in the process, the outcomes of the baseline conditions and background review and the UAV imagery were used to identify possible beneficial use opportunities across the area, as well as suitable sediment recharge methodologies (see Section 4). To start this process, an initial set of 15 potential recharge 'cells' was selected at which a sediment recharge project could theoretically be carried out and could potentially achieve societal benefit by:

- Delaying the rate of marsh deterioration and extending their 'lifespan';
- Improving the ecological quality of marsh habitat (including its value for breeding and roosting birds); and/or
- Raising the existing marsh or mudflat levels to enhance their functionality for wave and storm energy absorption and help reduce the pressure on existing flood defences and mooring sites.

These potential recharge cells were selected, objectively, based on factors such as habitat type, shoreline topography and location. To then select a short-list of preferred options from these 15 cells, the practicalities and potential difficulties associated with undertaking recharge at these locations. During this process, consideration was given to technical issues associated with delivering sediment to, and retaining sediment at, these deposition sites. This included consideration of aspects such as:

- The degree to which receiving areas would be accessible by different dredging and sediment handling vessels;
- The nature of the sediment delivery process;
- How best to discharge pumped sediment into the receiving environment to enhance sediment retention;
- How many, and what type, of structures would be required to retain sediment in the deposition areas and/or to protect the eroding edges of existing marsh habitats; and
- The expected sediment settlement patterns and the need for further intervention (e.g. creek/pool excavations).

Through this process, four main recharge approaches/options and a short-list of priority locations were identified. The findings from this review are presented in Section 4.3.

2.4 Stage 3 Cost and benefits analysis

Based on the findings from Stages 1 and 2, a CBA of beneficial use options in the West Solent was undertaken for Stage 3. To enable this CBA to be carried out, it was necessary to develop site-specific 'Project Examples' that would then be reviewed and compared. Four such projects examples were defined.

To inform the CBA, information was collated on the costs and benefits of recharge projects. This part of the review process was important because, as noted during BUDS Phase 1, there is currently a poor understanding about the costs and benefits of recharge projects. In large part this is because costs can be extremely variable, depending on the scale of the work, the approach taken, the equipment that is needed and whether that equipment is readily available. The costs just for mobilising dredging vessels can be highly variable for example depending upon the type of vessel needed, its location, and whether, or when, it can be made available.

There is also a high degree of variability in the benefits that can arise and still a lack of consensus on the quantification and valuation of such benefits. In addition to this variability, there is also a lack of communication about the costs incurred from existing and past practices (in part because of commercial sensitiveness) which can make it difficult to have clarity on the costs of future work. It is important, therefore, to continue gradually improving our understanding of, and communication about, the cost and benefit issues in order to inform future initiatives and to better understand their viability. This will also be important for informing and involving a range of potentially interested stakeholders and even possible funders in the future.

For each of the four project examples identified, the Stage 3 CBA compared the costs and benefits of doing nothing ('No Intervention') with the costs and benefits of implementing the 'Intervention'. The CBA focused on quantifying those costs and benefits that would be different between 'No Intervention' and 'Intervention'. The assessments were conducted for the period 2019 to 2100, recognising that many of the benefits of the interventions will be long term. The analysis was consistent with HM Treasury Green Book methodology (HM Treasury, 2018).

The results of the CBA are presented in Section 5. Information on potential funding sources is presented in Section 6. The findings of the work have then been summarised and recommendations made for progressing to Phase 3 of the Solent Forum BUDS project. The conclusions are presented in Section 7.

2.5 Stage 4 Review of funding opportunities

As a fourth stage of this project, possible funding opportunities were reviewed, with a particular emphasis on partnership working. This review drew on both existing literature and stakeholder consultation.

2.6 Meetings and consultations

Throughout the Phase 2 review project, regular consultations and meetings were held with several stakeholders and dredging specialists. These consultations were a key part of this project because it was particularly important to secure the views of specialists, regulators and advisors to agree the issues and benefits as well as to obtain information about the practicalities and potential costs of recharge options. These contributions were also important for capturing lessons from new and ongoing research, as well as commercial advice that is not available in published documents or even grey literature.

The main technical meetings and workshops that were held during this project were as follows:

- **BUDS Technical Group meeting and workshop (12 February 2019)**. This meeting was a 'technical start-up' for this project and included an initial workshop-style review of options. The main aim was to identify the actions that needed to be progressed. For this first meeting, the group was joined by Boskalis who presented on their experience of 'Building with Nature' projects in the Netherlands (including at sites such as Marker Wadden (Boskalis, 2019; Central Dredging Association (CEDA), 2019a);
- **Lymington Harbour Commission (LHC) Meeting (12 March 2019**). Following the Technical Group meeting and the ideas that emerged, a separate meeting was held specifically with the Harbour Master at LHC. This served to review some of the practical issues and licensing detail associated with the ongoing and potential projects in the Lymington approaches and surrounding areas;
- **Boskalis Team Meeting (19 March 2019**). To review the feasibility of undertaking larger-scale initiative(s) in this area, a meeting was held with a team of specialists from Boskalis. This was undertaken to review the practical issues associated with different recharge strategies and to discuss the key challenges as well as review the cost implications. Boskalis has experience of conducting large intertidal shingle and silt recharge projects for nature conservation and flood protection in the UK and Netherlands, including at sites such as Horsey Island, Allfleet's Marsh, Trimley, Shotley and the Marker Wadden;
- **Benefits Review Meeting (26 March 2019**). To review the issues and benefits associated with possible projects, a separate meeting was held between a range of parties responsible for nature conservation and flood protection along the Hurst to Lymington shoreline. This included NE, the Environment Agency, Hampshire and Isle of Wight Wildlife Trust (HIWWT), NFDC, New Forest National Park Authority, and the Royal Society for the Protection of Birds (RSPB);
- **Land and Water Ltd teleconference (8 April 2019**). To review the feasibility of undertaking smaller-scale initiative(s), a meeting was held with Land and Water Ltd who provided advice under their established 'not-for-profit' advice centre which has been set up to stimulate greater research. They provided specialist advice regarding the practicalities and costs of undertaking small or medium sized projects in the area (informed by their past work on this site for Wightlink Ltd (Land and Water, undated);

- **Royal Smals Meeting (25 April 2019**). ABPmer also met with Royal Smals who provided further in-kind advice regarding the techniques and costs for small-scale projects. Royal Smals have experience at sites such as Brightlingsea in Essex and are very familiar with the equipment requirements and other practical issues associated with using fine sediment to recharge saltmarshes;
- **Marine Management Organisation (MMO) and Cefas Meeting (26 April 2019)**. To scope the consents requirements for a Phase 3 project (or projects), a meeting was held with the MMO and Cefas. These advance discussions focused on the anticipated marine licensing process and associated information requirements, as well as other details (such as the need to register site(s) identified from this review as disposal grounds for future use); and
- **Environment Agency and NFDC Site Visit (6 August 2019)**. To further discuss issues and benefits associated with sediment reuse programmes, ABPmer joined the Environment Agency and NFDC on a site visit to Keyhaven and Hurst; for a high-level review of coastal management issues and the role that the BUDS work might play in that context.

This BUDS project was also discussed at two meetings of the newly formed beneficial use working group (BUWG) in November 2018 and July 2019. This BUWG was set up during the RSPB's 'SEA Change in the Beneficial Use of Dredged Sediment' (SEABUDS) project, the report from which was issued last year (RSPB, 2018). This study identified the need for a specialists group to provide guidance for future beneficial use projects. This group now meets on a rolling six-monthly basis to keep these topics 'live' and to review emerging projects and progress key actions.

All the above-listed meetings, and other consultations, have helped to underpin this Phase 2 project.

3 Stage 1 Baseline Review

3.1 Introduction

This section reviews the baseline conditions of the West Solent marshes with reference to relevant literature, previous key research studies, and analyses of available remote sensing survey data. Based on the information collated and analysed, the condition of the marshes and, especially, the rate at which they are declining is reviewed in Section 3.2. Details about the distribution of bird populations across the area are then described in Section 3.3.

In addition to these environmental baseline reviews, further background information has been reviewed to inform BUDS Phase 2. This includes an updated review of the dredging activities in the West Solent, and its close vicinity (up to the River Hamble) (Section 3.4), as well as a brief investigation of the coastal defence status of the study area (Section 3.5). A review of the benefits which marshes in general, and those in the West Solent, in particular, can provide is included as Section 3.6. Lastly, a brief overview of the key consenting issues has also been included in Section 3.7, based on early consultations that have been held with the MMO and Cefas to discuss BUDS and other local beneficial use initiatives.

3.2 Marsh condition

For this review, an updated analysis of marsh condition was undertaken, utilising the following data:

- Historic marsh vegetation extent data-layers (provided to by the CCO);
- More recent (2008 and 2016) marsh extent data-layers produced by the Environment Agency and NE for a joint review of marsh condition across the Solent;
- Environment Agency LiDAR data from 2007 to 2018; and
- The February 2019 UAV survey outputs.

A brief literature review of previous work was also undertaken; this is first presented in Section 3.2.1. An updated review of marsh erosion, based on comprehensive analysis of LiDAR data, is then presented in Section 3.2.2, before an updated vegetation/plant coverage review is given in Section 3.2.3. Section 3.2.4 discusses factors driving saltmarsh loss at the West Solent Marshes, based on the analysis of the previous sections, but also drawing on previous work.

3.2.1 Declining marsh extents – brief review of previous work

The intertidal habitats of the West Solent have been subject to progressive change for well over a century. Prior to the late 19th Century, the area was made up of gently sloping shallow mudflat habitat. This was then colonised by *Spartina anglica,* and saltmarshes consequently developed rapidly from the late 1800s to early the 1900s. From the 1920s onwards, however, saltmarshes in this area have been progressively declining (Tubbs, 1999; Chatters, 2017).

Today, there are a number of discrete marsh 'islands' along the shoreline between Hurst Spit and Sowley. The main marsh complexes, in part based on the names assigned to them for the purposes of the Hampshire County Council (HCC) bird monitoring work, are illustrated in Image 4. Each of these marsh areas have slightly different physical characteristics and are subject to different rates and patterns of physical and ecological decline, depending upon their situation, elevation and degree of wave exposure.

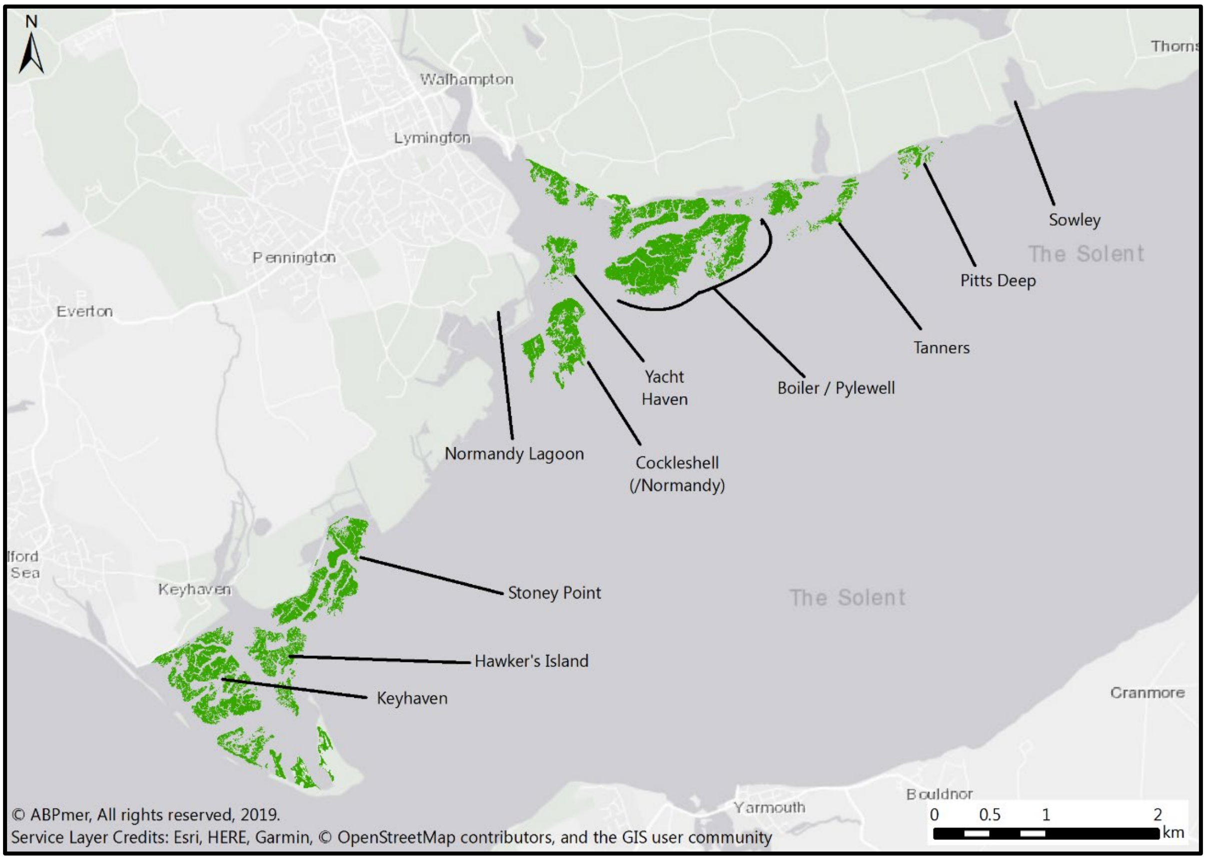


Image 4. Main marsh features along the Hurst to Sowley frontage

Detailed analyses of the rate and pattern of marsh decline in this area up until the early part of this century were made by the NFDC Coastal Group (NFDC 2007a; 2007b) and in the Solent Dynamic Coast Project (SDCP) (Cope *et al.*, 2008). The coastal group used aerial photographs taken after the 1940s to show that the typical rates of marsh edge retreat was in the order of 2 to 5 m year^{-1} on the outer exposed face of these marshes. They also identified some exposed locations that were eroding at faster rates of 8 to 11 m year^{-1}. Away from the exposed outer marsh edges, including the approach channels at Lymington and Keyhaven, as well as much of the marsh directly behind Hurst Spit, the retreat rates were shown to be generally lower; anywhere between 0.2 m year^{-1} and 1 m year^{-1}, depending upon the location.

The NFDC study also illustrated how erosion rates were generally highest to the east and away from the influence of Hurst Spit, which shelters the coast from prevailing south-westerly and southerly winds and waves. The retreat rates were considered to be consistent over time and were not thought to be accelerating. On the basis of this ongoing retreat, it was predicted that the effectiveness of the marshes as natural flood defences would be limited by 2030, and that they were likely to disappear altogether by about 2050.

The work done for the SDCP in 2008 took this analysis forward. For this study, both LiDAR data and aerial imagery were reviewed to map the physical and ecological changes to the marsh and also project the future timelines for their ongoing decline. Based on this SDCP work, the following was determined for three 'regions' of these marshes:

- **Hurst Spit**: For this complex, data from 1971, 1984 and 2001 was analysed by SDCP. Between 1971 and 2001, the marshes had reduced in extent from 62 ha to 40 ha, with the highest rates of loss observed between 1984 and 2001, at 1.8% per annum;

- **Keyhaven**: Again, data from 1971, 1984 and 2001 was analysed for these marshes. Having measured 86 ha in 1971, 30 years on, they had been halved in extent to 43 ha, with the highest rates of loss occurring in the period between 1971 and 1984, at 2.2% per annum; and
- **Lymington**: for this saltmarsh complex, data from 1946 and 1954 was also available in addition to the data sets analysed for the Hurst Spit and Keyhaven marshes. In 1946, the marshes measured 266 ha, and in 2001 only 111 ha remained. Between 1946 and 2001, an average annual loss rate of 1.1% was calculated, and the highest rate of loss was again observed in the period between 1984 and 2001, at 1.9%.

3.2.2 Updated marsh erosion review – LiDAR data analysis

In order to assess the scale and rates of the marsh change between the Hurst to Pitts Deep marshes, 2007 to 2018 LiDAR data was used to:

- Examine 24 cross-shore transects across the different marsh complexes to illustrate the erosional changes to the exposed outer edges of the marshes, as well as any vertical bed-elevation changes inside the marshes;
- Create vertical elevation 'difference plots' which highlight distinct spatial trends across the marshes and higher mudflat areas; and
- Calculate the overall changes in sediment volume across the higher intertidal areas (above the level of MHWN) over recent years.

The locations of the 24 cross-shore transects and the overall extent of lateral marsh retreat between 2007 and 2018 are shown in Figure 1. The shoreline profiles along each transect are presented in Appendix A as Figure A1 to Figure A17. The difference plots between the 2007 and 2017 LiDAR datasets are shown in Figure 2 to Figure 4. The volumetric changes are summarised in Table 1, to gain insights into how much sediment is added/lost from the system on an annual basis.

Considerations for LiDAR data analysis

When examining these results (in following sub-sections), it is important to emphasise the distinction between mapping physical erosion and decreasing vegetated marsh extent. For both, there is a need to take account of the influence of survey accuracy and the role this plays in making judgements about change over time. For example, the following important limitations to LiDAR data should be noted:

- LiDAR data has a stated vertical accuracy of around ± 0.15 m. Thus, where LiDAR analyses are presented, any changes within this range are removed from the resulting outputs. This means that the magnitude of physical erosion of the marsh edges is often relatively accurately described, given their generally steeper and more exposed nature. Away from the marsh edges profiles are shallower, there can be more 'noise' in the between-year comparative analyses such that the inter-annual changes can be less definitive.;
- Water in creeks and reflecting off mudflat can result in erroneous levels (depending on the state of the tide when the data was flown). For example, the 2018 dataset was not flown at the lowest state of the tide, and was hence not used for the difference plot, as otherwise changes on the mid to low mudflat levels would not have been apparent;
- Filtering LiDAR data can leave a numeric "pattern" in data and lower some areas inconsistently across different years. Unfiltered data was used for the analysis in this report[7];
- Shadow zones in different LiDAR flights can show as significant changes in elevation that are not real and areas of the flight path that are not directly below the aircraft can show a slight increase in elevation, which can appear as a "swath" in difference plots. To account for this, and

[7] This was amongst others due the unavailability of filtered LiDAR data for the study area between 2014 and 2018

aspects which could cause erroneous differences in elevation, the different LiDAR years used for the analysis were compared against an Ordnance Survey ground control point and/or hard surface areas present across the data-layers (and corrected where appropriate).

LiDAR cross-shore transects

Figure 1, together with the transects presented in Appendix A, illustrate the eroding nature of the study area's intertidal shoreline. Rates of retreat and erosion are particularly rapid along the more exposed sections of the Lymington to Pitts Deep frontage, and less pronounced in the more sheltered locations both behind Hurst Spit and behind major saltmarsh islands such as Boiler/Pylewell.

Based on analysis of the relevant transects that are aligned through saltmarshes, over the 11 years which were analysed, the highest rates of retreat have been at the Pylewell and Tanners marsh complexes, at 3.4 m and 3.7 m per year respectively (Transects I and D). The more protected marshes in the lee of Hurst Spit have seen lower rates of outer saltmarsh retreat of between 0.6 m and 1.1 m per year (Transects S, U and W).

The transects shown in Appendix A do not clearly indicate that the saltmarshes or the upper mudflats are vertically accreting. This may well be a reflection of survey accuracy; if these marshes are accreting at around a few millimetres per year (as identified by Ke and Collins, 1993), then this would not necessarily be recorded using LiDAR data. It is likely that the marshes are accreting, but not at a rate which would enable them to keep pace with ongoing relative sea level rise[8], as evidenced by the 2018 line generally being below that of previous years. It may well be that the marshes are also settling and compacting, which would counter any effects of accretion. However, changes from such processes, if they are happening, are not generally of a scale that can be recorded with LiDAR data

The cross-shore transects also illustrate quite clearly that these marshes occupy a slightly narrower tidal niche (also referred to as 'window of opportunity' (Hu *et al.*, 2015)) than one would typically associate with saltmarshes. Saltmarshes are typically expected to develop at the following tidal elevations (e.g. Nottage and Robertson, 2005):

- Low to mid saltmarsh between MHWN and MHWS (at 0.62 m Ordnance Datum (OD) and 1.12 mOD respectively at Lymington); and
- Upper saltmarsh between MHWS and Highest Astronomical Tide (HAT) (locally at 1.32 mOD) at Lymington.

However, within the study area, the saltmarshes typically occupy elevations between around 0.8 mOD and 1.2 mOD, so the saltmarshes occur at a higher elevation than might be expected. As a result, vegetated areas are mainly found at, or around the MHWS mark, and do not generally extend down to MHWN. As MHWN is at 0.62 mODN, the saltmarshes thus occur up to 0.2 m higher than might be expected. This is likely to be due to their exposed location and longer inundation duration due to local tidal patterns (in particular the prolonged double high tides (e.g. NFDC, 2010)).

It should also be noted that tidal elevations differ along the Hurst to Pitt's Deep saltmarsh frontage, with tidal range increasing by around half a metre between the two points (see Appendix A for more detail). This difference was also highlighted by Ke and Collins (1993), who noted that the level of Mean High Water increased 'from 2.2 m to 2.7 m [Chart Datum (CD)] to 2.6 to 3.0 m [CD]' between Keyhaven and Lymington.

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8 During the period 1980 to 2011 relative sea level has risen at a rate of 3.1 ± 0.7 mm year^{-1} at Southampton (Wahl *et al.*, 2013). This rate has been derived from analysis of tide gauge records and corresponds to a total sea-level rise of between approximately 0.08 and 0.1 m during this time.

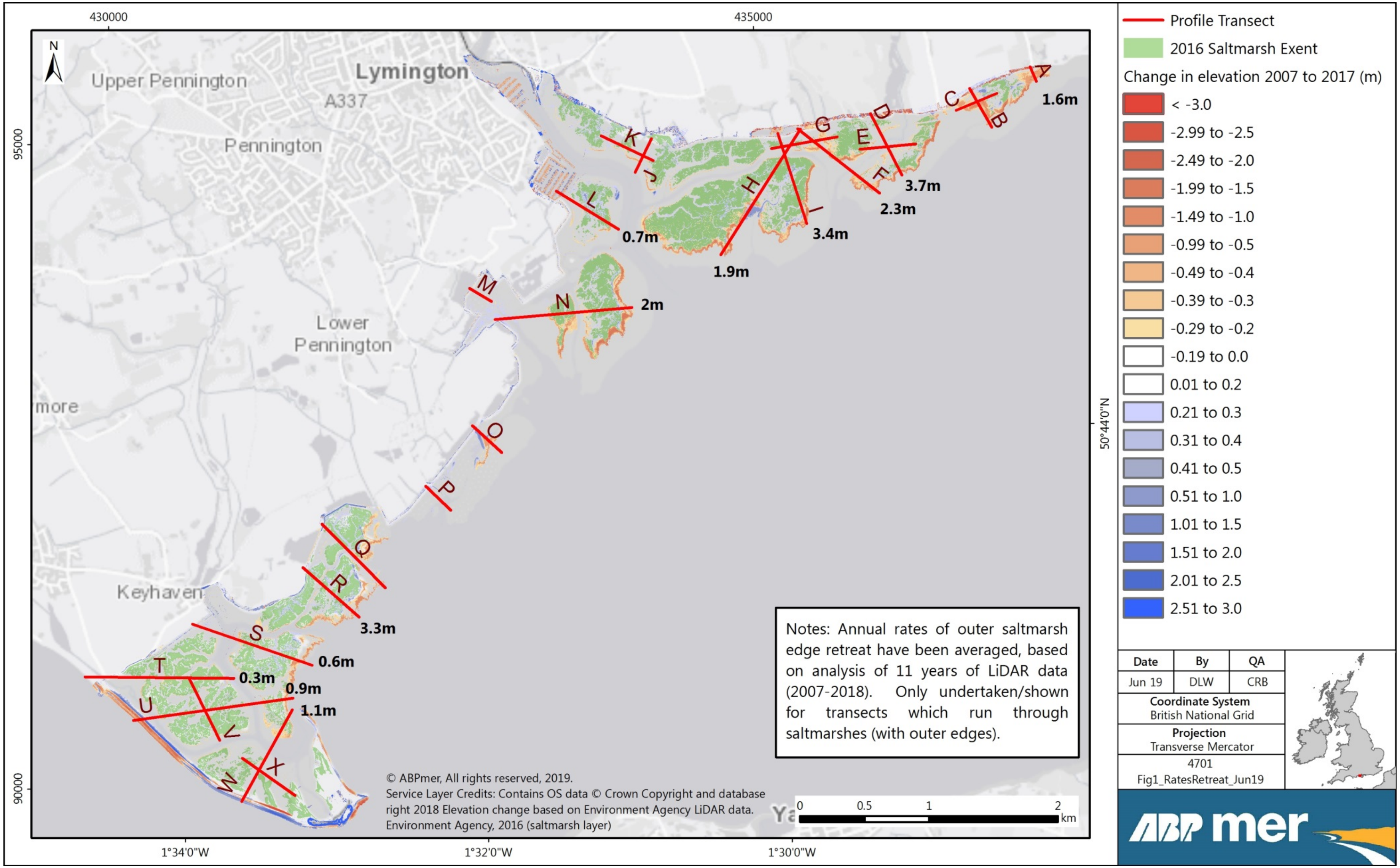


Figure 1. Average annual rates of lateral retreat for outer saltmarsh edges at saltmarsh transect locations (period from 2007 to 2017)

Along the study area frontage, there are very few marshes which reach up to the level of HAT; in fact, there are now not many locations where the elevations are between MHWS and HAT. Instead, upper saltmarsh zones appear to have all but disappeared (noting that this has not been verified with on-the ground vegetation surveys analysing plant communities). In the lee of Hurst Spit, it is apparent that the saltmarshes are lower lying and, while they are subject to less physical erosion than the more exposed Lymington marshes, they are slowly being 'drowned out'. These marshes are likely to disappear soon given their maximum elevation does not tend to reach the level of MHWS at all and is getting perilously close to the level of MHWN in many locations (see transects S to X in Appendix A).

LiDAR difference plots

Difference plots which further describe the bed elevation changes from 2007 and 2017 are shown in Figure 2 to Figure 4. These illustrate spatial trends across the marshes and higher mudflat areas. As noted above, due to the vertical accuracy of LiDAR data, changes to the intertidal areas within the ±0.15 m range were removed from the analysis (i.e. not coloured in). Furthermore, the 2017 dataset rather than the available 2018 dataset was used because the latter was flown when much of the mudflat area was covered by seawater. The 2017 dataset is therefore better for describing upper mudflat changes.

These difference plots show varying levels of vertical erosion in the study area. In summary, they reinforce the results of the transect analysis and past studies by showing how the exposed outer intertidal areas are subject to substantial erosion. Any detectable internal accretion is largely observed along the creeks (rather than saltmarsh surfaces).

The more sheltered intertidal areas show fairly limited change (whether erosional or accretional). This includes, for example, the big marsh complex behind Hurst Spit (in Figure 2), or the Lisle Court marshes that are sheltered by the Boiler/Pylewell marsh island (in Figure 3). The highest rates of erosion are noted along the outer edges in the section from Cockleshell to Pitt's Deep (see Figure 4), where elevations have been lowered by between 1 to 2 m along the majority of the outer edges of these intertidal areas over the 10 years studied (between 2007 and 2017). In the Keyhaven/Hurst section (Figure 2), the outer edges of the Hawker's Island and Stoney Point intertidal complexes experienced slightly lower rates of lowering, between 0.5 m and 1.5 m over 10 years. Where the largest outer edge erosion occurred, higher rates of internal accretion are also evident in the figures. This supports the hypothesis that much of the internal accretion occurs due to materials being derived from marsh erosion, i.e. not from external sources.

Those areas where recharge has taken place are also evident in the difference plots and have been highlighted in Figure 4. Further detail on these recharge projects is provided in Appendix B, Table B1; these all occurred over the past seven years, from 2012 onwards. With the exception of the RSPB's chenier recharge (which was eroded away relatively quickly and is not immediately evident in the difference plots), all other recharge areas are seen as clear areas of 'accretion' in the figure.

Relatively subtle benefits of the recharge schemes could be indicated in the adjacent marsh systems. Notably there appear to be slightly increased incidences of accretion in the creeks, and slightly reduced rates of erosion. At the Boiler/Pylewell mud recharge (by the Lymington Harbour Commissioners (LHC)), for example, slightly reduced rates of erosion when compared to the adjacent intertidal edges are seen in Figure 4, though between 0.5 to 1 m of erosion still occurred between 2007 and 2017. It should be noted however that the recharge campaign was only initiated in 2013 (see Table C1), halfway through the study period, so much of the erosion shown is likely to have occurred prior to the LHC starting to recharge). Ultimately, given the margins of error associated with LiDAR data, benefits to the land-side areas from localised erosion reduction and/or improved bed accretion are not yet conclusively apparent; these are anticipated to become clearer (i.e. be better detectable by LiDAR survey techniques) over a longer time frame.

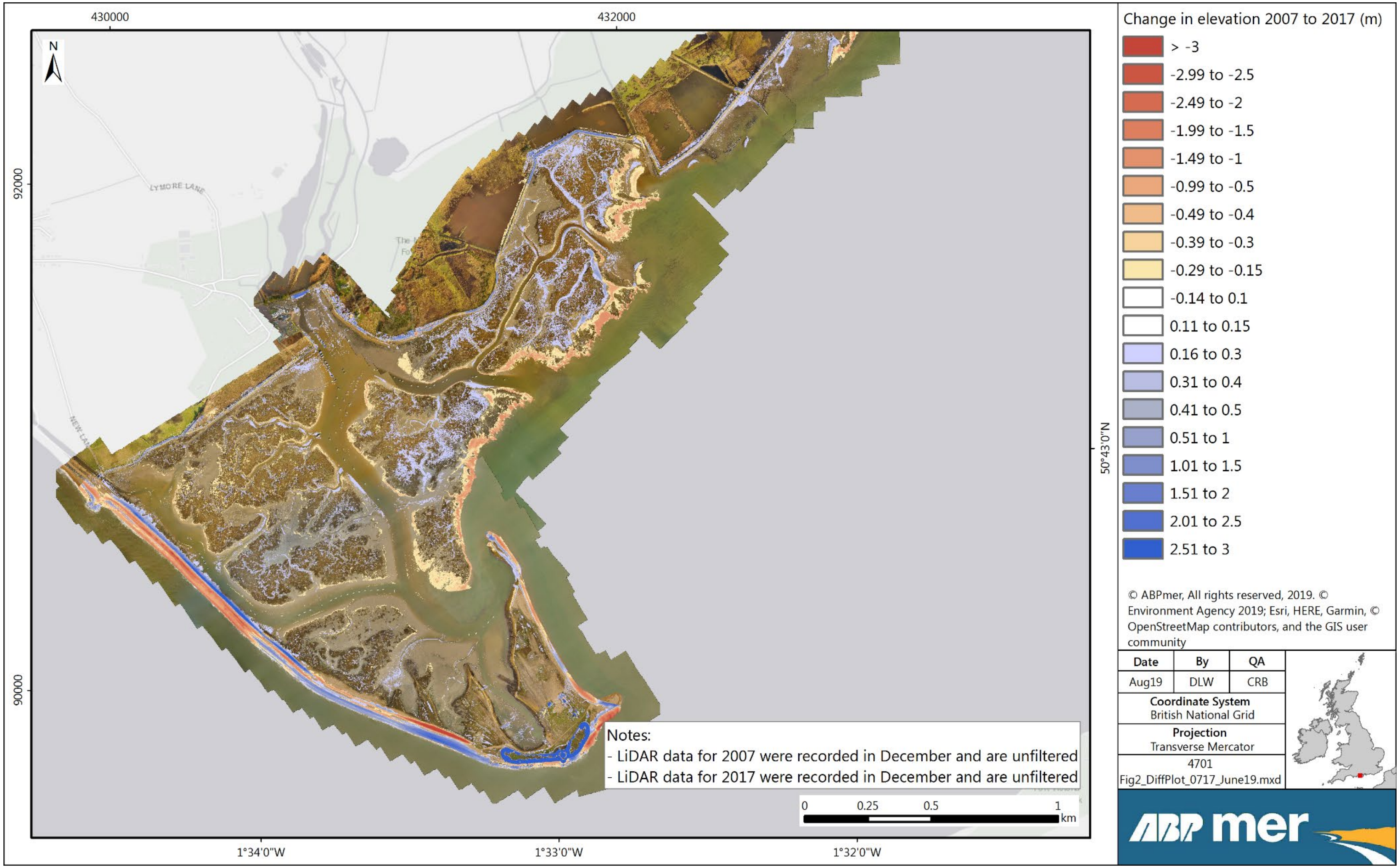


Figure 2. Spatial changes in upper intertidal elevation based on LiDAR data from 2007 and 2017 (Hurst/Keyhaven section)

Figure 3. Spatial changes in upper intertidal elevation based on LiDAR data from 2007 and 2017 (Lymington section)

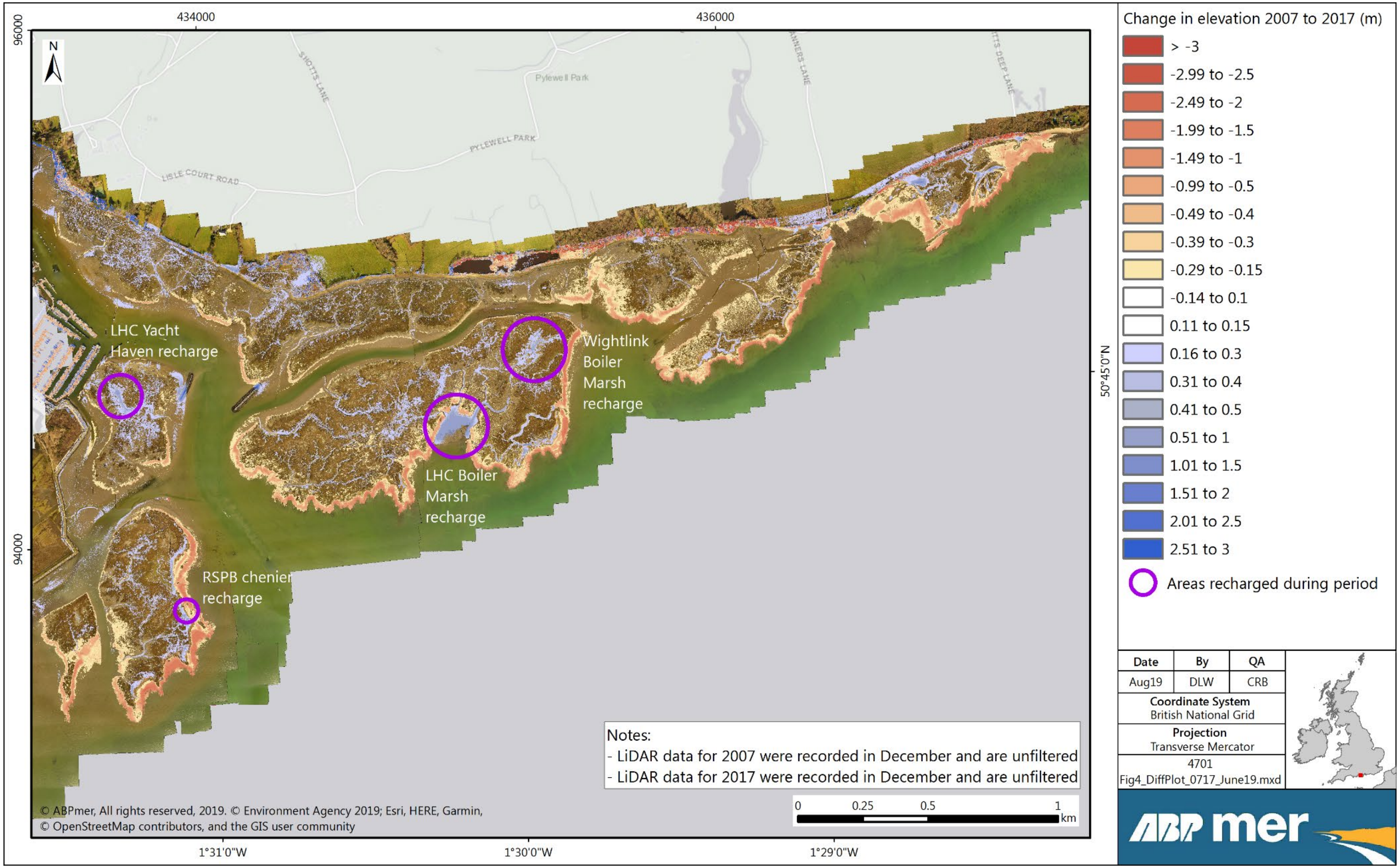


Figure 4. Spatial changes in upper intertidal elevation based on LiDAR data from 2007 and 2017 (Cockleshell to Pitt's Deep section)

LiDAR volumetric analysis

To carry out a volumetric analysis of the study area, 11 separate upper-shore mudflat and saltmarsh complexes were defined. These areas are shown in below in Image 5. Then, the corrected LiDAR data from 2007 and 2018 was processed to remove areas below the MHWN elevation (i.e. 0.62 mOD); this was done to limit the likelihood of standing water or 'mudflat mirroring' of the lower elevations areas influencing results (limitations highlighted above). The adjusted datasets were then used to make Geographic Information System (GIS)-based volumetric comparisons. In addition, two internal saltmarsh areas within these complexes were also analysed to obtain an indication of internal balances (away from the areas experiencing high levels of erosion), at the Boiler Marsh and Cockleshell complexes. Results are presented in Table 1.

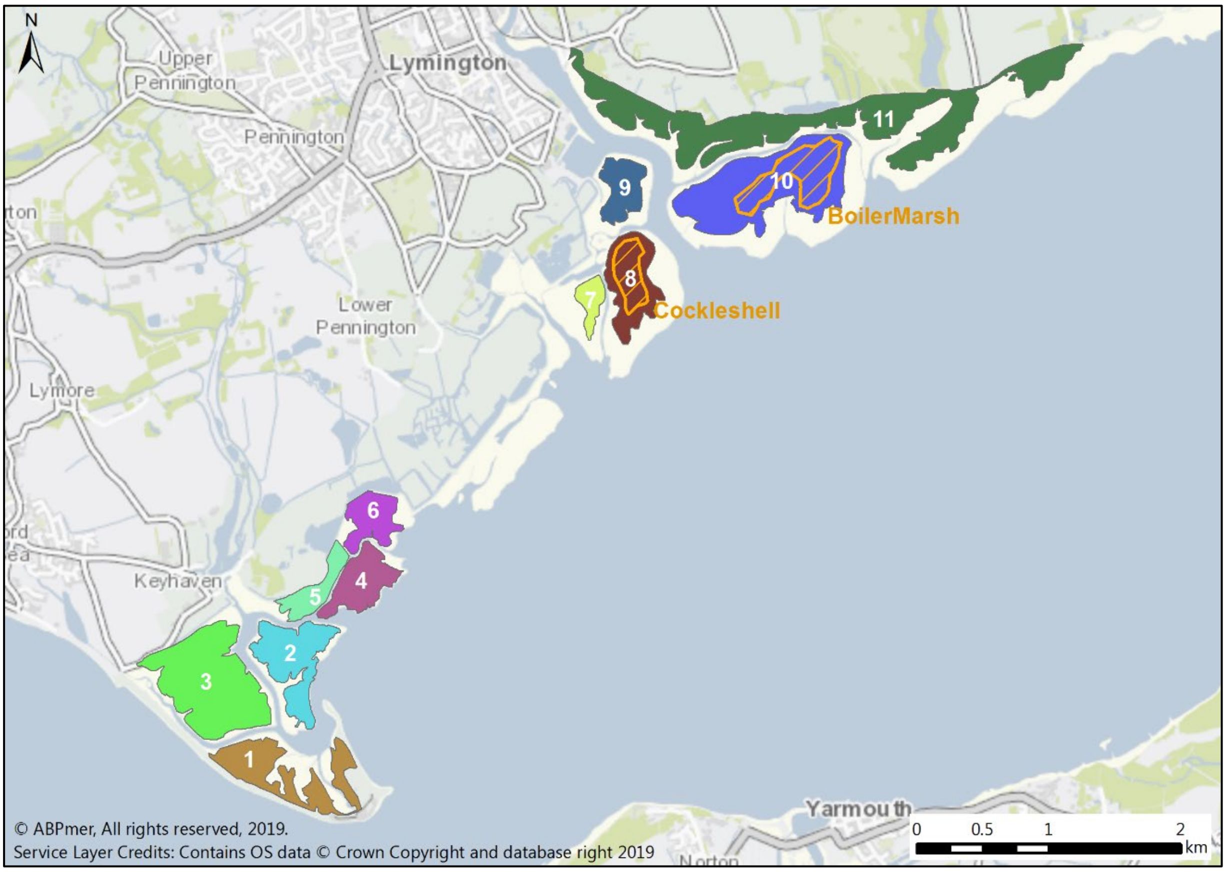


Image 5. Intertidal complexes used for volumetric analysis

The results presented in Table 1 should be viewed as indicative only, and limitations associated with LiDAR data borne in mind (see introductory part of this Section 3.2.2). Also, as only areas above MHWN are included, most of the surfaces which have benefited from recharge over the past decade would not have been included. Despite these limitations, the results reinforce the fact that there has been progressive intertidal erosion. They also provide another metric (i.e. volume loss) for quantifying this change. As with the area loss describe above, the volumetric losses that the marshes have experienced over the 12-year study period is also typically in the region of 2% per year. As expected, the more exposed areas incurred the largest volumetric losses, ranging of between 2.0 and 3.3% of total volume held (Complexes 2, 4, 8 and 10).

Complex 3, the sheltered marshes behind Hurst Spit, represent an anomaly in this picture, with annual losses of 4% shown. The relevant transects T to V in Appendix A indicate that this is likely to be related to relatively subtle vertical changes at this location, which are within the error margins of LiDAR data (and thus not shown in Image 3), but which nevertheless are supported by the transects. Given that 'unfiltered' LiDAR data was used in the volumetric analysis, the observed large scale volumetric changes are likely to have been in part related to the loss of saltmarsh vegetation due to relative sea level rise. The volumes extracted for the internal Boiler Marsh and Cockleshell Marsh areas support the hypothesis that less material is lost from the inside of marshes.

Table 1. Intertidal sediment volumes in intertidal complexes above 0.62 mOD (MHWN)

Site*	2007 volume (m^3)	Vol. loss 2007 to 2018 (m^3)	Area above MHWN (ha)	Mean per-ha losses (m^3)		Percentage loss	
				Over 12-yr study period	Per year	Over 12-yr study period	Per year
1	64,987	14,502	12	1,163	97	22	1.9
2	13,734	5,077	12	427	36	37	3.1
3	33,566	15,949	22	742	62	48	4.0
4	15,266	3,287	8	395	33	22	1.8
5	10,816	2,392	6	422	35	22	1.8
6	14,846	762	7	102	8	5	0.4
7	9,817	3,900	4	1,081	90	40	3.3
8	54,966	15,826	16	1,018	85	29	2.4
9	12,028	1,435	6	238	20	12	1.0
10	133,694	32,629	41	803	67	24	2.0
11	151,487	38,484	47	827	69	25	2.1
Boiler Marsh	43,961	8,616	14	627	52	20	1.6
Cockleshell Marsh	22,245	2,907	7	420	35	13	1.1

* Please see Image 5 for locations.

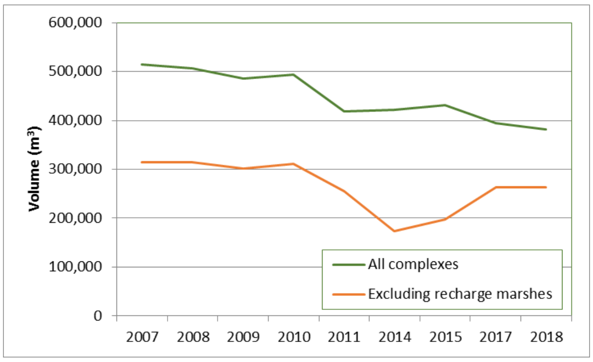
The decreases in volumes observed were not fully linear, as the graphs in Image 6 demonstrate[9]. Graph a) shows that, across all complexes, there was a steady fall in volumes between 2007 and 2011, and an apparent slight recovery between 2011 and 2015, before the volumes then reducing again to 2018. In order to indicate the possible influence of the recharge campaigns by LHC, the RSPB and Wightlink, statistics for all marsh complexes where recharge has taken place (notably complexes 8 to 10, referring to the Cockleshell, Yacht Haven and Boiler/Pylewell complexes) were excluded from a second line in Graph a). This line suggests that the recharge schemes, whereby varying volumes of sediment have been placed on some intertidal surfaces every year since 2012 (see Table B1, Appendix B), have had some influence on slowing volume losses. In particular, the recharge schemes seem to have aided in masking a dip evident in 2014

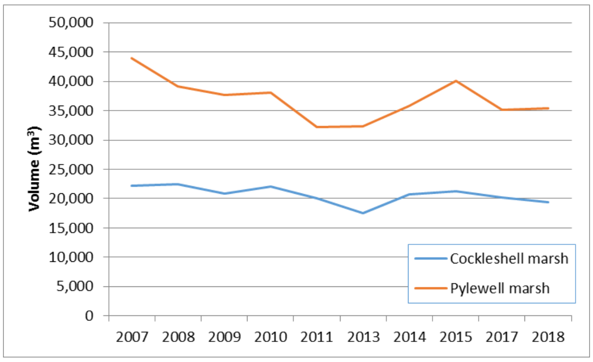
This reduction in 2014, is likely to have been due to the exceptionally stormy winter of 2013/2014 leading to extensive marsh erosion[10] [11]. The Pylewell Marsh line in Graph b) in Image 6 appears to support this impression. Here, both the direct influence of the Wightlink 2012/13 recharge, and the indirect impact of the annual LHC mudflat recharges (initiated in 2014) can be inferred from the graph. However, given the volumes involved, and also trends observed in the non-recharged marshes, it is clear that natural variability has also played a role, and that natural recovery from the 2013/14 storms has also taken place during the calmer subsequent winters.

9 Please note that the 2012 and 2016 datasets were excluded due to them being erroneous in some areas, and 2013, due to it not covering all the complexes (the latter applies to Image 6a) only).

10 During this winter, there was an unusual, and prolonged, period of intense storms. The return period probability of these storms has not been defined for Lymington/Keyhaven. Elsewhere on the South Coast however, at Chesil Beach, during the winter of 2013/14, there were: three storms with a return period above 1 in 50 years, three with a return period exceeding 1 in 2 years, and another two with a return period above 1 in 1 year (Watson, 2014).

11 Noting that the 2014 LiDAR flight date was 06 November 2014.





a) areas above MHWN b) internal marsh complexes

Image 6. Trends in upper intertidal volume from 2007 to 2018[12]

3.2.3 Updated plant coverage review – vegetation data-layer review

For this review, further analysis of the changes in vegetation cover was undertaken to describe the qualitative rates of marsh decline. Existing data on vegetation extent was obtained from the CCO, the Environment Agency and NE to describe past trends across the whole West Solent saltmarshes and to revisit previous projections of future marsh loss. The results of the 2019 UAV survey were also used to map the contemporary boundaries of vegetated marshes at indicative locations (Keyhaven, Cockleshell and Boiler/Pylewell Marsh). These 2019 areas were then compared against the equivalent boundaries which had been mapped recently (in 2008 and 2016) by the Environment Agency and NE.

Considerations for vegetation mapping analysis

In considering these results and comparing marsh vegetation boundaries, it is again relevant to bear in mind certain issue and limitations to the interpretation (as also applied with the review of LiDAR data, see Section 3.2.2). For example, there can be:

- Different interpretations placed on what constitutes saltmarsh (and misinterpretation of algae (e.g. *Enteromorpha* sp.) or wrack lying on mudflat, or vegetated shingle, as saltmarsh);
- Differences with regard to the thoroughness with which creeks and saltmarsh pans are included;
- Inconsistency between the approaches used by different mapping teams/individuals; and
- Differences in the level of ground-truthing or validation undertaken when imagery processing software is used to aid this process.

As a further consideration, it is also notable that there may be subtle decreases in vegetation cover on the ground that cannot be seen from aerial imagery. Also, the time of year that a given survey was undertaken can influence results, as annual marsh plants grow in the summer and decline/retreat in the autumn/winter months. Therefore, these boundaries can vary throughout the year. In this case however, given the rates of the losses observed in the area of interest, these survey inaccuracies are considered to pale in comparison against the observed losses.

Previous surveys (1946 to 2016)

To firstly describe past changes, the marsh extent data layers from the CCO/SDCP, Environment Agency and NE were collated for the whole area between Hurst to Pitts Deep (excluding the Sowley saltmarshes). To ensure consistency of analysis, these marshes were divided into the same four complexes/zones that

12 Data from a number of years were excluded due to suboptimal data quality and/or coverage

were used in the SDCP study (i.e. Hurst, Keyhaven, Lymington and Pitts Deep). Image 7 shows those zones, as well as the saltmarsh extents from the oldest (1946) and most recent (2016) mapping exercises. Table 2 summarises the total saltmarsh extents and losses over this period.

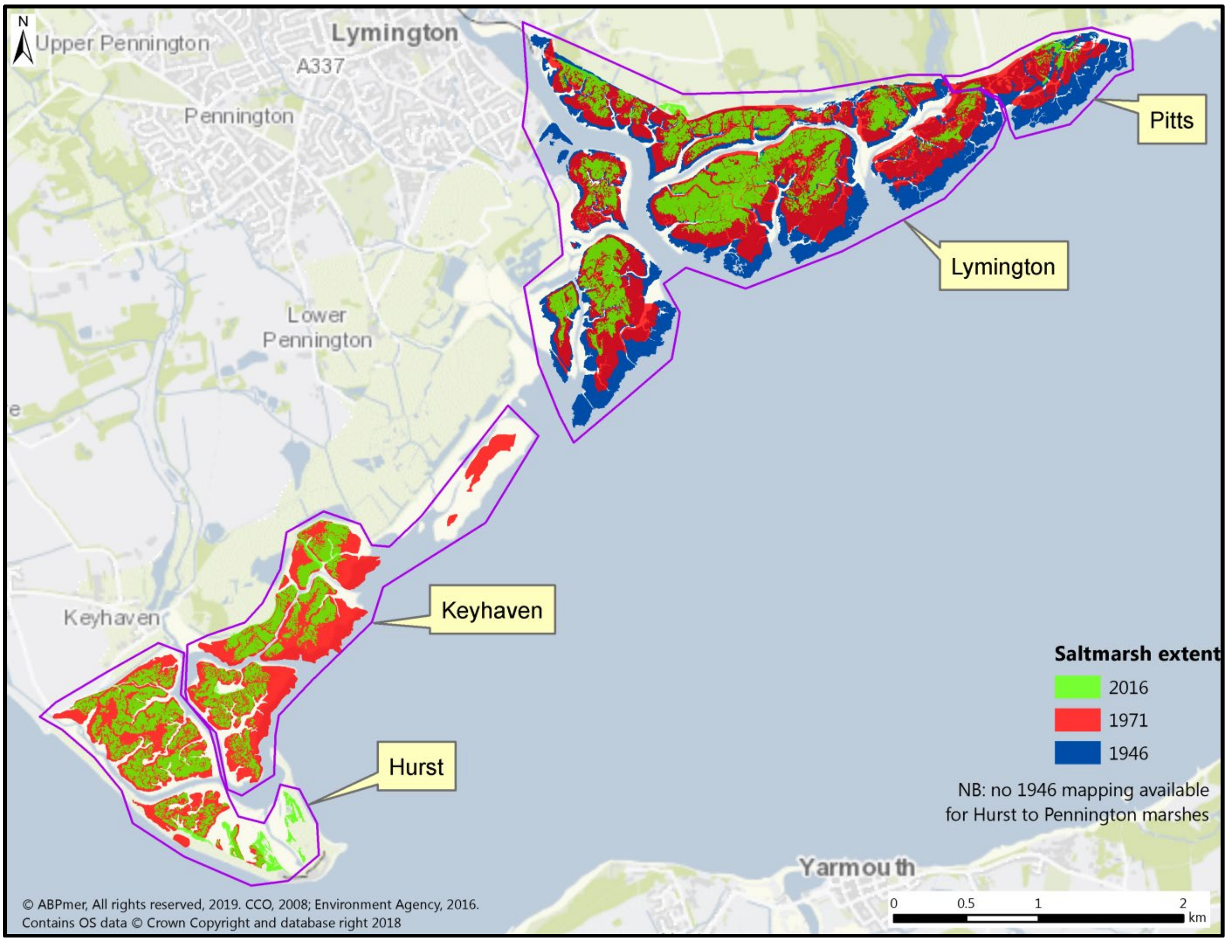


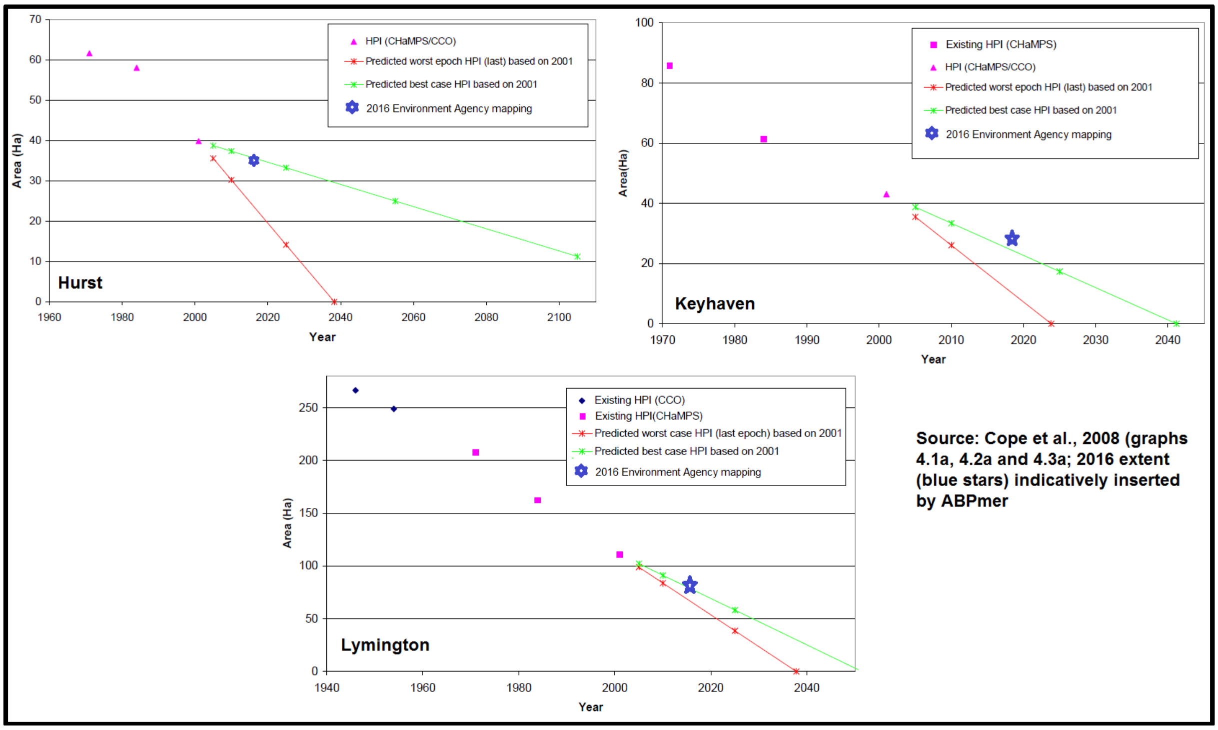
Image 7. Marsh loss between 1946 and 2016 (showing 'zones' used for SDCP analysis)

Both Image 7 and Table 2 describe the losses of marsh extent over the last 70 years. The Lymington marshes have decreased from 266 ha to 86 ha, and are now only 32% of their 1946 extent. The marshes in front of Pennington, part of the 'Keyhaven' zone, have completely disappeared (having last been mapped in 2001).

Table 2. Total saltmarsh areas and annual losses between surveys

Year	Total area mapped (ha)					Annual loss percentage			
	Hurst	Keyhaven	Lymington	Pitts	Total	Hurst	Keyhaven	Lymington	Pitts
1946	n/a	n/a	266.3	32.8	n/a	n/a	n/a	n/a	n/a
1951	n/a	n/a	248.7	28.14	n/a	n/a	n/a	1.3	2.8
1971	61.6	85.8	207.7	19.2	374.3	n/a	n/a	0.8	1.6
1984	58	61.3	162.2	15.7	297.2	0.4	2.2	1.7	1.4
2001	39.8	43	110.2	4	197	1.8	1.8	1.9	4.4
2008	42.2	39.3	99.9	3.9	185.3	-0.9	1.2	1.3	0.4
2016	36.6	32.6	86.3	2.6	158.1	1.7	2.1	1.7	4.2

For the SDCP study, the future changes in saltmarsh extent were also forecast for each of the complexes based on observed 'historical aerial photography interpretation' (HPI), using 'worst' and 'best case' scenarios. These graphs are reproduced below in Image 8. On these plots, the 2016 marsh extent as mapped by the Environment Agency has been inserted by ABPmer (blue star) to compare against these predictions. This indicates that the losses in recent years have been broadly in line with linear, 'best case', predictions from the SDCP study.



Source: Cope *et al.*, 2008, blue stars inserted by ABPmer

Image 8. SDCP saltmarsh graphs, with 2016 extent indicated by ABPmer (blue stars)

These graphs have not been reproduced for the Pitts Deep zone, as SDCP included the Sowley marshes in their zone, which are not within the area of interest of this current study. The Pitts zone however demonstrates that losses are not always linear, as this marsh has seen varying average percentage losses, and has now all but disappeared (see Table 2 and Figure A1 in Appendix A).

Latest marsh coverage (2019)

To further understand ongoing trends of erosion, the extent of vegetation cover over three individual marshes at Keyhaven, Cockleshell and Boiler/Pylewell Marshes was manually mapped using the 2019 UAV aerial imagery (and following a similar methodology as that employed by the Environment Agency (2011)). No further marshes were mapped due to the time intensive nature of the process.

The 2019 marsh extents were then compared against recent 2008 and 2016 mapping by the Environment Agency (and NE). The results are described in Table 3, and illustrated in Image 9. These show, as expected, that the marshes have further declined in extent over the 2016 to 2019 period.

As noted above however, certain aspects of the analysis, and particularly the differences of approach between years, mean that the data should be interpreted with care. For example, it appears that mapping work done in 2016 was not as accurate as the 2008 dataset. During the 2016 review (which covered a much larger study area (the Solent)), the internal pans were often not well defined and some of the external erosion was also not mapped precisely. Thus, a truer reflection of marsh changes may come from comparing the recent 2019 UAV results with the 2008 survey, rather than with the 2016 dataset for example.

Table 3. Extent of marsh vegetation at Keyhaven, Cockleshell and Boiler/Pylewell Marsh[13]

Marsh Area/Year	Total area mapped (ha)			Percent reduction 2008-2019	Percent reduction 2016-2019	Annual Loss Percentage since 2008
	2008	2016	2019			
Boiler/Pylewell	38.9	36.9	27.8	-29	-25	2.6
Cockleshell	14.6	12.1	9.7	-34	-20	3.1
Keyhaven North	2.7	2.4	2.1	-22	-13	2.0

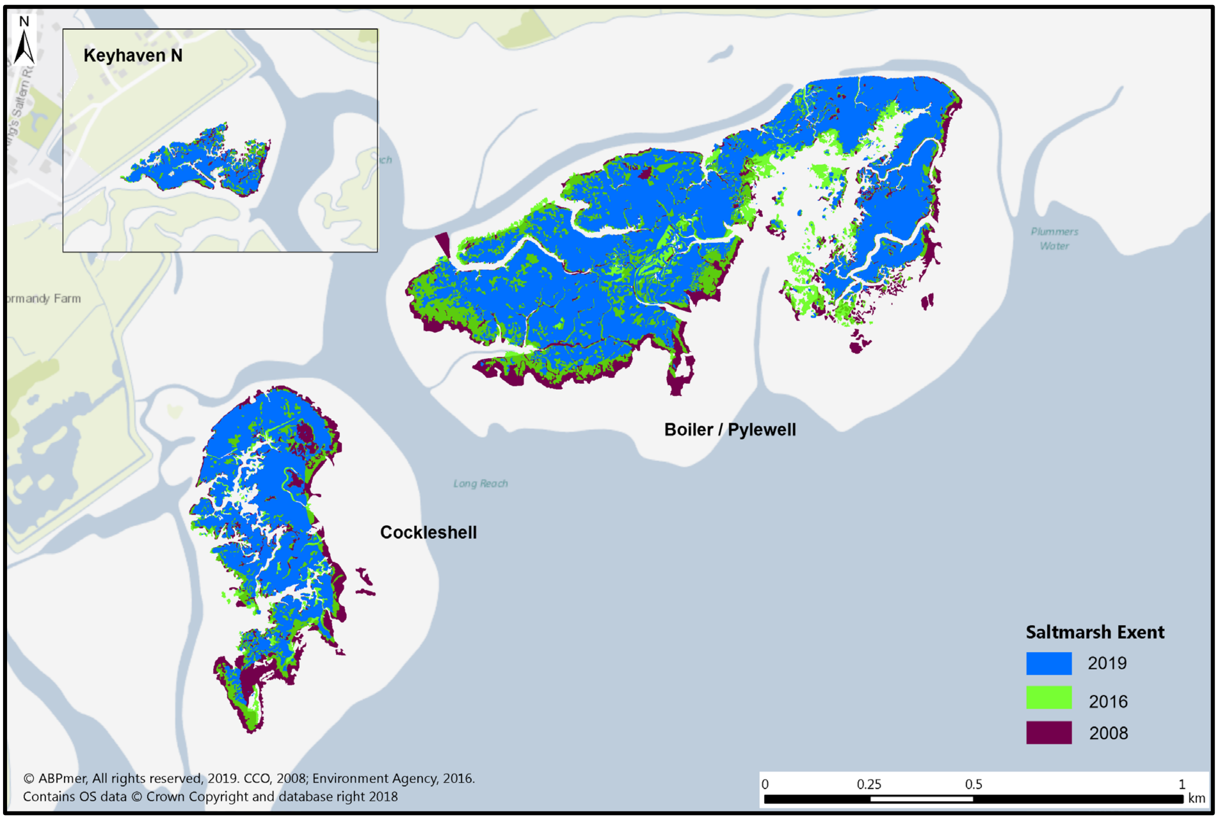


Image 9. Marsh cover at Keyhaven, Cockleshell and Boiler Marshes in 2008, 2016 and 2019

3.2.4 Factors driving marsh loss

When considering the approach for future management of the West Solent marshes, and specifically the opportunities for beneficial use, it is relevant to consider the possible reasons why the marshes are eroding. There are thought to be several interacting factors influencing the distribution and erosion of these saltmarshes. These reasons were summarised by NFDC (2007a) as follows:

- Wave action;
- Lack of sediment supply (mainly from offshore, alongshore and to a much lesser extent from downstream), resulting in minor or no sediment accretion;

13 The analytical approaches were different in the three years shown, therefore care must be taken when interpreting change between years. However, a net loss of around 20 to 30% of marsh cover over the decade from 2008 to 2019 is considered to be an appropriate estimate based on this evidence.

- Waterlogging of estuarine soils (inundation frequency and duration) and dieback of saltmarsh vegetation (possible a natural cycle, or as a result of successful establishment of vegetation)[14];
- Tidal currents (velocity, strength and duration); and
- Sea level rise.

Of these, one of the critical issues affecting the marshes, and their ability to deal with all of these factors, will be the sediment supply. In the study area, it is understood that the sediments are derived predominantly from marine sources. A literature review undertaken for the Standing Conference On Problems Associated with the Coastline (SCOPAC, 2004) concluded that there was a net input of suspended sediment into the West Solent through the Hurst Narrows. This was likely to include marine sediments and suspended clay sediments derived from cliff erosion to the west.

Analysis of fine sediments undertaken in the Beaulieu Estuary in the 1970s also confirmed that the majority of sediments deposited in the intertidal areas of this system were derived from marine rather than fluvial sources (Codd, 1972). This is very likely to be true for the Lymington Estuary, where the upstream causeway (built in 1731) will be constraining fluvial sediment releases. This is notwithstanding the Environment Agency's installation (in 2009) of a self-regulating tide-gate to allow controlled amounts of water up-river on the larger tides, which is likely to have somewhat improved the release of riverine sediments into the system (Environment Agency, 2011).

The sediment budget of the mudflat/saltmarsh system was recognised by SCOPAC (2004) as being complex. While it was considered likely that the erosional scour of the intertidal shore face would be supplying some suspended sediment input to the marsh surface, an on-going, very strong, trend of net sediment loss was concluded, especially from the more exposed marshes near Lymington. For example, Bradbury (1995) and SCOPAC (2004) quote the study by Ke and Collins (1993) who estimated that there was an average loss of saltmarsh at a rate of 3.6 ha per year and an export of around 120,000 m^3 of fine materials per year from the subtidal and intertidal zones, with around 38,000 m^3 being attributed to saltmarsh edge erosion. It was estimated that around 70% of the sediment yielded from intertidal erosion at these marshes was lost entirely as suspended sediment input into the remainder of the Solent system. The remaining 30% was thought to be available for accretion on the marsh surfaces (at a rate of 2-5 mm per year), and in the creek and channel boundaries. The accretion rates were estimated from isotopic geochemistry dating and *Spartina* deposit analysis.

The conditions are complex however and several influencing factors listed in the NFDC (2007a) study are inter-dependent and temporally variable. As a result, it is difficult to identify the relative contributions these individual factors make to observed trends. Taking just the issue of sea level rise for example, rather than just considering long-term and ongoing sea level rise, it is important to also recognise the influence of the lunar nodal cycle. This cycle causes the tidal range to vary by up to around 4% over an 18.6-year cycle (which last reached its maximum in 2015). With an average spring tidal range of 2.4 m, this could thus influence water levels by ± 0.1 m.

Furthermore, there are also ecological factors that will be relevant. For example, it is evident that macroalgal growth is occurring on or around the margins of the marshes and that green algal mats can form, or be 'thrown' by storms, on the marsh surface. This would then lead to localised shading and marsh plant growth retardation.

What is evident though is that the reduction in marsh sizes is leading to their increasing vulnerability and fracturing over time. In essence, it is likely that many of the marshes are simply too low in their elevation or too small in size to cope with any or all of the other factors influencing them. In this context,

14 ` The process of die-back may well be influenced by waterlogging and limited sediment porosity/drainage (given its tidal elevation, composition and compaction); this would restrict the extent to which oxygen reaches the roots.

the proposals for future recharge could help to re-supply sediment to, and at least stall the progressive decline. Any measures which raise the bed levels up and/or slow the erosion of the outer marshes edges can lead to marsh restoration. It is certainly known from past work that, where dredged sediment is introduced to impoverished marsh surfaces, then marsh vegetation can develop/recover quickly (see Appendix B).

3.3 Marsh bird populations

The West Solent marshes support large populations of overwintering and breeding coastal waterbirds. The marshes are of high conservation value and lie within the boundaries of the designated Solent and Southampton Water Special Protection Area (SPA) and the Solent and Southampton Water Ramsar wetland site. The SPA qualify bird species are listed in Table 4.

Table 4. Solent and Southampton Water SPA qualifying features.

Qualifying Bird Species in the Solent and Southampton Water SPA	
Internationally Important Populations of Regularly Occurring Annex 1 Species	
Species	Breeding Population
Mediterranean Gull	2 pairs (15.4% of British population) (1994-1998)
Sandwich Tern	231 pairs (1.7% of British population) (1993-1997)
Common Tern	267 pairs (2.2% of British population) (1993-1997)
Little Tern	49 pairs (2% of British population) (1993-1997)
Roseate Tern	2 pairs (3.3% of British population) (1993-1997)
Internationally Important Populations of Regularly Occurring Migratory Species	
Species	Wintering Population (5-year Peak Mean 1992/93-1996/97)
Dark-bellied Brent Goose	7,506 individual birds (2.5% of West Siberian/West European population)
Eurasian Teal	4,400 individual birds (1.1% of Northwest European population)
Ringed Plover	552 individual birds (1.1% of European/Northwest African population)
Black-tailed Godwit	1,125 individual birds (1.6% of Icelandic breeding population)
Internationally Important Assemblage of Waterfowl	
Importance	Wintering Population
Wintering waterfowl assemblage	51,361 individual birds (21,401 wildfowl, 29,960 waders) including Dark-bellied Brent Goose, Eurasian Teal, Ringed Plover and Black-tailed Godwit.

The marshes also lie alongside, and are intrinsically linked to, the adjacent Solent and Dorset Coast SPA, which has recently been designated for the protection of the foraging habitat of Terns (Table 5).

Table 5. Solent and Dorset Coast SPA qualifying features

Internationally Important Populations of Regularly Occurring Annex 1 Species	
Species	Breeding Population
Sandwich Tern	441 pairs (4.0% of British breeding population) (2008-2014)
Common Tern	492 pairs (4.8% of British breeding population) (2008-2014)
Little Tern	63 pairs (3.3% of British population) (2008-2014)

As noted in Section 2.2, in order to put the West Solent marshes into context with the wider Solent and Southampton Water SPA, data sourced from the British Trust for Ornithology (BTO), RSPB and HCC were analysed. Results for overwintering birds are presented in Section 3.3.1 and for breeding birds in Section 3.3.2.

3.3.1 Overwintering bird populations

The BTO Wetland Bird Survey (WeBS) data shows that the two local WeBS count sectors, 'Hurst to Lymington' and 'Pylewell', both contain nationally important numbers of multiple species, including Dark-bellied Brent Geese, Pintail, Black-tailed Godwit, Whimbrel, Greenshank and Mediterranean Gull. Alongside populations of national importance, many of the species are present in regionally important numbers, and represent a large proportion of the Solent and Southampton Water SPA populations (between 20 and 50% of each feature's population regularly occurs within this area).

The importance of the area to the region, not just the SPA features, should also be noted with the diversity of species and number of birds present representative of the wider Solent area. There is a wide range of habitats present within this area which supports a wide variety of birds, including, intertidal mudflat, shingle ridges, shallow saline lagoons, brackish lagoons, freshwater reedbeds, grazing marsh and saltmarsh.

Over the last five years, 41 bird species have regularly occurred in numbers >10; the most recent five years' of data is summarised in Table 6 and Table 7. Table 6 provides the data from the 'Hurst to Lymington' count sector and Table 7 is for the 'Pylewell' sector. The tables demonstrate that, overall, the number and diversity is greater for the 'Hurst to Lymington' sector, noting however that this sector covers a larger area. The tables also show that the majority of the peak counts occur during the winter months, when migratory species occur in large numbers all along the south coast.

3.3.2 Breeding birds

Analysis of the HCC 2018 breeding bird data and RSPB 2013-2018 breeding Tern data shows that, during the breeding season, several of the marshes and shingle banks in the study area are used by a range of species. The most common breeding coastal waterbird is Black-headed Gull, with approximately 6,000 active nests in 2018.

The majority of this breeding activity is focused within the middle area of the West Solent marshes, around Cockleshell Island and Pylewell. There has been anecdotal evidence that some areas previously used by several species are now no longer used due to a decrease in available area directly from erosion.

Several qualifying species of the Solent and Southampton Water SPA and Solent and Dorset Coast SPA also breed in this area. Sandwich, Common and Little Tern and Mediterranean Gull were all recorded as successfully breeding each year between 2013 and 2018 (noting that it is common to have mixed breeding colonies of terns and gulls), as can be seen in Table 8. Common Tern and Sandwich Tern peaked at 210 and 206 nests respectively (in 2013), with the most recent years data showing a marked decrease to 94 and 90 nests (Table 8).

In 2018, the central area of the marshes (i.e. Pylewell, Boiler and Cockleshell marshes) was an important area, with a large percentage of the species present here. Common Tern had a productive year with 38% of nests fledging, compared to 14% of Sandwich Tern nests. Little Tern and Mediterranean Gull occurred in lower numbers, with only eight and one nest respectively. The peak of eight Little Tern nests shown in Table 8 occurred on Normandy Marsh (part of the landward Keyhaven – Lymington Local Nature Reserve). Even though Little Tern occur in lower numbers, the productivity was very high, with 100% of the nests fledging.

Table 6. Peak count per survey season (July until June) in the Hurst to Lymington WeBS sector

Species	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	Mean Peak
Mute Swan	124 (NOV)	75 (SEP)	91 (SEP)	50 (SEP)	46 (APR)	77
Canada Goose	541 (DEC)	450 (OCT)	716 (OCT)	477 (MAR)	686 (NOV)	574
Brent Goose (Dark-bellied - *bernicla*)	1850 (JAN)	1960 (JAN)	2340 (JAN)	1746 (NOV)	1085 (DEC)	**1796**
Shelduck	180 (DEC)	246 (JAN)	164 (JAN)	200 (JAN)	148 (MAR)	188
Wigeon	1160 (JAN)	1500 (NOV)	1157 (FEB)	1528 (NOV)	1760 (DEC)	1421
Gadwall	29 (JAN)	96 (NOV)	(23) (MAY)	30 (MAR)	34 (MAR)	47
Teal	1890 (JAN)	1990 (JAN)	1943 (DEC)	1762 (OCT)	1530 (DEC)	1823
Mallard	400 (DEC)	303 (SEP)	276 (AUG)	265 (NOV)	326 (DEC)	314
Pintail	204 (OCT)	370 (NOV)	460 (DEC)	349 (JAN)	248 (JAN)	**326**
Shoveler	180 (JAN)	121 (MAR)	211 (DEC)	250 (JAN)	110 (MAR)	174
Tufted Duck	34 (NOV)	33 (NOV)	32 (NOV)	40 (JAN)	41 (FEB)	36
Eider	26 (MAR)	20 (MAR)	22 (SEP)	17 (APR)	19 (JUN)	21
Red-breasted Merganser	75 (DEC)	42 (DEC)	47 (JAN)	49 (JAN)	32 (FEB)	49
Little Grebe	42 (NOV)	42 (DEC)	40 (OCT)	31 (FEB)	38 (NOV)	39
Great Crested Grebe	12 (FEB)	11 (JAN)	15 (NOV)	20 (NOV)	8 (NOV)	13
Cormorant	25 (JAN)	30 (SEP)	21 (DEC)	21 (JAN)	23 (OCT)	24
Little Egret	40 (AUG)	34 (JUL)	34 (AUG)	45 (JAN)	31 (AUG)	37
Coot	93 (NOV)	34 (APR)	68 (MAR)	76 (SEP)	160 (OCT)	86
Oystercatcher	182 (DEC)	217 (JUL)	165 (NOV)	230 (JAN)	303 (DEC)	219
Ringed Plover	165 (AUG)	268 (SEP)	278 (SEP)	341 (AUG)	278 (AUG)	266
Golden Plover	100 (FEB)	65 (MAR)	220 (NOV)	500 (FEB)	250 (JAN)	227
Grey Plover	250 (DEC)	180 (SEP)	144 (FEB)	195 (JAN)	160 (OCT)	186
Lapwing	818 (DEC)	1284 (JAN)	924 (DEC)	1037 (JAN)	1205 (DEC)	1054
Knot	8 (MAR)	N/A	81 (MAR)	150 (FEB)	450 (DEC)	172
Dunlin	3000 (DEC)	2025 (DEC)	2050 (FEB)	1815 (JAN)	2480 (FEB)	2274
Snipe	22 (NOV)	12 (MAR)	5 (JUL)	50 (FEB)	33 (FEB)	24
Black-tailed Godwit	676 (OCT)	320 (SEP)	435 (MAR)	485 (DEC)	478 (FEB)	**479**
Bar-tailed Godwit	8 (SEP)	44 (APR)	23 (MAR)	12 (MAR)	9 (JAN)	19

Species	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	Mean Peak
Whimbrel	76 (APR)	49 (APR)	9 (APR)	25 (MAY)	N/A	**40**
Curlew	200 (DEC)	413 (JAN)	323 (AUG)	213 (JAN)	230 (AUG)	276
Spotted Redshank	16 (DEC)	11 (OCT)	5 (SEP)	11 (JAN)	8 (SEP)	10
Greenshank	18 (AUG)	20 (SEP)	20 (SEP)	24 (AUG)	18 (OCT)	**20**
Redshank	336 (SEP)	313 (JAN)	358 (SEP)	217 (FEB)	410 (SEP)	327
Turnstone	215 (SEP)	169 (SEP)	146 (SEP)	155 (APR)	141 (SEP)	165
Black-headed Gull	0	1000 (MAR)	750 (JAN)	0	N/A	438
Mediterranean Gull	138 (SEP)	5 (JAN)	9 (FEB)	8 (APR)	10 (APR)	34
Herring Gull	40 (AUG)	30 (APR)	N/A	69 (JUN)	N/A	70
Great Black-backed Gull	14 (JAN)	24 (APR)	8 (APR)	8 (AUG)	7 (APR)	12
Little Tern	27 (MAY)	19 (APR)	18 (MAY)	22 (MAY)	N/A	23
Sandwich Tern	16 (JUN)	12 (AUG)	7 (JUN)	12 (MAY)	N/A	14
Common Tern	19 (JUL)	8 (JUL)	12 (MAY)	10 (MAY)	N/A	12
Species highlighted in green show where mean peaks exceed the national threshold						

Table 7. Peak count per survey season (July until June) in the Pylewell WeBS sector

Species	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	Mean Peak
Mute Swan	19 (OCT)	4 (FEB)	6 (JUL)	3 (JUL)	6 (DEC)	8
Greylag Goose (British/Irish)	0	4 (MAY)	0	37 (OCT)	0	8
Canada Goose	57 (DEC)	429 (SEP)	40 (JUN)	17 (JUL)	11 (MAR)	111
Brent Goose (Dark-bellied - *bernicla*)	300 (DEC)	700 (JAN)	950 (FEB)	160 (FEB)	270 (FEB)	476
Shelduck	31 (FEB)	13 (FEB)	5 (APR)	6 (JAN)	18 (FEB)	15
Wigeon	340 (OCT)	1650 (OCT)	450 (NOV)	360 (OCT)	590 (DEC)	678
Teal	2 (MAR)	40 (OCT)	5 (DEC)	40 (DEC)	13 (FEB)	20
Pintail	10 (FEB)	14 (OCT)	50 (FEB)	16 (FEB)	28 (MAR)	24
Red-breasted Merganser	25 (NOV)	8 (FEB)	20 (DEC)	10 (NOV)	10 (NOV)	15
Cormorant	9 (OCT)	21 (DEC)	22 (SEP)	20 (OCT)	4 (DEC)	15
Oystercatcher	18 (JUN)	30 (JAN)	25 (SEP)	23 (MAR)	19 (MAY)	23
Ringed Plover	50 (AUG)	7 (AUG)	40 (SEP)	3 (MAY)	30 (JAN)	26
Grey Plover	50 (SEP)	124 (AUG)	100 (NOV)	100 (DEC)	100 (AUG)	95
Knot	0	100 (JAN)	400 (FEB)	600 (DEC)	250 (JAN)	270
Dunlin	850 (DEC)	400 (JAN)	800 (DEC)	700 (JAN)	700 (DEC)	690
Curlew	43 (DEC)	62 (FEB)	100 (DEC)	33 (FEB)	20 (OCT)	52
Redshank	12 (OCT)	50 (SEP)	60 (SEP)	30 (AUG)	8 (SEP)	32
Turnstone	80 (DEC)	100 (OCT)	60 (SEP)	19 (NOV)	28 (SEP)	57
Mediterranean Gull	10 (AUG)	40 (SEP)	7 (MAR)	9 (JUL)	3 (AUG)	14
Little Tern	6 (MAY)	0	0	0	No count	2
Sandwich Tern	1 (OCT)	2 (JUL)	1 (JUL)	1 (FEB)	No count	1
Common Tern	2 (JUL)	0	50 (AUG)	0	No count	13

Table 8. Breeding tern data provided by the RSPB, for Lymington River to Sowley

Tern Species	Nests recorded (per year)						5-year mean (2014-2018)	% change 2018 to 5-year mean (2014-18)
	2013	2014	2015	2016	2017	2018		
Common	210	156	74	55	122	94	100.2	- 6
Sandwich	206	45	87	81	48	90	70.2	28
Little	23	10	10	16	12	8	11.2	- 29

In the wider context, the latest 5-year mean represents 20, 15 and 17% of the Solent and Dorset Coast SPA populations of Common, Sandwich and Little Tern, respectively. The large percentage of the SPA features' population that regularly occurs within this area again highlights the importance of this region to multiple species of birds.

3.4 West Solent dredged sediment resource

To further underpin this beneficial use study, an extra analysis was carried out to understand the dredged sediment resource that exists in the West Solent and nearby and could thus be made available for restoration work. In this case the study area which could potentially supply materials to the Hurst to Pitts Deep marshes, has been defined as covering the area from the Hurst Narrows to Lee-on-Solent, including the full extent of Southampton Water, as well as the rivers Test, Itchen and Hamble to the limits of tidal influence and relevant Isle of Wight ports and marinas.

Availability of material arising from ongoing dredging commitments in this study area was identified from both the annual permitted dredge quantity (wet tonnes), and the annual permitted removal volume (m^3) within each current marine licence, using the MMO Marine Case Management System (MCMS). The dredge volume figures derived from these extant licences are indicative (maximum) volumes of material that are licensed for removal from each dredge area. It is recognised that actual dredge returns from each site are likely to differ from the numbers stated. Most historic returns throughout existing licences are not available on the MCMS; therefore, external consultation has also taken place to confirm 'true' dredge volumes where possible.

Further information on the nature ('classification') of the dredge material was also obtained for each licence, where this was available on the MCMS. Typically, material is divided into the following categories on the MCMS:

- Clay of grain size <31.25 µm;
- Silt of grain size 31.25 – 62.5 µm;
- Sand of grain size 62.5 µm to 2 mm; and
- Gravel of grain size 2 – 64 mm.

A summary of the review is provided below, and an updated summary diagram of both the spatial extent and material type of maintenance dredge activities throughout the study area is provided below in Image 10.

3.4.1 Southampton Water

Maintenance dredging throughout Southampton Water currently contributes the major proportion of annually disposed quantities of material throughout the study area. The Port of Southampton (ABP) has a licence to remove about 430,000 m^3 of silt and 60,000 m^3 of gravel each year to the Nab Tower disposal site until 2025. However, it should be noted that these figures include a proportion of mixed material dredged from the Nab Approach Channel under the same licence, which lies outside the study area.

Nationally important energy infrastructure facilities are also located within Southampton Water, at Hamble Point (BP Oil) and Fawley Marine Terminal (Esso Petroleum Ltd.). These have medium to large licensed removal volumes of 33,000 m^3 and 108,000 m^3 respectively. All of this material is exclusively silt and is currently disposed at the Nab Tower licensed site until 2020 (BP Oil) and 2026 (Esso Petroleum Ltd.). Both of these marine licences have relatively frequent sediment quality reviews due to the nature of their adjacent industrial use.

Additional dredge commitments are also licensed within the River Itchen at Saxon Wharf (7,000 m^3) and at Hythe Marine Village (around 35,000 m^3). Material from both sites is exclusively silt and is disposed at either the Nab Tower, Hurst Fort or Needles licensed disposal sites (weather dependant) until 2026 (Saxon Wharf) and 2027 (Hythe).

3.4.2 River Hamble

The River Hamble is a system where accretion patterns and dredge commitment are particularly well understood. This understanding has been aided by the detailed monitoring work that accompanied the recent ABP channel deepening in Southampton Water.

Currently, the following maintenance dredge licences are in operation:

- **Swanwick Marina** – licensed to remove *circa* 7,000 m^3 annually until 2023;
- **Mercury Yacht Harbour** – licensed to remove 7,500 m^3 annually until 2026; and
- **Hamble Point Marina** – licensed to remove 7,500 m^3 annually until 2026.

Material from all three licensed sites is exclusively silt and is currently disposed at the Nab Tower, Hurst Fort or Needles licensed disposal sites. The volumes have been combined into a single quantity for the entire river as shown in Image 10. It should be noted that the Hurst licensed deposit site is the disposal site utilised in bad weather, but otherwise, the material goes to the Nab, which is a comparatively long distance away (at costs that are roughly £15-16 m^{-3} as a result). In practice, the actual dredge commitment each year is lower than the licensed volumes (RHHA pers. comm). The routine maintenance at Mercury Yacht Harbour, Port Hamble Marina and Hamble Point Marina equates to around 3,000, 5,000 and 6,000 m^{-3}. The dredging at Swanwick Marina is also intermittent.

Capital dredging and periodic maintenance dredging has also been carried out at other marinas on the Hamble, although less frequently. For example, the Universal marina undertook a capital dredge around 12-13 years ago and has not done much maintenance dredging since then. The Royal Southern marina undertook a capital dredge back in 2012 but has not subsequently needed to maintenance dredge. In 2006 the RHHA also carried out a maintenance dredge.

If an alternative deposit site for beneficial use were available at Hurst/Lymington, then it may be that some of the Hamble sediment could be placed here (in bad weather especially), but care would need to be taken to ensure that this was a practically viable alternative given the existing transit times. The RHHA is represented on the Solent Forum BUDS technical steering group and is also looking, on a partnership basis, into other sediment management, ecological enhancement and nature flood protection opportunities in the Hamble.

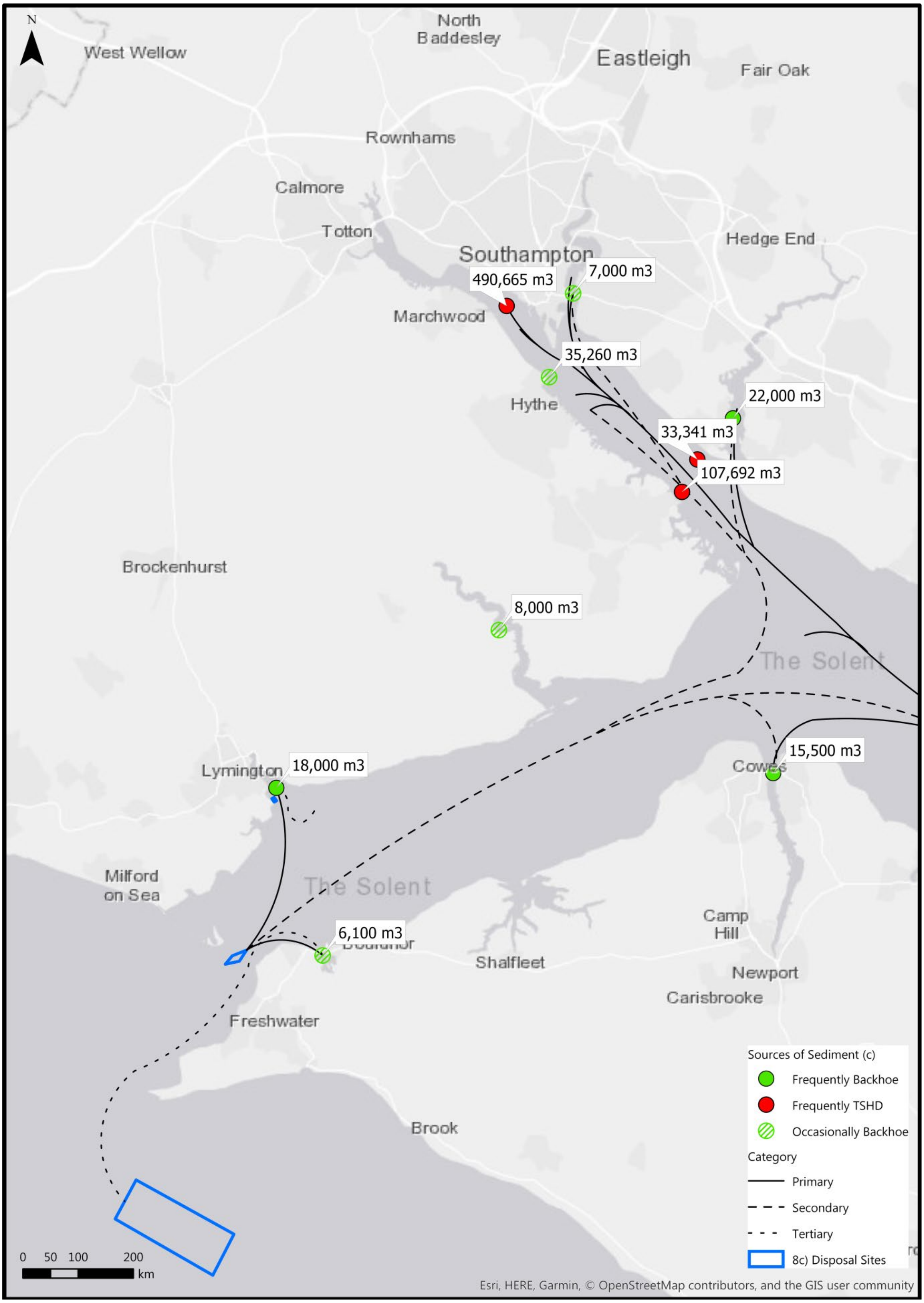


Image 10. Dredging and disposal activities for West Solent (Layer 8d)[15]

15 As noted in the main text, these volumes are based on marine licences and can exaggerate the total resource because volumes dredged are less than consented (e.g. in the Hamble the annual dredge is closer to 14,000 than 22,000 m^3)

3.4.3 Cowes

Cowes Harbour currently has three separate maintenance dredge licences in operation. These are:

- **Cowes Yacht Haven** – licensed to remove around 5,800 m^3 of silt every two years to the Nab Tower licensed disposal site until 2020;
- **Royal Yacht Squadron** – licensed to remove around 2,000 m^3 of silt every three years to either the Nab Tower or Hurst Fort licensed disposal sites (weather dependant) until 2026; and
- **Shepherds Wharf** – licensed to remove around 6,000 m^3 of silt every three years to either the Nab Tower or Hurst Fort licensed disposal sites (weather dependant) until 2026.

For the purposes of this report, the above licensed removal volumes have been combined into a single quantity for the entire river (see Image 10). As with the Hamble material, if an alternative deposit site were available at Hurst/Lymington, some of the Cowes sediment could be placed here .

3.4.4 Beaulieu River

A single licence in Beaulieu River is currently in operation for an initial capital dredge (15,000 m^3 between 2019 and 2021) and subsequent maintenance dredging (6,000 m^3 annually between 2021 and 2028) of the marina area and moorings located at Bucklers Hard. Material is exclusively silt and is currently disposed at either the Nab Tower or Hurst Fort licensed disposal sites. Some could be placed on the Hurst/Lymington frontage but it is also understood that opportunities for beneficially using this material locally within the Beaulieu Estuary are being explored.

3.4.5 Lymington River

Lymington Harbour Commissioners are currently licensed to remove around 29,000 m^3 of silt material annually from the Harbour Approach dredge area to the Hurst Fort licensed disposal site until 2024. A condition of the existing licence allows up to 25% of the annual disposal to be bottom dumped on surrounding marshland for beneficial use purposes. Further details about the practices in Lymington are set out in Appendix B, Section B.3.3.

3.4.6 Yarmouth

Maintenance dredging is ongoing throughout Yarmouth Harbour, with around 6,100 m^3 of silt licensed to be removed to the Hurst Fort disposal site every year. Some of this might be placed at the Hurst/Lymington frontage. An additional 1,500 m^3 of material is also removed as mixed material, consisting of finer clay and coarser gravel.

3.4.7 Summary

On the basis of this review, in theory over 600,000 m^3 of maintenance dredge materials are available annually from nearby sources (and 1 million from the Solent as a whole (ABPmer, 2018)). The majority is excavated in Southampton Water using large dredgers which could not easily discharge their materials at the West Solent marshes due to their size and the need for both specialist discharge equipment and substantial sediment-retaining infrastructure at the receptor site(s). Dredge arisings from smaller harbours/marinas such as Beaulieu, Yarmouth and the Hamble could be used more easily, due to the barges/dredging method employed and because many of them send at least some of their materials to the nearby Hurst offshore dredge disposal ground anyway.

It is thought that realistically each year, in the short term, some 15,000 to 30,000 m^3 of muddy sediment could be available for beneficial use from nearby harbours, in addition to approximately 20,000 m^3 from Lymington itself. There may also be beneficial use opportunities closer to these harbours which may represent a better disposal location than the West Solent marshes.

3.5 Coastal defences

Marsh recharge has the potential to improve existing coastal protection levels, and reduce related costs (which can be very high, see Section 5.1). Thus, in order to support the analysis for this Phase 2 BUDS study, the status of coastal defence in the study area has been briefly reviewed.

The future coastal management priorities and approaches from Hurst to Lymington are currently under review, and an initial Strategic Outline Case (SOC) is being developed by Environment Agency and NFDC. This will set out the general coastal defence considerations for this shoreline. Once the draft SOC is completed, its findings will be subject to a process of consultation and engagement with the public. This will be the next stage in an ongoing process of review and engagement through which the detail of the next flood protection actions will be developed. As part of this ongoing process, there will be a need to revisit the Hurst Spit Management Plan. As this spit is a very important coastal defence structure which affords shelter to this part of the Solent, the outcome of this review, and the role that marsh recharge can play in this context, will be very important.

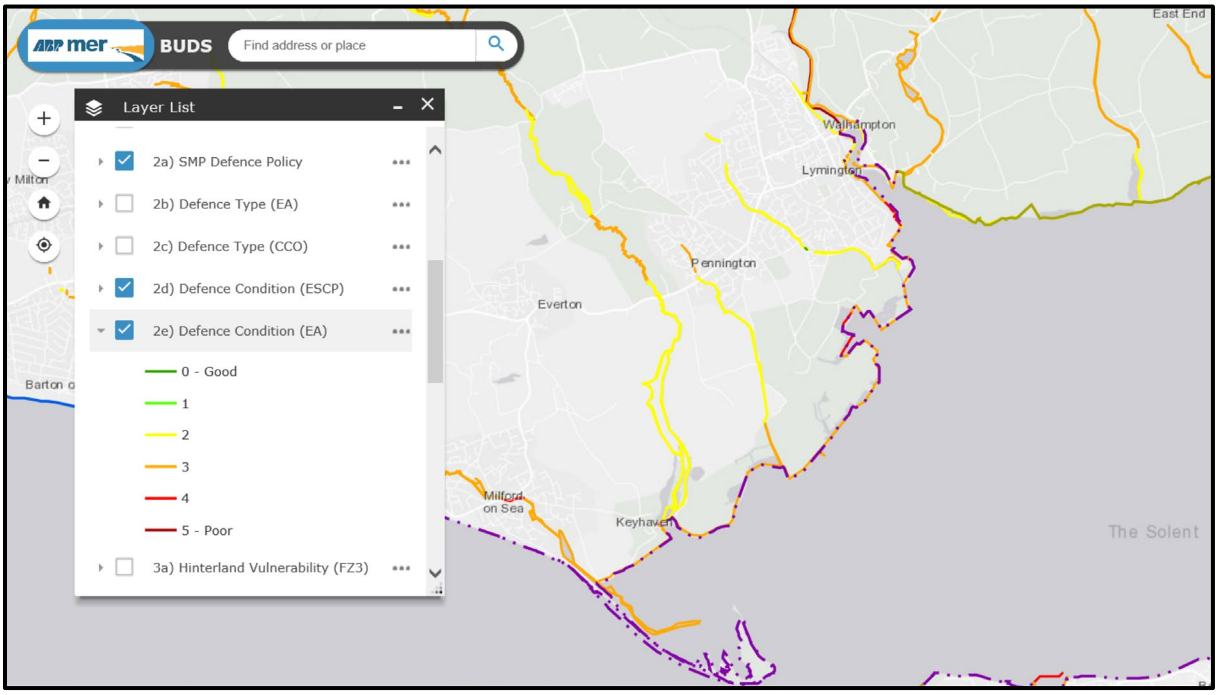
At this stage, the specific and immediate flood protection priorities and actions are not known and therefore benefits of marsh restoration work in this context are uncertain. From available information however, it is known that the full length of the coastline from Hurst to Lymington currently has a 'Hold the Line' Shoreline Management Plan (SMP) policy, while the section to the east of Lymington is 'No Active Intervention' (see Image 11).

The Environment Agency also regularly assesses the condition of the sea wall between Hurst to Lymington and considers it to be generally of 'intermediate quality' (Environment Agency Condition Score 3), although there are a few areas of a low quality (Environment Agency Condition Score 4). The Environment Agency database identifies one such low quality area at the defences fronting the Salterns (see Image 11). Where there are defences to the east of Lymington, these tend to be of a higher quality (Environment Agency Condition Score 2).

There is also evidence which reinforces the important function that the marshes play locally. For example, the sea wall crest heights are often lower in areas with fronting marshes. In 2005, the NFDC carried out an unpublished analysis for the West Solent Coastal Defence Strategy. It was concluded that the loss of saltmarsh would increase the risk of overtopping damage (see Image 12) and that, in future, the design of sea defences may need to be reconsidered in areas where there is currently saltmarsh present.

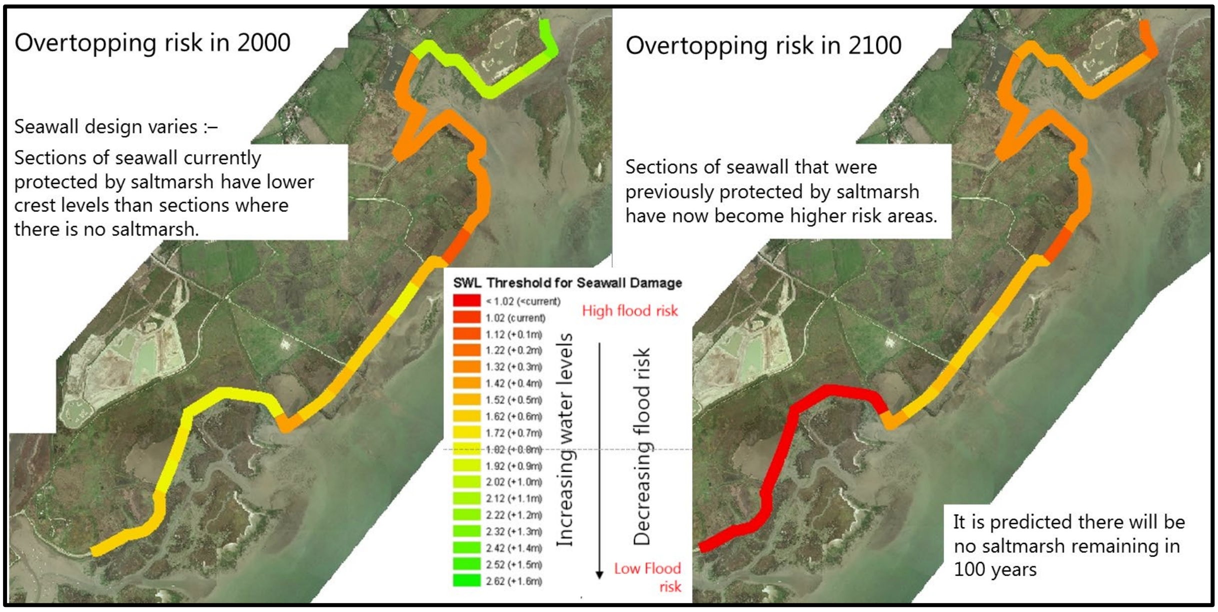
As sea levels rise, marshes decline in size and sections of the sea wall become increasingly vulnerable, these shoreline policies and priorities will clearly be subject to change and ongoing review in the context of views expressed by the local community. For example, options may well arise for managed realignment along this frontage in the future and it is also expected that recharge initiatives could play a key part in ongoing coastal flood protection in this region[16].

[16] These opportunities for using dredge sediment as a component of ongoing management are already being considered not least because there is already a technical overlap between BUDS and the future coastal management planning (the same representatives from Environment Agency and NFDC are present on the teams for both projects).



Source: BUDS Webapp; Environment Agency data-layers

Image 11. Defence Policy and Defence Condition (Layer 2a and 2e of BUDS Map)



Source: NFDC (Unpublished)

Image 12. Comparative analysis of seawall overtopping risk between 2000 and 2100

3.6 Benefits of marshes

In order to inform this review of sediment recharge options in the West Solent, or indeed similar work at any other location, it is important to understand the costs and benefits of a potential project as clearly as is possible. Having this understanding, and communicating it clearly, will be vital when seeking to prioritise, fund and implement any future recharge scheme.

One of the major issues with recharge schemes is that the cost of projects can be unclear and require multiple assumptions at an early stage. This is true also for the benefit values which are often quoted for marsh restoration as 'bundled' values that bring together multiple benefits based on available science and generic principles. However, to achieve more accurate and reasonable values for project feasibility studies such as this one, it is important to also understand and communicate the benefits on a more site-specific basis. The following sections therefore consider the generic and site-specific benefits in the West Solent as follows.

- **Natural Capital and Ecosystem Services**: The generic natural capital value of saltmarshes, as well as the ecosystem service benefits that 'flow' from them are described Section 3.6.1; and
- **Benefits of the West Solent Marshes**: The specific issues and potential benefits which are relevant across the West Solent marshes are reviewed in Section 3.6.2, and summarised in a non-technical benefits figure.

This information is then used to inform the options selection process which is set out in Section 4 and the subsequent Options CBA in Section 5.

3.6.1 Natural capital and ecosystem services

'Natural Capital' can be defined as 'the world's stocks of natural assets which include geology, soil, air, water and all living things'. It is from this natural capital that humans derive a wide range of services, often called ecosystem services, which make human life possible (World Forum on Natural Capital, 2019). Thus, the saltmarshes and mudflats, together with their flora and fauna, make up part of the natural capital of the Solent. Adopting a natural capital approach (with a greater recognition of the ecosystem services provided by coastal habitats) is in-keeping with the aims set out in the Defra 25-year environment plan (Defra, 2019).

Ecosystem services can be defined as 'the outcomes from ecosystems that directly lead to good(s) that are valued by people' (Austen *et al.*, 2010). The ecosystem services framework explicitly links ecosystem structure, processes and functioning to outcomes in the form of services which contribute to human wellbeing/ welfare. Intertidal habitats have long been known to be very valuable habitats which provide a wider range of beneficial ecosystem services. The evidence regarding the key ecosystem services they deliver is summarised in the following sections.

Primary production

Saltmarshes are generally considered to be one of the most productive ecosystems in the world, rivalling that of intensive agriculture (Niering and Warren 1980; Peterson *et al.*, 2008). They fulfil important functions in providing other marine habitats (and their fauna) with nutrients and fixed carbon (McKinney *et al.*, 2009). Intertidal mudflats are also important in the functioning of estuarine systems and may have a disproportionately high productivity compared to subtidal areas (OSPAR, 2009)). Biofilms, comprising microalgae at the air-mud interface, sustain all primary production on mudflats during the day (Herlory *et al.*, 2005). The biomass of benthic algae may exceed that of the phytoplankton in the overlying water column. In turn, this highly productive ecosystem supports macroinvertebrates (secondary production) and hence provides an important year-round feeding ground, for example, for fish and wading birds.

Fish and shellfish

Many juvenile fish, crustaceans and molluscs use saltmarshes as nurseries. When vascular plants die, the plant matter is broken down by microbes, invertebrate detritivores, deposit and filter feeders. Bivalves, shrimp and fish predate on invertebrates which are in turn prey for fish (Pennings and

Bertness, 2001). Juvenile stages of many fish species (including several commercial species) feed and find refuge amongst saltmarsh vegetation and within its shallow creeks (Dickie *et al.*, 2014). For example, Laffaille *et al.* (2000) showed that saltmarshes play a fundamental role in the feeding of juvenile sea bass, which ingested great quantities of live and detritic organic matter, even though foraging in the vegetated areas was only possible for about 5% of the tides. Intertidal mudflats have a low species diversity but very high overall invertebrate productivity, resulting in an important and perpetually exploited food source for fish (and birds) (OSPAR, 2009). The most notable fish predators on intertidal mudflats are sole, dab, flounder and plaice which feed on polychaetes, young bivalves and other molluscs (Jones *et al.*, 2000). Mudflats are thought to be at least twice as productive as their subtidal counterparts (Elliott and Taylor, 1989). Intertidal mud is also an important area for juvenile fish such as plaice (Jones *et al.*, 2000).

Provision of habitat

Saltmarsh is an important habitat and refuge from predators and physical stress for a wide range of fish and bird species (Peterson *et al.*, 2008). Upper saltmarshes provide breeding grounds for birds such as Lapwing, Redshank and many species of gulls. Many waders furthermore rely on these habitats as safe resting/roosting grounds. Mudflats (and shallow water areas) are also important sites for wading birds (Bale *et al.*, 2007). At low tide, mudflats provide feeding and resting areas for internationally important populations of migrant and wintering waterfowl, whereas at high tide they are also important nursery areas for flatfish and feeding grounds for numerous fish species (OSPAR, 2009). Intertidal mud is not usually associated with species rich communities but there are often very high abundances of those species present (Jones *et al.*, 2000).

Natural hazard regulation, increased resilience

Wave action on land causes erosion. Saltmarshes act to shelter coasts from this erosion (Pennings and Bertness, 2001). Saltmarsh can significantly increase attenuation of incident waves compared to unvegetated sand/mudflats. This is especially relevant with the increased risk of sea level rise and an increase in storm frequency (Möller, 2006; Möller *et al.*, 2014). In the US, Costanza *et al.* (2008) estimated that restored saltmarsh provided an economic value of US$ 8,236 ha^{-1} yr^{-1} in reduced hurricane damages. Filamentous algae, cyanobacteria and macrophyte roots strengthen sediment, further supporting erosion control (Aspden *et al.*, 2004). Saltmarshes accumulate sediment and organic matter at a rate that tends to compensates for sea level rise (Morris and Gibson, 2007). Mudflats also help protect coastal margins from erosion by dissipating wave and current energy (Bale *et al.*, 2007).

Waste breakdown, detoxification and storage

In areas receiving pollution, saltmarsh sediments sequester contaminants such as mercury, heavy metals (OSPAR, 2009; Coehlo *et al.*, 2009) and other substances such as uranium (Church, 1996). Saltmarsh plants have been shown to lead to TBT remediation in sediments (Carvalho *et al.*, 2010), and are able to regulate faecal pollution (Kay *et al.*, 2005). Microbial saltmarsh assemblages carry out nitrogen and carbon fixation services (Aspden *et al.*, 2004). Benthic microalgae on mudflats play significant roles in biogeochemical reactivity (MacIntyre *et al.*, 1996).

With regard to water quality and nutrient cycling, coastal saltmarsh vegetation is involved in the regulation of water purity through the take up of excess inorganic nutrients such as nitrates and phosphates, therefore reducing the potential for eutrophication (Peterson *et al.*, 2008). Saltmarsh sediments tend to be anoxic and carbon-rich, providing ideal conditions for denitrifying bacteria (Drake *et al.*, 2009). Denitrification rates in saltmarshes are generally high, and can be accountable for a majority of nitrogen flux in saltmarshes (Davis *et al.*, 2004). The vegetation found on saltmarshes is also an important nutrient sink through the generation of plant biomass (Verhoeven *et al.*, 2006).

Climate regulation, carbon sequestration

Recent work on carbon sequestration in tidal habitats indicates that, while the extent of these habitats on a global scale might be relatively small (<2% of the ocean's surface), they are 'hot spots' for carbon burial and have a significant role to play in global carbon storage (Duarte *et al*., 2005, Laffoley and Grimsditch, 2009, Chmura *et al*., 2011). One mechanism for this carbon retention is through plant biomass growth (Pidgeon, 2009). However, the biomass of living plants is not seen as a key carbon trapping mechanism (Trulio *et al*., 2007). Instead, the crucial process driving carbon trapping in coastal ecosystems is sediment accretion. This process, coupled with the anaerobic conditions in the saline sediments, leads to an accumulation of organic matter in the soil which effectively creates a carbon sink that can continue to grow over timescales of thousands of years (Connor *et al*., 2001; Duarte *et al*., 2005).

Sediment deposition also traps the algal matter of macrophytes and microflora that grow on soil surfaces (Conner *et al*., 2001). It has been estimated that globally at least 430 Tg (teragrams) (or million tonnes) of carbon is stored in the upper 50 cm of tidal saltmarsh soils, with healthy saltmarsh able to sequester around 200 g C m^{-2} yr^{-1} (Chmura *et al*., 2003). This is equivalent to around 7.33 t CO_2 ha^{-1} yr^{-1}. In addition to locking carbon away, coastal wetlands are also less likely than inland freshwater habitats to release carbon though bacterial processing within the sediment. This is because the sulphate/salinity suppress methanogenic bacteria and thus the release of methane (which is 25 times more potent as a greenhouse gas than CO_2) (Forster *et al*., 2007).

Other benefits

This review focussed on key ecosystem services; in addition to these, there will also be further services that can be provided include cultural heritage, education and research, soil formation, and tourism/amenity/recreation. Many of these will be relevant in the West Solent, as described in Section 3.6.2. The nature and value of such benefits will vary greatly, depending on the scale of a given project and the extent to which marsh habitat is increased or its loss delayed. The practical benefits of key recharge options identified in this review are considered further in the CBA presented in Section 5.

3.6.2 Benefits of the West Solent marshes

The West Solent marshes emerged as a prime candidate for conducting a beneficial use project (or projects) during BUDS Phase 1, because an initiative in this part of the region has the potential to achieve the largest range of ecological, social and economic benefits. These benefits include: improving sea wall protection, delaying or reversing the marsh loss and protecting moorings and harbours. These benefits were further discussed with a range of interested parties at the meeting held on 26 March 2019 (see Section 2.6). To collate the findings from this meeting, as well as the other background/baseline work undertaken for this study, the key issues and benefits have been summarised into a single (non-technical) map, which is shown in Figure 5.

Section 3.2 has shown that the saltmarshes between Hurst and Lymington have been progressively eroding since the early part of the 20th Century. This decline has been described by many previous studies and this BUDS review has provided updated evidence of its ongoing, and serious, nature. For example, it is anticipated that all of the Boiler/Pylewell saltmarsh habitat will have disappeared by around 2050 without further intervention.

With this process of marsh decline, there have also been changes to the bird usage, as indicated by the review presented in Section 3.3. The most valuable gull nesting areas currently are on the West side of Boiler Marsh and the Cockleshell Marsh complex. Common and Little Terns also nest on the scattered chenier features that fringe the marshes at several locations. There are five areas that were historically of great(er) value for nesting gulls, but which have greatly declined in usage, due to changes in habitat quality, rising sea levels and increased marsh inundation/erosion. Four of these marshes are at Keyhaven, Hawker's Marsh, Stoney Point and the West side of Boiler Marsh. The fifth such site is Pennington, where marshes used to support gulls and terns up to the early 1990s (pers. comm., HCC ecologist). The marsh habitat in this area has now gone.

With regard to coastal defence benefits, related implications of any recharge project in the West Solent will be strongly influenced by the future coastal management requirements along this section of the shoreline. However, as noted in Section 3.5, detailed local benefits are difficult to estimate given that there is an ongoing, yet to be finalised study by the Environment Agency and NFDC into the future approach to its management. Certainly, it is known that several stretches of sea wall are in need of repair and at increasing risk of overtopping.

With respect to dredged sediment sources in the West Solent, there will be an ongoing and annual supply of fine sediment from Lymington (see Section 3.4) due to channel and marina dredging commitments. Smaller quantities of mud are also regularly dredged at Yarmouth. The regional availability of coarse sediment is currently limited, but there is a resource, from the recent Southampton Water capital dredge, that has been placed on the seabed near the Nab disposal ground. Other coarse sediment could furthermore become available from any future capital deepening work in the region.

Based on the aspects reviewed above, and discussions with stakeholders, the key reasons why the West Solent is such an important area for the increased application of the beneficial use concept, are as follows (most of these are also illustrated in Figure 5):

- The saltmarshes are located on an exposed shoreline, and protecting and preserving them will have a benefit for flood protection and wave energy reduction;
- Along this section of the coast, there is a 'hold the line' policy in relation to shoreline protection, and recharging these marshes would be in-keeping with this policy;
- The protection of the hinterland is important because:
  - Much of it is low-lying and includes populated areas of Milford on Sea and Lymington;
  - It includes areas that are highly designated for their nature conservation value;
  - It contains large historic landfill sites;
  - Therein are located many historically important buildings and features;
- The marshes provide direct protection to the many buoy moorings and the harbours of Keyhaven and Lymington. It is noteworthy that, due to the fronting marshes declining and no longer affording enough protection to Lymington Harbour, the LHC has started to build rock-armour breakwaters at the harbour entrance; therefore, recharge of these marshes could reduce (or defer) costs incurred by LHC for anticipated future extension works.
- A number of previous and ongoing recharge projects have been carried out at Lymington which provide a useful basis for understanding the approaches that could be adopted for larger-scale initiative(s);
- These marshes have been progressively eroding since the 1940s, and there are thus large areas of mudflats and shallow subtidal habitat that could provide a platform for recharge projects;
- Despite the historic and ongoing erosion, there is still a large expanse of remaining marsh and protection of this habitat will maintain a range of ecosystem service functions including:
  - The shoreline project benefits listed above;
  - Preserving important roosting and nesting habitats for waterbirds;
  - Providing feeding and nursery habitat for fish species;
  - Slowing/prevention of the release of trapped Carbon; and
  - Sequestering nutrients.

- The marshes are highly designated, so recharging them could make a major contribution to the achievement of favourable conservation targets and site improvement ambitions. In summary, the Keyhaven to Lymington marshes and environs are nationally and internationally important because:

- They form part of the Hurst Castle and Lymington River Estuary Site of Special Scientific Interest (SSSI);
- They are part of the Solent and Southampton Water SPA and Ramsar site as well as part of the Solent Maritime Special Area of Conservation (SAC);
- They lie adjacent to the Solent and Dorset Coast SPA;
- The easterly marshes (Pylewell onwards) are also part of the 'Boldre Foreshore' Local Nature Reserve (LNR);
- The defences at Keyhaven to Pennington protect a landward reserve, the Lymington-Keyhaven Marshes LNR, which takes in most of the old salt working lagoons.

3.7 Marine licensing and beneficial use of sediment

3.7.1 Key issues and context

It is well-recognised, and often cited, that one of the major obstacles to implementing beneficial use projects is a given country's consenting and licensing regime (e.g. PIANC, 2009; MMO, 2014). These consenting tasks are, of course, legally required and crucial for safeguarding the marine environment and the activities and health of those who use it. Often though, problems can arise as a result of associated uncertainties and inconsistencies. These can stop a beneficial use project by introducing unexpected extra costs (including for monitoring) or delays. Such delays can lead to it no longer being possible to integrate the timing of a dredging event with a potential beneficial use action.

Even just in recent years, there have been some clear examples of this, including:

- The original Holes Bay projects (Poole Harbour, see Appendix B, Section B.3); this was stopped because new issues, costs and risks were introduced by regulatory advisors late in a consenting process that was already well advanced and agreed (ABPmer, 2016a).
- The new Mersea project (Blackwater Estuary, Essex; see Appendix B, Section B.3); obtaining a licence for this project took nearly 18 months and cost £83,000 (excluding more substantial in-kind contributions from volunteers), this was due to the need to resolve/agree multiple issues.

Relatively recent concerns also exist with respect to waste licensing processes and the definitions of waste 'recovery' or 'disposal' (Jones and Streeton, 2016), which are for example understood to be hampering the ability of the RSPB to progress land-side wetland restoration at Cliffe Pools (Kent), using dredged sediment from the Thames. This issue could also lead to future projects which are similar to the now completed Wallasea wetland restoration project (Essex) being potentially unlawful.

It is hoped that better clarity and consistency in the consenting regimes can in part result from the work of several national and regional working groups; please refer to Section B.2 of Appendix B for a list of current groups. Implementing and then learning from real-world projects will also be essential for building confidence across regulators, advisors and implementers. In this respect, it is envisaged that recent practical initiatives such as those at Lymington (see Appendix B, Section B.3) will also play a crucial role, together with any schemes that are promoted by this BUDS project.

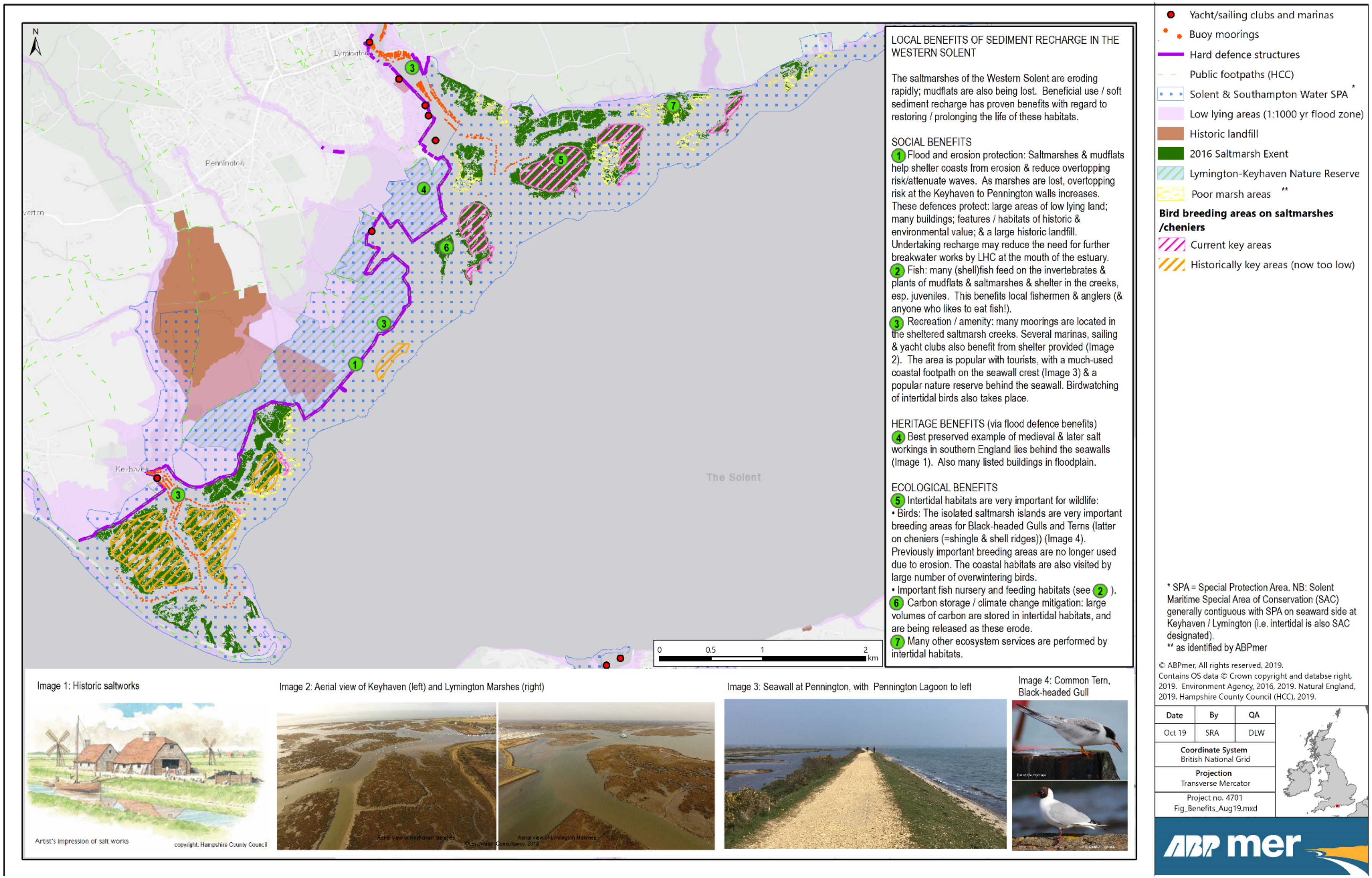


Figure 5. Map of potential benefits from marsh restoration work in the West Solent

3.7.2 MMO and Cefas review/meeting for BUDS

In recognition of the importance of the consenting regime and the need to maintain and enhance communication on this subject, as part of the BUDS project, a meeting was held with the MMO and Cefas on 26 April 2019. At this meeting, the consenting requirements for beneficial use projects were discussed and three types of initiatives reviewed in order to provide a tangible focus for the discussions:

- **Multiple emerging options over a wide spatial area (this BUDS Phase 2 project)**: The range of future project aspirations, from small to large scale, being developed under this Solent BUDS initiative for the Hurst to Lymington frontage;
- **Multiple options over a smaller site (Holes Bay):** To mark the recommencement of investigations into the feasibility of recharge work at Holes Bay marshes by the new Bournemouth, Christchurch Poole Council (BCP); and
- **Well-defined new proposals for additional LHC sites (Lymington):** LHC will shortly seek a variation of their existing licence, to enable them to increase the number of locations where dredged sediments can be 'bottom placed' to help protect marshes at the mouth of the Lymington Estuary (see Section B.3).

These three initiatives include multiple different individual projects that will vary greatly in terms of their scale, approach and timing. They range from short-term smaller scale proposals to longer-term larger ambitions. It was helpful to review this wide range of different projects in order to understand both the specific and generic consenting requirements that apply to such projects. Many issues were discussed during the meeting, and the key issues and observations can be summarised as follows:

- It was recognised that useful lessons had been learned from recent projects (especially those at Lymington), and from the licensing and monitoring work undertaken for these. Such project-level lessons will continue to inform future consenting processes;
- As a general rule, there is a direct relationship between the scale of any proposed project and the scale/detail of the assessment work needed to obtain the required licence(s). However, the upfront evidence requirements and the scale of the post-implementation monitoring work will also be influenced by: lessons learned from past projects, available data, and project risks;
- Monitoring programmes can reduce the need for marine licence conditions;
- Undertaking beneficial use in the marine environment is classed as a disposal activity and is thus subject to the 2014 OSPAR. Amongst others, this requires all new disposal/receiver site(s) to be characterised. The following was noted in relation to this:
  - The scope of such characterisation will be project specific, but characterisation of a standard set of physical and chemical determinants within the sediments is often necessary (including Particle Size Analysis (PSA) as a minimum;
  - Whilst a minimum of three samples per site is advised, for smaller projects (<25,000 m^3/yr), a smaller number of indicative/representative samples may be appropriate;
  - The need for, and scope of, such sampling is determined by Cefas/MMO based on the project, the existing information available for the area, the extent and likelihood of sediment dispersion, and the project risks; and
  - Prior to any marine licence application being submitted, a request for a sample plan should be submitted to the MMO. A sample plan will then be provided outlining the number of samples required as well as the aspects to be tested (for).
- The results of the sediment sampling at both the beneficial use site, and the source/dredging sites need to be supplied with other licence application documents for the works. Where no (recent) results for the source sites are available, then dedicated sampling may also need to be undertaken (and a sampling plan requested).

- The characterisation of the source materials and the receptor surface environment is required to prove that materials 'match'. However, it was noted that there was room for some variation, e.g. for material that is slightly finer/coarser than that at the receiver site to be deposited. This is assessed on a case-by-case basis.
- Other aspects to provide evidence on for a beneficial use licence application include:
  - Storage volume of a site and potential disposal quantities;
  - Pattern of anticipated sediment dispersal; and
  - Benefits of the work and, especially, the consequences of not doing it at all.
- Where applicants desire to have a flexible approach and use multiple disposal sites on an optional/'as-appropriate' basis (as is the case for the LHC proposal), MMO/Cefas advise that closely defined, individual, disposal sites will need to be licensed/registered. This is as opposed to having a broad regional zone which would encompass all such areas collectively, together with intervening areas of the seabed and different habitat types where no direct deposition would be intended.

It is worth noting that specific licensing guidance documents are anticipated to be developed in the near future, to clarify these and other beneficial use licensing considerations (under the SEABUDS initiative ('precipitating a SEA Change in the Beneficial Use of Dredged Sediment' – see Appendix B, Section B.2 for more detail)). In the meantime, it is hoped that the brief overview given above provides a useful starting point for any future BUDS projects or similar initiatives.

4 Stage 2 Technical Options Review

4.1 Introduction

To identify how and where sediment might be beneficially used in the West Solent, a three-step process was followed. This sequential process was carried out to ensure the review was auditable and there was a clear rationale behind the BUDS Phase 3 option prioritisation. It was also designed to ensure that the outputs can be used later for ongoing management in this part of the Solent.

The approach taken involved simultaneously considering where recharge could be undertaken, and the range of different techniques (from small to large scale) that could be adopted. At this stage, the scope of what can be achieved and funded has not been fully resolved and therefore this review seeks to describe the full scope of future potential projects. Indeed, it is possible that recharge projects will begin at a modest scale at selected locations but then rapidly increase in size, ambition and coverage as confidence in the techniques increases. It is also noted that approaches will evolve and develop over time and, possibly, that new technologies and materials may become available. The aim of the review therefore was to provide information to underpin a long-term, and evolving strategy for the management of this shoreline and not just to focus on a few 'next stage' options.

To achieve these aims, as a **first step**, an initial high-level review of **possible recharge locations** across the area was undertaken. This identified all sites where a recharge project could technically be undertaken (Section 4.2), based principally on tidal elevation. A suite of 15 theoretical locations were identified in this step.

From these 15 sites, a few preferred areas for recharge work were then selected for further review (Section 4.3). This **second-step, site selection,** was made based on a range of factors including: the potential to achieve the greatest benefits; the practical challenges and costs associated with a possible recharge; and the potential for adverse effects (e.g. to navigation).

For the **third step** of this analysis, different indicative **approaches** were identified **for carrying out recharge work at the preferred locations** (see Section 4.4). These approaches deliberately ranged from small to large-scale in order to indicate the spectrum of options that can be pursued. Having this range of approaches was also important for illustrating the implications of undertaking projects with different levels of ambition, cost, benefits and ultimately effectiveness in reducing marsh loss.

4.2 Step 1 Potential recharge locations

To start selecting potential recharge sites, a suite of theoretical locations was identified by carrying out a 'first sweep' objective analysis. For this initial selection, the February 2019 aerial imagery was reviewed alongside the latest LiDAR elevation data. Areas were selected as 'potentially suitable sediment receptors', where they:

- Were relatively (or completely) denuded of vegetation,
- Had a lower elevation (generally between MLWS and MHWS),
- Were devoid of major land drainage outfalls (where these were easily identifiable from aerial imagery); and/or
- Ideally had a 'bowl-shaped' morphology which could make them suitable to retain sediment.

In total, 15 sites were identified as illustrated in Figure 6. The sites are scattered throughout the whole study area, which indicates that there are potential opportunities for recharge throughout. This should be recognised for the ongoing long-term management of the region. However, some areas are more appropriate for recharge, in the short-term, than others and the aim of the Step 2 analysis (Section 4.3) was to identify these preferred/priority locations.

4.3 Step 2 Preferred/priority locations

The 15 sites identified at Step 1 were reviewed further to prioritise the best sites for the next stage of recharge work, as well as the CBA presented in Section 5; the results of this review are presented in Table 9. This table includes further details about each of the sites, along with a summary of the potential opportunities, methods, benefits and constraints associated with them. The table also ranks the projects into High, Medium and Lower priority options and identifies the proposed next actions for the High and Medium priority sites.

The outcome of this review (see Table 9) is that the main preferred sites are:

- Boiler Marsh B and Cockleshell Marsh, which are each protecting the Lymington Harbour entrance;
- Hawker's Island or Stoney Point Marshes, which are each protecting the Keyhaven Harbour entrance and many buoy moorings; and
- The shoreline at Pennington, where the defences are most exposed and where a notable opportunity exists for a larger-scale project to protect the sea wall.

When considering these findings, it should again be emphasised that the flood defence priorities for this shoreline are under review and are uncertain at this stage (as noted in Section 3.5). Flood defence benefits will be a key factor in any future initiative (as well as being an indicator of its chances for securing funding) and could in the future be used to derive an objective measure of value to underpin similar site prioritisation exercises. In advance of these details being available however, a subjective/relative evaluation was applied for the flood defence benefits in Table 9, the same way as it was for the other key benefits.

4.4 Step 3 Potential restoration approaches

As was shown in the Phase 1 BUDS reports, and again in Appendix B of this report, there are several ways that recharge projects could technically be carried out and also multiple locations where these might be applied. There are also many variations and different strategies that could be applied for each technical approach and these could range from small-scale trials to larger scale initiatives. It is also possible that approaches could be implemented in a phased and adaptive manner starting at a small scale and then building (hopefully, quite rapidly) to more ambitious measures over time.

This ability to be adaptable/flexible both spatially and temporally is one of the valuable characteristics of recharge projects, but it also means that it can be misleading to select definitive approaches at this feasibility stage. Therefore, the approach taken for the purpose of this study has been to identify four indicative and illustrative approaches that could be pursued over key sites identified through Stage 2. These indicative options increase in their scale, technical complexity, cost and the levels of benefit achieved and are outlined in the following sections.

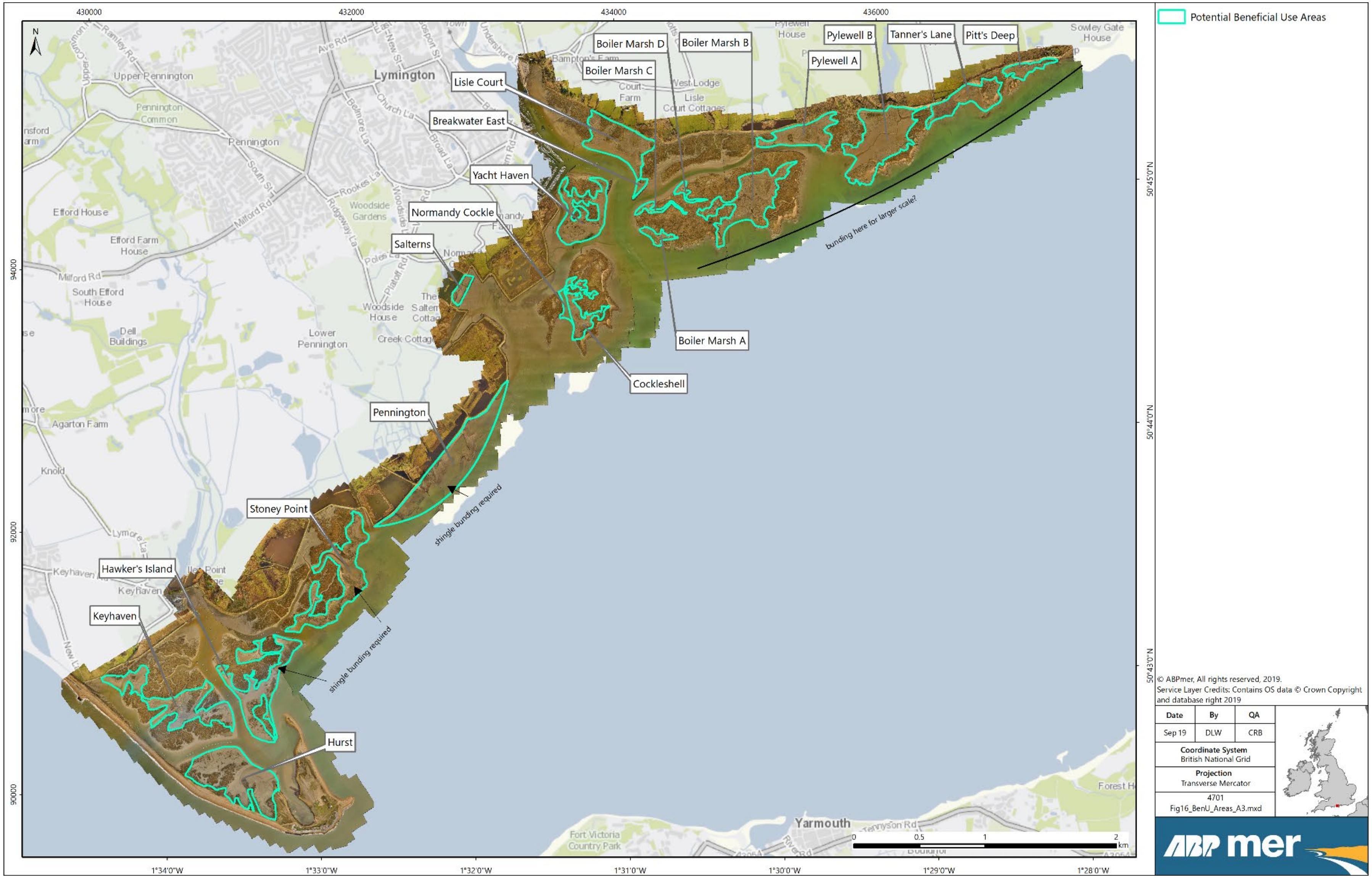


Figure 6. Location of the potential receptor sites based on a 'first sweep' objective review

Table 9. Review and prioritisation of the 15 potential receptor sites

No.	Area Name	Review of Key Issues	Prioritisation & Recommendation for BUDS Phase 3
1	Pitt's Deep	**Opportunities /constraints:** The hinterland is at low risk from coastal flooding (not currently defended), and related benefits from a recharge project would thus be very low. The marshes are very low lying and exposed. They are of limited value for breeding/roosting birds as a result. **Approaches:** Potential site for carrying out bottom placement (although sediment deposited is likely to move out of this system to the east relatively quickly). Not considered to be an important area for pursuing higher cost/pumped beneficial use work.	**Low**: No immediate action
2	Tanner's Island	The issues at Pitt's Deep also apply to this location.	**Low**: No immediate action
3	Pylewell B	**Opportunities /constraints:** The coastal defence situation is similar to Pitt's Deep. The site's bowl shape could be advantageous/used to trap large volumes of sediment. A drainage outfall would require consideration/splitting the site into cells. If there was substantial sediment export, this could affect the adjacent channel which is currently navigated by some recreational craft at high water. **Approaches:** Potential site for pumped and bottom placement, although sediment retainment structures would need to be substantial for pumped placement (large fences, geotubes etc.), and would require testing at other priority sites before being pursued here.	**Medium:** No immediate action, but potentially good site for bottom placement in short term (next 2 - 3 years), and possibly more active and larger scale restoration subsequently.
4	Pylewell A	**Opportunities /constraints:** The issues at Pylewell B also apply to this location. **Approaches:** Vessel access would be more difficult than ant Pylewell B; less sediment could be received, and more retention fencing would be needed relative to the site's size (pumped placement).	**Low:** No immediate action
5	Boiler Marsh B	**Opportunities /constraints:** Contains an important nesting site that is relatively isolated from predation. The Marsh protects the Lymington harbours and moorings from easterly wind/waves especially. It is one of the largest marshes, so anything that can be done to reverse/slow erosion here has the potential to retain the largest amount of carbon. Any new work could also efficiently tie in with past and ongoing initiatives by Wightlink and LHC (see Appendix B), with LHC's recharge helping by creating a 'natural bund' feature. **Approaches:** This site offers the best and most valuable opportunity for undertaking a major project (mixed techniques). It has a large bowl-shaped area that could receive large volumes of sediment.	**High:** Mixed techniques and trials. This should be seen as a priority site that could achieve the largest benefits in the area. It is well suited to receiving pumped or bottom placed sediment. It would be valuable to also trial erosion protection measures on its exposed outer edges.

No.	Area Name	Review of Key Issues	Prioritisation & Recommendation for BUDS Phase 3
6	Boiler Marsh A	**Opportunities /constraints:** The site is quite small and is also relatively exposed. **Approaches:** Sediment retention work here would be challenging. Some small-scale extra bottom placement could possibly be carried out but here (though some of it is too high); there is a risk of the sediment will washing back into the navigation channel.	**Low:** No immediate action
7	Lisle Court	**Opportunities /constraints:** The hinterland is at low risk from coastal flooding (not currently defended), and related benefits from a recharge project would thus be very low. **Approaches:** Any work at this site would be technically difficult - sediment retention and vessel access could be challenging. Also, any sediment that is released is likely to settle in the adjacent channel and increase future dredging commitments and costs.	**Low:** No immediate action
8	Yacht Haven	**Opportunities /constraints:** Recharge work has been undertaken at the heart of the Yacht Haven Marsh in recent years (see Appendix B). Building up this marsh will help to protect the harbour, which it is in close proximity to. However, the site is relatively small and it will be difficult/costly to retain sediment in a number of areas. **Approaches:** There may be opportunities to undertake more direct pumping from the adjacent marina. Also some bottom placement along the marsh edges.	**Medium:** Short-term (next 2-3 years): bottom placement in sheltered margins could be valuable. Longer term (pending lessons from work in priority areas): additional sediment pumping into marsh area.
9	Salterns	**Opportunities /constraints:** This is a small area and vessel access would be difficult. Recharge here could help protect coastal defences. The site's sheltered situation in the Owey Lake embayment could be advantageous in retaining sediment. Several drainage outfalls are in this area, and would require consideration. **Approaches:** Bottom placement (on the highest tides).	**Medium**: Short-term bottom placement could be valuable(next 2 - 3 years).
10	Cockleshell	**Opportunities /constraints:** The marsh is an important area for nesting and roosting birds. Building up this marsh would help to protect the harbour. **Approaches:** Bottom placement; it is understood that LHC is interested in pursuing this in the near future in the channel that currently fractures this marsh complex. This work could also include trials of geotextile fencing/curtains. Further recharge though marsh-level pumping could also be undertaken (depending on approach and lessons from LHC work).	**Medium:** Short-term (next 2 - 3 years) bottom placement in channel between marshes (LHC is pursuing). Longer-term (pending lessons from work in priority areas): additional sediment pumping into marsh area.
11	Pennington	**Opportunities /constraints:** There is no marsh left here, but there is a shallow platform that could form the basis of a large-scale project in the future. The viability of such a high-cost project very much would depend on the longer-term coastal defence needs and agreed management approaches. A drainage outfall in the middle of the area would require consideration.	**High:** Large scale initiative (longer-term ambition). However, its viability would depend heavily on future, agreed, coastal management approaches/priorities.

No.	Area Name	Review of Key Issues	Prioritisation & Recommendation for BUDS Phase 3
		Approaches: Large scale scheme, with rainbow shingle bunding and pumped mud placement behind.	
12	Stoney Point	**Opportunities /constraints:** Although shielded by Hurst Spit to a large degree, the marsh's exposed seaward face is in a very poor condition/ very denuded, leaving an exposed clay ledge which would be a good platform for beneficial use work. This marsh helps to protect Keyhaven harbour and many buoy moorings from easterly wind/waves especially. It also contributes to protecting coastal defences in this area. Historically, this marsh was a valuable bird roosting and breeding site (it is now too low). **Approaches:** In the first instance, this is a site where erosion protection measures could be introduced, also some bottom placement pursued. Over time (depending on lessons elsewhere), pumped recharge work could then be undertaken to warp up the marsh levels.	**High:** Mixed techniques and trials. Early trials of erosion protection measures recommended. Valuable site for recharge work (pumped and bottom placement).
13	Hawker's Island	**Opportunities /constraints:** The issues at Stoney Marsh also apply to this location. **Approaches:** Unlike Stoney Point there is more potential area to carry out recharge work to warp up the marsh levels. It is recommended that both erosion protection and recharge work are undertaken.	**High:** Mixed techniques and trials. Early trials of erosion protection measures recommended. Valuable site for recharge work (pumped and bottom placement).
14	Keyhaven	**Opportunities /constraints:** Located in the lee of Hurst Spit. There are several constraints, including difficulty of vessel access, interactions with the moorings and potential complications with the land drainage. While the habitats are low in elevation and vulnerable to sea level rise, they currently appear to be ecologically in a good condition (probably because of the relatively sheltered environment). **Approaches:** The site is relatively sizeable and could technically accommodate a large volume of sediment. Its suitable shape means that only relatively short lengths of sediment retaining bunding would be needed. Any work here could achieve habitat restoration or flood protection benefits, but would need to be integrated into plans for the management of the Spit. Indeed, large volumes of sediment could potentially be introduced as part of a spit management and stabilisation operations.	**Medium:** No immediate action recommended, but this could be a very important area for large-scale (mixed technique) work in the longer term. Any such work would need to be done as an integral part of Hurst Spit Management.

No.	Area Name	Review of Key Issues	Prioritisation & Recommendation for BUDS Phase 3
15	Hurst	**Opportunities /constraints:** Most of the issues at Keyhaven also apply to this location (although it has a more open shape than Keyhaven and will require more bunding as a result; works here are also unlikely to affect land drainage channels). **Approaches:** A larger-scale beneficial use scheme aimed at both habitat restoration and flood protection could be carried out here. This could potentially be done from larger vessels moored in the deeper waters alongside Hurst Spit. Work here would need to link to, and potentially support, longer-term plans for the management of the spit.	**Medium:** No immediate action recommended but, as with the Keyhaven site, this could be a very important area for large-scale work in the longer term. Any such work would need to be done as an integral part of Hurst Spit Management.

4.4.1 Option 1 Extended bottom placement

Bottom placement, whereby material is deposited by opening a split hopper barge directly above a deposit location, has been practiced by the LHC at the edge of Boiler Marsh for a number of years now (see Appendix B). The LHC material has been deposited as high up the shoreline as possible, with the aim of such deposits acting as a temporary 'sacrificial bund' or feature that will progressively erode over time (as per the other areas of the surrounding marsh edge). However, the persistence of LHC's Boiler Marsh deposits over periods of months and years has been very encouraging.

This scheme has demonstrated the value of making regular/cumulative placements in a single area and, also, of ensuring that the deposits are placed in less exposed areas, as high up the shoreline as possible. Due to this success, the LHC are now seeking permission to extend this approach to four more sites at the mouth of the Lymington Estuary. This extension to the LHC's existing work will provide valuable lessons for BUDS, and also represents a sensible next stage in the drive to carry out increasing beneficial use work.

For the next stages of BUDS, this approach could relatively easily be rolled out across the wider marshes. While the ideal locations will be sheltered upper mudflat areas accessible only at high water, this could include some nearshore sites that are accessible at a broader range of tidal states. Possible locations for this were identified; these are shown in Figure 7, and include the four sites which LHC are already seeking permissions for. These sites shown in Figure 7 are all sites:

- Which are relatively easily accessible,
- Where the intertidal elevation is appropriate,
- Where the deposited sediments are generally afforded some shelter from wave attack; and
- Where the sediments are not expected to hamper existing land drainage, or wash straight back into a navigation channel or harbour.

The inherent benefit of this technique is that it will help, at low or no additional cost, to add or retain more sediment within the local sedimentary system. It will help to slow marsh decay and the rate of marsh fracturing to some degree, depending upon the location and scale of the work, as well as on the composition and persistence of the deposited sediments.

This technique cannot, however, be used to directly create or restore marsh habitat because it is not possible to place the sediment high enough in the tidal frame to achieve this. However, it could be used to raise intertidal areas high enough to support other recharge approaches and contribute to sediment retention on the marshes.

If this extended bottom placement approach were to be adopted, and a range of further deposit sites licensed, then sediment could be deposited not only by LHC, but also by other operators from nearby harbours and marinas, including Yarmouth, Cowes, Beulieu or from the Hamble.

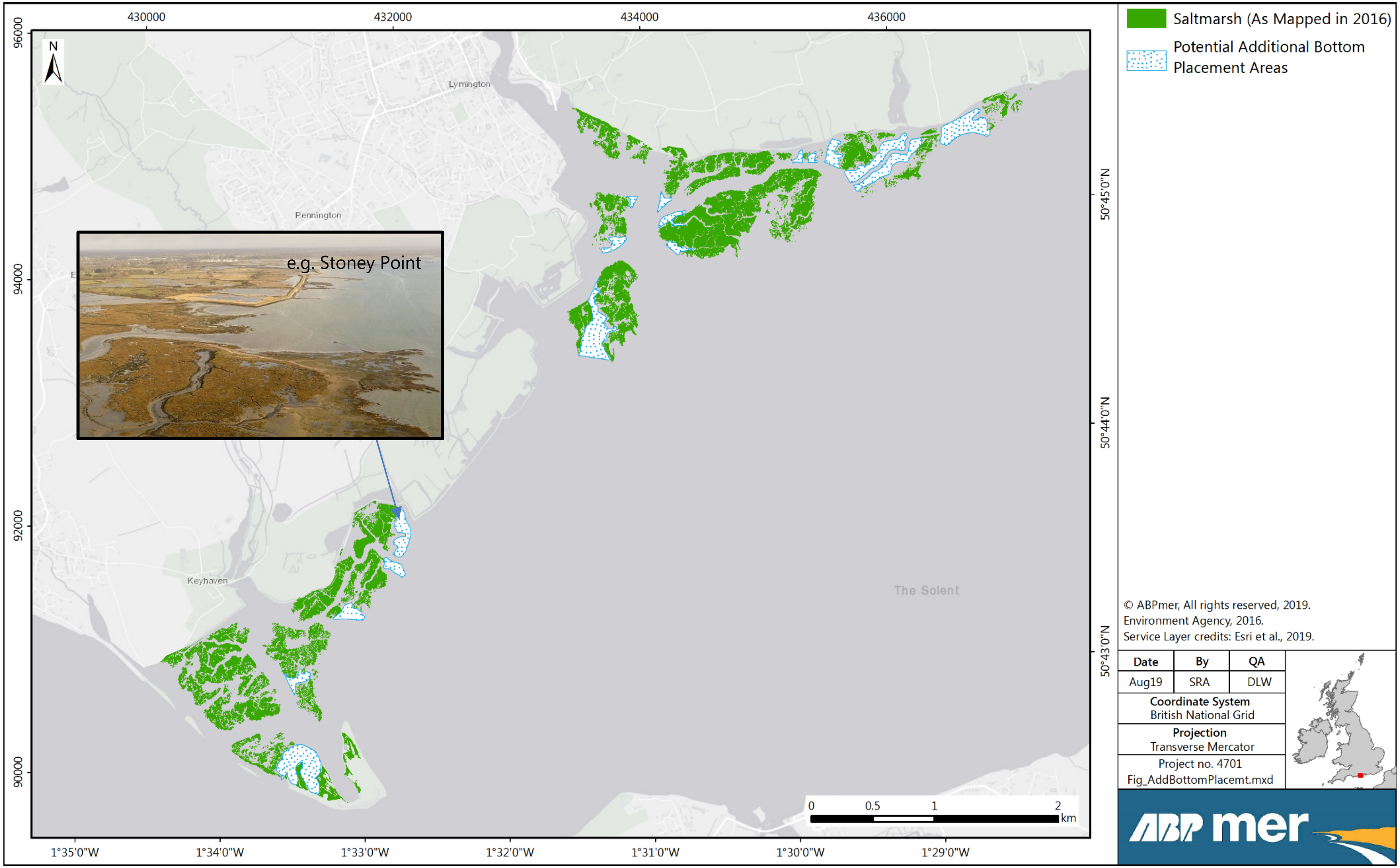


Figure 7. Potential bottom placement locations across the Hurst to Lymington marshes

4.4.2 Option 2 Moveable transfer station for 'thin layer' placement

Thin layer placement involves the piped, direct, delivery of sediment to high tidal elevations, onto and around existing vegetated saltmarsh areas. This technique has the following (potential) benefits:

- It helps to raise marsh bed levels;
- It helps marshes keep pace with rising seas;
- It can lead to both qualitatively and quantitatively enhanced marshes;
- It may modestly delay the rate of physical erosion and fracturing of the internal marshes by increasing plant and root mass cover (which will then help to bind and strengthen the surface sediments), and increasing sediment supply.

To achieve the direct delivery of dredged sediment to the higher intertidal elevations, it would be necessary to adopt methods similar to those pursued for LHC and Wightlink on the Lymington Marshes in 2012 and 2013 (see Appendix B for detail); which were:

- **Direct pumping from a cutter suction dredger**, as employed by the LHC Project, when sediment was pumped directly from the Yacht Haven Marina to the Yacht Haven Marsh[17]; and
- **Double-handling with pumping from pontoon**, as practiced for the Wightlink Ltd. project (undertaken by Land and Water Ltd). This involved delivering sediment by barge to a pontoon and then pumping sediment to the marsh.

The former approach of direct pumping from a cutter suction dredger should be less costly because it does not involve double handling of the sediment. This method was also used in the recent Brightlingsea project to fill established borrow pits in a nearby marsh complex. However, this approach can only really be applied where the receptor marsh lies close to the site of the dredging work itself, generally no further than 0.2 to 0.3 km. Pumping sediment to receptor sites over greater distances is difficult for various reasons, including the potential for causing navigation hazards where a discharge pipeline crosses main channels. The direct pumping approach also delivers sediment at relatively low densities (high water content) and therefore tends to require the inclusion of more structures on site to retain this more fluid sediment at the receiving location.

The second (double handling) approach is likely to be more costly, because it requires double handing of the sediment (excavation followed by transport to, and pumping at, a separate site). However, crucially, it offers more control over the locations for deposition and the manner in which the sediment is pumped to the receiver area. It also offers an opportunity to deliver sediment at high densities/viscosities. For example, for the Wightlink work, pumping densities of up to around 50% sediment to water were achieved as opposed to 10% with a direct cutter suction pump delivery. With this greater control, it was then easier to retain more of the deposited sediment. Pursing a variant of this approach is therefore proposed for BUDS Phase 3, and further details about the different pumping and sediment retention techniques are summarised below.

Different pumping techniques

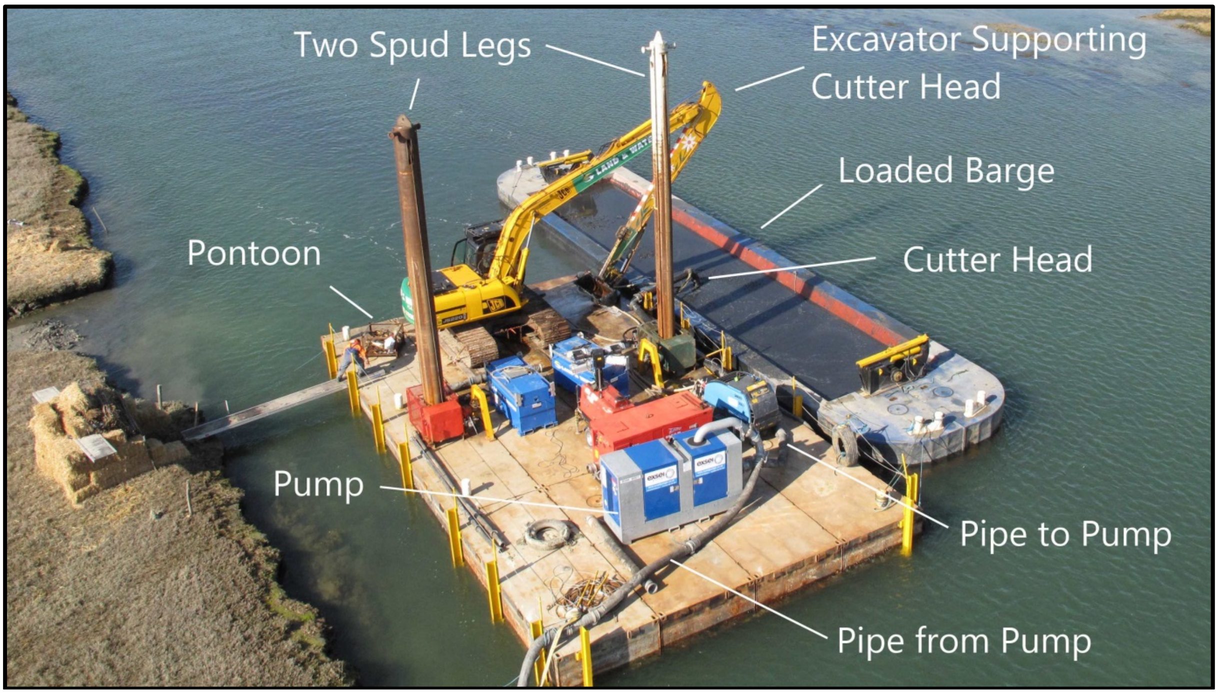
There are a few different ways in which the pumping could be pursued. One method would be to deploy cutter suction pumping equipment, as per the 'Wightlink approach' (see Image 13). For this technique, the docking and double handling platform/pontoon would be equipped with a cutter suction pump

17 A similar technique (but different equipment) was used be Royal Smals for the Brightlingsea work (see Appendices B and C) which pumped sediment over a distance of 500 to 1600 m. Depending on the sediment type and fluidity, pumping distances of 3,000 m to nearly 8,000 m (with two boosters) could in theory be achieved with existing technology

and associated equipment, to allow the sediment to be extracted from the barge and delivered to the marsh (via a pipe).

A variation to this would involve having a hopper on the platform, connected to a high-viscosity concrete pumping mechanism. In this case, the sediment would be excavated from a barge (by back hoe) into the hopper on the platform, and then delivered onto the marsh via a high viscosity pump (and connected pipe). This type of approach was used in the Norfolk Broads Salthouse Spit project to fill and cover large geo-textile tubes (see Appendix B).

The advantage of this approach is that sediment could be delivered at a high density (low water content). It could even be discharged using a positive displacement pump which would deliver sediment with a very low water content (akin to toothpaste from a tube), thus further maximising sediment stability and retention, and reducing the need for retaining structures. One of their key disadvantages however is a reduced speed at which the hoppers could be emptied (when compared to the cutter suction dredger approach), thus leading to an extended dredging period and higher costs.



Taken by: Suave air photos (2012) for Land and Water Ltd. (annotations by ABPmer)

Image 13 Equipment used for the Wightlink Ltd project on Boiler Marsh in 2012 and 2013

It might also be possible to have a pipe fixed onto a platform to which a larger trailer suction hopper dredger could attach. In this way it would be possible to have larger vessels moored up against the moveable transfer station and attached to a pipe which is already deployed on site and secured to the platform. The onboard pumping system could then be used to pump the sediment straight to the marsh. This approach could be used to deliver a wider range of grain sizes, from coarser gravels to finer silts.

Finally, a novel idea identified by Royal Smals during consultations could be to set up dredging and pumping equipment (whether cutter suction or high viscosity) on the marsh itself and then excavate a berthing 'pocket' into the adjacent mudflat. The sediment used to excavate this pocket could be used for the recharge and then spilt bottom barges could deposit directly into this pocket, with the aim of the accumulated deposited materials to be excavated and used for recharge later on. The main advantage of this approach would be that it would allow sediment to be placed as quickly as possible, and even continuously, throughout a much longer tidal window. This would ensure that there was a quick barge turnaround, thus making it relatively cheap when compared to other double handling strategies reviewed above. Disadvantages include:

- The high water content of the pumped sediment, requiring more retaining structures; and
- Damage to the existing intertidal (potentially only temporary) due to the excavation of the existing berthing pocket and the presence of plant on the marsh. This would however need to be viewed in the context of the greater gains achieved by this approach.

Lastly, fluid sediment could also be released to the site in the form of a rainbow discharge. In the US, this is done as part of a technique called 'thin layer placement' (see Image 14). Given the bathymetry in the study area, it would not be possible for a rainbow discharging vessel to approach close enough for such discharge to occur straight from a vessel. However, a pump on a mobile platform could theoretically be connected to pipes to spray discharge to spread the sediment evenly over the marshes.

Source: US Fish and Wildlife Service Northeast Region, undated

Image 14 Example of 'thin layer deposition' at the US Blackwater National Wildlife Refuge

Different sediment bunding techniques

The density of the sediment that is discharged to a receiving site will influence the distances over which the sediment can be pumped, the speed of sediment dispersion and the extent of bunding that is needed. In most cases, at least some bunding would need to be installed at the receiving marsh to help retain as much sediment as possible in the discharge area. The aim though should be to try and minimise the amount of bunding and fencing and maximise the 'naturalness' of the outcomes, although it may not always be possible to avoid artificial non-biodegradable materials.

In the first instance, the existing vegetation on site could be used to retain sediment, but extra bunding that is then needed should ideally be made of natural materials. For most previous recharge projects, this has included 'polder'/brushwood fences. Non-biodegradable geotextile tubes have frequently been employed, and may be appropriate and cost-effective. If possible, these should not be left *in situ* and should be removable within a few months (after the main sediment settlement and consolidation period). Although less tested, biodegradable geotextile tubes (e.g. made of jute) could also be employed in deeper locations or novel structures such as biodegradable 'reef' features made of processed potato starch trialled in sheltered and shallow (channel) areas. For the higher viscosity pumping techniques, bunding may not needed at all. Bottom placing materials in order to create raised mudflat areas/bunds (Option 1) could also be employed as part of the solution.

Generic approach for Option 2

Although many different variants of this technique are conceivable, for the purpose of this report, and the cost benefit analysis carried out in Section 5, it has been assumed that a pontoon or spud barge platform would be purchased/constructed and the necessary pumping and pipeline equipment bought. This equipment could also be hired every year, which would likely increase the overall, long-term, fees, but would have the benefit of reducing capital expenditure and passing on storage and maintenance fees to the hire company. It may be that the best approach would be a balance of these two (i.e. to purchase/build all the static equipment but then hire in the pumping equipment in each year), however, this was not tested for the purpose of this report/phase.

It is assumed that the spud barge/mobile platform would be positioned at locations which will be accessible by vessels with draughts of 2.3 m (as per that of the local hopper barges when fully loaded). Figure 8 identities two possible locations for such a mobile transfer station, showing approximate available draught on a means spring tide. The barges would moor up against the platform, and from there sediment would be pumped onto the most vulnerable and valuable marshes. Then, in every year going forward, this pontoon and equipment would be used to pump sediment from barges directly onto targeted areas. This recharge work would occur during the winter months when maintenance dredging is typically carried out.

This approach would provide an opportunity to deliver sediment directly onto the priority areas of the local marshes, using more sediment beneficially than is currently possible and from more locations. This approach would also allow for adaptive implementation, such that material placement can be monitored and volumes increased as confidence in the technique improves.

4.4.3 Option 3 Erosion protection and recharge

The measures proposed under Options 1 and 2 (whether carried out alone or together) will help to enhance the marsh habitats and could also, depending on the scale of the work, slightly slow the rate at which they are eroding. However, to significantly slow the erosion of the exposed outer edges of the marshes, it will be necessary to install more substantial physical protection features and to then, ideally, place dredged sediment directly behind these features at the eroding marsh edge. This dredged material could include silt but also surface layers of shingle (to provide nesting tern habitat) in some locations.

As described in the preceding section, the philosophy should probably be to employ natural and or biodegradable material such as straw/heather bales, wooden posts, polders or biodegradable geotextile tubes. However, because these structures would be exposed to stronger tidal flows and wave attack, it may be necessary to use rock, shingle or non-biodegradable geotextiles.

The advantage of this approach is that it will substantially reduce or halt the ongoing losses of marsh habitat. However, it is also likely to be more costly than Options 1 and 2 due to the extra challenges of installing the bunding walls and of directly placing sediment behind.

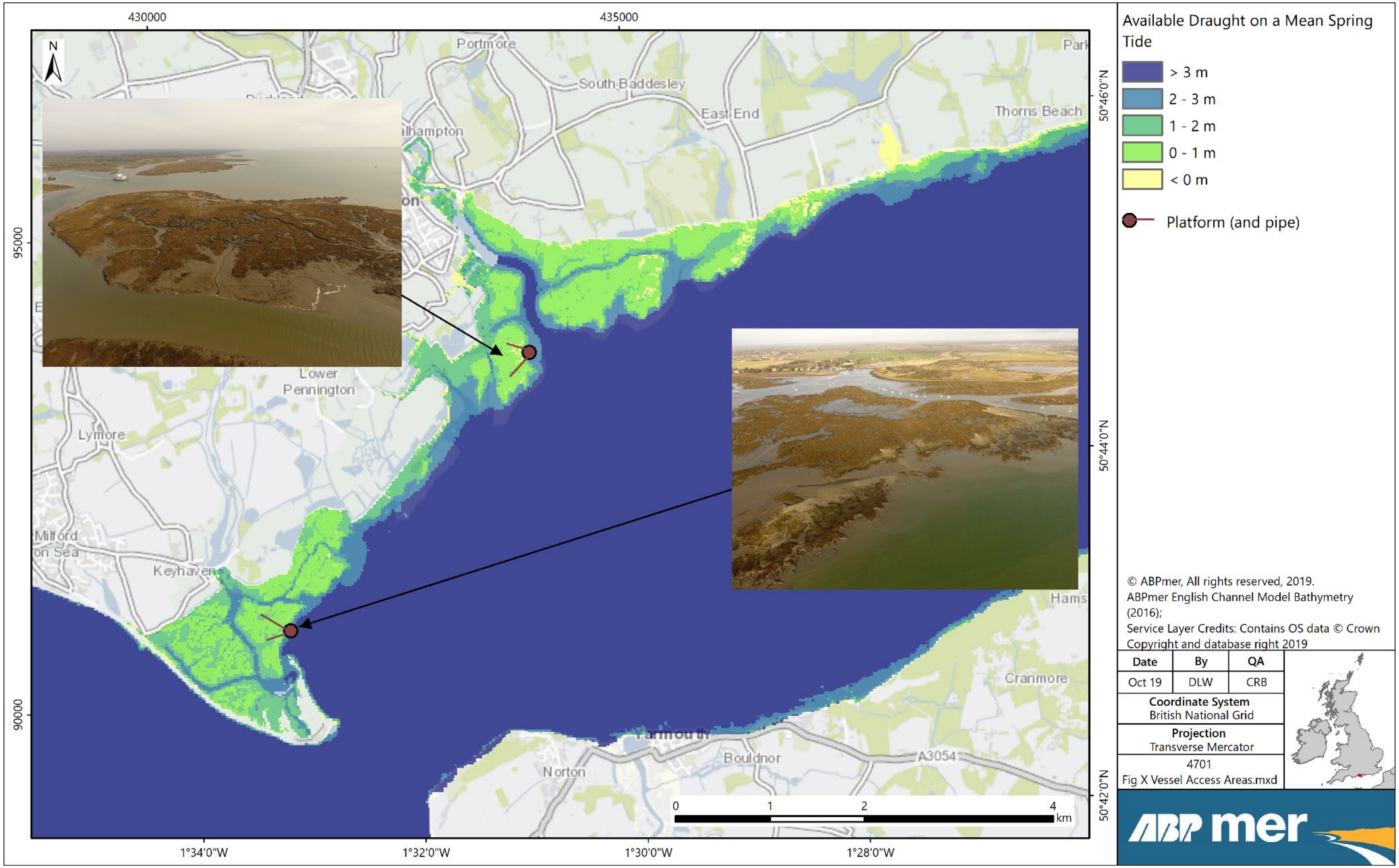


Figure 8. **Two possible locations for setting up moveable transfer stations/platforms for thin layer placement**

Generic approach for Option 3

As with Option 2, several techniques are conceivable for providing erosion protection along the outer marsh edges. For the purposes of this this report, and the cost benefit analysis carried out in Section 5, the following technique has been envisaged[18]:

- Construction of an erosion fence consisting of substantial (at least 3 m long) double row of fence posts, holding in place a big geotextile tube; and
- Backfilling of sediment between fence and marsh edge (with the sediment delivered by the movable transfer station).

4.4.4 Option 4 Large-scale recharge and bunding

In addition to the preceding approaches, there is also the possibility of pursuing a project at a larger-scale, to create saltmarsh habitat, rather than restore and protect existing habitat. To achieve this it would be necessary to create a large retaining bund and then to recharge with silt behind. This would, in essence, be a large-scale version of Option 3 and would mimic the kind of initiatives that have been undertaken in Essex at Horsey Island (see Image 15), Trimly and Shotley. Rather than carrying this work out on the fronting existing marshes edge this could be pursued, like the Essex examples, against an exposed sea wall. This is both because the wall will act as a stable and elevated structure to contain the materials but also because the work would then provide for direct protection for the sea wall.

Source: Google Earth Image

Image 15. Horsey Island aerial view

As noted in Section 4.3, the main location where this could be undertaken in the study area at this time is along the Pennington section where there is no longer any marsh at all. There is, though, a mudflat/shallow subtidal area that could be used as the platform for this work.

18 This builds on implemented projects as reviewed in Appendix C, whilst noting that this particular technique has not been applied is such an exposed location before, and that trials are thus recommended.

During the course of stakeholder consultation work for this second BUDS Phase, it has also been proposed that a large-scale sediment recharge could be carried out in the lee of Hurst Spit, using sediment to stabilise and/or manage the spit itself. For example, sediment could be used infill the channel in the lee of Hurst to facilitate barrier roll back or set directly against the barriers on its eastern side to stabilise it. This assistance with the management of Hurst Spit could have further major benefits in terms of helping to enhance coastal protection for the flood plain area behind the spit.

4.4.5 Monitoring and research

When reviewing the options above it was frequently emphasised that this work could/should be carried out in an adaptive way, with initial trials being pursued and monitoring leading to increasingly ambitious work over time. Therefore, monitoring and research will need to be a fundamental element of any work undertaken.

This does not have to, and probably should not, be an excessively costly component of a given overall project though. A lot of very valuable information is already provided by the established LiDAR survey programme and, in many cases, its analysis may merely need to be supported by targeted ground-truthing studies in the field. Also, there will be opportunities to use new cost-effective technologies including UAV and satellite imagery. Such remote sensing techniques, as well as on-site water sampling and visual observations, are probably more valuable for describing how the sediments behave than deploying much more costly water quality recording devices for example.

As part of any project implementation work, it would be very valuable to consider undertaking research work that is perhaps not essential to project delivery and consenting, but could provide important insights into benefits and fill evidence gaps, including for example:

- Planting regimes to test ways of enhancing floristic biodiversity and/or sediment binding;
- Analysis of local carbon sequestration patterns and losses;
- Analysis of physical bed level development/compaction; and
- Analysis of sediment oxygenation and influencing factors such as drainage; etc.

Such research investigations could be explored in collaboration with universities, as part of MSc and PhD research studies for example. They could also involve local residents in the form of citizen science projects.

4.4.6 Summary and drivers

To summarise this section, it is perhaps helpful to explore the anticipated cost and motives for the different techniques. Section 6 considers in much greater details the costs, the benefits and the beneficiaries in mic greater detail. In summary though:

- **Option 1**. Could increase the volumes of sediment deposited from harbours/marinas intertidally rather than offshore. This may achieve cost savings for some of them and there would be a net increase in sediment delivery directly to the West Solent. The benefits to coastal protection, harbour protection, carbon sequestration and nature conservation will be modest;
- **Options 2 and 3**. Each of these approaches would cost more than extending bottom placement, but would provide greater benefits for coastal protection, harbour protection, carbon sequestration and nature conservation. Both the costs and the benefits would be larger for Option 3 than for Option 2;
- **Option 4.** This would be the most expensive option, but it would deliver the largest amount of habitat and potentially also the largest benefits for coastal protection, harbour protection, carbon sequestration and nature conservation. This could be a compensation measure linked to coastal development, but there would also need to be certainty of net habitat improvement.

5 Stage 3 Cost Benefit Analysis

5.1 Introduction

To understand and help prioritise possible beneficial use interventions along the West Solent frontage, the potential costs and benefits of four example projects were assessed. These four example projects tested the four intervention options described in Section 4.4 above at specific locations as follows (see Image 16):

- **Project Example 1**: Bottom placement (mud) at Stoney Point;
- **Project Example 2**: Moveable transfer station for thin mud layer placement at Boiler/Pylewell Marsh;
- **Project Example 3**: Erosion protection and behind-fence mud recharge at Boiler/Pylewell Marsh; and
- **Project Example** 4: Large scale shingle bund and behind-bund mud recharge at Pennington.

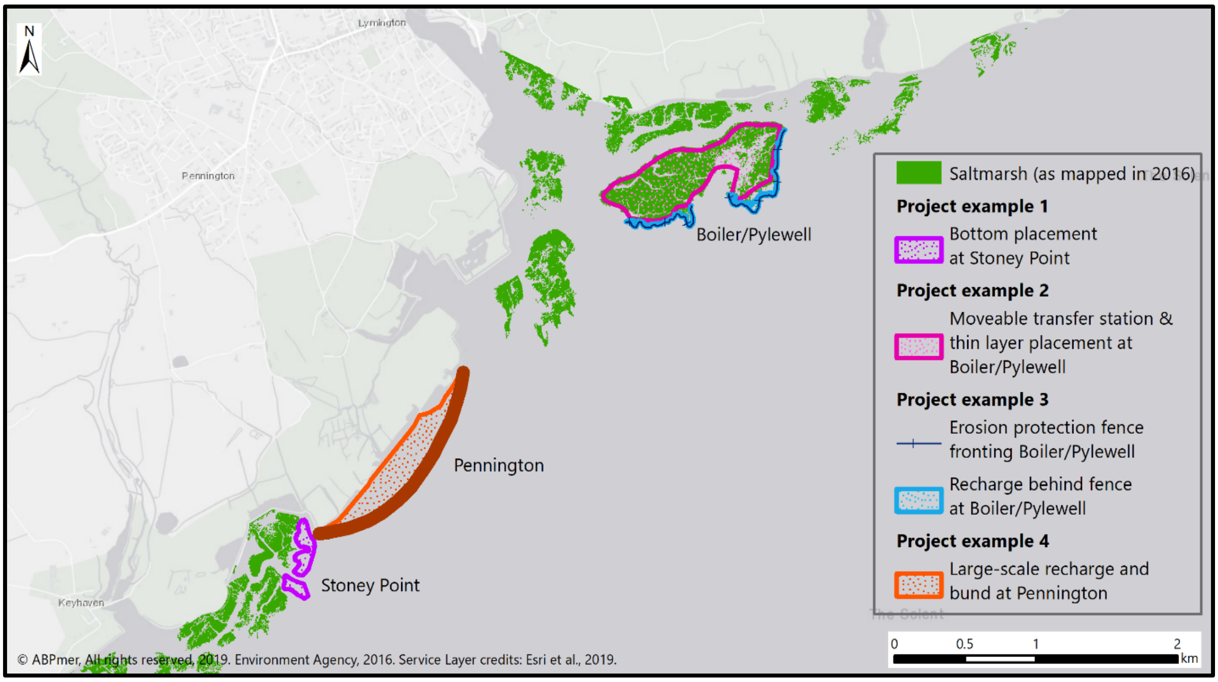


Image 16. Location of the CBA case study sites

5.1.1 Costs of beneficial use projects

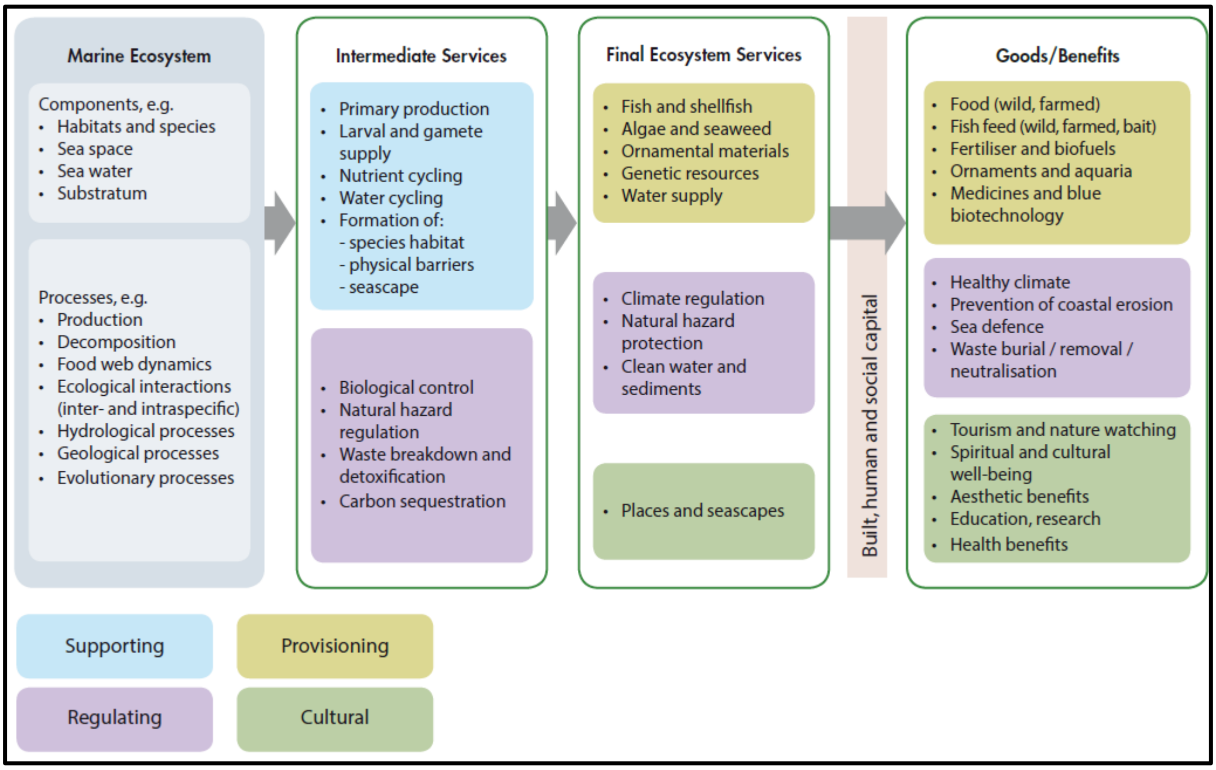
To inform this analysis, an updated review of the costs of recharge projects was carried out, which is included as stand-alone text in Appendix C. This review includes cost details and other information obtained from stakeholders and specialist contractors.

As described during the BUDS Phase 1 review (ABPmer, 2017), the main costs associated with intertidal sediment recharge are those associated with transport, handling and placement of material. However, the consenting and monitoring costs can also be a significant proportion of the overall fee. For the purposes of this review therefore, costs projections are included for these elements.

5.1.2 Benefits valuation

There is little project specific information on the quantified benefits of completed intertidal sediment recharge projects in the literature, or from practitioners. The analysis has therefore largely focused on the generic benefits of saltmarsh and mudflat creation, taking an ecosystem services approach.

The National Ecosystem Assessment Follow-on project (NEAFO) developed a framework for describing marine ecosystem services (Turner *et al.*, 2014) (see Image 17) and the benefits that humans derive from them. This framework is useful in supporting the valuation of environmental benefits, as it focuses on the final ecosystem services benefits that humans derive from ecosystems and thus avoids the risk of double counting.



Source: Turner *et al.*, 2014

Image 17. Marine Ecosystem Services Framework showing key benefits to humans

Key benefits associated with the creation of marine habitats (principally mudflats and saltmarsh) through the implementation of beneficial use projects include (see Section 3.6.1 for more detail on most of these aspects):

- **Food**: enhanced fish production; shellfish and aquaculture;
- **Healthy climate**: carbon sequestration;
- **Prevention of coastal erosion** by providing shelter;
- **Sea defence**: reduced costs of maintenance; delay/avoidance of new defences;
- **Waste burial/removal/neutralisation**: avoidance of impacts at disposal site (Kay *et al.*, 2005; Peterson *et al.*, 2008);
- **Tourism and nature watching**: increased opportunities for nature watching;
- **Spiritual and cultural well-being**: increased recreational opportunities, non-use benefits (UK National Ecosystem Assessment (NEA), 2011);
- **Aesthetic benefits**: improved visual appearance (UK NEA, 2011);
- **Education/research**: opportunities to study restoration (UK NEA, 2011); and
- **Human health**: the values for health and well-being (UK NEA, 2011).

Various estimates of the monetary value of marine ecosystem services, and of the specific contributions from saltmarsh and mudflat habitats, are available from The Economics of Ecosystems and Biodiversity (TEEB) database (Balmford *et al.,* 2008) and other online sources. However, care needs to be taken in seeking to transfer habitat values to other situations, because the values often reflect bundles of marine ecosystem services relating to a specific location which may not be transferable to different situations (United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), 2011).

Available data does, however, indicate that the ecosystem service values of intertidal habitats such as saltmarsh can be high. For example, a review of European wetland valuations by Brander *et al.* (2006) concluded that saltmarsh had a value of approximately £1,400 ha^{-1} yr^{-1} (at 2008 prices) (across a range from £200-£4,500 ha^{-1} yr^{-1}), while that of intertidal mudflats was around £1,300 ha^{-1} yr^{-1} (at 2008 prices) (ranging from £200-£4,300 ha^{-1} yr^{-1}). This was based on default 'indicative economic values' for habitats on the basis of them providing the following 'bundled' ecosystem services of: water quality improvement, recreation, biodiversity and aesthetic amenity.

Importantly, these bundled values do not include values for several benefits, notably those associated with carbon sequestration or flood protection. Both carbon sequestration and flood protection are potentially important additional ecosystem services benefits provided by saltmarsh compared to mudflat. As noted in Section 3.6.1 above, healthy saltmarsh can sequester significant quantities of carbon, equivalent to around 7.33 t CO_2 ha^{-1} yr^{-1}. Based on the current non-traded price of carbon of £68 per tonne (2019 prices), this equates to a value of over £500 ha^{-1} yr^{-1}. As non-traded carbon prices increase significantly over time, the economic value of carbon sequestration will also increase in future. For example, the non-traded carbon price is projected to reach £300 per tonne of CO_2 over the next 50 years.

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 £4,950 km yr^{-1} in flood defence expenditure on the Blackwater Estuary. The presence of healthy saltmarsh may also avoid the need for the construction of new flood defences. King and Lester (1995) indicated than an 80 m width of saltmarsh could avoid a construction cost of £4,800 m^{-1} of new sea defence. Hudson *et al.* (2015) indicate that the construction costs of impermeable revetments and seawalls can range between £700 – 5,400 m^{-1} (at 2007 prices).

There is limited information on wider non-use values associated with intertidal habitat restoration/ creation projects, but Willingness-to-Pay studies have indicated that non-use values can be significant. For example, Luisetti *et al.* (2011) estimated a non-use benefit of around £2,000 yr^{-1} for a hypothetical 81.6 ha managed realignment project on the Blackwater Estuary (around £25 ha^{-1} yr^{-1}). However, it is unclear whether the non-use value of saltmarsh might be different from mudflat and thus whether there is any additional non-use value associated with the creation of saltmarsh in place of mudflat.

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

5.1.3 West Solent beneficial use cost benefit analysis assumptions

Cost and benefit estimates (2019 prices) have been prepared for the four example projects based on assumptions about continued change along the West Solent frontage and the impacts of the proposed interventions. For each example project, an assessment has been carried out of the costs and benefits associated with

- Business as usual ('No Intervention'), and
- The specific 'Intervention' – implementing the example project.

These estimates have sought to focus on those costs and benefits that are likely to be different between each 'No Intervention' and 'Intervention' option and therefore provide a partial CBA. For example, the assessment does not consider the port and harbour related benefits of the dredging activity, as these benefits will be the same in both the 'No Intervention' and 'Intervention' scenarios.

The assessment has been carried out using a time period to 2100, reflecting that many of the benefits will only accrue over long time scales. Costs have been discounted over time following HM Treasury Green Book guidance (HM Treasury 2018) to estimate a Net Present Value (NPV) which enables the costs and benefits of 'No Intervention' and 'Intervention' for each option over time to be compared.

It is important to note that in comparing the costs and benefits, the main interest is in the relative NPV for 'No Intervention' and 'Intervention' for each option. This is because the CBA is only examining those costs and benefits that may change as a result of 'Intervention'. Thus, for example, where 'Intervention' results in an overall reduction in net cost compared to 'No Intervention', then the 'Intervention' is providing an overall benefit.

In order to undertake the CBA, a large number of assumptions needed to be made in relation to:

- The costs of the beneficial use options;
- The consequences of doing nothing (likely future rates of marsh decline and timing of new capital flood defence and harbour protection works);
- The effects of the beneficial use options in reducing rates of marsh erosion and deterioration and in deferring capital investment in flood defence and harbour protection works; and
- The monetary values of these benefits.

These assumptions were informed by evidence from the baseline and background review, including that of costs and benefits. In particular, the quality of evidence on historic and current rates of marsh erosion and deterioration for the West Solent is good and provides a reasonable basis for projecting future change. Similarly, emerging confirmation on the effectiveness of existing beneficial use schemes at Lymington and elsewhere provides a useful evidence base in understanding the effectiveness of different interventions in reducing erosion and deterioration of the marshes and thus informs judgements of the extent to which interventions might delay the requirement for capital investment in flood protection or harbour protection works. The work to better understand the costs of beneficial use schemes also provides greater assurance on the likely costs of projects.

With regard to the sediment required for each of the options which assume the use of maintenance dredge arisings (i.e. Options 1 to 3), it is assumed that at least 15,000 m^3 will be available from various sources every year. Section 3.4 describes the licensed dredged resources from other nearby locations, and their existing disposal practices. It also explains how the dredging commitments for these harbours varies greatly from year to year and that there may be beneficial use sites local to them (e.g. at Beaulieu) which may represent a better beneficial use opportunity for that harbour than the Hurst to Lymington area.

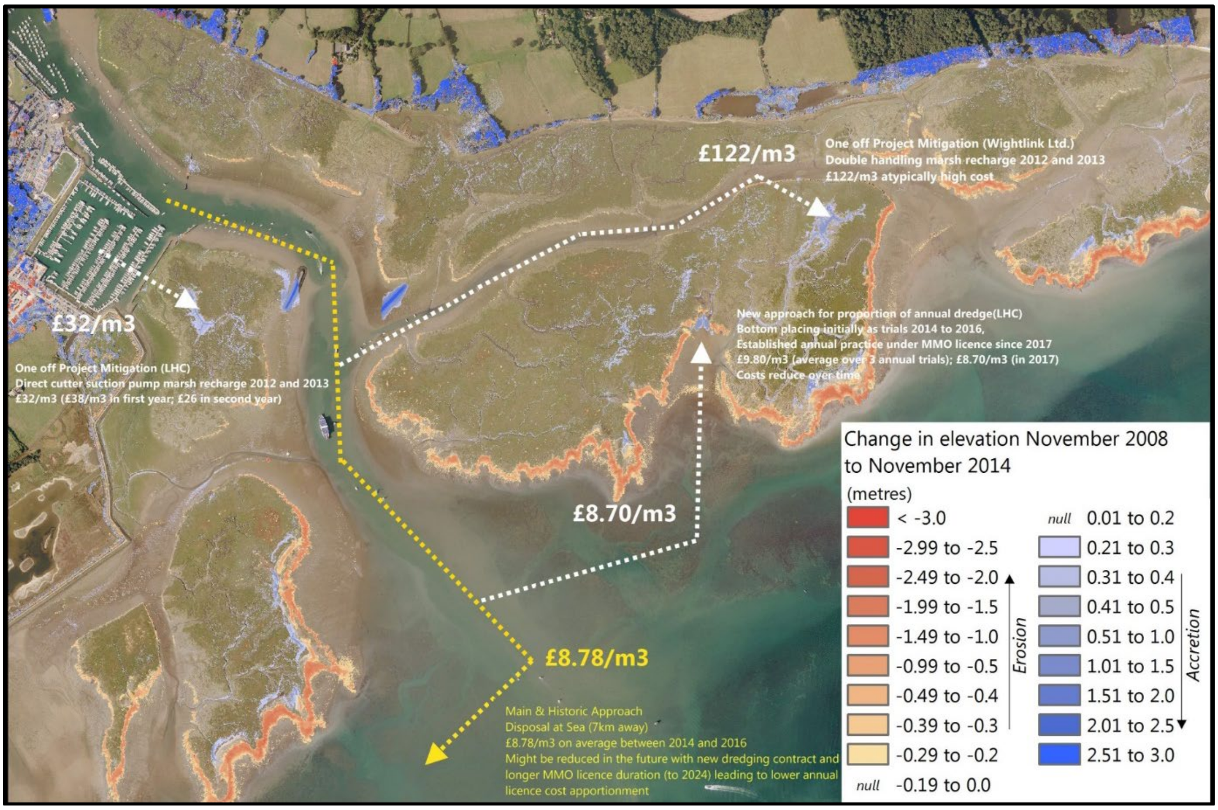
In theory though, the maximum amount of sediment that could be obtained from all these sources is around 15,000 m³ annually (in addition to approximately 20,000 m³ from Lymington alone), but it is assumed that at least a third of this volume (around 5,000 m³) could be readily and realistically obtained for use in the West Solent marshes in the short term. However, the ambition would be to achieve at least double this volume annually within a short space of time[19].

5.2 Option 1 Extended bottom placement

5.2.1 Cost assumptions

A relatively clear idea of the costs that would be incurred for the Option 1 'extended bottom placement approach' is provided by the work that is already being done, using the same method, at Lymington. It is of immense value that the costs for this established work have been clearly audited, and shared, by the LHC.

LHC's average costs have reduced from £9.80 m^{-3} during the trial phase to £8.70 m^{-3} for deposition over the last two winters. The latest average costs are slightly lower than the costs of taking this material to the Hurst disposal ground (which is £8.78 m^{-3} on average). This reduction is largely due to a reduction in monitoring costs/effort. Comparisons between this cost and those from other beneficial use approaches at Lymington are shown in Image 18. The LHC fee includes an annual apportionment for securing the dredge and disposal licences. For the initial beneficial use trials, additional licencing fees amounted to roughly an extra £20,000.



Environment Agency LiDAR data; ESRI *et al.*, 2019

Image 18. Overview of the costs (per m³) of recent Lymington beneficial use options

[19] From latest available Defra data on offshore deposits from 2015 to 2017, around 25,000 m³ is typically placed at Hurst deposit ground each year, and the aim would be to try and make this site almost redundant. If this can be done, there is every reason to believe that an annual placement of 10,000 m³ could be achieved.

When considering future cost savings, the differences in sediment transport distances and timings are important considerations. It is notable that transporting sediment from Lymington to the Hurst disposal site takes 1.5 hours, whereas a return trip to the Boiler Marsh recharge site takes around 30 minutes. However, it needs to be borne in mind also that disposal at both sites is tidally constrained. Disposal at Boiler Marsh is confined to high water periods, and disposal at Hurst is restricted to the first four hours of the ebb tide (to avoid deposits onto nearby shellfish beds). Thus, the rate of disposal and therefore overall duration, and potentially the cost, of a full dredging and disposal programme are influenced not just by haulage time and fuel costs but also temporal scheduling to fit in with appropriate tidal windows.

These tidal windows will also influence the availability of dredged sediment from other harbours in the Solent. It is expected that, with careful planning and scheduling, additional bottom placement beneficial use sites in the study area could receive a good proportion of sediment from the following sources:

- **Yarmouth** – marginal increase in haulage distance;
- **Beaulieu** - marginal reduction in haulage distance;
- **Cowes** - reduction in the haulage distance by around half; and
- **Hamble**- reduction in haulage distance by around third.

To maximise the opportunities for beneficial reuse from Lymington or other harbours, the ambition would be to license a number of locations between Hurst and Lymington where sediment from these harbours could be bottom-placed. While the ideal locations will be upper mudflat areas accessible only at high water, this could include some nearshore sites that are accessible at a broader range of tidal states.

5.2.2 Project Example 1 - Stoney Point

To carry out the CBA for the bottom placement work, it is assumed that Stoney Point site will be used as a new bottom placement deposit ground which can receive sediment from Lymington and other West Solent locations. As described in Section 4.4.1, the marsh and sea wall could provide shelter for these deposits, as well as benefiting from them to a small degree. The expectation is that much of the deposits will winnow away in the prevailing drift and will modestly recharge the mudflat and marsh areas to the east (including along the Pennington frontage). Some small quantities may also recharge the surface of Stoney Marsh.

There are two discrete deposit locations on the seaward of these marshes that lie either side of a channel through the marshes. These two deposit areas are collectively 5 ha in size. This area could theoretically receive around 40,000 m^3 in total up to the 0.1 m ODN tidal level (i.e. just below mean sea level (MSL) depth that will allow for vessel access). Assuming 10,000 m^3 is placed every year and only 20% of it remains by the following winter season, then this deposit ground would have capacity for around 20 years. However, it may well be that even more of the placed sediment erodes and that reaching capacity takes longer or is never achieved. Around 1 km of sea wall benefits from protection by the marsh behind the recharge.

The cost and benefit assumptions for this approach are described further in Table 10 ('No Intervention') and Table 11 ('Intervention'). A cost benefit analysis was carried out for those elements of the assessment where there were differences between 'No Intervention' and 'Intervention'. These were restricted to:

- Differences in costs between disposal and beneficial use;
- Differences in costs and timing of sea wall expenditure; and
- Differences in timing of carbon release from eroding saltmarsh.

The overall NPV net cost under 'No Intervention' was estimated to be £1.812m. The overall NPV net cost under 'Intervention' was estimated to be £1.716m. The lower NPV net cost under 'Intervention' is wholly accounted for by the deferring of capital expenditure to rebuild sea wall by 5 years. This more than offsets the small additional costs associated with implementing the beneficial use project.

The Benefit:Cost ratio for the intervention is estimated to be around 2.1.

While carbon release occurred more slowly under 'Intervention' scenario, overall NPV costs were similar due to escalating price of non-traded carbon over the time scales of the assessment (which offset effect of discount rate used) and thus the effect of delayed erosion.

Table 10. Project Example 1 - Assumptions for 'No intervention'

Costs/Benefits	Assumptions
Costs of No Intervention	
Existing 'at sea' disposal cost per year	Cost will vary depending upon the source location. It will be lower (~£8 m^{-3}) from Lymington and Yarmouth and higher (anywhere between £10-16 m^{-3}) from Cowes or Hamble. An average cost of £10 m^{-3} is assumed.
Sea defence costs	Maintenance costs of around £60 m^{-1} every 5 years, or £12 $m^{-1}yr^{-1}$ (based on Environment Agency pers. comm.), until 2029. Rebuild will occur in 10 years' time (2029), at a cost of £1,000 m^{-1}, after which maintenance is reduced by half to £6 m^{-1} for the next 15 years (until 2044)[1].
Value of carbon being released by eroding marsh (frontal erosion only[2])	The value of the carbon contained within a cubic metre of marsh sediment is estimated at £2.81 (2019 values)[3], increasing to £9.49 by 2050 and £12.72 by 2100. The marsh currently holds a volume of around 272,000 m^3 (above MHWN). The following rates of erosion have been assumed: 2,720 m^3 $year^{-1}$ (3 m $year^{-1}$), 2019 to 2050; 16,320 m^3 $year^{-1}$, from 2050 (with all of the sediment volume lost by 2061).
Benefits of No Intervention	
Benefits of ecologically deteriorating and physically eroding saltmarsh	Without intervention, the 16 ha of vegetation in the lee of the recharge will be gone by around 2045. Vegetation decreases will continue at established 2% $year^{-1}$ for the next decade, before then increasing more rapidly as exposure increases and sea level rise continues to have an effect. The benefits of the residual marsh area have been assessed taking account of the area of this marsh and assuming that it only provides 50% of the Brander bundle of benefits provided by a healthy marsh (2019 values; £848 ha^{-1} yr^{-1}).
Benefits from 'mudflat' formation	The loss of marsh habitat will create 'new' mud habitat. However, this habitat is expected to be of low quality comprising a clay matrix with reduced benthic infauna. 'Mud' assumed to provide a benefit of only 50% of the value of the Brander mudflat bundle (£787 ha^{-1} yr^{-1} at 2019 prices)
Carbon sequestration by residual marsh	The residual marsh continues to sequester carbon, but at a rate of only 25% of that of healthy marsh (25% of 7.33 t ha^{-1} yr^{-1}).

1 As noted previously, it is not currently known when/whether a substantial capital investment is needed in the sea wall.
2 Vertical erosion also contributes to carbon loss to some extent, but this is considered to be a smaller loss and has not been included in the calculations here, so frontal erosion is the focus.
3 Estimates of the value of lost carbon have been based on observed rates of ongoing sediment losses, the bulk density of the sediment, the proportion of organic matter in the sediment, the CO_2 equivalent value of the carbon in that organic matter, and BEIS (Department for Business, Energy and Industrial Strategy) non-traded carbon value projections.

Table 11. Project Example 1 - Assumptions for 'Intervention'

Costs/Benefits	Assumptions
Costs for Intervention	
Beneficial use disposal cost (additional fees)	**Consenting:** £40,000 in Year 1, to secure licences for deposition[1]. **Mobilisation:** No additional cost for plant and equipment is anticipated beyond the business as usual approach (assumes that operational hopper barges will be able to place sediment at suitable elevations). **Implementation:** Management costs of around £5,000 yr^{-1} for the first 5 years (£25,0000 total); cost neutral thereafter (as the practice becomes established). **Monitoring:**. £7,000 yr^{-1} on average over the first 5 years (£35,000 total); cost-neutral thereafter (no extra differential).
New sea defence cost per m	Sediment placement delays the requirement for a new sea defence by 10 years (to 2039) by reducing the frontal erosion rate of the existing marsh. Prior to the construction of the new sea wall, it is assumed that annual maintenance costs will be £12 m^{-1}, reducing to £6 m^{-1} for the 15 years following its construction (i.e. to 2054), thereafter reverting to £12 m^{-1}.
Value of carbon being released from eroding marsh	Rate of physical marsh erosion reduced by 10% based on observations of the impact of existing sediment placement schemes, 10% less carbon lost.
Benefits of Intervention	
Benefits for ecologically deteriorating and physically eroding saltmarsh	Very little of the sediment is expected to recharge the marsh surface and therefore this approach is unlikely to materially delay the loss of vegetated marsh in the face of other acting processes (sea level rise and sediment biogeochemistry). It has therefore been assumed that the rate of marsh loss is the same as for 'No Intervention'.
Benefits from 'mudflat' formation	The rate of mudflat formation and the quality of that mudflat will be the same as for 'No Intervention' as the intervention is not expected to slow the rate of marsh loss (as benefits of higher mudflat elevations difficult to value).
Carbon sequestration by residual marsh	Carbon sequestration will be the same as for 'No Intervention' as the intervention is not expected to slow the rate of marsh loss.

1 This is based on experience at Lymington but recognises that an increased amount of assessment and sampling work would be needed to secure consents and licence these new sites. It is assumed that no detailed hydrodynamic modelling would be required but this might cost a further £25,000.

5.3 Option 2 Transfer Station for 'Thin Layer' Placement

5.3.1 Cost assumptions

For this option, the costs are more uncertain than for Option 1 because this is not an approach which has been regularly carried out in the past. It is clear though that fees will be incurred for the following key elements:

- Obtaining consents,
- Retaining bund/structures installation,
- Purchase or hire, and/or mobilisation of pontoon and equipment;
- Maintenance and servicing of pontoon and equipment (where purchased);
- Additional time required for barge turnaround; and
- Carrying out monitoring.

The costs will be higher than the bottom placement work in Option 1, but will also be highly variable, depending on a range of factors, including:

- Scale (which influences project duration);
- Location (which influences haulage distances, transfer times, pipeline lengths and pumping requirements); and
- Whether the equipment is purchased or is hired for each season.

While there are many uncertainties associated with this approach, a high-level fee for a specialist team to mobilise and hire the necessary equipment for a moveable transfer platform has been quoted at £30,000, and the fees for such a team to carry out the work itself (i.e. the receiving and transferring of sediment from hoppers to the marsh) has been quoted at around £10/m^3. If it was assumed that initial campaigns would involve the reuse of 5,000 m^3 of materials, this would equate to an additional cost of £50,000 yr^{-1} compared to normal sea disposal. On this basis, an annual cost of around £80,000 to £100,000 would seem to be appropriate for pursuing a hire approach (£30,000 for mobilisation; £50,000 for the work plus further costs for monitoring and consenting requirements).

However, these hire-related costs are high and an alternative approach (which has been applied for the CBA) would be to purchase certain components (e.g. pipes), have others bespoke built (e.g. pontoon platform), and then only hire in what is needed (e.g. pumping equipment). This would raise the Year 1 costs, but allow for reductions over time. Purchase of the pontoon and equipment has been estimated at around £300,000[20].

Having the equipment on site and paid for, as well as lower annual fees, would also mean that projects are more likely to be undertaken on a reliable basis each winter. Most importantly, there would be a greater level of local ownership and involvement in the process through the purchase. However, there are disadvantages of purchasing equipment compared to hiring related to staff training, annual maintenance, storage and equipment becoming dated/not adaptable (e.g. longer lengths of pipeline or concrete pumps with different power levels that are appropriate to the proposed pump distances).

While it might be possible to drive costs down over time as operations become more efficient and as confidence grows in the effectiveness of the approach, it is unlikely that this approach would ever become cost-neutral when compared to the current situation/disposal at Hurst. Savings on fuel will be made from having shorter haulage distances, but other costs will be higher. In terms of time, barges will have shorter haulage distances, but will be stationed at the transfer station for longer such that the overall annually dredging programme would likely be slightly extended. There would also be, as described above, ongoing fees for aspects such as plant maintenance and storage.

For this marsh recharge technique, there will be a need for some internal fencing to retain sediment. The aim (as noted in Section 4.4.2) is to minimise this bunding and use the landform and vegetation as much as possible. However, some carefully placed short lengths of bunding/fencing will be needed to maximise the effectiveness of this approach. It is estimated that a 70 m length of brushwood fencing is installed which is likely to cost £10,000. This is a lower fee than has been incurred for previous Lymington restoration projects but reflects the fact that the bunds will not need to be as extensive as for these previous projects.

It would also be possible to complement a brushwood fence with other cost-effective structures. One such feature might be 'Biodegradable Elements for Starting Ecosystems' (BESE). These come as 2 cm-high sheets that cost around €5 each. They need to be laid as three sheets clipped together (i.e. 6 cm

20 This is on the basis of six Ravestein units at £20,000 each, plus the spud legs and a concrete pump with associated pipeline.

total height) and there would be 6 sheets/m² (thus costing around €30/m²). One advantage of this material is it could be laid sequentially over time to gradually raise a bed level. A higher bund that is 24 cm high and 20 m long would cost around €2,400 (using 480 individual sheets). Extra costs would be incurred for the equipment to fix the elements in place (e.g. posts and biodegradable ropes/ties), and for the labour and monitoring. Given that the use of such elements for beneficial use is as yet untried, trials are recommended, and the CBA below has not assumed the use of BESE elements. Overall costs of a trial are anticipated as roughly £7,000 (again not included below).

5.3.2 Project Example 2 – Boiler/Pylewell Marsh

To carry out a CBA for the moveable transfer station, it is assumed that the Boiler/Pylewell Marsh site will be used and will receive sediment from Lymington and other West Solent locations.

The marsh surface is around 50 ha and this could theoretically receive at least 110,000 m^3 to the 1.12 m ODN tidal level (i.e. MHWS), to achieve dense marsh plant coverage and effective bird nesting areas. Assuming 5,000 m^3 is placed every year and 80% of it remains by the following season, then this deposit ground would have capacity for around 100 years. However, it may well be that more of the placed sediment erodes and that reaching capacity takes longer or is never achieved.

The cost and benefit assumptions used for the project example are described further in Table 12 ('No Intervention') and Table 13 ('Intervention').

Table 12. Project Example 2 - Assumptions for 'No Intervention'

Costs/Benefits	Assumptions
Costs for No Intervention	
Existing 'at sea' disposal cost per year	Cost will vary depending upon the source location. It will be lower (~£8 m^{-3}) from Lymington and Yarmouth and higher (assumed anywhere between £10 and 16 m^{-3}) from Cowes or Hamble. An average of £10 m^{-3} is assumed.
New harbour protection cost	It is assumed that additional harbour protection works will be required from 2030. It is assumed that these are constructed over the period 2030 to 2039 at a cost of £2m per year (2019 prices) (£20m over 10 years).
Value of carbon being released from eroding marsh Loss per year	The value of the carbon contained within a cubic metre of marsh sediment is estimated at £2.81 (2019 values)[3], increasing to £9.49 by 2050 and £12.72 by 2100. The existing marsh holds a volume of around 855,000 m^3 (above MHWN, the following rates of erosion have been assumed: 12,825 m^3 per year (1.5% year-^{1}) 2019 to 2050. 5% $year^{-1}$ from 2015 (with all of the sediment volume lost by 2061).
Benefits for 'No Intervention'	
Benefits for ecologically deteriorating and physically eroding saltmarsh	Without intervention the existing 37 ha of vegetation will be gone by around 2050. Vegetation decreases will continue at the established 2% per year for the next decade, before then increasing more rapidly as exposure increases and as sea level rise continues to have an effect. The benefits of the residual marsh area have been assessed taking account of the area of this marsh and assuming that it only provides 50% of the Brander bundle of benefits provided by a healthy marsh (£848 ha^{-1} yr^{-1} at 2019 prices).
Benefits from 'mudflat' formation	The loss of marsh habitat will create 'new' mud habitat. However, this habitat is expected to be of low quality comprising a clay matrix with reduced benthic infauna. This 'mud' is assumed to provide a benefit of only 50% of the value of the Brander mudflat bundle (£787 ha^{-1} yr^{-1} at 2019 prices).
Carbon sequestration by residual marsh	The residual marsh continues to sequester carbon, but at a rate of only 25% of that of healthy marsh (25% of 7.33 t ha^{-1} yr^{-1}).

A cost benefit analysis was carried out for those elements of the assessment where there were differences between 'No Intervention' and 'Intervention'. These were restricted to:

- Differences in costs between disposal and beneficial use;
- Differences in costs and timing of harbour protection expenditure;
- Differences in timing of carbon release from eroding saltmarsh; and
- Differences in benefits from increased longevity and function of residual marsh.

Table 13. Project Example 2 - Assumptions for 'Intervention'

Costs/Benefits	Assumptions
Costs for Intervention	
Beneficial use disposal cost (additional fees)	**Consenting:** £60,000 in Year 1, to secure a licence for deposition[1]. **Mobilisation:** Would depend on whether the project was sub-contracted to specialists or undertaken 'in house' using purchased/hired equipment. The latter approach has been assumed. £300,000 assumed for Year 1 to purchase (and assemble/build): the pontoons, pipes and bunding/brushwood fencing. Thereafter, only the pumping equipment is hired each season at estimated fee of £10,000 yr^{-1}. **Implementation and monitoring:** based on project scale of 5,000 m^3 per annum[2], an extra £15,000 $year^{-1}$ assumed for first 5 years for: project management, equipment maintenance and monitoring. Reduced to £5,000 $year^{-1}$ from year 6 onwards (equipment maintenance only).
New harbour protection cost	Additional harbour protection works delayed by 5 years (so required from 2035), now constructed over the period 2035 to 2044 at a cost of £2m per year (2019 prices) (£20m over 10 years).
Value of carbon being released from eroding marsh	Rate of physical marsh erosion reduced by 10%, to 2050. From 2050 onwards, it is assumed that rates of loss increase to 2% $year^{-1}$ (rather than 5% $year^{-1}$ assumed in no intervention scenario) with complete erosion of the marsh by 2082.
Benefits for 'No Intervention'	
Benefits for ecologically deteriorating and physically eroding saltmarsh	The sediment is expected to recharge the marsh surface and delay, to some extent, the loss of vegetated marsh in the face of other acting processes (sea level rise and sediment biogeochemistry). The quality of the marsh is also improved. The rate of marsh loss is reduced, with marsh persisting until 2080. Marsh is lost at a rate of 1% $year^{-1}$ for the next decade, rising to 1.5% $year^{-1}$ to 2050 and then 2% $year^{-1}$ until all marsh is lost in 2080. The residual marsh provides 75% of the Brander bundle of benefits provided by a healthy marsh (£1272 ha^{-1} yr^{-1} at 2019 prices).
Benefits from 'mudflat' formation	The loss of marsh habitat will create new 'mud habitat. The habitat is expected to be of low quality comprising a clay matrix with reduced benthic infauna It is assumed that where marsh is converted to 'mud' this provides a benefit of only 50% of the value of the Brander mudflat bundle (£787 ha^{-1} yr^{-1} at 2019 prices)
Carbon sequestration by residual marsh	It is assumed that the residual marsh continues to sequester carbon at a rate of 50% of that of healthy marsh (50% of 7.33 t ha^{-1} yr^{-1}).

[1] this is higher than for bottom placement in recognition of the likely need for extra assessment and sampling work to secure consents and licence the new sites. This sampling work would likely include field surveys for habitat mapping and to ground truth available remote sensing data.
[2] the assumption being that larger projects which use greater volumes of sediment would be more expensive.

The overall NPV net cost under 'No Intervention' was estimated to be £13.5m. The overall NPV net cost under 'Intervention' was estimated to be £11.5m.

The differences are accounted for by:

- Increased disposal costs (additional NPV cost of £1.4m)
- Deferred capital expenditure to build harbour protection works (reduced NPV cost of £1.9m)
- Slower rates of carbon release (reduced NPV cost of £1.0m)
- Increased benefits from increased longevity of saltmarsh (additional NPV benefit of £0.5m)

The additional costs of beneficial use are more than offset by the savings from deferred capital expenditure on harbour protection works. There is also a significant benefit as a result of slower release of carbon from the marsh. There is also some benefit from greater persistence of saltmarsh but the scale of these benefits is assessed as being smaller than the effect of deferring harbour protection expenditure or reducing erosion.

The Benefit:Cost ratio for this intervention is estimated to be around 2.4.

5.4 Option 3 Erosion protection and recharge

5.4.1 Cost assumptions

The issues and the estimated costs that were quoted in the preceding section for Option 2 will also general apply for this approach. That is because both approaches involve pumping sediment to the existing marshes, although some of the pumping for this option could be direct from a vessel, depending on available draught.

With this approach there will be some addition technical challenges when compared to Option 2. The bund structures will be fundamental, rather than advisory, and they will need to be more robust (e.g. geotextile tube) to provide erosion protection as well as more effective sediment retention. The volumes of sediment that will be needed are also greater and the disposal locations more exposed/difficult to access. On this basis, and following discussions with contractors, it is estimated that the costs of sediment placement and geo(textile) tube filling would be around £30 m^{-3} (with the costs of the geo tube assumed to be included in this cost).

Given the relatively novel nature of this approach, consenting and monitoring fees would likely be higher than those incurred for Options 1 and 2.

5.4.2 Project Example 3 – Boiler/Pylewell Marsh

To carry out a CBA for the erosion protection and recharge option, it is assumed that the Boiler/Pylewell Marsh site will be used and will receive sediment from Lymington and other West Solent locations. This option assumes that a geotube fence will be constructed along the outer face of Boiler/Pylewell Marsh (excluding the existing LHC bottom placement area). This will be 1,750 m long and would be constructed by placing geotubes between high fenceposts and filling them *in situ*[21]. It is assumed that 13,000 m^3 is required in Year 1 (to fill behind the fence, and the geotextile tube(s)), and then 5,000 m^3 every year to top up/ fill recently eroded edge areas.

21 It is recognised that filing *in situ* in a tidal environment is likely to be very technically challenging and would certainly be novel. Alternatives such as land-side filling and transport to site may be required. Testing new strategies for achieving this will be a key aim of the next phase of this work, if this approach is pursued.

The cost and benefit assumptions used for the project example are discussed further in Table 14 ('No Intervention') and Table 15 ('Intervention'). A cost benefit analysis was carried out for those elements of the assessment where there were differences between 'No Intervention' and 'Intervention'. These included:

- Differences in costs between disposal and beneficial use;
- Differences in costs and timing of harbour protection expenditure;
- Differences in extent and timing of carbon release from eroding saltmarsh;
- Differences in benefits as a result of slower degradation of existing saltmarsh

The overall NPV net cost under 'No Intervention' was estimated to be £14.8m. The overall NPV net cost under 'Intervention' was estimated to be £11.6m. The differences are accounted for by:

- Increased disposal costs (additional NPV cost of £3.5m)
- Deferred capital expenditure to build harbour protection works (reduced NPV cost of £4.7m)
- Slower rates of carbon release (reduced NPV cost of £1.9m)
- Increased benefits from increased longevity of saltmarsh (additional NPV benefit of £124k)

Table 14. Project Example 3 - Assumptions for 'No Intervention'

Costs/Benefits	Assumptions
Costs for No Intervention	
Existing 'at sea' disposal cost per year	Cost will vary depending upon the source location. It will be lower (~£8 m^{-3}) from Lymington and Yarmouth and higher (assumed anywhere between £10 and 16 m^{-3}) from Cowes or Hamble. An average of £10 m^{-3} is assumed.
New harbour protection cost	It is assumed that additional harbour protection works will be required from 2030. It is assumed that these are constructed over the period 2030 to 2039 at a cost of £2m per year (2019 prices) (£20m over 10 years)
Value of carbon being released from eroding marsh Loss per year	The value of the carbon contained within a cubic metre of marsh sediment is estimated at £2.81 (2019 values)[3], increasing to £9.49 by 2050 and £12.72 by 2100. The existing marsh holds a volume of around 855,000 m^3 (above MHWN). The following rates of erosion have been assumed: 12,825 m^3 per year (1.5% $year^{-1}$) 2019 to 2050; 5% $year^{-1}$ from 2050 (with all of the sediment volume lost by 2061).
Benefits for 'No Intervention'	
Benefits for ecologically deteriorating and physically eroding saltmarsh	Without intervention, the existing 37 ha of vegetation will be gone by around 2050. Vegetation decreases will continue at the established 2% per year for the next decade, before then increasing more rapidly as exposure increases and as sea level rise continues to have an effect. The benefits of the residual marsh area have been assessed taking account of the area of this marsh and assuming that it only provides 50% of the Brander bundle of benefits provided by a healthy marsh (£848 ha^{-1} yr^{-1} at 2019 prices).
Benefits from 'mudflat' formation	The loss of marsh habitat will create 'new' mud habitat. However, this habitat is expected to be of low quality comprising a clay matrix with reduced benthic infauna. This 'mud' is assumed provides a benefit of only 50% of the value of the Brander mudflat bundle (£787 ha^{-1} yr^{-1} at 2019 prices)
Carbon sequestration by residual marsh	The residual marsh continues to sequester carbon, but at a rate of only 25% of that of healthy marsh (25% of 7.33 t ha^{-1} yr^{-1}).

Table 15. Project Example 3 - Assumptions for 'Intervention'

Costs/Benefits	Assumptions
Costs for Intervention	
Beneficial use costs	An average beneficial use cost of £30 m^{-3} is assumed (to both fill the geotextile tube, and backfill behind the fence; assumed to be a combination of mobile platform and direct pumping from dredger hopper) (so £20 m^{-3} more than non-intervention). Assumes that annual mobilisation is included in £30 m^{-3} per unit cost. **Fencing capital costs:** £210,000 (£120/m, 1,750 m long fence required), Year 1. **Fencing maintenance** costs: 5% of capital costs, so £10,500 $year^{-1}$. **Consenting**: additional fee of £80,000 in Year 1 is estimated to secure a licence for fence erection and deposition. **Implementation:** £6.500 $year^{-1}$ management for 5 years; £19,500 monitoring in Year 1, reducing to £7,500 $year^{-1}$ for years 2-5, cost neutral thereafter.
New harbour protection cost	Additional harbour protection works delayed by 10 years (so required from 2045). It is assumed that these are constructed over the period 2045 to 2054 at a cost of £2m per year (2019 prices) (£20m over 10 years)
Value of carbon being released from eroding marsh Loss per year	Rates of loss have been assumed to be 30% of those on the 'No Intervention' i.e. sediment placement reduces erosion by around 70% p.a. compared to baseline.
Benefits for 'Intervention'	
Benefits for ecologically deteriorating and physically eroding saltmarsh	Some of the sediment is expected to recharge the marsh surface and therefore this approach is likely to materially delay the loss of vegetated marsh. The rate of marsh loss is 1% $year^{-1}$ for 30 years (until 2049) and then rising to 2% $year^{-1}$ until all marsh is lost by 2085.
Benefits from 'mudflat' formation	The rate of mudflat formation will be slower compared to 'No Intervention' as the intervention is expected to slow the rate of marsh loss. Development of mudflat is inversely related to marsh loss.
Carbon sequestration by residual marsh	Carbon sequestration will be greater compared to 'No Intervention' as the intervention is expected to slow the rate of marsh loss as above.

The additional costs of beneficial use are more than offset by the savings from deferred capital expenditure for harbour protection works. There is also a significant benefit as a result of slower release of carbon from the marsh. This occurs because, in the intervention scenario, only around 300,000 m^3 of the 855,000 m^3 of sediment associated with Boiler/Pylewell Marsh is estimated to have been eroded by 2100. There is some benefit from greater persistence of saltmarsh but the scale of these benefits is assessed as being much smaller than the effect of deferring harbour protection expenditure or reducing erosion.

The Benefit:Cost ratio for this intervention is estimated to be 1.9.

5.5 Option 4 Large-scale recharge and bunding

5.5.1 Cost assumptions

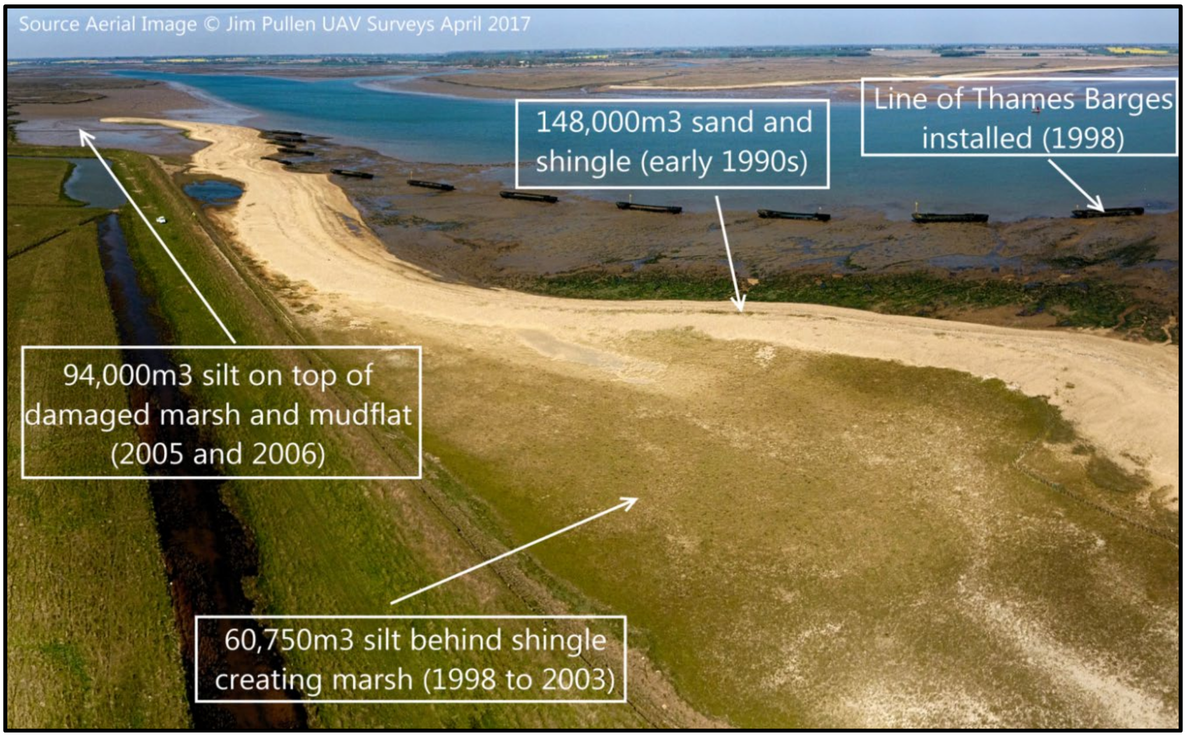
This is the largest and most costly of the four different options. Costs for such a large scale scheme would depend greatly upon the exact scale of the work and the nature of the bunding.

One approach to bunding would be to use a coarse shingle barrier. Such coarse materials could either be derived from capital dredges or marine aggregates areas. Also, as part of ABP's last Southampton Water capital dredge, around 2 million tonnes (or 1,000,000 m^3)[22] of such material was placed on the seabed at the Nab disposal site (west of the Isle of Wight). Some maintenance dredge campaigns might yield shingle occasionally (notably from Portsmouth Harbour), though unlikely at sufficient quantities.

To deliver the shingle, the use of a dredger that can rainbow discharge would be required. The 'Sospan Dau' has been used for previous similar projects across the UK. This has a (loaded) draught of 3.3 m and, allowing for clearance, would need 4 m depth of water. From whatever location it could reach at high water, discharge could be to a further 40 to 50 m forward of its position.

This vessel would be able to transport 700 m^3 in each load and thus around 12 loads (8,400 m^3) could be moved per week. The dredger would be confined to discharging at the peak of high water and so the number of trips would be constrained.

As a high-level estimate, the costs would be in the region of £15 m^{-3} (derived from industry consultation). For previous and current equivalent projects in Essex (e.g. Horsey Island, see Image 19 and Appendix B, shingle materials have cost around £3 m^{-3}. However, these materials were be sourced during coincidental local capital dredge campaigns, and projects were only charged the differential costs (i.e. additional to offshore disposal) by the local port of Felixstowe/Harwich. In the West Solent, it is not expected that any large-scale dredging of coarse material will occur in the near future and therefore the opportunity for a low differential cost is not expected. Thus, the higher value of £15 m^{-3} was applied as a conservative working figure for the CBA.



Take by: Jim Pullen UAV Surveys, 2017

Image 19 View of Horsey Recharge (April 2017) showing volumes in each campaign

With such a shingle barrier in place, it would be possible to recharge silt behind to stabilise. This would have to be done relatively quickly and with large volumes if the barrier is to be stabilised (as the work

22 Using a conversion factor of 2.0 'gravel/stone' (HELCOM, 2015)

at Horsey Island/Essex has shown, see Appendix B). Thus, this approach does not lend itself to incremental small deposits. Similar projects in Essex have incurred the same differential costs for silt as those quoted above for shingle, i.e. £3 m^{-3}.

It is worth noting, that, while using shingle is a process that has been adopted before (and would be probably the easiest strategy to employ), there are other ways that could be considered, especially if the aim is to create a fixed feature.

5.5.2 Project Example 4 - Pennington

To carry out a CBA for the erosion protection and recharge option, it is assumed that Pennington will be used and will receive sediment from capital or large maintenance dredge campaigns, as well as from the Nab disposal site (and possibly small volumes from Lymington and other West Solent locations).

It is assumed that a recharge of 450,000 m^3 is carried out along the Pennington frontage. It is assumed that the mud material is retained through the creation of a shingle bund containing 150,000 m^3 of shingle obtained from the Nab disposal site (deposited at the Nab from a previous capital dredge). This bund would be 2.2 km long and have an initial crest height at around the level of HAT (so just above 1.3 mODN). 300,000 m^3 of muddy sediment would then be pumped behind the shingle barrier in the same winter, piped directly from a dredger. This would be piped to MHWS levels.

The recharge would cover an area of approximately 23 ha, replacing 16 ha of existing mudflat and 7 ha of shallow subtidal habitat. The elevation of the recharge would be suitable for saltmarsh formation.

The cost and benefits assumptions used for the project example are discussed further in Table 16 ('No Intervention') and Table 17 ('Intervention'). A cost benefit analysis was carried out for those elements of the assessment where there were differences between 'No Intervention' and 'Intervention'. These included:

- Differences in costs between disposal and beneficial use;
- Differences in costs and timing of sea wall expenditure;
- Differences in benefits as a result of saltmarsh creation; and
- Differences in carbon sequestration from sediment placement.

The overall NPV net cost under 'No Intervention' estimated to be £6.4m. The overall NPV net cost under 'Intervention' was estimated to be £8.8m. The differences are accounted for by:

- Increased disposal costs (additional NPV cost of £4.8m);
- Deferred capital expenditure to rebuild sea wall (reduced NPV cost of £0.7m);
- Increased benefits from creation of saltmarsh (NPV benefit of £1.4m); and
- Increased benefit from sequestration of carbon in placed sediment (£0.3m).

In this example, the additional costs of beneficial use are much greater than the savings from deferred capital expenditure on flood protection works.

The Benefit:Cost ratio for the intervention is estimated to be around 0.5.

While there are some potentially significant benefits from creation of 23 ha of saltmarsh and a smaller benefit from storing the carbon in the dredge material within the recharge, the benefits are not sufficient to close the gap between sea disposal and beneficial use costs.

In order for the costs of the project example to be lower than the 'No Intervention'; scenario, the cost of beneficial use placement would need to reduce from £15m^{-3} to £8m^{-3}. While there is uncertainty relating to the value of the benefits from creating the saltmarsh, these benefits would need to have been underestimated by a factor of at least 3 in order to affect the balance of costs between 'No Intervention' and 'Intervention'.

Table 16 Project Example 4 - Assumptions for 'No Intervention'

Costs/Benefits	Assumptions
Costs for No Intervention	
Existing 'at sea' disposal cost	The 'Intervention' assumes that 450,000 m^3 of mud/geological material would have to be placed in year 1. In the 'No Intervention' option it is assumed that this material is disposed of at sea, at an average of £10 m^{-3}. The shingle would be derived from the Nab disposal ground, so no disposal costs assumed for this under 'No intervention'.
Sea defence costs	Maintenance costs of around £60 m^{-1} every 5 years, or £12 m^{-1} yr^{-1} (based on Environment Agency, pers. comm.), until 2029. Rebuild will occur in 10 years' time (2029), at a cost of £1,000 m^{-1}, after which maintenance is reduced by half to £6 m^{-1} for the next 15 years (until 2044)[1].
Benefits for 'No Intervention'	
Benefits from existing 'mudflat'	There is currently 14 ha of mudflat remaining in the proposed recharge area. It is assumed that this is lost at a rate of 1% year^{-1} for the next 10 years (to 2028), increasing to 2% year^{-1} up to 2048, and then to 2.5% year^{-1} to 2068, by which time all of the intertidal mudflat will have been lost.
[1] As noted previously, it is not currently known when/whether a substantial capital investment is needed in the sea wall.	

Table 17 Project Example 4 - Assumptions for 'Intervention'

Costs/Benefits	Assumptions
Costs for Intervention	
Beneficial use costs	An average beneficial use cost of £15 m^{-3} is assumed (for both the shingle and mud/geological material; assumed to be direct pumping from dredger hopper). 450,000 m^3 mud, 150,000 m^3 shingle required. Mud assumed to be from a capital dredge campaign, shingle from Nab (conservative costs based on consultation with Boskalis). **Consenting**: additional fee of £200,000 in Year 1 is estimated to secure a licence for deposition. This recognises the need for comprehensive assessment and sampling work to secure consents and licence consent. **Mobilisation and implementation**: assumed to be included in per unit cost above. **Monitoring and management**: £20,000 yr^{-1} for the first 5 years reducing to £5,000 yr^{-1} for the next 5 years.
Sea defence costs	It is assumed that the sediment placement will delay the requirement for a new sea defence by 15 years (to 2044) by creating a new marsh, and through the shingle bund. Annual maintenance costs will be £12m^{-1}, reducing to £6m^{-1} for the 15 years following its construction (i.e. to 2059), thereafter reverting to £12m^{-1}.
Benefits for 'Intervention'	
Benefits of saltmarsh creation	23 ha of saltmarsh is created, with saltmarsh function increasing over 5 years to reach full 'Brander Bundle' function over 5 years and this is maintained to 2100.

Costs/Benefits	Assumptions
Benefits from declining mudflat	16 ha of mudflat (the rest is subtidal at present) declines in function over 5 years as it converts to saltmarsh.
Carbon sequestration by residual marsh	The carbon sequestration function of the saltmarsh increases over 5 years to reach 100% of function and that this is maintained until 2100.
Carbon sequestration as a result of retention within bunded area	The placement of dredged material and its long-term retention within the bunded area will sequester carbon in the dredged material. In the 'No Intervention' scenario, the material would be disposed of at a dredge disposal site and dispersed within the wider environment. The amount of carbon sequestered will depend on the nature of the material deposited. If the material is of geological origin it will contain very little carbon. Muddier/surficial sediment is likely to contain relatively high levels of carbon. For the purposes of the assessment, it has been assumed that 50% of the deposited material (225,000 m^3) comprises surficial/muddy sediment with an organic content that is 50% that of the value used for eroding saltmarsh (which tends to be naturally high in organic material).

5.6 Summary

The four project examples used for undertaking a CBA for potential recharge work in the West Solent differ in terms of their scale of intervention, and in their cost and expected benefits. This has been deliberately done to show the scale of what could be done and understand the societal benefits across the full range of options available.

In reviewing these options it should be noted that the projects assessed in the CBA are examples, and while they are sensible projects in their own rights, the findings of the CBA are primarily intended to inform the development of a strategy for the West Solent as a whole. This future strategy will need to link to the ongoing flood risk management review being led by the Environment Agency, as well as similar initiatives. It is likely to be appropriate to implement different options in different locations, including multiple combinations of options at specific locations, in order to maximise the benefits of beneficial use.

Based on the assumptions used, the CBAs for project examples 1, 2 and 3 all demonstrated lower overall net costs for the beneficial use intervention compared to the 'No Intervention' scenario. Project example 4 demonstrated higher overall net costs for 'Intervention' compared to 'No Intervention' (see Table 18).

For each of the first three examples, the beneficial effect of reducing marsh erosion was assumed to enable deferring of capital investment in flood protection and harbour protection. In each example, the monetary benefits of deferring this capital expenditure (by 5 to 15 years) more than offset any additional costs associated with beneficial use. For project example 3, significant additional benefits were estimated to accrue from the anticipated large reduction in marsh erosion and deterioration.

For project example 4, the estimated capital cost of the sediment recharge was a large and upfront cost. This additional cost was not offset by savings from deferring flood defence investment, nor benefits from the creation of 23 ha saltmarsh (although these benefits were large). Based on the assumptions used, in order for this project example to provide an overall reduction in net cost, the per-unit cost of the sediment recharge would need to reduce from £15 m^{-3} down to around £8 m^{-3}.

Table 18. Summary of Cost Benefit Analysis (£m discounted costs at 2019 prices)

Project Example	No Intervention Net Cost £m (discounted value to 2100 at 2019 prices)	Intervention Net Cost £m (discounted value to 2100 at 2019 prices)	Benefit: Cost Ratio
Project Example 1: Bottom placement at Stoney Marsh	1.8	1.7	2.1
Project Example 2: Movable transfer station/thin layer placement at Boiler Marsh	13.5	11.5	2.4
Project Example 3: Erosion protection (and behind- fence recharge) at Boiler Marsh	14.8	11.6	1.9
Project Example 4: Large scale shingle and mud recharge at Pennington	6.4	8.8	0.5
Cells coloured green indicate net benefit to society; Cell coloured orange indicates net cost (in this case due to high projected up-front project fee)			

The key conclusions from the CBA are:

- Relatively low-cost interventions which defer capital expenditure on flood risk management or harbour protection works are likely to be cost effective;
- Where interventions significantly reduce rates of erosion of existing marshes or create new saltmarsh, this can also provide substantial benefits;
- The assessments are particularly sensitive to assumptions on the extent to which beneficial use projects might delay the need for capital investment in flood protection and harbour protection works, but these assumptions are reasonably well supported by the emerging evidence on the effectiveness of beneficial use projects; and
- While there are uncertainties concerning the monetary values of some of the ecosystem service benefits associated with West Solent saltmarshes (the 'Brander bundle' benefits), these uncertainties do not appear to be material to overall decision-making which is more influenced by assumptions on the timing of capital investment and the loss of sequestered carbon.

6 Stage 4 Review of Funding Opportunities

6.1 Introduction

Beneficial use projects are complex projects involving multiple actors which result in a range of different costs and benefits to these actors. It is generally the case that those bearing the additional costs of undertaking such a project are not the main, or only, beneficiary from a given project and therefore may lack the incentive to incur additional costs. However, where such projects result in an overall reduction in net costs and deliver environmental benefits, there is a societal case for proceeding with them.

For example, for the Stoney Point project example assessed in Section 5.2, it is likely that the (slight) additional costs of beneficial use would be borne by the harbour authority, in seeking to obtain a marine licence for beneficial use at the site, and in managing and monitoring the project. The beneficiaries of the project would be the flood protection authority (deferred capital investment in flood defences) and society (reduced erosion rate of marsh). In order to unlock the potential of beneficial use schemes, close partnership working will be needed between the various actors and additional funding may be required to facilitate projects.

This section explores various funding options for beneficial use projects, within the context of partnership working. Section 6.2 provides a high-level review of generic funding opportunities for beneficial use projects, whereas Section 6.3 focusses on funding avenues for West Solent beneficial use projects in particular. A brief summary is provided in Section 6.4.

6.2 Funding opportunities - Review

Over the last decade, increasing consideration has been given to finding new ways to secure funding for environmental enhancement measures and Natural Capital delivery. This is due to funding for environmental efforts being scarce, and 'traditional' funding relying on government and NGO/philanthropic sources being insufficient to achieve meaningful sustainable development (see, for example, Clark *et al.*, 2018). The Brexit-related cessation of access to EU funding, which has in the past been an important funding source for nature conservation projects, makes such a search for alternative sources of funding even more important. This is notwithstanding calls from NGOs and other actors for such previous EU funding (notably LIFE funding) to be matched with equivalent UK funds in the future (see, for example, RSPB, 2019a).

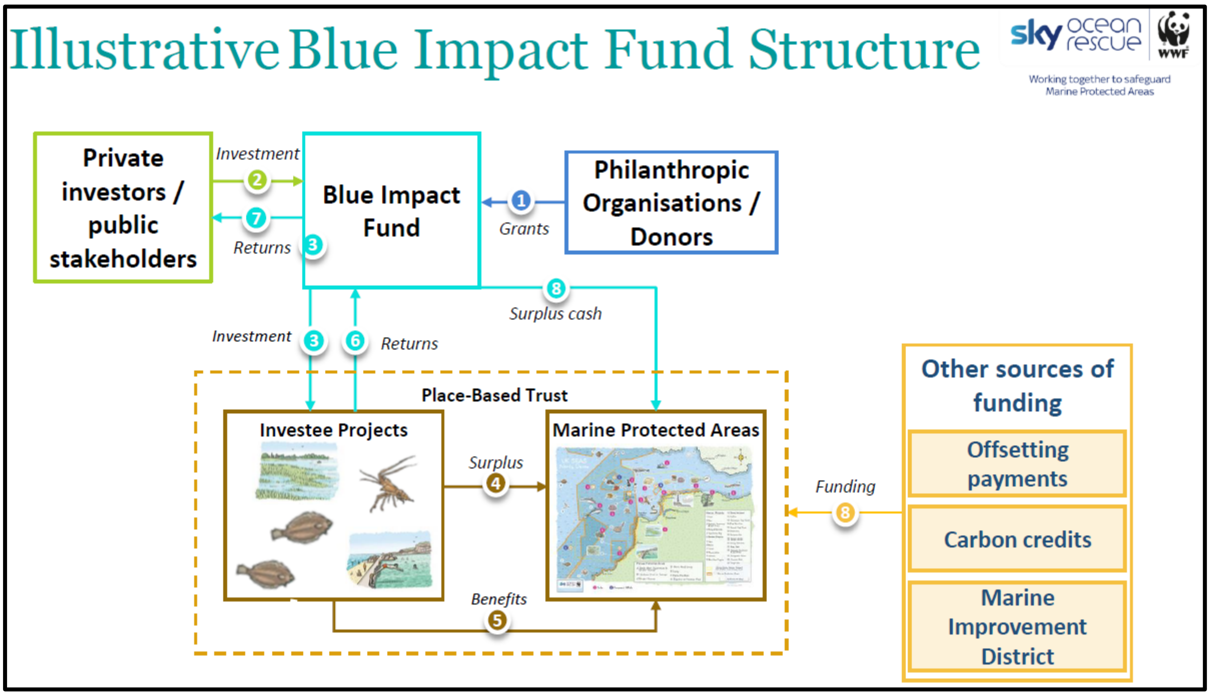
A recent RSPB-led review of the ways in which increased conservation financing could be achieved has highlighted that, while there is not a lack of money for investment, the process of securing investment for conservation is hampered by (RSPB, 2019b):

- Higher uncertainty of outcome of such projects;
- The small-scale nature of many projects;
- The need for clear metrics to inform investing;
- The lack of sufficient financial expertise in many conservation organisations; and
- The need for Government support.

This study also noted that schemes related to ecosystem services such as flood mitigation, carbon storage or water quality improvements can often be more suitable for larger nature reserves/landscape scale interventions, whereas smaller schemes generally deliver mainly health and recreation benefits. This distinction also applies for the small-scale and large-scale schemes that have been identified in this BUDS Phase 2 review.

The RSPB review also concluded that there were '*many business models and legal structures that would allow practitioners to partner with others - in both the private and public sectors – who have complimentary financial and transactional expertise or aligned objectives*'. It was furthermore argued that 'blended finance' approaches were worth exploring. These are conceivable where habitats, or natural capital, which deliver multiple benefits, may be attractive to different investors or donors. For example, a woodland restoration scheme may be attractive to actors such as the Government, high net worth individuals, local communities, carbon neutral companies and the NHS, as this could lead to enhanced biodiversity, sequestered carbon, improved air quality, recreational opportunities and/or provide mental health benefits.

A World Wildlife Fund project has recently looked into developing innovative long-term finance mechanisms for Marine Protected Areas (MPAs) by tapping into alternative sources of finance. It led to the development of ideas for a blended finance blue impact fund, whereby it is hoped that strategic investment in environmentally sustainable marine and coastal businesses would generate both financial and environmental benefits for MPAs (Nelson, 2019). The principles of this particular blended finance model are illustrated in Image 20.



Source: Nelson, 2019

Image 20 Illustration of 'Blended Finance' in relation to Marine Protected Areas

Table 19 lists these and other possible sources of funding for beneficial use projects based on a literature review.

Table 19. Summary of Potential Funding Sources for Beneficial Use Projects

Funding source/type	Description
A Local Levy	Monies from the local community might be obtained through a council levy. This approach has for example been used to fund the Holes Bay (Poole Harbour) beneficial use feasibility work.
Coastal Communities Fund	From this Governmental fund, money goes to projects (over £50,000) that will ultimately lead to regeneration and economic growth whilst directly or indirectly safeguarding and creating sustainable jobs.
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.
Local Enterprise Partnerships (LEPs) and LEP Network	These are partnerships between local authorities and private sector businesses which influence local economic priorities and activities to drive growth and job creation. This includes funding nature recovery initiatives.
Developer contributions to achieve Net Gain	The Government has expressed a favourable view on mandating net gain for developments in England under the Town & Country Planning Act. Intertidal habitats will be included (ABPmer, 2019a) and recharge projects that achieve intertidal gain could thus be funded by developers.
Developer contributions to create compensatory habitat	Under the Habitats Regulations, developers need to compensate for damage to designated sites. This includes the Environment Agency having to compensate for coastal squeeze losses. Currently, such (Regional Habitat Creation Programme) projects focus on intertidal habitat creation through managed realignment, but NE are looking at the potential role of recharge works (as part of BUDS).
Developer contributions to deliver net gain	Under the Environment Bill (when enacted), there will be a requirement for coastal developments that have impacts to intertidal habitats to deliver net gain. BUDS projects may be one very critical way of delivering net habitat gain although, as things stand, the need to be assured of no adverse effects on designated sites integrity under Habitats Regulations is a dominant consideration, especially in the Solent, which is highly protected.
Extra disposal fee levy	Extra disposal fees could be sought from those carrying out dredging work to add to a bespoke levy fund that can support recharge projects. This idea is understood to have been mooted before (including in an ongoing CEDA review which is as yet unpublished)*.
Flood protection funding	Through the Flood Defence Grant in Aid (FDGiA) partnership funding methodology, there is a positive financial credit for work that achieves Outcome Measures (OM4a or OM4b particularly apply to beneficial use) (Defra, 2011). Currently, it is understood that a project would only be eligible where additional saltmarsh/mudflats is created rather than protecting existing habitat from loss. There are however precedents for securing such FDGiA funding, e.g. £800,000 to protect the RSPB Leighton Moss site in Morecambe Bay.
Heritage Lottery Fund	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, including the mandatory outcome of having a wider range of people involved in heritage.
Environment Agency Water Improvement Environment Fund	The Water Environment Grant (WEG) scheme provides funding to improve the water environment in rural England. The status of this project and its budget would however, need to be clarified.

Funding source/type	Description
Investment Fund for multiple projects	Accrued monies are often used as a foundation for further grant applications. This is the approach being pursued by the HIWWT for their new Wildlife Investment Fund, in anticipation that a fund of £25,000 could unlock £250,000 (HIWWT, 2019), and that fundraising efficiencies can be achieved by having a larger fund.
Private/corporate or in-kind funding	Such funding could be forthcoming to support the community, achieve corporate social responsibility (CSR) and/or publicity goals.
Restoring Estuarine and Coastal Habitats in the North East Atlantic (REACH)[23]	This new Environment Agency-led programme deals with restoration of saltmarsh, reef and seagrass and the BUDS work was presented by ABPmer at the first REACH conference in July 2019. Initiatives under this programme may help unlock monies from coastal management funds and/or facilitate broader funding bids.
Solent Recreation Mitigation Strategy (Bird Aware Solent)	Raises housing development contributions, designed to manage bird disturbance from recreational activities. Mostly funds wardens and projects which create alternatives to visiting the coast, but also site-specific projects to better manage visitors and bird habitats.
Standing Conference On Problems Associated with the Coastline (SCOPAC)	This is a network of local authorities and other key organisations that share an interest in the sustainable management of the shoreline of central southern England. This could be a source of funds, especially for small-scale research studies.
* Although care would need to be taken that no inappropriate fees are applied outside of a sensible 'polluter pays' principle. Applying such fees may also reinforce an unhelpful idea that beneficial use is a dredging sector topic only whereas it is a much broader subject that provides multiple benefits to multiple parties.	

6.3 Funding for West Solent beneficial use projects

In order to facilitate the increased application of beneficial use in the West Solent, and ultimately help safeguard the local saltmarshes for future generations, the increased reliance on non-traditional funding sources is likely to be required. This is notwithstanding there being a clear case for more government funding being made available for maintaining these valuable and highly designated habitats. Potential funding sources for West Solent beneficial use projects will now be discussed in the context of the project examples used for the CBA in Section 5 above.

6.3.1 Funding for Project Example 1: Bottom placement (mud) at Stoney Point

Of all the project examples assessed, the bottom dumping Project Example 1 had the lowest one-off/advance costs. Upfront/advance costs were related to licensing and testing, and ongoing costs to monitoring and deposition. There were also assumed to be extra costs related to management of timings/haulage delays (see Table 11). In total, compared to no intervention, this option was estimated to be up to £100,000 more expensive over the first five years of its implementation.

As noted in Section 5.2.1, the ambition is to have several sites licensed for bottom placement by several operators which currently utilise the Hurst offshore disposal ground, and to have the latter almost become obsolete. Further funds than those costed for the one site for Project Example 1 are likely to be required to finance such an ambition.

[23] This is also closely linked to the Environment Agency's new REMEMARE (REstore MEadows, MArshes and REefs) project which is exploring opportunities to restore saltmarsh, seagrass meadows and oyster reefs (Peters and Pwroudfoot 2019)

Whilst it is considered that bottom dumping will be good for landward saltmarshes and flood defences to some extent, benefits have to date proven difficult to quantify and may be more ephemeral than those for the other project examples; this is due to no saltmarsh being restored (but 'merely' mudflat being raised), and sediment not necessarily being retained for prolonged periods. Whilst there is clear evidence in the literature that mudflats fulfil a role in wave absorption (see Section 3.6.1), and it is logical that higher mudflats would be better at this than lower ones, such arguments may not be enough to convince government bodies to contribute funding. Similarly, it is logical to assume, that some of the winnowed sediments would be supplied to the same marshes for accretion, and that this, combined with somewhat reduced rates of erosion, would lead to carbon being stored for longer. However, as noted above, at the one current scheme at Boiler Marsh, benefits to the land-side areas from localised erosion reduction and/or improved bed accretion are not yet detectable by the bathymetry and LiDAR survey techniques. This will likely make it fairly difficult to obtain funding from flood risk management or nature conservation bodies, and from carbon trading related activities.

6.3.2 Funding for Project Example 2: Thin layer placement at Boiler/Pylewell

This project example had fairly high differential costs of £475,000 during its first five years (see Table 13), related to licensing and monitoring, and equipment purchase, storage and hire. As noted in Section 4.4.2, the ambition would be to use the purchased transfer station equipment across several of the marsh complexes along the Keyhaven to Pitts Deep frontage, and not just at Boiler/Pylewell.

More proven benefits arise from this technique when compared to Project Example 1; these are in relation to saltmarsh habitat related ecosystem services and indirect flood defence benefits. Also, the CBA case examples clearly showed how deferred capital expenditure on harbour protection schemes can lead to beneficial use projects being clearly cost effective. Hence, there is a case to be made for cost contributions from harbour authority and/or flood risk management bodies.

With the technique also helping to sustain the saltmarshes for longer, and at a height whereby the continued, and possibly enhanced, use by birds is facilitated, then NGOs and nature conservation government bodies would also have a good case for monetary contribution.

Furthermore, given the clear benefits the saltmarshes provide to the local community, and its wildlife (see Section 3.6.2), then some form of local contribution is very much justifiable. This could take the form of a local levy, a one-off crowdfunding campaign, or a tourism tax. Blended finance, whereby many organisations and individuals contribute through various avenues in order to accrue a large amount of money, is possibly the most appropriate solution for this ambition. Links with local/regional initiatives should also be investigated; for example, the (New Forest) Green Halo initiative, which seeks to bring together multiple partners to enhance the New Forest's environment, landscape and natural capital 'in harmony with a thriving, economically successful community' (Green Halo Partnership, 2019).

6.3.3 Funding for Project Example 3: Erosion protection at Boiler/Pylewell Marsh

For this project example, a mixture of per-unit and estimated costs were applied for the CBA as this is how practitioners communicated costs to ABPmer (see Table 15). It is estimated that the costs for this example would likely range between and £600,000 to £900,000 over the first five years.

In terms of benefits, it was assumed that this technique would mostly halt front edge erosion but would not necessarily slow the ongoing process of internal marsh lowering. In order to achieve this, a combination of Project Examples 2 and 3 would be required.

With regard to ways of obtaining funding for this technique/example, a similar blended finance approach as that proposed for Project Example 2 above would likely be appropriate.

6.3.4 Funding for Project Example 4: Large-scale bund at Pennington

This Project Example is unusual in that it assumes the occurrence of either a substantial nearby capital dredge, whereby large volumes of both shingle and mud are derived, or a substantial (mud) maintenance dredge combined with shingle import. The volumes involved (600,000 m^3) could certainly not be satisfied by the relatively small local and nearby harbours, with the obvious exception of those in Southampton Water (as evidenced by the dredging review presented in Section 3.4). This Project Example was included to illustrate what could be achieved should such a dredge occur in the near future and should the collaboration of the responsible authority be obtained (and several other circumstances align, as evidenced by the Mersea example provided in Appendix B).

Upfront and initial costs would be substantial, with the differential 'intervention' costs for the Project Example totalling well over £3 million over the first five years of the project (see Table 17). However, it was noted that other similar projects had achieved lower per-unit differential costs of around £3 per cubic metre of sediment (e.g. Mersea example, see Table C1 of Appendix C); such lower costs would reduce overall costs to just over £2 million.

The project example would have clear flood defence and saltmarsh ecosystem service-related benefits. The shingle bund, whilst not envisaged to reach the height of the embankment crest, would nevertheless certainly fulfil a wave attenuation function, as would the saltmarsh behind. The project would also lead to the actual creation of saltmarsh habitat, which would mean that it would be eligible for FDGiA grant in aid funding, as this currently only applies to actual habitat creation (as opposed to restoration/enhancement) (see Defra, 2011). The current payment rate is £50,000 per hectare, and as 23 ha would be created, 1.15 million of FDGiA funding could be achieved for this Project Example in relation to 'Outcome Measure 4' (re. statutory environmental obligations). Further FDGiA funding could also potentially be justified under the other three 'Outcome Measures', which are related to overall/other benefits, flood risk reduction and improved coastal erosion protection.

As described in Section 3.5, the Environment Agency and NFDC are actively engaged in reviewing the coastal defence requirements for this section of the coastline and are developing a strategic business case. Prior to this process being concluded, it is difficult to know what contribution such a large-scale beneficial use project could make. However, the value of the properties protected may well not be sufficient to secure priority Government funding with associated local partnership contributions through the usual mechanism and Flood and coastal erosion risk management (FCERM) funding metrics. Therefore, alternative sources of funding may need to be considered. It is noteworthy at this juncture that it is likely that more emphasis will in the future be placed on the ensuring that the role of Natural Capital delivery is included into the FCERM metrics. It is understood that the mechanisms for embedding Natural Capital in the funding is being considered, but that no formal approach has yet been agreed. Therefore, the process of developing coastal defence options for the Hurst to Lymington frontages may yet offer an opportunity to develop and test such an approach.

6.4 Summary

A high-level review of a wide range of funding options was undertaken; potential options include 'traditional' means such as government, NGO or developer funding, as well as more recent approaches such as crowd funding, blended finance and Net Gain related funds.

In order to facilitate the increased application of beneficial use in the West Solent, a combination of sources will likely be required, with a relatively large contribution from government financing, notably flood risk related.

With regard to the latter, once the current Environment Agency/NFDC review/SOC process has concluded, there will be a better understanding about the work to be done, the level of public support, and the funding available in the future. However, it is strongly recommended that the concepts, costs, risks and benefits of carrying out recharge projects along the frontage are presented as part of the related public consultation process. It may well be that local organisations, partnerships, communities and/or individuals will be particularly willing to contribute to measures that protect and preserve the shoreline landscape and, therefore, they should be made aware of such opportunities.

7 Conclusions and Recommendations

7.1 Conclusions

This report reviews the work undertaken for Phase 2 of the Solent Forum's BUDS project. This second phase of the BUDS project involved an investigation into the feasibility and value of conducting a major beneficial use project (or multiple smaller projects) on the West Solent saltmarshes along the Hurst Spit to Lymington frontage. The key objectives for this phase were to:

- Clarify how and where dredge sediments can be beneficially placed on the West Solent marshes,
- Understand the costs and benefits of such an initiative on a more site-specific basis; and
- Recommend how practical projects can be pursued in BUDS Phase 3 and further define the roles that different stakeholders might play in future initiatives.

The results obtained from this Phase 2 review are designed not only to determine how and whether a project might go ahead in the West Solent, but also to provide information that helps guide other projects in the Solent region and, it is hoped, more widely in the UK and internationally. For this BUDS Phase 2 study, a number of different tasks were carried out which were progressed through the following four-stage sequence:

- **Stage 1 Baseline Conditions and Background Review:** This involved the review /analysis of several aspects, including marsh condition, bird distribution, dredging activities, etc.
- **Stage 2 Technical Options Review:** This involved the identification and assessment of possible locations and approaches for a recharge campaign (or campaigns);
- **Stage 3 Cost and Benefits Analysis**: The anticipated costs and benefits of four potential projects were then assessed, across a range of techniques and locations; and
- **Stage 4 Review of funding opportunities:** A brief review of possible future funding sources and mechanisms was undertaken based on existing literature and stakeholder consultation.

The review was high-level in nature and, as such, several assumptions are embedded in the analysis and residual uncertainties remain that need to be recognised and addressed during the next stages.

One of the main uncertainties relates to the future coastal defence priorities for this shoreline, which are currently under review. Clarity on this is needed to understand how a recharge programme might best fit into future coastal defence planning, although it is also recognised that this will be a two-way process and clarity on the effectiveness and value of recharge work will be needed to inform coastal defence planning.

Another key issue to clarify is how major recharge projects can be viewed, in policy terms, and whether they can be seen as offsetting the effects of coastal squeeze, compensating for developments and/or contributing to the ongoing conservation management of the Solent European Marine sites. These judgements will influence factors such as the regulatory path, consenting costs and sources of funding. Available guidance on implementing the Habitats Directive (EC, 2000; EC 2018) for example indicates that compensation can take place within the boundaries of the Natura 2000 site and if this approach were to be adopted [more] it would open up new opportunities for funding and delivering such saltmarsh improvement projects. However, under existing legislation, such compensatory measures would also need to have certainty of outcome which will be a key consideration.

There are also residual uncertainties associated with the long-term costs of the proposed approaches and with the valuations that can be assigned to the benefits. These can all be refined and resolved both as an integral part of ongoing and future projects (i.e. continuing to learn by doing) and through further analysis and, especially, engagement with the local community.

Notwithstanding these uncertainties, it is evident that continuing to let these valuable marshes rapidly decline is not an option and that there is a clear way forward. More recharge of the marshes needs to be undertaken soon and on a substantial scale, while there are still sufficient marsh extents left to work with. As a bare minimum, more locations should be selected across these marshes where sediment can be placed through bottom placement (Option 1). This should include a proportion of the dredged sediment from harbours other than Lymington. It is hoped that, in time, sediment could be placed in the system on an almost cost-neutral basis. This approach would also begin a process of strategic and collaborative regional sediment management and monitoring that could in turn be the foundation of increasingly more ambitious/substantial measures into the future.

It is also clear however, that there is a need to advance more substantial/ambitious measures at the earliest opportunity and probably in tandem with the extended bottom placement work. This is because, with increased bottom placement alone, the decline of the marshes will only be partially slowed (and this will possibly be at an undetectable scale), and they will thus continue to disappear along with the multiple societal functions they provide. It is estimated that the annual value of ecosystem services lost as a result of saltmarsh erosion along the Keyhaven to Pitt’s Deep frontage every year is at least £50,000 (mainly related to the loss of sequestered carbon). Also, if there is much further delay before a substantial intervention, there will be less baseline marsh to work with and the costs of any starter project(s) will only increase as a result.

It is recommended therefore that active efforts are made as soon as possible to halt lateral erosion by installing erosion protection (e.g. fencing), and to improve the quality of the marshes by raising the bed levels. To begin this, it is proposed that a variant of Option 3, with elements of Option 2, is progressed at the earliest opportunity. This should probably start at Boiler/Pylewell Marsh, but then be applied throughout the wider marsh complex over time, in a flexible/adaptive manner whereby locations, volumes and approaches can be adjusted where needed.

As part of these actions it will be important to improve understanding about the values that can be placed on these marshes, particularly in a site-specific context. This includes understanding the value that is placed on these habitats by those who live nearby and visit this site. The process of obtaining such a local valuation will be crucial not just as a way of clarifying project rationales, but as a mechanism for actively involving people in the decision making. This engagement and valuation process could be embedded with local consultations that the Environment Agency and NFDC will be undertaking to inform future coastal defence work. This would also represent a valuable opportunity to ensure that coastal defence priorities are integrated with the future marsh restoration work.

It will also be fundamental to seek funding from a range of partners and stakeholders. As part of this process, it will be necessary to further address and clarify the key issues of both coastal planning and habitat creation/protection policy cited above. This will be important for determining whether substantial funding contributions for recharge projects can be forthcoming based on their coastal defence and habitat restoration/compensation benefits. Aside from these elements, it is expected that funding can be obtained from many different sources given the clarity of the case that can be made for intervention in this area. These could include: crowd funding, local levies and lottery funding.

7.2 Recommended next steps (for BUDS Phase 3)

Based on the findings from the Phase 2 review, it is recommended that the next stage(s) of the BUDS project should include the following tasks, with direction from the BUDS Technical Group (which includes most of the key local stakeholders):

- **Doing more bottom placement in the first instance**. The very next step should be to adopt variants of Option 1 (bottom placement) in several locations. This should be at the earliest opportunity and will include work already envisaged by the LHC, as well as other possible initiatives (using locations identified in this study);
- **Progressing quickly to marsh edge protection and thin layer placement:** In the very near future, trial projects should be pursued to halt marsh edge erosion and improve the marsh quality and resilience by raising the bed levels. This would involve combination of the Option 2 (transfer station) and Option 3 (protective fencing) approaches. This should probably begin at the exposed Boiler/Pylewell Marsh, but then, if successful, be developed throughout the wider marsh complex over time; and
- **Ensuring that there is ongoing lesson learning and advocacy.** There will be many useful lessons that emerge out of the next stages and it will be important that these are communicated regionally, nationally and internationally. This is to inform and direct external initiatives (whether these are practical projects or regulatory developments) and also to help ensure ongoing buy-in to the BUDS programme.

In pursuing these tasks, a general aim should also be to avoid focussing on a single technique but instead apply and test multiple techniques across different locations (as well as combinations of techniques at specific locations) to maximise benefits. It is also recommended/expected that BUDS is progressed in an adaptive and strategic manner that allows for progressive 'scaling up' such that projects are progressed (relatively rapidly) as increasingly ambitious initiatives over time with each providing the lessons and confidence to move on to the next stage(s). Adopting this 'scaling-up over time' approach will allow for the monitoring and communication of findings clearly across partners, funders and the local community. This will also help with building partnerships, verifying the effectiveness of the techniques used, providing reassurances they deliver with requisite certainty, where needed, and improving overall understanding about costs and benefits.

As part of the lesson learning and costs and benefits, it will be also be vital to improve understanding about the value that can be placed on these specific marshes rather than having to rely only on generic valuations. This should include determining the particular value that is placed on these habitats by those who live nearby and visit this site. This value (referred to as 'non-use') was not included in the CBA for this project and could be very high given the location and history of these marshes. The process of obtaining such as a local valuation would not only help clarify the project rationale but could also help facilitate the active involvement of local people in the decision making about the valuable resource on their doorstep.

The approach taken will also need to integrate with, and learn from, the flood defence review being conducted by the Environment Agency and NFDC, as well as the ongoing/extended bottom placement work that LHC are pursuing already. A business case for developing an Option 2/3 fencing and recharge concept will need to be progressed and detailed procurement exercises undertaken, as well as funding opportunities explored.

7.3 Next Steps

To deliver these principles and recommendations, the tasks over the next few years should involve:

- **Spring 2020 to Spring 2021**: Key tasks are as follows:
  - Seek funding and in-kind supporting roles across partners, regulators and advisors;
  - Discuss further with all the relevant harbours and marinas to agree and develop a strategic plan for future recharge work. This should include clarifying the annual dredge volume contributions that they would be able to make to: Option 1 (bottom placement), and/or Option 2/3 (fencing and recharge);
  - Engage with, and actively involve, the local community, and carry out a non-use local community valuation study (perhaps in tandem with the Environment Agency and NFDC's consultation on flood defence priorities);
  - Seek permission (starting with a sampling plan) to licence more local deposit grounds for bottom placement work, including all/most Option 1 sites;
  - Carry out Option 1 extension work during the 2020/21 winter period;
  - Promote lesson learning and advocate for policy clarifications and changes (e.g. clarity of relevant issues such as compensation, mitigation, conservation management and FCERM/Outcome Measure funding) through regional, national and international forums;
  - Continue full-Solent oversight though work of the Solent Forum and maintenance of the BUDS online map;
  - Agree, among partners, the detail and the timing of an Option 2/3 approach;
  - Develop project detail and a business case/plan and then begin procurement work for an Option 2/3 approach to be done in late 2021 or early 2022;
- **Spring 2021 to Spring 2022**: Most above actions are ongoing and will need to continue. The key tasks for this year to include
  - Carry out monitoring and continue engagement work (including lessons from Option 1);
  - Apply for consents for an initial Option 2/3 approach;
  - Start the first trials of an initial Option 2/3 approach; and
- **Spring 2022 and beyond**: On an annual basis, continue all of the above and expand the scale of the work and/or the number of locations where it is carried out in response to findings.

From the consultations held during the review, there is expected to be a relatively broad consensus for the increased application of beneficial use across the parties. It is therefore hoped that this programme of work will be strongly supported.

As a final consideration it is worth placing a high level of emphasis on the application of strategically-driven lesson learning, communication and monitoring (including possible citizen science approaches) to inform future projects. Phases 1 and 2 of the Solent Forum BUDS work have proven to be good examples of these principles and exemplars of strategic planning. The BUDS project is demonstrating how broad regional policies for beneficial use (e.g. those set out in the MMO's South Coast Marine Plan) need to be proactively investigated at progressively more local levels in order to crystallise them into more distinct and deliverable projects that have the potential to attract investment and engender stakeholder participation.

This process needs to continue in the West Solent to engage and involve the local community and deliver projects. As part of this strategic oversight, it will also be important that completed projects provide a clear audit of the costs incurred as this will greatly help to inform planning of local recharge projects as well as other proposals for the rest of the Solent and other parts of the UK.

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9 Abbreviations/Acronyms

ABP	Associated British Ports
BCP	Bournemouth, Christchurch Poole Council
BEIS	(Department for) Business, Energy and Industrial Strategy
BESE	Biodegradable Elements for Starting Ecosystems
BTO	British Trust for Ornithology
BUDS	Beneficial Use of Dredged Sediment
BUWG	Beneficial Use Working Group
CBA	Cost Benefit Analysis
CCO	Channel Coastal Observatory
CD	Chart Datum
CEAMaS	Civil Engineering Applications for Marine Sediments
CEDA	Central Dredging Association
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CHaMPS	Coastal Habitat Management Plan
CO2	Carbon Dioxide
CSR	Corporate Social Responsibility
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
EC	European Commission
EEC	European Economic Community
ESCP	Eastern Solent Coastal Partnership
EU	European Union
EwN	Engineering with Nature
FCERM	Flood and coastal erosion risk management
FDGIA	Flood Defence Grant-in-Aid
gC	Grams of Carbon
GIS	Geographic Information System
HAT	Highest Astronomical Tide
HCC	Hampshire County Council
HCC	Hampshire County Council
HELCOM	Baltic Marine Environment Protection Commission - Helsinki Commission
HIWWT	Hampshire and Isle of Wight Wildlife Trust
HM	Her Majesty's
HPI	Historical Aerial Photography Interpretation
LEP	Local Enterprise Partnership
LHC	Lymington Harbour Commissioners
LiDAR	Light Detection and Ranging
LIFE	EC financial instrument for the environment
LNR	Local Nature Reserve
MCMS	Marine Case Management System
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MMO	Marine Management Organisation
MPA	Marine Protected Areas
MSc	Master's degree in a science
MSL	Mean Sea Level
NE	Natural England

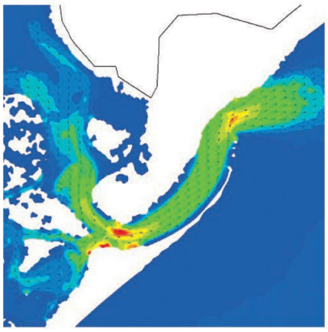
NEAFO	National Ecosystem Assessment Follow-on
NFDC	New Forest Distinct Council
NGO	Non-Governmental Organization
NHS	National Health Service
NPV	Net Present Value
NTS	Non-Technical Summary
OD	Ordnance Datum
ODN	Ordnance Datum Newlyn
OM	Outcome Measures
OMREG	Online Marine Register
OSPAR	Oslo and Paris Conventions
PhD	Doctor of Philosophy
PIANC	Permanent International Association of Navigation Congresses
PRISMA	Promoting Integrated Sediment Management
PSA	Particle Size Analysis
REACH	Restoring Estuarine and Coastal Habitats in the North East Atlantic
REMEMARE	REstore MEadows, MArshes and REefs
RHHA	River Hamble Harbour Authority
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SCOPAC	Standing Conference On Problems Associated with the Coastline
SDCP	Solent Dynamic Coast Project
SEA	Strategic Environmental Assessment
SEABUDS	SEA Change in the Beneficial Use of Dredged Sediment
SedNet	European Sediment Network
SMP	Shoreline Management Plan
SOC	Strategic Outline Case
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
St	Saint
SURICATES	Sediment Uses as Resources in Circular and Territorial Economies Project)
SWL	Sea Wall Level
TBT	Tributyltin
TEEB	The Economics of Ecosystems and Biodiversity
Tg	Teragrams
TSHD	Trailing Suction Hopper Dredger
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UN NEA	UK National Ecosystem Assessment
UNEP	United Nations Environment Programme
US	United States of America
USA	United States of America
USAR	Using Sediment as Resource
WCMC	World Conservation Monitoring Centre
WeBS	Wetland Bird Survey
WEG	Water Environment Grant
WG	Working Group

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices




Innovative Thinking - Sustainable Solutions

A Marsh Change Analysis Using LiDAR Data

This appendix includes a set of figures depicting intertidal bed profiles across 24 transects as derived from Environment Agency LiDAR surveys undertaken between 2007 and 2018. These figures were produced for this Phase 2 BUDS review to describe changes across all the marshes between Hurst and Lymington. The transects are labelled A to X (in an east to west direction along the coast) as shown in Image A1. Figure A1 to Figure A17 present the results for each transect. At the top of each of these figures, the transect alignment and the elevation difference between the 2007 and 2018 LiDAR surveys is superimposed over the aerial imagery from the February 2019 BUDS UAV survey.

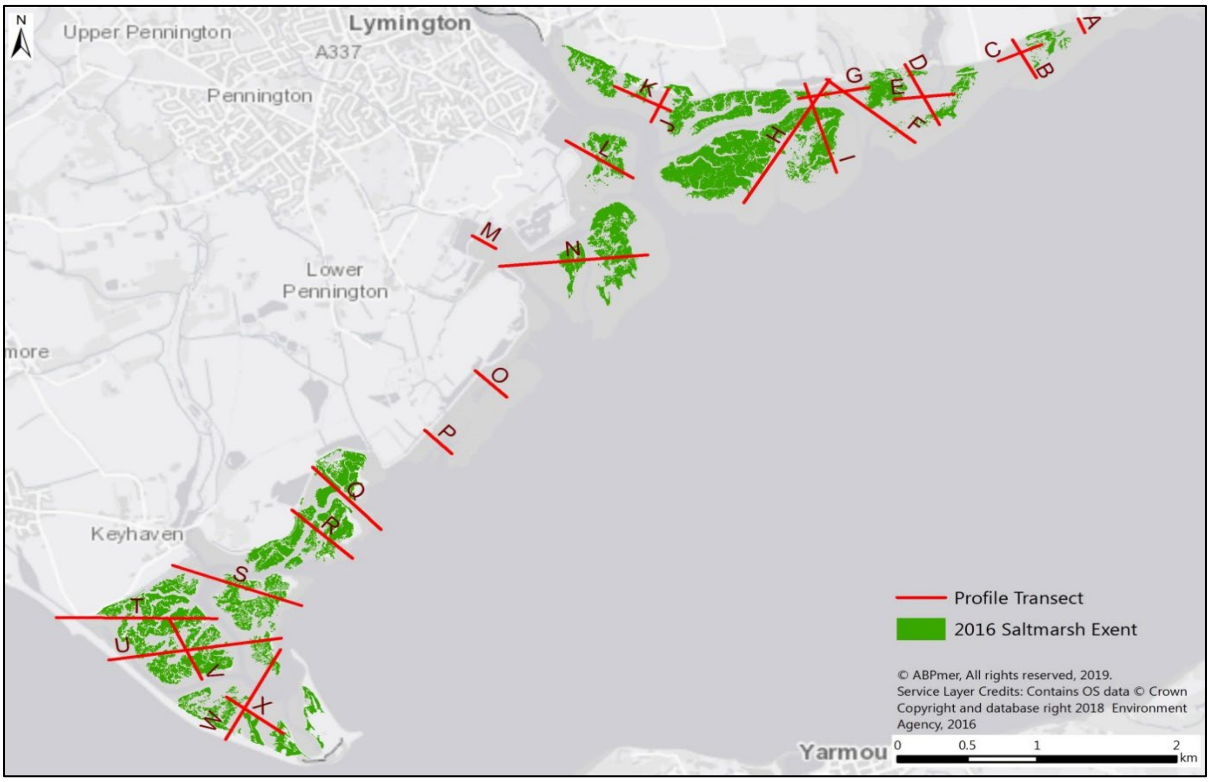


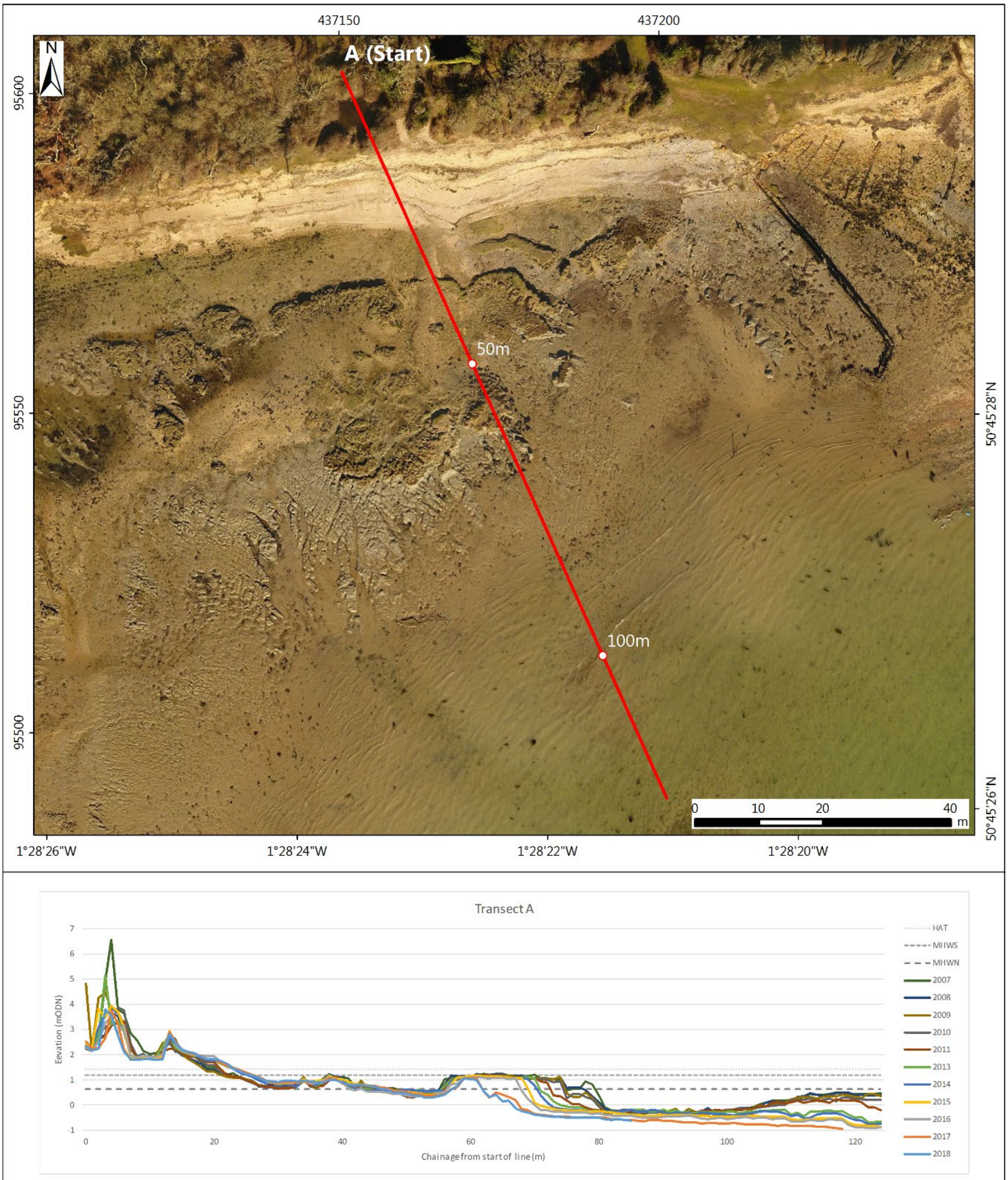
Image A1. Location of the intertidal transects

On each cross-shore profile, the elevations of the following tidal levels are shown: Mean High Water Neaps (MHWN), Mean High Water Springs (MHWS) and Highest Astronomical Tide (HAT). This is because intertidal habitats are generally expected[24] to develop at the following tidal elevations

- **Mudflat** between Mean Low Water Springs (MLWS) and MHWN;
- **Saltmarsh** between MHWN and MHWS; and
- **Upper Saltmarsh** between MHWS and Highest Astronomical Tide (HAT).

It is recognised however that 'marsh habitat predictions' based on bed elevations alone can result in an inherent simplification of likely intertidal habitat formation. This is because habitat composition and vegetation growth particularly are dependent on a number of site specific factors (especially drainage patterns, substratum, and wave and tidal current exposure). Please refer to Section 3.2.2 of the main report for a summary of the insights gleaned from the transects.

[24] Nottage, A.S. and Robertson, P.A. (2005). The Saltmarsh Creation Handbook: A Project Manager's Guide to the Creation of Saltmarsh and Intertidal Mudflat (RSPB Management Guides). RSPB, Sandy, 128p



Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect A.mxd		

Profile Transect

Figure A1. Transect A showing elevations between 2007 and 2018

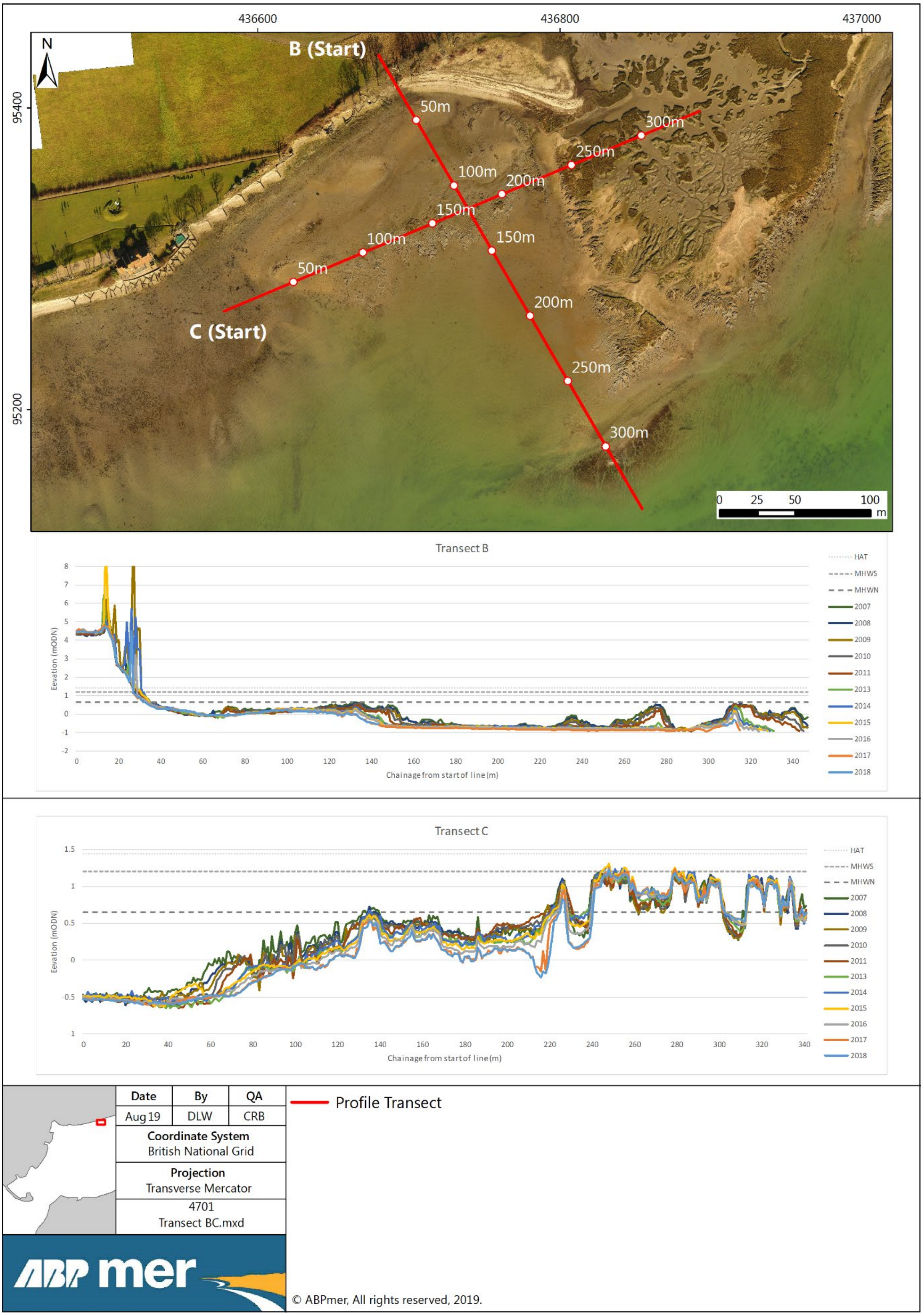
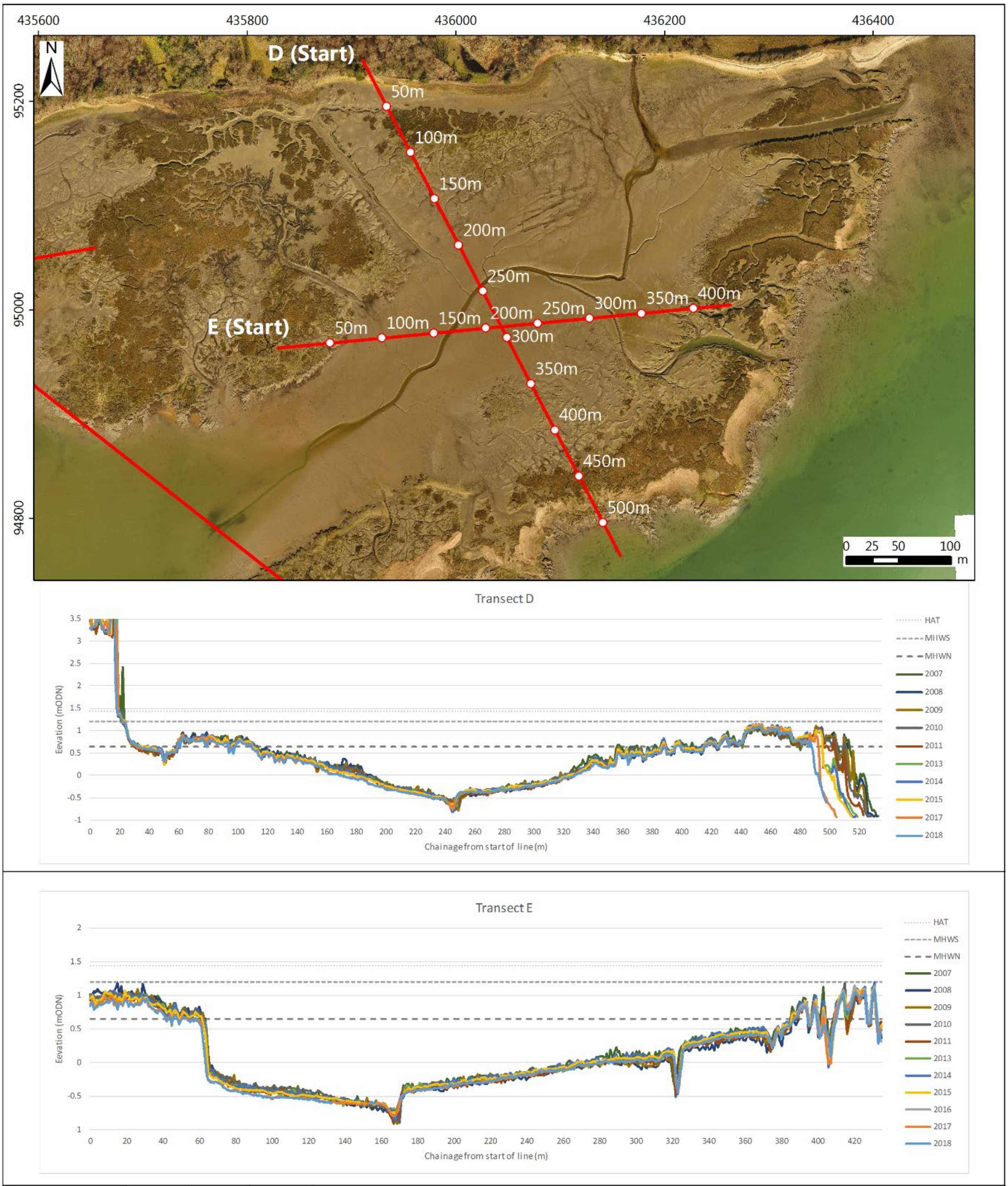


Figure A2. Transects B and C elevations between 2007 and 2018



Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect DE.mxd		

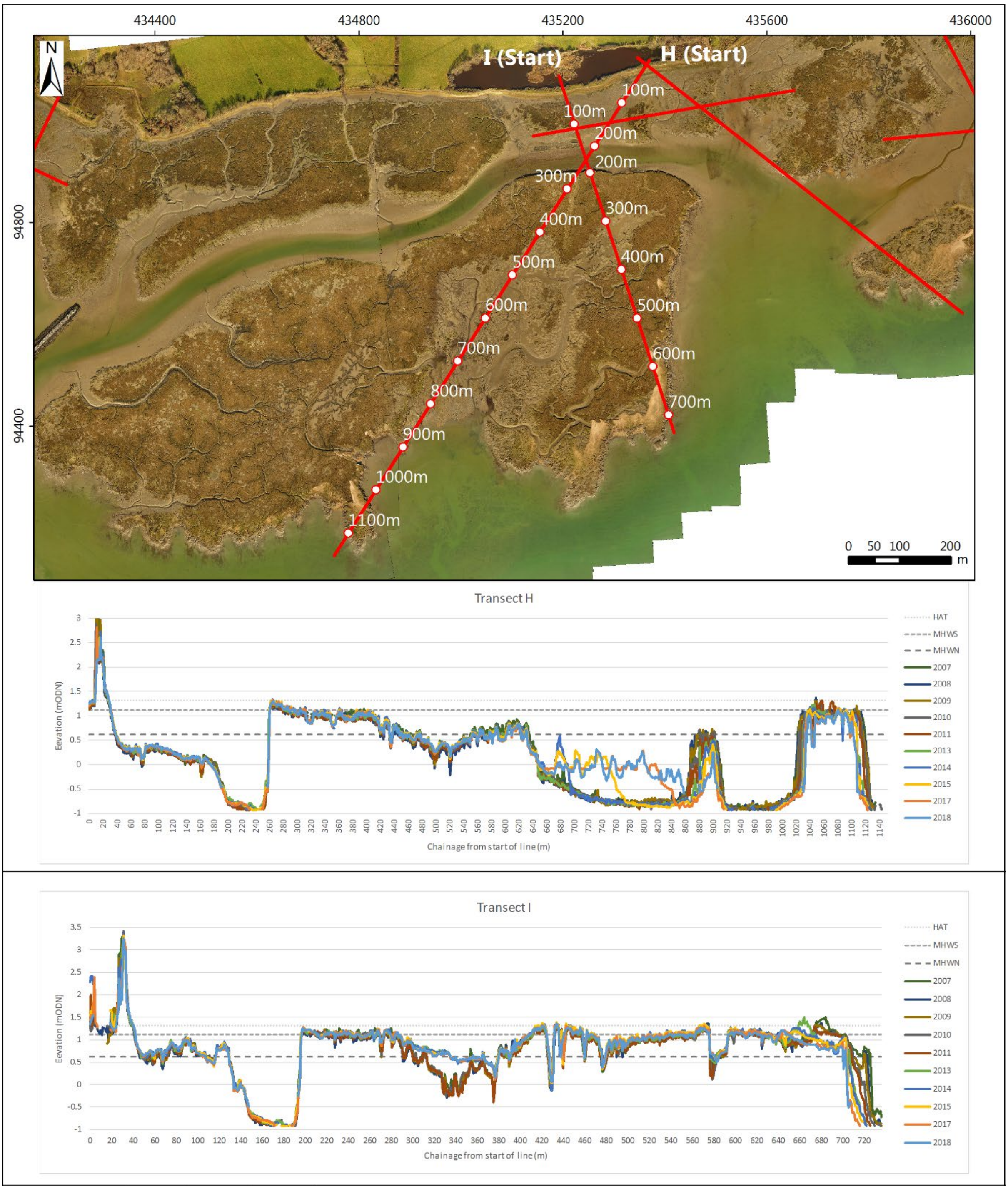
Profile Transect

Figure A3. Transects D and E elevations between 2007 and 2018

Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect FG.mxd		

Profile Transect

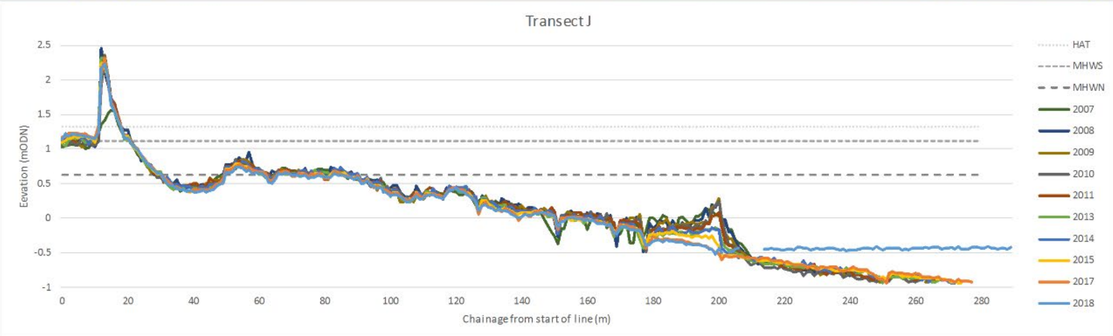
Figure A4. Transects F and G elevations between 2007 and 2018

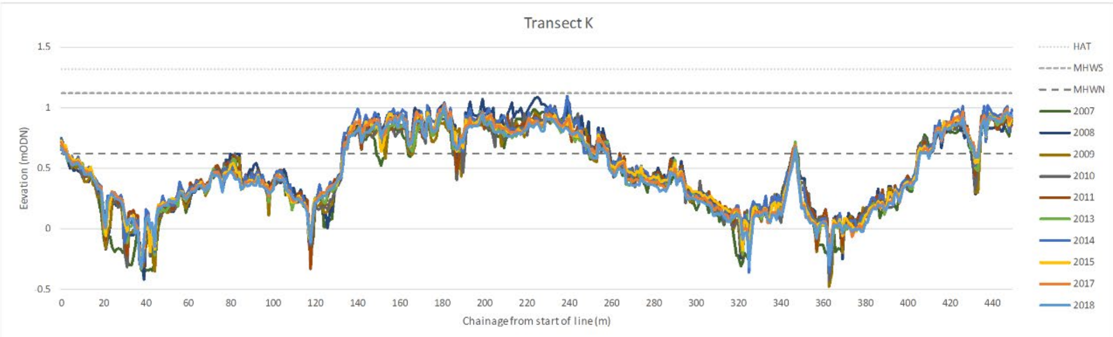


Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect HI.mxd		

Profile Transect

Figure A5. **Transects H and I elevations between 2007 and 2018**

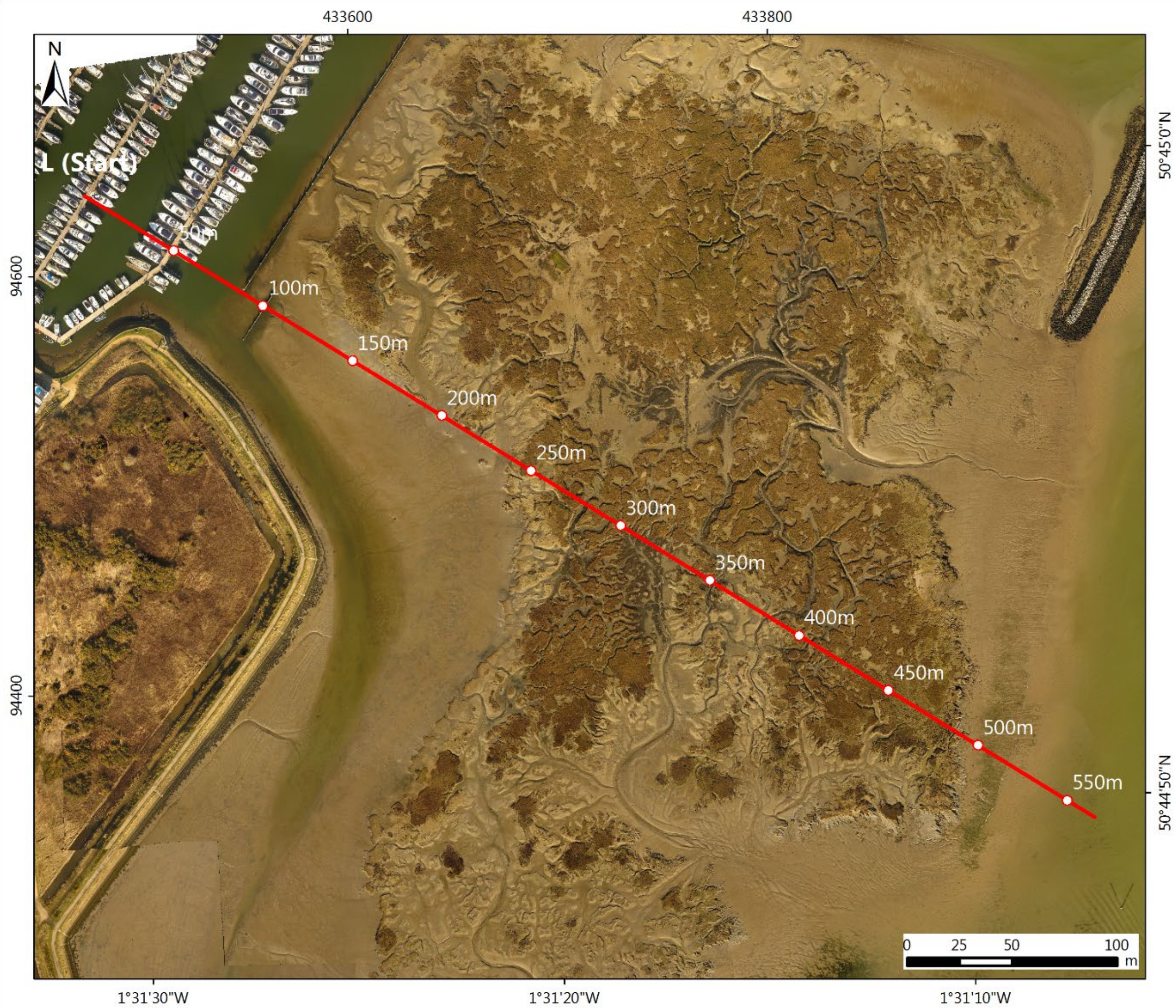


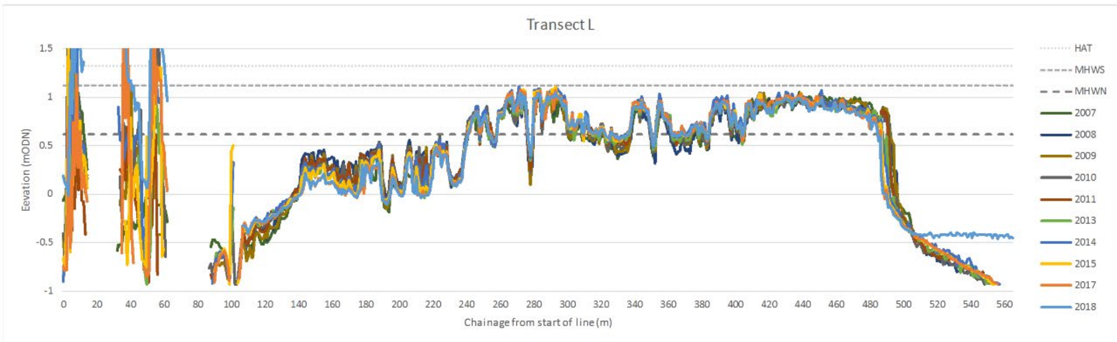


Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect JK.mxd		

Profile Transect

Figure A6. Transects J and K elevations between 2007 and 2018

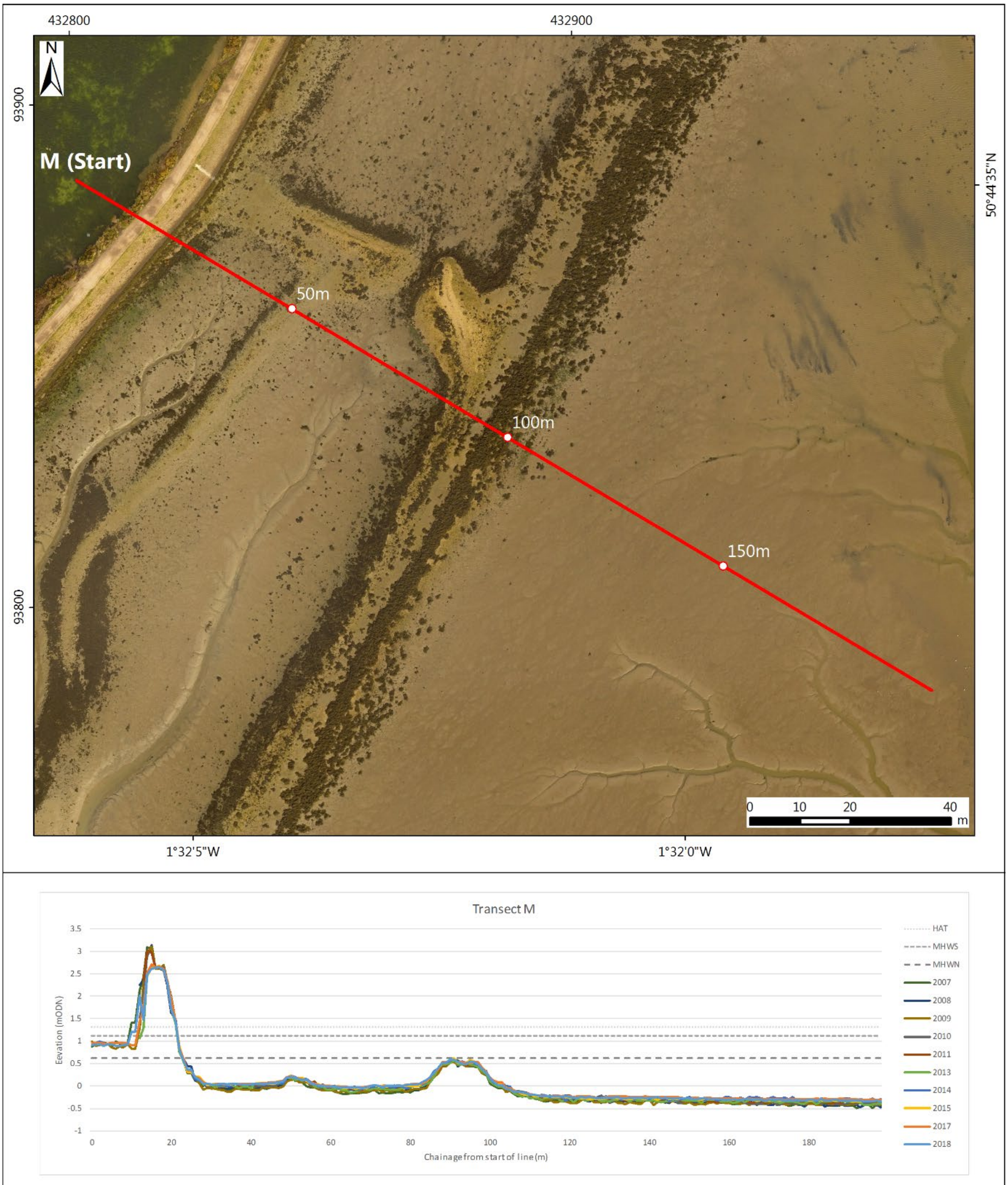




Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect L.mxd		

Profile Transect

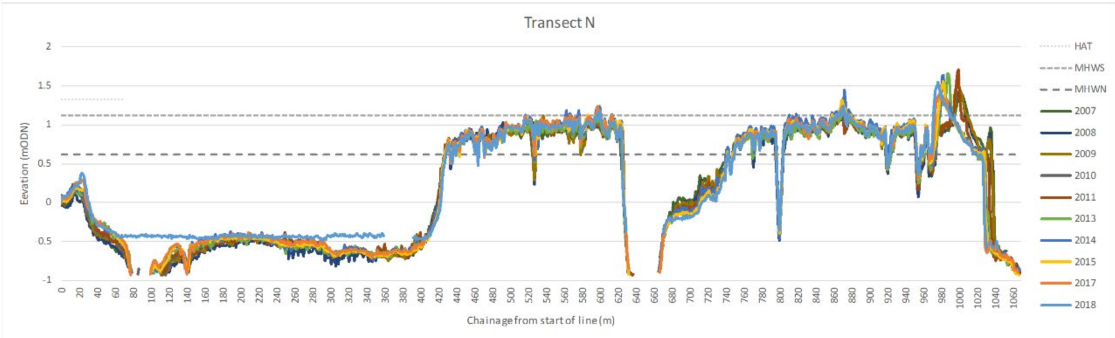
Figure A7. Transect L elevations between 2007 and 2018



Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect M.mxd		

Profile Transect

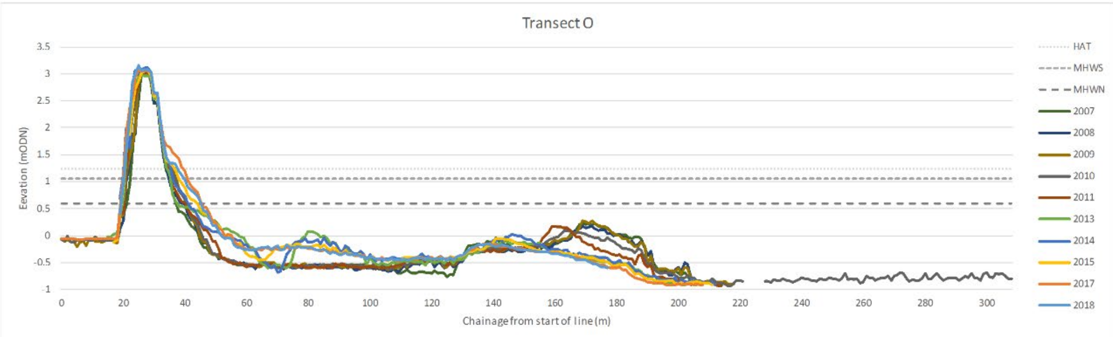
Figure A8. Transect M elevations between 2007 and 2018



Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect N.mxd		

Profile Transect

Figure A9. Transect N elevations between 2007 and 2018



Date	By	QA
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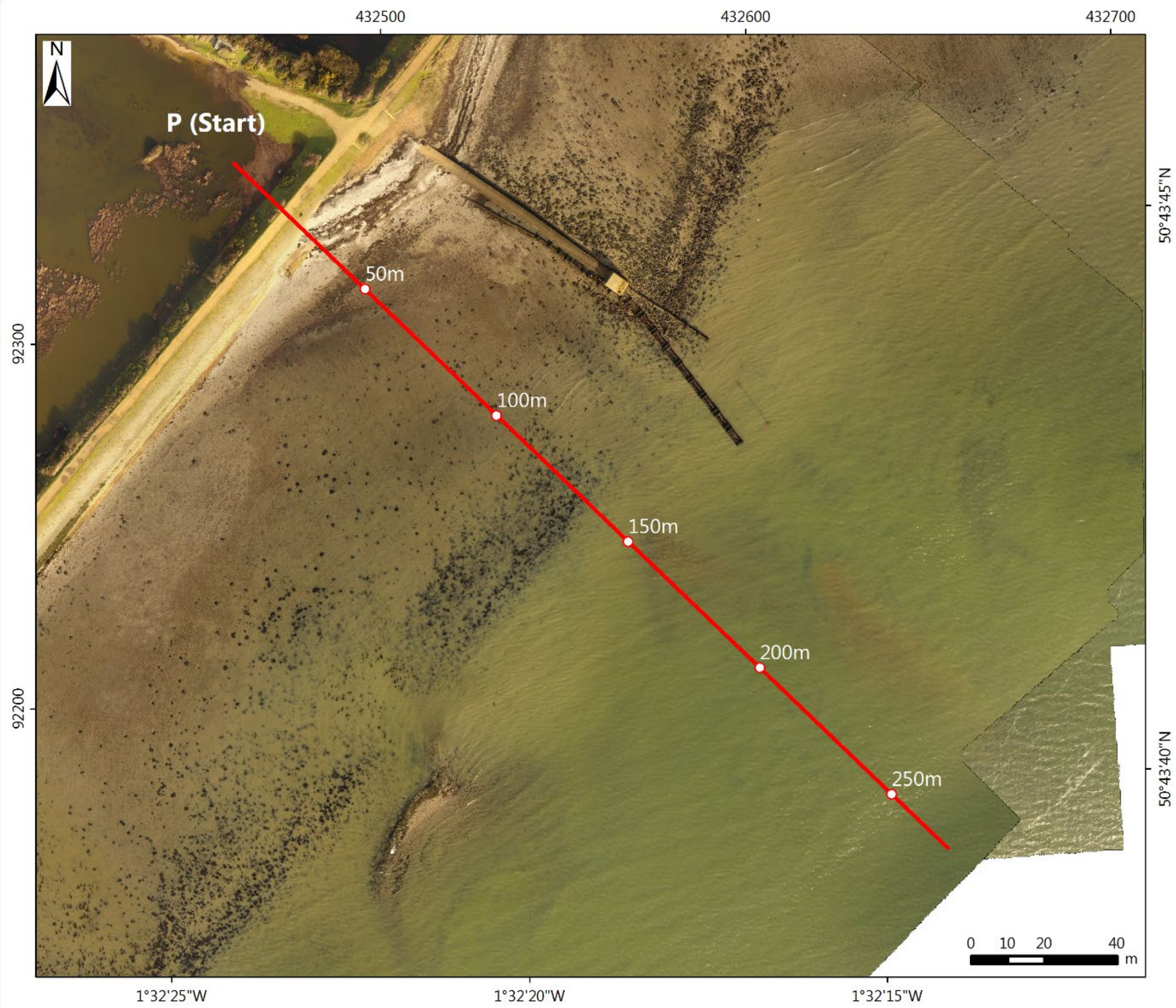
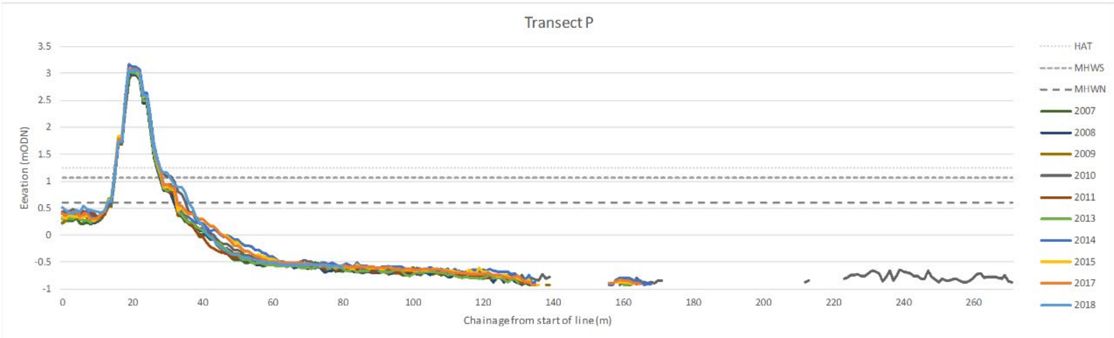
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect O.mxd		

Profile Transect

Figure A10. Transect O elevations between 2007 and 2018





Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect P.mxd		

Profile Transect

Figure A11. **Transect P elevations between 2007 and 2018**

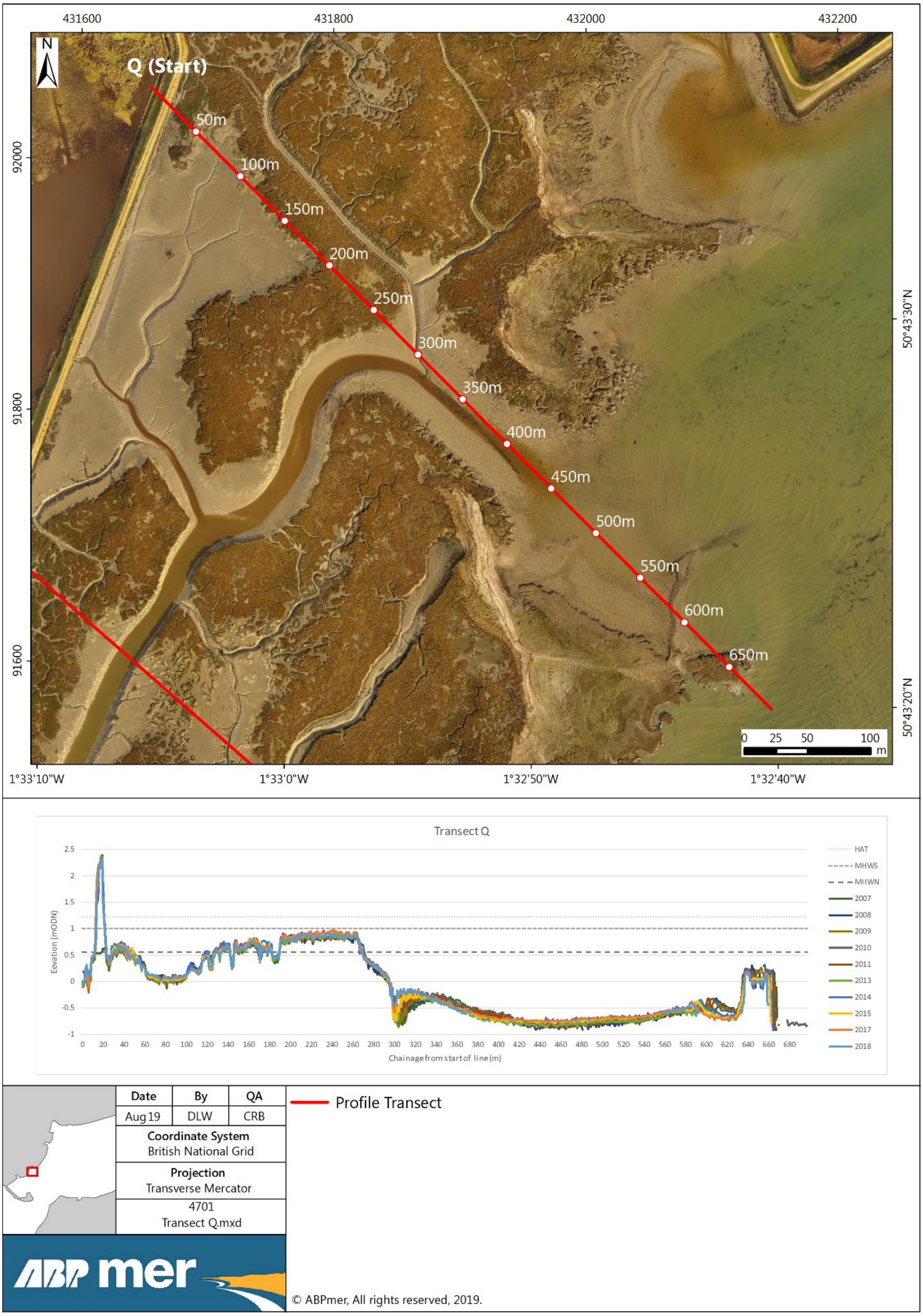
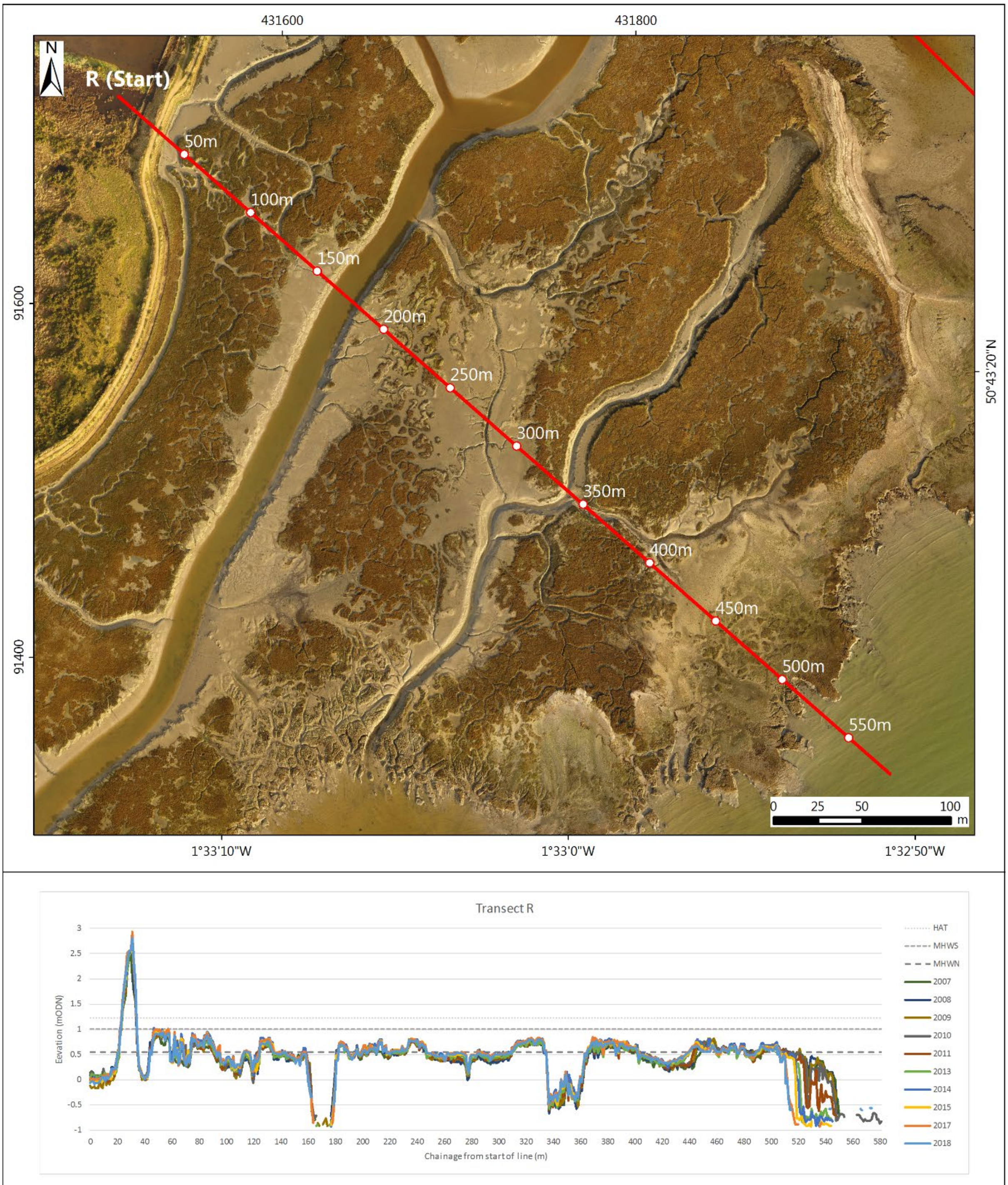


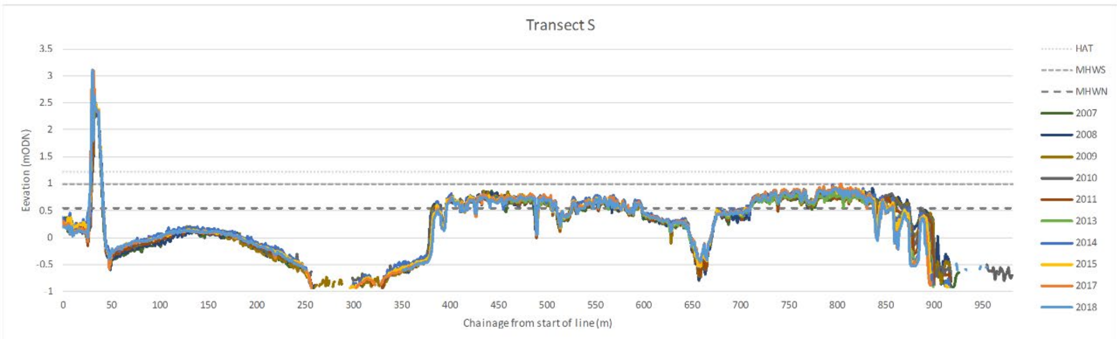
Figure A12. Transect Q elevations between 2007 and 2018



Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect R.mxd		

Profile Transect

Figure A13. Transect R elevations between 2007 and 2018



Date	By	QA
Aug 19	DLW	CRB

Coordinate System
British National Grid

Projection
Transverse Mercator

4701
Transect S.mxd

Profile Transect

Figure A14. Transect S elevations between 2007 and 2018

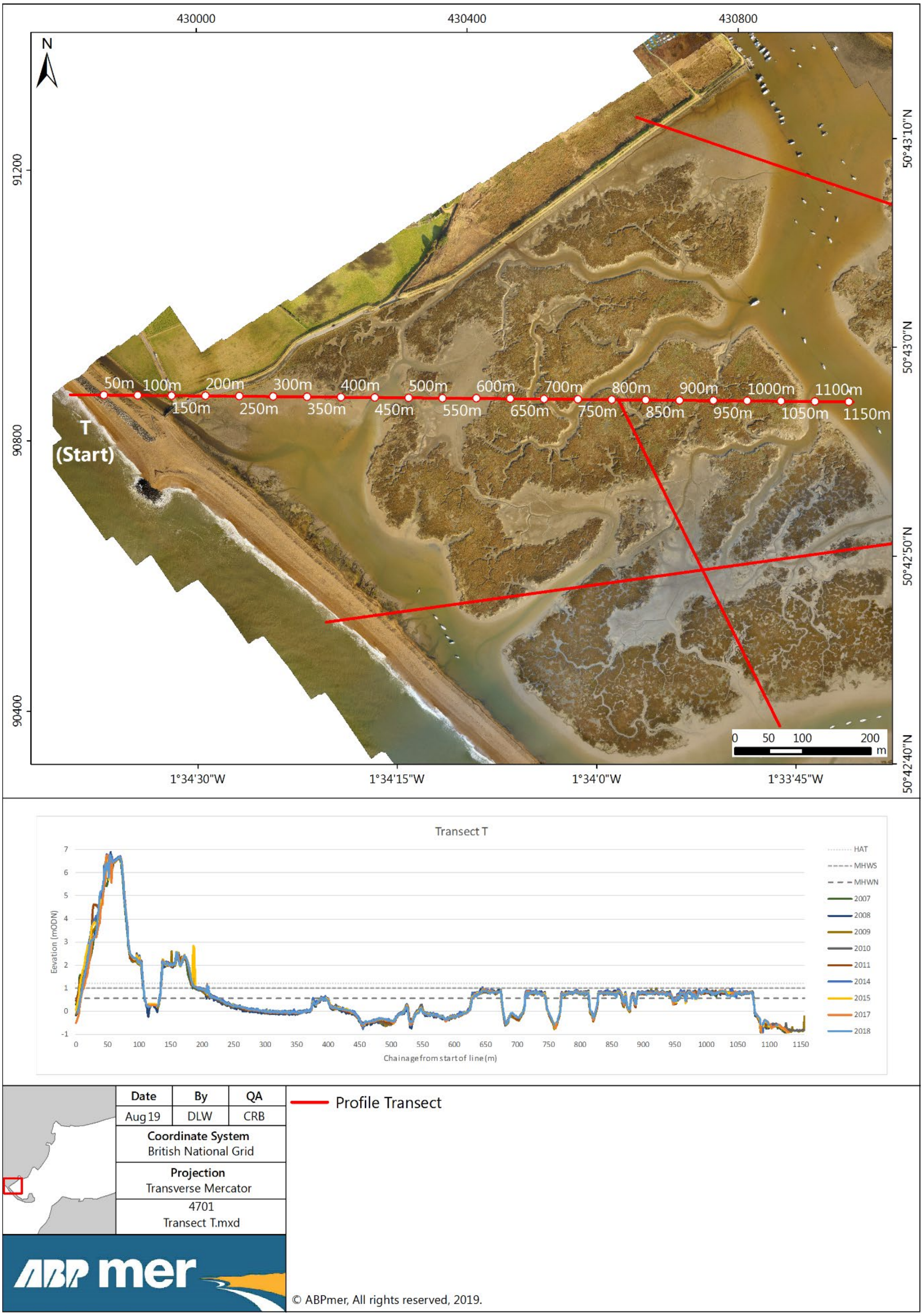
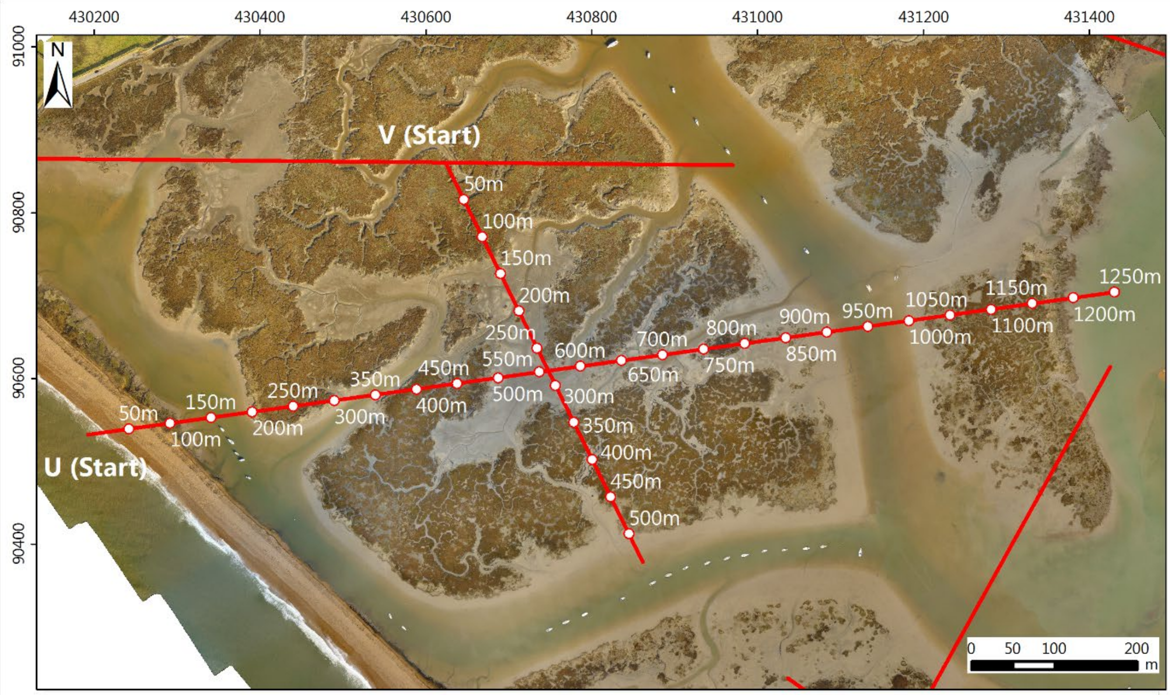
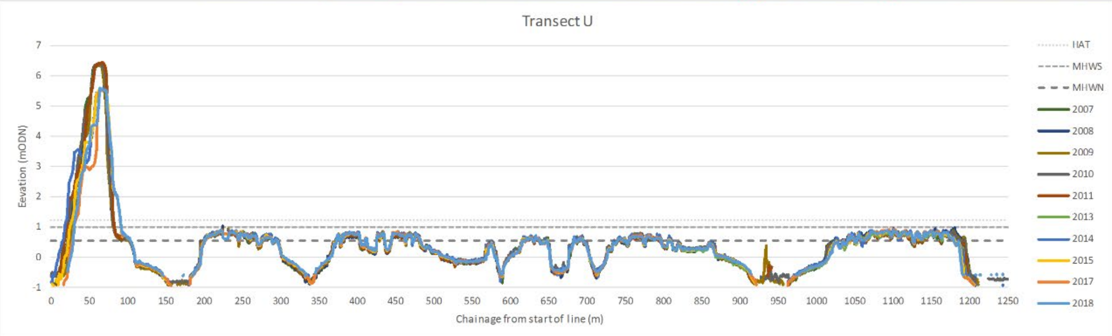
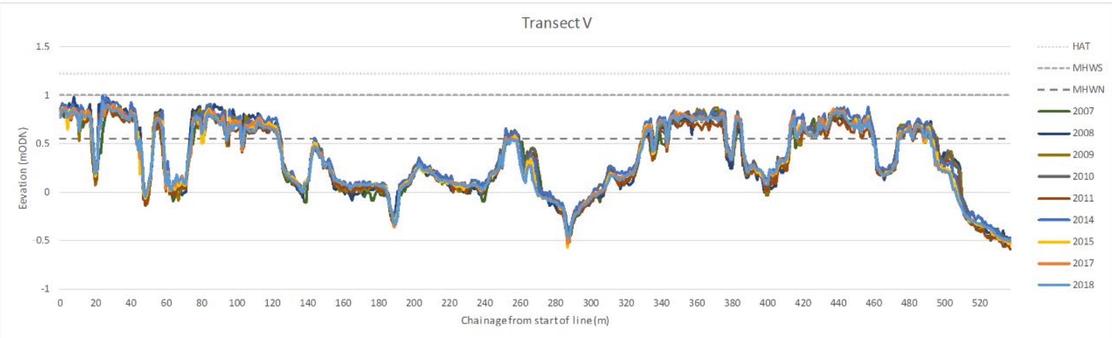


Figure A15. Transect T elevations between 2007 and 2018







Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect UV.mxd		

Profile Transect

ABPmer

Figure A16. Transects U and V elevations between 2007 and 2018

Date	By	QA
Aug 19	DLW	CRB
Coordinate System British National Grid		
Projection Transverse Mercator		
4701 Transect WX.mxd		

Profile Transect

Figure A17. Transects W and X elevations between 2007 and 2018

B Review of Beneficial Use Projects

B.1 Introduction

The Phase 1 BUDS report (ABPmer, 2018) included a detailed review of the background to, and some of the challenges and successes associated with, beneficially using sediments to restore intertidal/saltmarsh habitats. Since that report was completed, there have been further developments which reflect an evidently mounting national and international drive towards seeing greater proportions of the dredged sediment resource used beneficially.

The BUDS project is a leading example of these new initiatives and is a particularly valuable because it is seeking to change the 'business as usual' approach. It is doing this by proactively identifying habitat restoration measures and to secure the necessary consents to see them realised. It is crucial that this proactive 'needs-led' approach in order to overcome the technical and funding challenges that exist with using sediment beneficially.

To ensure that it is understood how the BUDS work fits in to the wider context, other recent national and international initiatives are outlined below in Section B.2, while recent UK beneficial use projects/developments are summarised in Section B.3 (this includes a summary/update of the Lymington projects in Section B.3.3).

B.2 New working groups

As an indication of the increasing attention being paid to the concept of beneficial use, initiatives which are underway or are recently completed include the following:

- **The SEABUDS National Working Group**. This 'beneficial use working group' was set up in 2017 by the RSPB and includes national representatives from the MMO, the Environment Agency, NE, Cefas and RSPB as well as ABPmer. This group meets every six months to explore ways in which more beneficial use projects can be realised and to develop guidance in this field.
- **CEDA International Working Group:** CEDA set up a beneficial use working group in early 2017 and, over the last two years, this group collated details on 34 international case studies and produced two short reviews on the subject of beneficial use generally and the use of contaminated sediments particularly. These reports were issued in June 2019 (CEDA, 2019b).
- **PIANC International Working Group.** A new PIANC working group (WG214) was set up at the start of 2019 to investigate approaches for beneficially using dredged sediments. Its formation was prompted by an increasing recognition of the challenges with depositing harbour dredge arisings as well as the missed opportunities to achieve benefits from this resource. It is also motivated by increasing public concerns over established practices and finite space within Dredged Material Containment Facilities. This project is seen as very urgent and this working group expects to report in Summer 2020;
- **MMO National Mapping exercises:** The MMO has recently completed (June 2019) a high-level exercise to map existing and potential future opportunities for beneficial use in four marine plan areas (the North East, North West, South East and South West) (MMO, 2019). This follows on from an equivalent exercise that was carried out five years ago for the south marine plan area (MMO, 2014); and
- **CEDA UK National Review:** In 2018, the CEDA UK Committee set up a Liaison Group to investigate the economic factors affecting the viability of beneficially using dredged material in the UK. This group consulted with a wide range of interested parties and are preparing a report of this work that will revisit and clarify the economic and technical challenges and will provide

recommendations for measures to encourage beneficial use. A report from this study is expected in the near future.

In addition to these projects, there are many other research studies that have been completed in recent years, or are still progressing. These include the following European and US projects:

- **SedNet from 2002 (ongoing)**. SedNet is a European network aimed at incorporating sediment issues and knowledge into European strategies to support the achievement of a good environmental status and to develop new tools for sediment management. It covers sediment quality and quantity issues on a river basin scale, ranging from freshwater to estuarine and marine sediments.
- **PRISMA to 2013** (Promoting Integrated Sediment Management) – Investigated methods for processing, treating and reuse of sediment in estuaries and coastal waterways from dredging to recycling. Considered new dredging methods and new methods of reusing sediment in varying applications such as dykes, riverbanks, roads and agriculture.
- **CEAMaS to 2015** (Civil Engineering Applications for Marine Sediments) - Promoted, through EU funding, initiatives to encourage knowledge and consensus to raise new solutions of reuse of marine sediments applicable to all of Europe. This project dealt mainly with engineering beneficial reuse options;
- **USAR to 2020** (Using Sediment as Resource) introduces an alternative, resource efficient approach based on the potential to use sediments as a resource for new materials. In the UK, it has supported beneficial use initiatives in Brightlingsea (Essex) and by the West-Country Rivers Trust.
- **EU SURICATES to 2021** (Sediment Uses as Resources in Circular and Territorial Economies Project) which is aiming to increase sediment reuse for erosion and flood protection, including new large-scale solutions for sediment reuse in north-west European ports, waterways and coastlines.
- **Engineering with Nature (EwN) 2018 and 2020/21**. Initiated by the US Army Corps of Engineers' Engineer Research Development Center. The EwN programme seeks to develop knowledge and collate practical experience regarding the use, and reuse, of dredged sediment in relation to resilience and nature restoration. Their work is documented in many completed and on-going case studies. At the end of 2018, EwN published an Atlas with numerous cases studies, most of which incorporate the beneficial use of sediments (Bridges *et al*., 2018). They also have plans for a second volume of this atlas to be completed in 2020/21.

B.3 Recent beneficial use projects

Over the last year or so (since the BUDS Phase 1 study was completed), progress has also been made on a few UK beneficial use projects. Some details of these new/further progressed projects are presented below with a view, again, to informing this BUDS Phase 2 review.

B.3.1 Holes Bay (Poole Harbour) marsh restoration Initiative

In July 2018, the newly integrated Bournemouth Chichester Poole (BCP) Council restarted the Holes Bay marsh recharge initiative. This project was stalled in 2015 due to the uncertainties associated with the requirements and costs for consenting.

Now a feasibility study is being undertaken by BCP for a project in Holes Bay (see Image B1). In the embayment, the maximum marina dredge volume is around 10,000 m^3 per annum, so a project extending over 5 years could potentially reuse as much as 50,000 m^3. The proposed approaches for this work are being reviewed, and it is likely that multiple different techniques will be used. Possibly there will be some bottom dumping to deeper areas, as well as some thin layer/piped placement sediment onto areas of the shallower saltmarsh.

The methods of retention could be as simple as creating islands using hessian-wrapped straw, but there may be a requirement for silt curtains to retain deposited material if sediment suspension/dispersion is judged to be an issue. Once the BCP feasibility review is complete, and if proposals are agreeable with the various funding partners, further discussions will be had with the consenting bodies to determine the steps needed to obtain permissions (see also Section 3.7 which describes how there have been initial consultations with MMO and Cefas as part of BUDS Phase 2).

Source: Google earth and data from Bournemouth, Christchurch Poole (BCP) Council

Image B1. Location of Holes Bay where BCP is investigating potential beneficial use options

B.3.2 Mersea climate change adaptation project (Blackwater, Essex)

In March 2018, permissions were obtained for a coarse sediment (shingle) recharge project on the islands and marshes near west Mersea (MMO Ref MLA/2016/00386). This is the 'Mersea Harbour and Tollesbury Wick Climate Change Adaptation Recharge Project', which has not been carried out yet, but will involve the use of dredge arisings from the deepening of the Harwich Haven Approaches. For this project, a total of 98,000 m^3 of sediment will be placed across five separate locations.

The work is being overseen by the Mersea Harbour Protection Trust and its timing will, necessarily, need to coincide with the Harwich dredging work. This project is a valuable example of how it is possible for consent for a beneficial use project to be achieved in advance of the need to undertake the dredging work itself. It has also demonstrated how such a project needs independent vision from, and advance communications between, the provider and the user of the sediment resource. The project has furthermore highlighted the regulatory challenges that exist, as the consenting process was long (18 months), complex and expensive (see Appendix C, Table C1 for some costs details for this project).

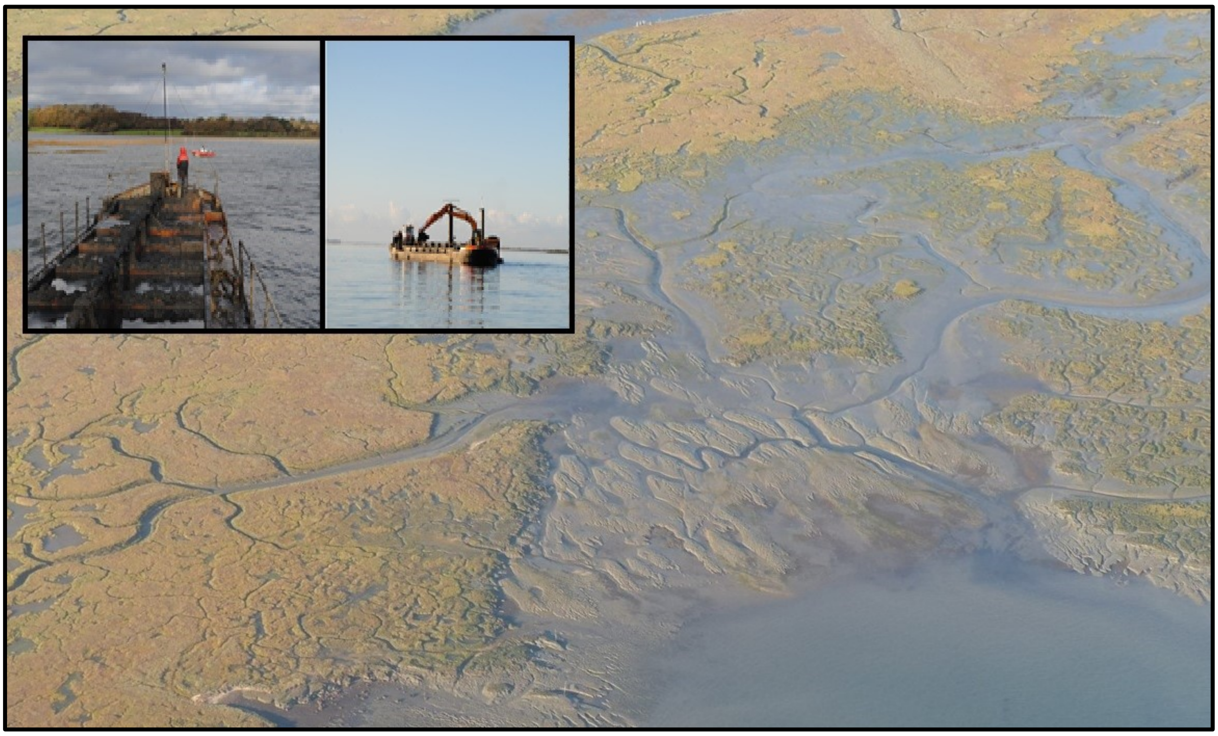
B.3.3 Lymington projects summary/update

LHC bottom placement update

In recent years, LHC have carried out new 'bottom-placement' recharge work in front of Boiler Marsh at the mouth of the Lymington Estuary. For this work, dredged material (silt) is loaded into barges by back hoe at channel and mooring dredge areas in the estuary. Then the barges move to the new disposal ground and discharge the sediment by opening the hopper doors in the bottom of the barge before then return to the dredging site to collect more sediment. This project has been licensed in two phases as follows

- As initial trials for three years (2014 to 2016); and
- As ongoing work for seven years under a licence dated 28 September 2017: Variation consent for the annual beneficial bottom placement of up to 10,000 tonnes of dredged material at the established saltmarsh recharge site.

The aim of the latest bottom placement work is to get sediment as high up the intertidal zone as feasible so it has the greatest chance of feeding the adjacent marsh and acting as a 'sacrificial bund' feature to shield the inner marsh. To help achieve these aims and extend the amount of time that the deposited sediment remains *in situ*, the disposal is undertaken only on the larger high tides. To also try and ensure that each new deposit is placed as close as possible to previous ones (thus maximising the amount of sediment that is reused within the deposit ground), barges are guided into their deposit location by post markers. The deposition process itself lasts only a few minutes.



Source: S. Nunn (main), LHC (inset)

Image B2. Lymington bottom placement (deposit location with hopper in transit and loading)

This work has proven to be relatively effective, with the more consolidated materials showing quite a high degree of persistence (Black and Veatch, 2017; ABPmer, 2019b). The continued regular/annual placement of sediment at this deposit site is expected to further help to maintain and potentially build up this feature, although its size and persistence will always be influenced by a range of factors, including the consolidation of the deposits as well as the occurrence and nature of storm events (ABPmer, 2019b). In light of the success of this work, the LHC are exploring ways to expand this work to include new beneficial deposition areas.

With regard to costs, the LHC have clearly audited, and shared, these. During the LHC's initial three-year trial phase deposition (2014 to 2016) a total of 16,781 m^3 was beneficially bottom dumped at an average cost of £9.80 m^{-3}. Over the same period the established process of taking this material to the Hurst disposal ground cost £8.78 m^{-3} on average. This fee included an annual apportionment for securing the dredge and disposal licences.
Based on these values, and the fact that there will be cost sharing benefits from integrating the licensing of both the at-sea disposal and the beneficial use licences, the trials using 16,781 m^3 of sediment cost roughly an extra £20,000 over the business as usual approach. That is equivalent to 2% of the fees for all the disposal work during this period. This value essentially corresponded to the extra costs that were incurred to carry out the monitoring.

In the two years following these trials, the beneficial use work has been continued under a new longer-term licence. There are now signs that some costs savings are being made, or at least that the costs of placing the sediment at the beneficial use ground are reaching parity with disposal at Hurst. It is possible that, over the next few years, disposal at Hurst option will become the marginally more expensive of the two options. This is because the intensity of monitoring at the beneficial use site has decreased.

RSPB chenier enhancement

In March 2017, the RSPB undertook a shingle recharge on Cockleshell Island close to the mouth of the Lymington estuary. A shallow draft barge and deck crane was used to lift 88 tonnes of shingle on to the marsh and this material was then distributed by hand to form a nesting bund (see Image B3).

Source: RSPB

Image B3. Chenier recharge using shingle material at Lymington River entrance

This was done to try and increase the profile of pre-existing chenier beaches, which is the primary nesting habitat for terns in the West Solent Sea-level rise has reduced the amount of available nesting space and cheniers are frequently flooded at high tide. It is hoped that the recharge will lower the risk of nest flooding as a large proportion of the bund lies above high water (RSPB, 2017).

Projects summary

The ongoing work by LHC and the RSPB chenier recharge follow on from the previous marsh recharge work carried out by LHC and Wightlink Ltd in 2012 and 2013. This previous work was carried out as mitigation measure to offset the actual and potential effects of development activities in the Lymington Estuary. Further details about this previous recharge work was included in Phase 1 BUDS report and a summary of all these Lymington campaigns, including the volumes of sediment used, is presented in Table B1.

Table B1. Beneficially use projects at Lymington over the past seven years[25]

<table>
<tr><th>Years</th><th>Quantity (Wet Tonnes)</th><th>Quantity (m^3)</th><th>Notes</th><th>MMO Licence Reference</th></tr>
<tr><td colspan="5">Lymington T-Yacht Haven Marsh Restoration (LHC Project)</td></tr>
<tr><td>2012 and 2013</td><td>4,063</td><td>3,125</td><td>Two annual campaigns</td><td></td></tr>
<tr><td colspan="5">Lymington Boiler Marsh Restoration (Wightlink Ltd Project)</td></tr>
<tr><td>2012 and 2013</td><td>5,850</td><td>4,500</td><td>Two annual campaigns</td><td></td></tr>
<tr><td colspan="5">Lymington Intertidal Bottom Placement Boiler Marsh (LHC)</td></tr>
<tr><td>2014 (Nov/Dec)</td><td>2,287</td><td>1,759</td><td>Year 1 Trial</td><td rowspan="3">L/2014/00084/6</td></tr>
<tr><td>2015 (Nov/Dec)</td><td>6,883</td><td>5,295</td><td>Year 2 Trial</td></tr>
<tr><td>2016 (Oct to Dec)</td><td>9,942</td><td>7,648</td><td>Year 3 Trial</td></tr>
<tr><td>2017/18 (Nov to Jan)</td><td>9,286</td><td>7,143</td><td>Year 4 Main Licence</td><td rowspan="2">L/2014/00396/2</td></tr>
<tr><td>2018 (Nov/Dec)</td><td>6,446</td><td>4,958</td><td>Year 5 Main Licence</td></tr>
<tr><td colspan="5">Lymington RSPB Chenier Recharge</td></tr>
<tr><td>2017</td><td>88</td><td>-</td><td>One off</td><td></td></tr>
</table>

B.3.4 Depositions at Loder's Cut (Deben Estuary, Suffolk)

The Loder's Cut Island project involved using dredge arisings at a small-scale to restore a small marsh area. Sediment from Woodbridge quayside was excavated using a clam-shell bucket dredge and placed on a local area of marsh by the reverse process. For this work, a small 65 ft barge (carrying 70 tonnes or 50 m^3 each) was used with an aft-mounted excavator. This was suitable for use in the constrained and busy upper estuary. The unloading was done on the top of the high tide with the barge being floated in and out over separate high water periods.

In total 1,400 m^3 silt were placed over two campaigns (in 2015 and 2017). The recharge site was located alongside a small navigation channel that had been historically created (i.e. 'cut') by hand excavation in this part of the upper Deben estuary. The deposits raised a 1,369 m^2 area of marsh by around a 1 m which became a small 'island' at certain high tides. This island was quickly used by roosting birds and the deposits were relatively rapidly colonised by pioneer marsh plants.

25 As the volumes were made available either as wet tonnages (for the LHC bottom placements) and in cubic metres (as is the case for the LHC and Wightlink Marsh recharges) then a 1.3 conversion factor for 'soft silt mud' (HELCOM, 2015) is used to provide an estimates in both units for all the work undertaken at Lymington.

The first campaign (in 2015) involved the transportation of 16 barge loads of dredge sediment from Ferry Quay at Woodbridge. A visit in 2016 (a year after this first campaign) indicated that the placed material had remained stable and *in situ*. The upper margins of this deposited strip had a thick cover of Salicornia spp. as well as occasional Sea Aster (6-7 plants) and one Spartina plant. There were also signs of invertebrate burrows and bird feeding on the un-vegetated lower margins on the channel/cut side.

B.3.5 Brightlingsea Creek (Essex)

In recent years a couple of different projects have been undertaken at Brightlingsea to reuse accreted sediment within the harbour. In 2017 a cutter suction dredger was used to excavate and pump sediment around the yacht moorings (working alongside and underneath the boats and floating pontoons that remained *in situ*) in the South Channel and pump the silt into 23 borrow pits within the adjacent saltmarshes.

The receptor pits used in this case had been dug after the 1953 floods in order to obtain material to build up the sea walls. They covered around 2 hectares and were situated between 500 and 1,600 m upstream from the dredging area along Brightlingsea Creek. This work was undertaken under the EU Interreg 2 Seas initiative 'Using Sediment As a Resource' (USAR) this work was led by Exo Environmental and undertaken by Royal Small Dredging and Miles Water Engineer Ltd. In addition to this work there has also been separate cutters suction dredging work whereby sediment is then released into the estuary as well as areas where poldered fences have been put in place and sediment deposited behind with a long-reach excavator.

B.3.6 Horsey Island (Hamford Water, Essex)

The Phase 1 BUDS report included a summary of the recharge work that has been done at Horsey historically and this work as in a stand-alone review prepared by ABPmer (ABPmer, 2016b). This was the largest UK project and was carried out in three separate placements which totalled around 150,000 m^3 of silt (and more shingle) over around 16 years to restore around 3 ha of habitat.

The RSPB is now starting to options of adding extra shingle to the existing Horsey Island recharge site. This is because the original project was successful in delivering persistent intertidal habitat and particularly has become an important Little Tern nesting site (the only site in Essex where this species has bred successfully. As a result the RSPB is exploring whether more shingle can be placed at this locations to increase the sustainability of this tern breeding habitat in the face of rising sea levels.

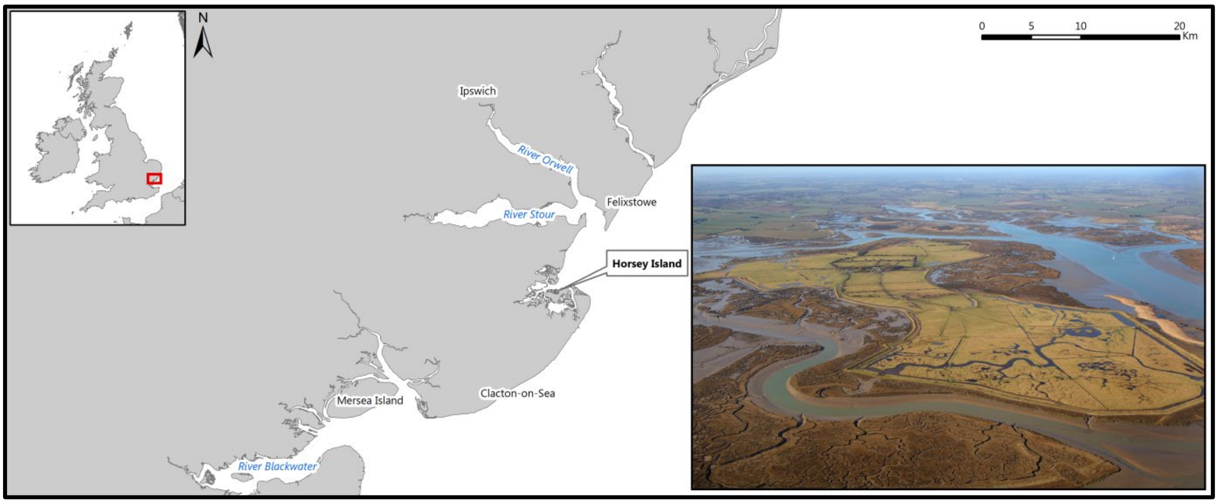


Image B4. Location of Horsey Island with aerial view of the site

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C Review of Beneficial Use project costs

C.1 Introduction

One of the widely-recognised barriers to implementing 'recharge' schemes is that they often incur extra costs when compared with standard practices for dredge material disposal (PIANC, 2009; ABPmer, 2014). This is because recharge schemes introduce new approaches that require the purchase, mobilisation, hire, storage and/or maintenance of new equipment as well as extra fees for consulting, consenting and monitoring. This extra cost between the established 'business as usual' practices and any proposed recharge is referred to as the 'cost differential'.

This situation is not helped by the fact that there is generally a poor understanding about the scale of the cost increases or the benefits of the recharge work. This is because relatively little effort has been made to collate cost information or to undertake reviews of the costing information that does exist. This lack of clarity on costs, as well as benefits, can make it difficult for stakeholders to understand the implications of different options, and to be clear about funding constraints and funding sources.

This issue is further confounded by the fact that the cost differential and the net benefit can vary greatly on a site-by-site basis, depending upon a range of factors such as the location, method and scale of operation. It is also greatly influenced by variables such as equipment availability (which influences mobilisation costs), or the accessibility of a recharge location (which can influence the tidal states under which recharge work can be carried out and, hence, the overall duration of a project).

The cost differential can be particularly high for large-scale projects which typically incur substantial extra fees over and above those for standard 'at sea' disposal; but also, there are instances where recharge can be cheaper than standard 'at sea' disposal options. These factors make it very difficult to accurately cost a project and hence to plan and budget for such work. This uncertainty about the fees that could be incurred, and the risks associated, are therefore key reasons why it has proved to be difficult to instigate recharge initiatives in the past.

The 'cost differential' can also change over time and should theoretically reduce progressively year-on-year, after an initial up-front expenditure is incurred. However, the up-front expenditure of such projects can still present an obstacle to project implementation (especially at a large scale). Also, few long-term projects are being implemented to verify this principle and, even where they are carried out, there is limited available evidence to quantify the cost-reductions over time. The fact that such cost auditing has been done at Lymington (see Image 18) has proven to be immensely valuable for this BUDS review.

There are other factors which can make it difficult to obtain clear cost benefit projections, and these include:

- The fees being incurred for the established practices (in advance of any change) are not always widely agreed or communicated and are themselves variable between locations (e.g. depending upon the haulage distance between the dredge site and the to the deposit grounds);
- The mechanisms and fees for a proposed beneficial use initiative (including the practical exercise itself as well as the work needed to secure the consents[26] and conduct monitoring) can often be unclear; and

[26] One illustration of this was the original Holes Bay recharge proposal which was halted because of uncertainties with the regulatory process and costs incurred to achieve necessary consents. This project illustrated how such uncertainties can hamper the ability of practitioners to pursue such initiatives (ABPmer, 2016a).

- There is limited information and consensus on the monetary benefits of such projects (e.g. for reduced wall maintenance or extended habitat longevity) which means that the extent and value of many benefits are poorly understood.

This situation then further limits the extent to which such projects can be implemented.

C.2 ABPmer costs overview

To explore these gaps in understanding, ABPmer carried out a review of the techniques, costs and benefits associated with specifically using muddy dredged sediment to restore and create intertidal habitat (ABPmer, 2017). For this review, a framework was developed for comparing the costs and potential benefits of intertidal sediment recharge schemes which incorporates impacts on ecosystem services and provides a consistent basis for evaluating projects.

The review indicated that both costs and benefits of intertidal sediment recharge projects are site specific. It noted that, where the costs of intertidal sediment recharge projects are less than the alternative 'at sea' disposal option, the benefits to society are effectively provided for free. In other situations, where the costs of intertidal sediment recharge are higher than 'at sea' disposal, societal benefits may exceed costs. In such circumstances, there is an overall benefit to society from such projects proceeding, but this may need to be facilitated by payments to those incurring costs (typically port and harbour authorities) by those deriving benefits (flood protection authorities and nature conservation bodies).

The review also noted that, because the costs of intertidal sediment recharge projects can be driven down over time, particularly for repeat operations, one key way to realise future projects is to identify 'long term' sites where the consenting requirements and infrastructure are all set up so that sediment can be placed regularly on an ongoing basis. These sites would, of course, need to be close enough to a reliable sediment source.

It was noted that the case for intertidal sediment recharge is likely to be strongest where costs for 'at sea' disposal are high, or where such projects create/retain saltmarsh in front of important flood defences, delivering important flood protection benefits. It concluded that, based on the scenarios explored, larger beneficial use schemes (>100,000 m^3 yr^{-1}) might typically justify an increase in cost of 50% to 400% when compared to 'at sea' disposal costs.

For the purpose of this BUDS 2 project, an updated cost review was undertaken throughout 2019. The results of this process are summarised in Table C1. The results in this table to a large degree reinforce the message that there is a lot of between-project variability and inherent complexity when considering costs. It also highlights that one of the main factors to always be aware of is the distinction between a **stand-alone cost** for a project and the **costs differential** which describes the difference between that full project fee and the cost that would be incurred for an alternative and otherwise required disposal activity. Some projects only occur as one-off initiatives for which there is no relevant alternative and therefore only the full stand-alone fees apply. In others, it is relevant to consider the fees that would have been incurred for the alternative disposal offshore.

Table C1. Intertidal or low shore recharge works undertaken or proposed over the last 25 years summarising methods and indicative fees

Operational Approach	Project	Technical Approach	Year(s)	Volumes	Transport Distance	Estimated Cost As £/m^{-3}	Approximate Lump Sum Fees
Backhoe Extraction to Bottom Placement	Lymington Intertidal Restoration (LHC Boiler Marsh Project) (Solent, Hampshire)	Sediment bottom dumped in the shallow sublittoral fronting Boiler Marsh; no fencing. Posts used to guide dredgers to most recent deposit locations.	2014 to present	5,000 m^3 yr^{-1} (on average over first five years); currently licensed to use up to 7,700 m^3 yr^{-1}	2 to 3.5 km	£10 m^{-3} average (2014 to 2016) reducing to £8 m^{-3} in 2017 & 2018 Differential began at ~£2 m^{-3} becoming cost saving from 2017.	~£50,000 $year^{-1}$ on average (not differential) but reducing over time Differential began at £10,000 $year^{-1}$ and became cost saving from 2017. For 3-year trials, total fees were £164,400 of which around 10% was for marine licence monitoring. On average £20k extra on business as usual
Backhoe Extraction to Backhoe Placement	Maldon, Blackwater (Essex)	Backhoed and 'dewatered' sediment; no fencing	2001 to present	~. 2,000 m^3 yr^{-1}	1.5 to 2.5 km	£12.5 m^{-3}	~£25,000 $year^{-1}$ (not differential)
	Loder's Cut Island, Deben (Suffolk)	Backhoed and 'dewatered' sediment; no fencing	2015, 2017	1,400 m^3	800 m	£20.5 m^{-3}	~£17,000 (not differential)
Back-hoe Extraction to Pumped Placement	Boiler Marsh, Lymington (Wightlink Ltd. Project) (Solent, Hampshire)	50% sediment in pumped with water; 10 poldered fences with 3 m high stakes.	2012 and 2013	4,500 m^3 over two annual campaigns	2 km	£122 m^{-3} as average over two years (2012 to 2013)	£550,000 for 2-year project (not differential) and in theory it would still be £514,000 as

Operational Approach	Project	Technical Approach	Year(s)	Volumes	Transport Distance	Estimated Cost As £/m^{-3}	Approximate Lump Sum Fees
		Hay bales inlaid in fences and placed below them (to stop under cutting)					a differential from business as usual
Cutter Suction Extraction to Pumped Placement	Brightlingsea Creek (Essex)	Two projects, including cutter suction dredger excavation and pumping of sediment from yacht moorings to St Osyth borrow pits	2017	12,000 m^3	500 to 1,600 m		EU Interreg 2 Seas initiative 'Using Sediment As a Resource' (USAR); this work was led by Exo
	Lymington Intertidal Restoration (LHC Yachthaven Project) (Solent, Hampshire)	25% sediment in-pumped with water; polder fences/faggots, coir mats and hay bale structure plus some corrugated sheeting were installed to retain sediment and stop under cutting	2012 and 2013	3,125 m^3 marsh recharge mitigation over two annual campaigns	200 m	£32 m^{-3} as average over two years (2012 to 2013)	£100,000 for 2-year project (not differential) ~£75,000 for 2-year project as differential from business as usual
	Suffolk Yacht Haven, Levington, Orwell	10% sediment in-pumped with water; various retention techniques between locations include: wattle hurdles, faggots (bundles of twigs) or coir logs	Several years/ Annual	~ 10,000 m^3 yr^{-1}	300-600 m	£8-9 m^{-3}	£85,000 year^{-1} (not differential but lower fee than disposal at more distant licenced deposit site)
	Blue Lagoon, Poole Harbour	Suction head and slurry pump carried on a floating work platform removes material from the channel and pumps direct to disposal areas.	Several years/ Annual	Very small scale regular work of ~ 600 m^3 yr^{-1}	Side-cast	Not Known	Not Known

Operational Approach	Project	Technical Approach	Year(s)	Volumes	Transport Distance	Estimated Cost As £/m^{-3}	Approximate Lump Sum Fees
Cutter Suction Extraction to Pumped or 'Rainbowed' Placement (shingle with silt)	Mersea Island Harbour (Blackwater, Essex)	Rainbow discharge bunds; some brushwood containment fences.	Consented & Proposed for 2021	98,000 m^3 of sand and gravel	42.7 km	likely to be ~ £3 m^{-3} (differential)	Consenting & licensing: expected to be £75,000. Excludes unpaid volunteer time of around £180,000
	Horsey Island, Hamford Water (Essex)	After initial phases of shingle and silt import in early 1990s 107,750 m^3 used over four campaigns in two areas. piped from dredger. Combination of steel and flexible piping used (latter to minimise marsh damage). Various containment techniques employed: lines of sandbags, brushwood and geo-textile fences.	1998 to 2006	200,000 m^3 material from annual maintenance dredgings	8.2 km	Harwich Haven Authority contributed £169,500 in dredged materials; Environment Agency paid for works and materials at the sum of £77,110 (incl. 200 m of flexible, 410 mm hose and connectors).	
	Shotley (North), Orwell (Suffolk)	Gravel bund created fronting 2 km earth wall with maintenance dredge silt then pumped behind the retaining gravel barrier	1997	22,000 m^3 silt a 75,000 m^3 gravel	4.5 km	Not known	Not known
	Trimley, Orwell (Suffolk)	Gravel bund created 1.4 km long 50-60 m in front of seawall then	2003	22,000 m^3 for gravel bund (volume of silt not known)	5.5 km	Not known	Not known

Operational Approach	Project	Technical Approach	Year(s)	Volumes	Transport Distance	Estimated Cost As £/m^{-3}	Approximate Lump Sum Fees
		backfilled with mud (similar to Shotley					
	Shotley (South), Orwell (Suffolk)	of dredged gravel and silt (retained using clay and gravel bund)	2003	15,000 m^3	4.4 km	Not known	Not known
Cutter Suction Extraction to Pumped to hinterland rather than direct to intertidal.	Allfleet's Marsh, Wallasea, Crouch (Essex)	One-off large-scale placement on managed realignment before tidal inundation. Silt pumped behind sea wall into containment area defined by new wall and clay bund.	2006	550,000 m^3	52 km	£3 m^{-3} (mainly the extra differential compared with business as usual of offshore disposal)	£1.6 million as differential which does not include preparatory land-forming
	Ems Estuary (Germany) Federal Waterways and Shipping Agency	Sediment pumped with water onto agricultural fields			7 km	6.8 € m^{-3} in 2015	

Source: www.omreg.net

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