Review of the Effectiveness of Natura 2000 Sites Compensation Measures in England

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Executive Summary

Background

This report presents the findings of an investigation into the effectiveness of compensation measures secured in England under Article 6(4) of the European Habitats Directive (which is transposed into domestic legislation by the Conservation of Habitats and Species Regulations, 2010, as amended).

Compensation is required where projects are consented because there are imperative reasons of overriding public interest that outweigh the predicted negative impacts.

Over 30 projects have been approved in England where an adverse effect on site integrity has been determined. In some cases they have not proceeded further and compensation has yet to be created.

Fifteen cases in which compensation has been undertaken were selected by Natural England and Defra for detailed investigation. The chosen sites were considered to be representative of the overall range of compensatory projects (coastal and inland) and comprise the majority of examples that had been implemented at the time the study was commissioned. Most of these projects involved managed realignment but freshwater wetland and grassland habitat creation projects were also represented. A full list of consented plans and projects (in 2013) is included in Annex 3 of the separate report on European experience).

The study had twelve objectives, several of which comprise a series of subsidiary questions. These objectives can be summarised as:

1. Review documentation and evaluate progress to date. Particular emphasis was placed on the degree to which design objectives had been met; whether functional habitat had been achieved; and the mechanisms used to deliver effective management.
2. To evaluate accessible monitoring documentation and comment on the degree to which data gathered informed assessment of each site's performance.
3. To visit individual compensation sites and make a visual assessment of progress to date, including identification of any issues that may arise/have arisen; including any perceived or real threats to the long-term future of the compensation the sites provide.
4. To identify examples of good practice and wider 'ecosystem service' benefits that may arise from individual sites or from the broad spectrum of projects.
5. To investigate any potential ecological barriers to the achievement of objectives and, therefore, future notification of the site as a Natura 2000 site and/or Ramsar site.

6. To undertake a brief investigation into the delivery of Natura 2000 compensation elsewhere in Europe and to identify any examples of good practice that might inform better regulation in the UK.

Reporting against the specific questions has been presented in a separate annex to this report (Annex 2), with a synopsis presented in the main body of the report. The one exception is a study into experience of compensation projects elsewhere in Europe, which is dealt with in a completely separate report[1].

The study was jointly funded by Natural England and Defra. Its findings are intended to assist Natural England in the provision of advice to developers and competent authorities. They will also inform Defra's own judgements in determining new proposals on behalf of the Secretary of State.

Methods

This investigation was commissioned as a desk study. It did not call for the collection of primary data on the ecology of individual sites, but relied on the provision of archived documents by Natural England and Defra. The ideal composition of this literature comprised: the Environmental Statement; Appropriate Assessment; Compensation, Mitigation and Monitoring Agreement (CMMA)[2]; Decision letter; Form for submission of information to the European Commission; and monitoring reports. It was not anticipated that data would have to be acquired from third parties (such as competent authorities, other consultants and the internet), but this eventually became a necessity and required visits to various parts of the UK to investigate the files of other organisations.

Available documents were assessed using a standard pro-forma, agreed with the Defra/Natural England project management team. The pro-forma broadly replicated the original questions posed in the project specification. The notes in the pro-formas were then used to populate the site assessments reported in Annex 1. The organisation of the pro-forma and subsequent approach to reporting was agreed with the Defra/Natural England project management team. In essence, the reporting process aimed to provide a synthesis of relevant information rather than to answer each question and sub-question for each site.

The European study was conducted by Alterra, a Dutch consultancy that was considered to be better placed to access European information that might be achieved from the UK. This study involved seven cases, chosen in consultation with Defra and Natural England to represent a range of

[1] Broekmeyer, M.E.A., Morris, R.K.A. & Jones-Walters, L.M., 2014. An investigation into European examples of implementation of Article 6(4) of the Habitats Directive. Report for Defra and Natural England. 79pp.

[2] Compensation, Mitigation and Monitoring Agreements (CMMA) are non-statutory documents drawn up with the agreement of various parties, usually involving the developer and the statutory Nature Conservation Organisation, but sometimes also including NGOs such as the RSPB. They become part of the legal obligations of the consent when it is granted.

development scenarios and to ensure coverage of a range of Member States. It had been hoped that critical information could be accessed from the European Commission, but in the event individual Member States had to be approached directly.

In addition to the desk exercise, a programme of short visits to the UK sites was conducted. Each visit lasted no more than 4 hours, during which any relevant issues were noted and a photographic record was made of key site features. One site (Moughton), scheduled for a visit, was not visited owing to complications over current ownership. In its place, a visit was made to Medmerry, which at the time was recently breached and had not had time to fully attain ecological functionality.

All documents collected have been archived and copied to Defra and Natural England, and individual site reports are provided in Annex 1.

Findings: general comments

i. In the 15 cases examined, it can be confirmed that compensation for loss of extent within the Natura 2000 Network in England has been, or is in the process of being delivered.

ii. In all cases, the ratio of loss of extent to replacement habitat achieves a ratio of at least 1:1 and in most cases exceeds this ratio.

iii. Each compensation scheme was influenced by a unique set of environmental and practical considerations and is it not possible to use any one case study as a model for future schemes.

iv. The extent to which compensation schemes have been successful varies when assessed against a number of criteria. In all cases, the key issue of loss of extent has been satisfied.

v. The majority of compensation sites can be expected to meet their design objectives in the short- to medium-term. Academic studies of older realignments show that mudflat within realignment sites normally develops into saltmarsh.

vi. Each compensation site is at a different state of evolution and some are still experiencing rapid and significant species and habitat changes.

Findings: data availability

vii. The audit trail recording the rationale for particular compensation measures is incomplete. In almost all case studies some relevant information could not be located.

viii. Accessibility and presentation of monitoring data was very variable. This meant that it was not possible to draw conclusions for all sites and detailed comparisons could not be made between some sites.

ix. Making monitoring data publicly accessible would facilitate scrutiny by third parties such as researchers.

Findings: ratios of loss to replacement

x. Where habitat was lost to commercial development and new coastal flood defences, roughly a 2:1 ratio has been used. Compensation for coastal squeeze has been based on a ratio of 1:1.

xi. In two cases the ratio of replacement to loss has risen to between 4:1 and 6:1. These involve compensation to address functionality that cannot be resolved by smaller ratios and by compensating for losses at a different Natura 2000 site much further afield.

xii. Ratios of compensation to loss above 1:1 reflect issues of uncertainty, and anticipated delays in the timescales in which compensation habitat takes to develop replacement functionality.

xiii. A simple metric of replacement to loss clearly does not work in inter-tidal situations because there is strong evidence that sustainable mudflats are very difficult to create. More work is needed to arrive at designs for realignment that will be self-maintaining mudflat.

Findings: study sites and objectives

xiv. The range of study sites comprised: inter-tidal mudflat and saltmarsh (10), annual vegetation of drift lines, perennial vegetation of stony banks (1), bare sandy inter-tidal habitat (1), reedbed (1), limestone grassland (1), open freshwater pools (1).

xv. There is scope for refining the descriptions of compensation objectives in future projects.

xvi. Objectives for compensation sites are highly case-specific and are not necessarily directly transferable to new projects.

Findings: practical considerations

xvii. The choice of compensation sites can be limited by a variety of considerations, including the size of available land parcels, land topography and the presence of dwellings, transport and service infrastructure.

xviii. Many compensation sites to date have involved significant costs, arising from land acquisition and the large scale engineering required.

Findings: like-for-like habitat creation

xix. Annual vegetation of drift lines, perennial vegetation of stony banks, and some inter-tidal muddy and sandy habitats have not been fully replicated at the time of the study and it is believed by

the review team that these objectives are unlikely to be met because they rely on very specific coastal processes and sediment conditions.

xx. Whilst in the short-term, mudflat habitat has been created by managed realignment, most case studies point to a long-term evolution into saltmarsh. This observation is reinforced by a variety of published research into saltmarsh evolution.

xxi. It is therefore clear that saltmarsh habitat is largely re-creatable. Published research indicates that it may take many decades before re-created saltmarsh is fully comparable with long-established saltmarshes.

xxii. Where the design objectives for mudflat or sandflat creation have not been met, evidence points to the need to create substantially larger sites.

xxiii. The study has also identified some parts of the country where suspended sediment levels are very high (e.g. the Humber Estuary) where mudflat or sandflat habitat is unlikely to be the long-term outcome of managed realignment.

Findings: functionality

xxiv The science of habitat creation could also be improved by increasing consistency in the approach to predicting the time-scale for compensation to become functionally viable. Clear success criteria would enable more objective assessment of success.

xxv. In the majority of cases there has been a lag between the loss of Natura 2000 habitat and the point where compensation measures have become functionally effective.

xxvi. Monitoring has largely concentrated on the compensation site, rather than on the whole Natura 2000 site. Consequently, it cannot be ascertained with absolute certainty that there has not been a short-term deleterious effect from individual developments.

xxvii. Inter-seasonal variation in waterbird numbers means that it is extremely difficult to disentangle issues arising from habitat loss and replacement from natural variation.

Findings: Monitoring

xxviii. Monitoring for longer periods and over wider areas would help to show how compensation sites evolve. It could also show how they influence bird populations, which range over wider geographical areas.

xxix. A peer-reviewed final monitoring report could form the final stage of the consent process. This would provide a clear end to the project and would resolve existing difficulties accessing the

results of monitoring. It would also make it possible for future practitioners to use lessons learned to improve compensation site design, decision-making and regulatory processes.

xxx. Making monitoring data publicly accessible would improve transparency in decision-making and would mean that past experience can be used to inform the better regulation agenda.

Findings: habitat sustainability

xxxi. Recently created inter-tidal habitat is likely to be viable for the foreseeable future, even taking account of the twin pressures of sea level rise and increased storminess.

Findings: scientific interest

xxxii. In all cases, the level of monitoring of compensation sites makes them scientifically important because there are important lessons to be learned from the evolution of the compensation site.

xxxiii. The scientific value of compensation sites would be enhanced if the key findings from monitoring were to be published in the peer-reviewed literature.

Findings: better regulation and delivery

xxxiv. There is considerable scope to improve consistency and transparency in advice and decision-making. This largely involves the need for a clear audit trail of the rationale for particular decisions, when and why they were taken.

xxxv. A checklist of key documents that should be retained for each Natura 2000 compensation case would help to ensure that the audit trail is maintained in the long-term.

xxxvi. There is currently no publicly accessible electronic library of key documents for Article 6(4) cases i.e. a transparent audit trail of decision-making and the entire compensation process. If such a system was in place, public scrutiny would be greatly improved.

xxxvii. The case of compensation for Arcow Quarry highlights the risks to the integrity of the Natura 2000 network where compensation sites have not been formally designated.

xxxviii. Where used, 'Regulators Groups' have proven to be an excellent way of ensuring ongoing dialogue between regulators and developers, and establishing a process to track progress and sign off key stages. Standardised implementation of such an approach might help to avoid some of the historic problems identified in this report.

xxxix. Useful lessons can be learned from individual compensation sites. Evaluations of completed projects, published as reports would greatly improve long-term evolution of site design. Reports

should include searchable key words and a brief synopsis of the findings to help to ensure that lessons are learned and embedded in the knowledge-base for both developers and decision-makers.

xl. Although there is ample guidance on how to create certain habitats, there is no clear distinction between general environmental improvement and the specific needs of compensatory habitat provision. A comprehensive yet simple report, setting out the relevant stages in objective setting, site selection and design, monitoring and reporting, could help to improve engagement with developers and to avoid confusion.

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Tables

1. Introduction

1.1. The overall objective of this study was to review the effectiveness of compensatory measures secured under Article 6(4) of the EU Habitats Directive in England (i.e. the extent to which effective compensatory habitat has been provided). The findings will help Natural England to improve the advice it offers to developers and competent authorities. The findings will also inform Defra's own judgements in determining whether competent authorities may approve new proposals. Defra and Natural England commissioned this study.

1.2. Any plan or project likely to have a significant effect on a European site[3], either individually or in combination with other plans or projects, requires an 'Appropriate Assessment' to determine the full implications for the European site(s). Competent authorities can only consent a plan or project after having ascertained that it will not adversely affect the integrity of the site concerned (Article 6.3). In exceptional circumstances, a plan or project may still be permitted, even though a possible adverse effect on the designated site(s) has been identified. Such consent can only be given once it has been established that there are no feasible alternative solutions to the plan or project and there are imperative reasons of overriding public interest. An idealised representation of the processes involving consent and subsequent delivery and assessment of compensatory habitat creation is shown in Figure 1 (page 5).

1.3. Where a project is consented to proceed despite it not being possible to determine that the development will not have an adverse affect on site integrity, appropriate compensatory measures must be secured. The compensation is required to ensure the maintenance of the overall coherence of the Natura 2000 network (Article 6.4). Since the original transposition of the Habitats Directive into domestic legislation in 1994, the UK Government has approved over 30 projects where compensatory measures have been necessary, although some of these projects have yet to be completed or are ongoing. In England the vast majority of these projects are at coastal locations. Most cases are linked to either flood risk management (including coastal squeeze[4] [Doody, 2004, 2013]) or to port development.

1.4. European Commission guidance advises that compensation measures should normally be completed before the adverse affect on the integrity of the European site occurs (EEC, 2007/2012). In certain circumstances, which are

[3] The network of European sites known as Natura 2000. European sites are defined in regulation 8 of the Conservation of Habitats and Species Regulations 2010 but are principally Special Areas of Conservation designated under the EU Habitats Directive and Special Protection Areas classified under the EU Wild Birds Directive and as a matter of Government policy pSPAs and Ramsar sites.

[4] Coastal squeeze arises where hard structures such as flood defences or quays prevent the sea from naturally moving landward as sea levels rise. The result is erosion of foreshores so that they steepen and lose sediment (and saltmarshes erode away).

described within the European guidance, damage to European sites may be allowed to occur before the compensatory measures are fully functional. This should be in exceptional cases, and additional measures, such as an increased ratio of new habitat to that being lost, may be agreed for such cases, therefore increasing the area initially providing partial functionality, to offset the time lag before full functionality occurs. The competent authority in liaison with statutory nature conservation bodies carefully considers such cases. Analysis of cases where a time lag has occurred forms part of this study.

1.5. Fifteen cases in which compensation has been undertaken were selected by Natural England and Defra for detailed investigation (Table 1 page 6). The sites represent the majority of compensation sites in place or under development at the time the study was commissioned and were considered to be representative of the overall range of compensatory projects (coastal and inland). The majority of these projects involved managed realignment but freshwater wetland and grassland habitat creation projects were also represented. A full list of consented plans and projects (in 2013) is included in Annex 3 of the separate report on European experience).

1.6. A total of 12 objectives were set for the investigation:

1.6.1. A review of the documentation for each case to describe and determine:

i. The nature of the predicted adverse effect on the integrity of the site.

ii. The adequacy and clarity of the design objectives (and whether and when these were established).

iii. Whether the area provided as compensation has been clearly defined.

iv. How the size of the compensation site compares to the size of the site that has been lost or damaged by the development.

v. A comparison between the point at which the development took place and when:

a) work on the compensation site was initiated;

b) when practical habitat creation was completed; and

c) when the habitat became functional as compensation.

vi. Whether there were predictions or estimates of when it would be functional as a compensation site.

vii. Any agreed timelines for assessment of the effectiveness of the site including criteria/indicators relating to functionality.

viii. Whether an independent management group or similar was established to review the development of the site, and whether or not this group was effective.

1.6.2. To review monitoring documents to determine the effectiveness of the compensation measures, including critical comment on whether the monitoring programme was fit for purpose and how, if necessary, it could be improved.

1.6.3. To make a site visit to the selected sites to determine, in broad terms, whether the sites meet, or are likely to meet, their design objectives. If a lag in functionality of the compensation site remains, how long it is likely to take to meet these objectives.

1.6.4. To determine the level, extent, type and effectiveness of the long term management arrangements for the compensation site provided as part of the planning / development permission(s) and whether this is fixed for a number of years, until a certain state is met, or in perpetuity.

1.6.5. To determine whether any modification to the compensation site, or management of it, has been necessary after establishment. If a change was needed, to determine the trigger for the necessary changes and whether they proved effective.

1.6.6. To identify examples of good practice in the provision of Natura 2000 compensation at a whole site level, within individual compensation projects and the wider landscape/ecological network context.

1.6.7. To identify potential ecological barriers to the achievement of objectives and, therefore, future notification of the site as a Natura 2000 site and/or Ramsar site.

1.7.8. To establish whether the compensation site has been threatened or compromised by other development proposals in close proximity to it. If so, to determine whether the impacts on the compensation site were considered to be impacts on the Natura 2000 site for which it was providing compensation.

1.6.9. To determine any apparent gaps between the damaging impacts of the development, the design objectives for the compensation site and the conservation interest that the compensation site now supports.

1.6.10. To identify any additional ‘ecosystem services’ benefits over and above that originally provided by the habitat lost, such as potential measurement and use of natural capital (intentional or unintentional) arising from the project (e.g. public access or a more sustainable approach to flood and coastal risk management).

1.6.11. To identify any specific issues for coastal compensation sites that relate to coastal change and dynamic evolution of the conservation interest. For each compensation site, information on the following was sought:

i. Whether the habitat type provided was 'like-for-like' and, if not, the alternative type of habitat that was created.

ii. Whether the geographic location in relation to the habitat that was lost was factored in to the amount of compensation that was provided (e.g. where breeding birds have been displaced).

iii. Whether the compensation has the capacity to be adapted to unfolding circumstances in the future.

iv. Whether it is resilient in the face of sea level rise, climate change and other pressures and if it is likely to be sustainable for at least 50 years.

v. Who had control over the land during the development of the compensation site, and whether this has subsequently changed or is expected to change in the future.

1.6.12. A review (including any available literature) of the effectiveness of Natura 2000 compensation sites elsewhere in Europe.

1.7. This report considers the first 11 objectives of the project. Findings of the investigation into European examples of compensation are described in a separate report (Broekmeyer *et al*., 2015).

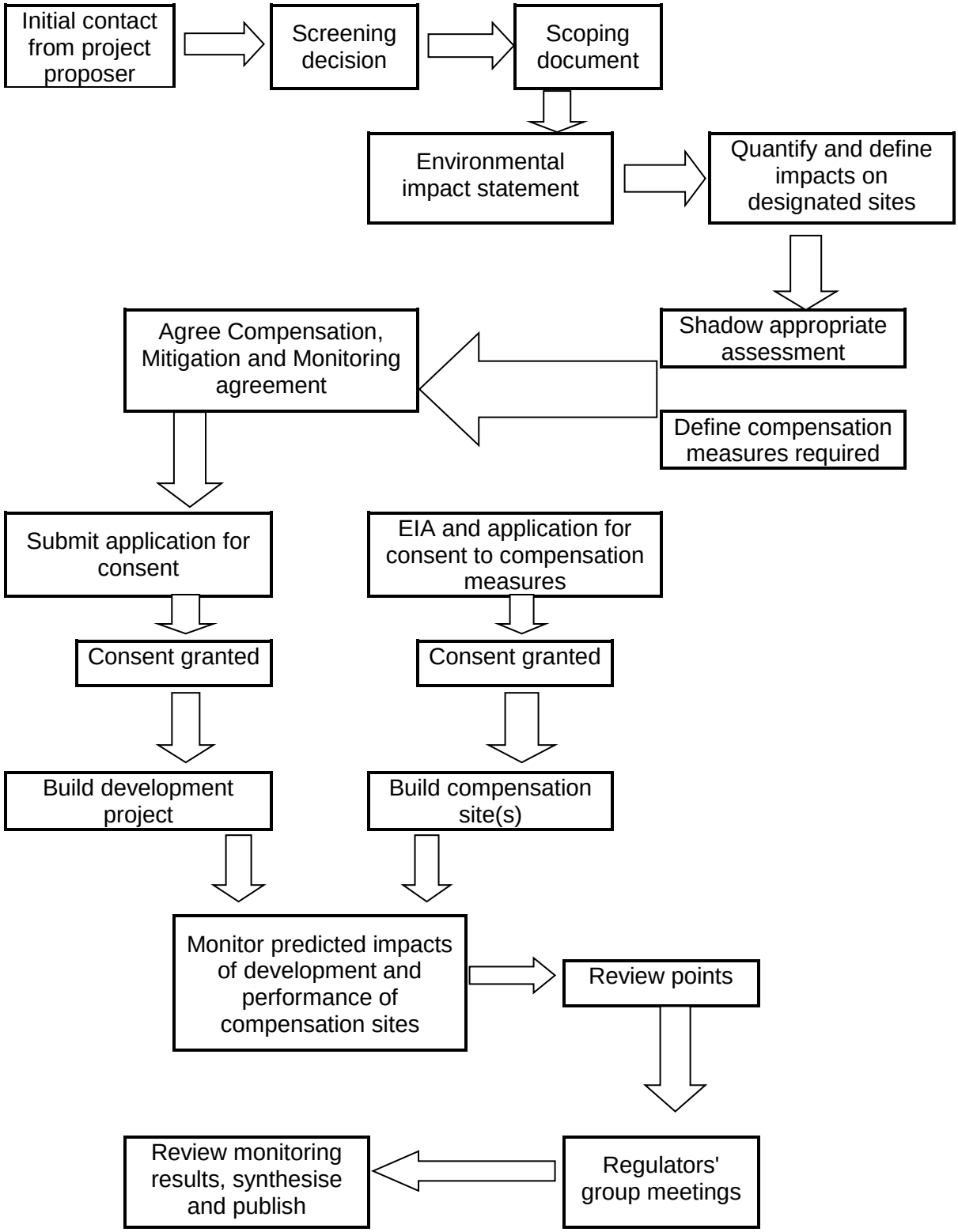

Figure 1. Schematic representation of the processes involved in consenting and building a plan or project where it cannot be ascertained that it does not have an adverse affect on the integrity of a Natura 2000 site.

Table 1. Study sites.

Developer	Development project	Region	Consent Date	Compensation site(s)
Anglian Water Services	Wing Water Treatment Works	Rutland	2005	Rutland Water
Associated British Ports	Hull Quay 2005 Container Terminal	East Riding of Yorkshire	2007	Chowder Ness & Alkborough
	Immingham Outer Harbour	North-east Lincolnshire	2004	Welwick, Chowder Ness & Doig's Creek
	Green Port Hull	East Riding of Yorkshire	2013	Welwick, Chowder Ness & Alkborough
Defra	Port of Sheerness - Lappel Bank Port of Felixstowe - Fagbury Flats	Kent and Suffolk	1993 1990s	Allfleet's Marsh, Wallasea Island[5]
Dubai Ports World	London Gateway Container Terminal	Essex		Stanford Wharf & Cliffe Marshes
Environment Agency	Cley/Salthouse Flood Management Scheme	North Norfolk		Hilgay
	Hullbridge Tidal Flood Defence Scheme	Essex	2003	Brandy Hole
	Humber Estuary Flood Risk Management Strategy	Humber-side	2001	Paull-Holme Strays
	Pett Frontage Tidal Flood Defence Scheme	Kent/ Sussex	2005	Rye Harbour
	Portchester Castle to Emsworth Flood Risk Management Strategy	Hampshire	2012	Medmerry
Harwich Haven Authority	Approach channel deepening	Suffolk/ Essex	1998	Trimley

[5] Two port development cases in which the land concerned was not designated but formed an integral part of the habitat used by the migratory waterfowl for which SPA designation was made. A European Court judgment concluded that the UK Government had not followed correct designation and assessment processes. As the fault lay in the way the UK Government had interpreted European law, it was required to adequately compensate for the loss of habitat (rather than the developers).

Highways Agency	A249 Iwade to Queensborough road improvement scheme	Kent	2002	Chetney Marshes
Lancaster City Council	Morecambe Coastal Defence Works	Lancashire	2005	Hesketh Outmarsh
Lafarge-Tarmac Ltd	Arcow Quarry	North-west Yorkshire	2004	Moughton

2. Methods

Desk studies

2.1. Documents were assembled for all case studies. The ideal composition of this literature comprised: the Environmental Statement; Appropriate Assessment; Compensation, Mitigation and Monitoring Agreement (CMMA)[6]; Decision letter; Form for submission of information to the European Commission; and monitoring reports. The majority of the required documents were sourced from the files of Natural England and Defra but, in a small number of cases, it was necessary to obtain these from other bodies. In many of the more recent cases, it was possible to assemble a reasonably complete literature relating to the project but, for a minority of older cases, full documentation proved difficult to obtain.

2.2. In some cases, documentation did not adhere to what might be regarded as a 'standard format' but relevant information was accessible from supporting documents such as correspondence between the statutory adviser and the competent authorities. The extent of documentation available is shown in Table 2 (page 11).

23. Searches of the internet were also made to ascertain the level of public availability of key documents. Very few documents were accessible through the internet, although Local Authorities and the Planning Inspectorate now publish new cases.

2.4. An inventory of documentation was prepared and all documents were compiled into an archive that has been returned to Defra and Natural England.

Analysis of documentation

2.5. The cases were analysed using a standard approach, which involved the completion of a pro-forma to capture salient information in as consistent a manner as possible. The design of the pro-forma was undertaken in consultation with Defra and Natural England. A blank version of this pro-forma is included as Appendix 2 (pages 101-106). This analysis was undertaken by three members of the project team, two of whom were already familiar with the port development cases.

2.6. This investigation was commissioned as a desk study and did not call for the collection of primary data on the ecology of individual sites. It relied on the provision of archived documents by Natural England and Defra. Key

[6] Compensation, Mitigation and Monitoring Agreements (CMMA) are non-statutory documents drawn up with the agreement of various parties, usually involving the developer and the statutory Nature Conservation Organisation, but sometimes also including NGOs such as the RSPB. They become part of the legal obligations of the consent when it is granted.

documents sought included original Environmental Impact Statements, Compensation, Mitigation and Monitoring Agreements, It was not anticipated that data would have to be acquired from third parties (such as competent authorities, other consultants and the internet), but this eventually became a necessity and required visits to various parts of the UK to investigate the files of other organisations.

2.7. Available documents were assessed using a standard pro-forma, agreed with the Defra/Natural England project management team. The pro-forma broadly replicated the original questions posed in the project specification. The notes in the pro-formas were then used to populate the site assessments reported in Annex 1. The organisation of the pro-forma and subsequent approach to reporting was agreed with the Defra/Natural England project management team. In essence, the reporting process aimed to provide a synthesis of relevant information rather than to answer each question and sub-question for each site.

2.8. Critical information has been synthesised into tables presented in this main report, and in the individual site reports in the accompanying Annex 1.

Site visits

2.9. Site visits complemented the desk-based assessments. These visits took place between May and July 2014. Moughton was not visited because access to the site is no longer controlled by the developer. Medmerry was not scheduled for a visit in the contract but was visited in August 2014 as an alternative to Moughton. Members of the project team undertook a walk-over visit of each site, noting key issues and making a photographic record of the site. Locations for each photograph were logged, together with the direction of the view. The site visits were designed to give a simple overview to confirm that the compensation had been delivered and broadly met the design criteria that were listed in relevant documents. No biological surveys were undertaken.

2.10. A photographic library was compiled and has been lodged with Defra and Natural England, together with detailed notes from each visit.

Interpretation of reported outcomes

2.11. This report is based on the information gathered in as standardised a manner as possible. No two projects, however, were undertaken in the same manner and the scale of detail and document availability varied so much that it was not possible to make direct comparisons between all of the projects. For example, port developments and flood risk management strategies present information in very different formats and seek to resolve different issues (for example immediate direct loss of habitat as opposed to cumulative loss of habitat as a result of coastal squeeze).Consequently the pro-forma approach only worked as far as it was possible to populate them. A further consequence is that this report has been structured to discuss the critical issues rather than to present results for each of the original objectives.

2.12. Where a judgement was required on issues such as whether habitat created was 'like-for-like', it was not possible to go further than to determine whether the aim was to create broadly similar habitat. For example, was the intention to create saltmarsh, mudflats or a particular habitat suitable for supporting a particular assemblage of waterfowl?

2.13. Assessment of possible levels of re-creatability, environmental sustainability and potential adaptive capacity are highly subjective. This is because there is little or no empirical evidence upon which to base any judgements. The science of habitat creation is relatively new and in many cases evaluation of effectiveness is complicated by the dynamic nature of many sites, the processes of ecological succession and the way sites evolve. Morris *et. al*., (2006) highlighted this weakness in data. More recent studies into saltmarsh evolution (Garbutt & Wolters, 2008) demonstrate the progressive evolution of saltmarsh communities after breaches in seawalls. This study concluded that 'even after 100 years regenerated salt marshes differ in species richness, composition and structure from reference communities.' It should be noted, however, that this is an historic analogue that may not be applicable to a period of more rapid sea level rise.

2.14. The most reliable analysis can therefore only be based on what has happened in the past, combined with a strong reflection on the critical issues that would dictate the way in which a particular site evolves. There are natural analogues. For example, there is a strong body of evidence of numerous 'natural' breaches in seawalls, which occurred over the last century, being followed by the development of mudflats and saltmarsh. Many such sites form a significant proportion of the habitat currently classified as SPA and designated as SAC (e.g. extensive areas of the Blyth and Alde-Ore Estuaries in Suffolk, and various saltmarshes within the Essex Estuaries SAC).

Table 2. Documentation available for analysis of case studies

	Wing Water Treatment Works	Hull Quay 2005 Container Terminal	Immingham Outer Harbour	Green Port Hull	Lappel Bank & Fagbury Flats	London Gateway Container Terminal	Cley/Salthouse Flood Management Scheme	Hullbridge Tidal Flood Defence Scheme	Humber Estuary Flood Risk Management Strategy	Pett Frontage Tidal Flood Defence Scheme	Portchester Castle to Emsworth Flood Risk Management Strategy	Harwich Approach channel deepening	A249 Iwade Bypass	Morecambe Coastal Defence Works	Arcow Quarry
Scoping/Screening documents	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N
Environmental Impact Assessment	N	N	Y	Y	Y	N	N	N	N	Y	N	Y	N	Y	Y
Maps	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y
Appropriate Assessment	Y	Y	Y	Y	N	Y	P	N	Y	Y	Y	N	N	Y	Y
Compensation, Mitigation and Monitoring Plan	Y	Y	Y	N	N	Y	N	Y	N	N	N	Y	Y	N	Y
Progress reports	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y
Monitoring reports	N	N	Y	N	Y	P	N	N	Y	Y	N	Y	Y	P	Y
Regulation 33/35 advice/ Conservation Objectives	N	Y	Y	N	N	Y	Y	Y	Y	N	Y	N	Y	Y	N
Decision letter	Y	Y	N	Y	N	Y	N	N	N	N	Y	N	Y	N	Y
Article 6(4) form	N	Y	Y	Y	N	Y	N	Y	N	N	N	N	Y	Y	Y
ES/EIA for compensation package	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y	N
Non-standard documentation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Key: N = This document was not available Y = This document was available in some form P = Documentation was partially available.

3. Findings - pre-construction processes and documentation

3.1. This section covers the first stage of analysis. It is closely aligned to the original questions set out in the project specification, as listed in Section 1 of this report.

Impacts and compensation scheme design criteria

3.2. Development of compensation schemes has been an ongoing process, which has involved a large number of individuals and numerous organisations. It has inevitably evolved, based on a relatively small number of cases offering examples of past practice. This review involves a considerable level of hindsight, which is only possible once a variety of examples are available for analysis. Compensation packages were clearly based on best available evidence at the time and were expected to fulfil the requirements of the Habitats Directive. Since that time new research and experience has become available, and it is important to consider the 15 cases in light of the available information at the time. Future compensation packages will therefore benefit from more comprehensive evidence. and should continue to evolve, in the light of experience.

3.3. The range of effects studied include:

i. Linear impacts along the edges of designated sites arising from road improvements and several flood risk management projects. Similar impacts caused by changes to tidal propagation as a result of dredging projects were predicted by detailed modelling and allowed for in assessment of designated sites.

ii. Direct loss from development footprints. These were primarily associated with major port developments in which quaysides extended over an area of inter-tidal and sub-tidal habitat.

iii. Changes in the morphological response of estuaries, either increasing or decreasing sediment deposition, or causing inter-tidal erosion. In these cases, the impacts were predicted using well-established models.

3.4. Where impact pathways are identified, it is necessary to relate these to possible changes in both the physical extent and functionality of designated sites. Consequently, the compensation packages for sites vary according to circumstances. In general, Environmental Statements and Habitats Regulations Assessments adequately identified the likely effects and provided the basis for agreement of appropriate compensation measures.

3.5. The process of arriving at a compensation package is relatively poorly documented in some of cases we examined. The exceptions were port development projects and flood risk management strategies, which were supported by detailed information:

i. Port development projects examined included a 'Compensation, Mitigation and Monitoring Agreement' (CMMA), which was signed by both the developer and the relevant conservation agency, often in association with the RSPB.

ii. Flood risk management strategies (FRMS) often include a 'Coastal Habitat Management Plan' (CHaMP), which considers the likely level of direct habitat loss and the predicted levels of habitat loss to coastal squeeze over a series of epochs. In some cases, the boundaries of the CHaMP and the FRMS completely overlap, whereas in others there may be different boundaries. Addressing the required habitat creation to offset predicted losses takes place *via* Regional Habitat Creation Plans (RHCP).

3.7. The majority of cases (9 out of 15) within this study fall into the approaches defined above. The exceptions are: Lappel Bank and Fagbury Flats; Wing Water Treatment Works; A249 Iwade to Queensborough road improvement scheme; Arcow Quarry rock face stabilisation; Hullbridge tidal flood defence scheme; and the Cley-Salthouse flood management scheme.

What were the predicted adverse effects on site integrity?

3.8. Impacts can be broadly categorised as:

i. Loss of habitat extent;

ii. Changes in functionality;

iii. Reductions in carrying capacity for migratory waterfowl;

iv. Reductions in carrying capacity for breeding birds;

v. Changes in physical processes leading to longer-term loss of extent and functionality;

3.9. These effects are summarised in Table 3 (page 17) in respect of the case studies examined.

Adequacy and clarity of design objectives

3.10. Clear design objectives are required to optimise the potential for success of the measures. The relationship between design objectives and the impacts that they address is also critical from the perspective of two important recording mechanisms. Firstly, it is necessary to provide concise details of the case and compensation measures to the European Commission. Secondly, there is the question of linking monitoring to the audit process to maintain the coherence of the Natura 2000 network.

3.11. In general, for the fifteen case studies considered, design of compensatory habitat was directly related to the identified impacts, but this was not always clearly explained. The design of compensation for many (but not all) of the Flood Risk Management Strategies (e.g. Humber FRMS) was clearly linked to the outputs of relevant CHaMPs or in accordance with Regional Habitat Creation Strategies (e.g. Portchester Castle to Emsworth FRMS). Similarly, most port-related packages largely focussed on replacing habitat lost to

development (e.g. Immingham Outer Harbour) or upon habitat functionally altered as a result of infrastructure (London Gateway). Compensation therefore emphasised the extent of replacement habitat in relation to the area lost, and set targets for the provision of feeding grounds for displaced migratory waterfowl, based on numbers of birds using the compensation site. In the case of both port and flood risk management projects the design of compensation packages has become relatively uniform. This is partly because issues were very similar (i.e. loss of inter-tidal habitat that is important for over-wintering migratory waterfowl, and loss of specific habitats in the context of SAC designation). In addition, many of the same consultants were involved.

3.12. The question of whether compensation measures were 'adequate' is highly subjective and, in the absence of an agreed framework against which judgements can be made, we have not commented on the adequacy of the compensation measures in detail. In all cases, the measures were considered to be adequate at the point when consent was granted. It could, however, be argued that at least some of the inter-tidal habitat creation cases had not or, ultimately, will not result in target habitat and species in the long term because they are developing into saltmarsh.

Location of compensation sites

3.13. There was generally good information on the location and boundaries of the compensation site. Managed realignment sites are also usually straightforward to identify from aerial photographs and sources such as Google Earth.

3.14. In one case (Brandyhole), the maps are extremely difficult to interpret and it was far from certain, when on site that the correct location had been visited. In another case (Arcow Quarry), the maps follow no obvious features on the ground, making it very difficult to interpret. A similar situation occurs at Rye Harbour, as on the maps no obvious features are followed, however, on the ground the actual boundaries are helpfully pegged out.

3.15. In most cases, the compensation sites lie in close proximity to the point of habitat loss. It is clear, for example, that port developers have made considerable efforts to create habitat nearby. There are three cases in which the compensation site is a significant distance from the point of damage (Hesketh Outmarsh, Hilgay and Medmerry), all of which are located away from the affected Natura 2000 sites. In these cases, the choice of location followed careful analysis of local geography, land ownership, willingness to sell, the sustainability of the location in the face of sea-level rise and the potential for success (including the consent process for the compensation site).

Ratios of damage to replacement

3.16. Details of individual cases are given in Table 4 (page 21). Although simple ratios can be constructed to provide an indicative level of compensation, they

need to be explained on a case-by-case basis. This caveat is necessary because compensation in a number of cases involves a combination of direct loss of habitat, changes to habitat functionality and possible reductions in carrying capacity for breeding and over-wintering water birds. In addition, consideration has been given to the time lapse between the timing of habitat loss and the point where replacement habitat is predicted to become functional. It is not, therefore, possible to represent the replacement need against loss as a simple ratio and the ratios published in other reports (e.g. Jacobs, 2014) could be seen as an over-simplification of complex situations.

3.17. Environment Agency packages are generally designed to address two separate impacts. Firstly, the direct footprint of flood defence works, which are usually limited incursions into the designated site over several kilometres. In these circumstances, the incursion may be less than a metre but, over a long distance, this adds up to substantial areas of loss. This direct habitat loss was typically addressed by a ratio of 2 ha for every ha lost. Secondly, the measures address to 'coastal squeeze' caused by construction and maintenance of flood defences that prevent the migration of inter-tidal habitat. The impacts of 'coastal squeeze' take place over a long period of time and therefore they can be addressed incrementally. Consequently, cited packages may form just one of several iterations of compensation. Some packages (e.g. Hesketh Outmarsh, Medmerry and Rye Harbour), are included within bigger habitat creation projects designed to generate both compensation and wider biodiversity and flood risk management benefits. As a general rule, predicted coastal squeeze losses were addressed on a 1:1 basis.

Coincidence between site damage and compensation provision

3.18. In general, the case studies demonstrate that providing functional compensatory habitat prior to development impacts is rarely achieved. In those instances where functional compensation habitat is provided ahead of impacts, this is either due to projects being delayed but compensation being progressed (e.g. Quay 2005 / Hull Green Port) or because strategic planning allowed compensation measures to be taken ahead of predicted losses (e.g. Portchester Castle to Emsworth Flood Risk Management Strategy).

3.19. In the majority of cases, compensation sites have provided limited or no functionality at the time that impacts on designated features started to occur. This is particularly true where direct, potentially rapid habitat loss arose (e.g. A249 road improvements, Arcow Quarry) and replacement habitat was not provided prior to the start of works for the development taking place. The compensatory habitat for such schemes will have developed functionality, but only significantly after the damaging impacts has occurred.

3.20. European guidance states that a time lag in functionality should only be allowed in exceptional cases. Consequently, where it has been agreed that a time lag in functionality is acceptable, normal practice has been to provide a greater amount of compensatory habitat in relation to the area / interest affected by development. This may offset the lag between impact and functional development of new habitat through the provision of lesser function

over a greater area. In practice its effectiveness may be difficult to demonstrate without much more detailed and extensive monitoring. Unfortunately, the audit trail for these decisions is not clear.

3.21. It is not always the case that compensation needs to be coincident with the initiation of development, as the impacts on designated features may not arise until part way through or following the completion of works. One obvious example is provided by the channel deepening for Harwich / Felixstowe. In this case, the full effects of changes to the hydrodynamic regime were predicted to arise some time after the dredging works had been completed. As compensation was initiated at the beginning of the works and complete by the end of the dredging, habitat functionality (which occurred relatively quickly) developed in advance of the predicted full effect of the hydrodynamic changes to estuarine habitats.

3.22. Table 5 (page 26) provides an overview of the timing of the development of functional compensation habitat in comparison to the start of project works for each of the cases examined.

Table 3. Summary of impacts arising from the 15 case studies.

Developer	Development project	Loss of Extent	Predicted impacts
Anglian Water Services	Wing Water Treatment Works	N/A	**Rutland Water SPA and Ramsar site**: Possible reductions in the carrying capacity of for waterfowl as a result of greater drawdown during periods of low flow/drought, when water levels drop below existing licensed thresholds.
Associated British Ports	Hull Quay 2005 Container Terminal	**4ha**	**Humber Estuary SAC, SPA and Ramsar site**: Direct permanent loss of inter-tidal mudflat.
	Immingham Outer Harbour	**27 ha** 27ha 5 ha	**Humber Estuary SAC, SPA and Ramsar site**: Permanent loss of inter-tidal mudflat (down to Lowest Astronomical Tide (LAT)). Indirect - potential permanent loss of an additional 5ha of mudflat through morphological response of the estuary to the development.
	Green Port Hull	**8.1 ha** 3ha 4.5ha 0.6ha	**Humber Estuary SAC, SPA and Ramsar site**: Direct loss of sub-tidal habitat within the footprint of the development. Direct loss of mudflat. Indirect loss to altered coastal processes.
Defra	Lappel Bank & Fagbury Flats	**22ha** **32ha**	Exclusion of inter-tidal mudflat from SPA designation (Medway Estuary). Exclusion of inter-tidal mudflat and saltmarsh from SPA designation (Stour & Orwell).
Dubai Ports World	London Gateway Container Terminal	**98 ha** 5ha 25ha	**Thames Estuary and Marshes SPA and Ramsar site** Conversion of inter-tidal to shallow sub-tidal. Loss of undesignated inter-tidal in the reclamation footprint that

			supported some SPA designated birds. 68ha Loss of undesignated sub-tidal habitat in the reclamation footprint. Changes in function Changes to sedimentation over inter-tidal area of Mucking Flats, ~60ha with site gaining elevation and undergoing functional changes. 1.4 ha per year Reduction in the rate of increase in the area of Blyth Sands.
Environment Agency	Cley/Salthouse Flood Management Scheme	Indirect impacts	**The Wash and North Norfolk Coast marine SAC; North Norfolk Coast SAC; North Norfolk Coast SPA; North Norfolk Coast Ramsar site**: Indirect impact resulting from predicted changes in the frequency of saline inundations at Cley, with knock-on effects on food sources for two pairs of breeding bittern.
	Hullbridge Tidal Flood Defence Scheme	**2.95ha**	**Essex Estuaries SAC and Crouch and Roach Estuaries SPA and Ramsar Site**: 0.05 ha direct loss of inter-tidal mudflat due to placement of toe protection works and gabions. 2.95 ha indirect loss of Atlantic Saltmeadows to coastal squeeze and perpetuation of ongoing habitat loss.
	Humber Estuary Flood Risk Management Strategy	**379 ha** 58ha 286ha	**Humber Estuary SAC, SPA and Ramsar site**: Encroachment of improved defences and maintenance works (c.20 ha Inner, c.34 ha Middle, c.2 ha Outer South and c.2 ha Outer North). Changes within the estuary as a consequence of coastal evolution and coastal squeeze are predicted to be, over 50 years: • ~330 ha gain Inner estuary • ~510 ha loss Middle estuary • ~168 ha loss Outer South • ~62 ha gain Outer North.

		35ha	Caused by cross-estuarine impacts as a result of the Strategy (c.15 ha Inner, c.10 ha Middle, c.7 ha Outer South, c.3 ha Outer North).
	Pett Frontage Tidal Flood Defence Scheme	**3.1ha**	**Dungeness SAC; Dungeness to Pett Levels SPA; Dungeness to Pett Levels pRamsar Site**: A mixture of temporary and permanent loss, including: Annual vegetation of drift lines (0.08ha) Perennial vegetation of stony banks (0.23ha). Loss of 3.1ha of perennial vegetation of stony banks that is expected to be largely naturally re-created over a ten year period.
	Portchester Castle to Emsworth Flood Risk Management Strategy	**35.5ha**	**Portsmouth Harbour SPA and Ramsar site; Chichester and Langstone Harbours SPA and Ramsar site; Solent Maritime SAC; Solent and Isle of Wight Lagoons SAC** Losses due to 'coastal squeeze' through maintenance of existing lines of coastal defence.
Harwich Haven Authority	Approach channel deepening	**16.5 ha** 4ha 12.5 ha	**Stour and Orwell Estuaries SPA and Ramsar site**: Predicted loss of 4 ha of inter-tidal due to changed tidal propagation. The main impact of the project was a reduction in sediment available to maintain inter-tidal mudflat that was already eroding To mitigate this a sediment feeding programme was introduced but it was not certain whether this would work and how quickly its effects would become apparent. A further 12.5 ha were therefore created as a precaution for the possible delays in sediment feeding becoming effective.
Highways Agency	A249 Iwade to Queensborough road improvement scheme	**3.9ha** 0.005 ha	**Medway Estuary and Marshes SPA and Ramsar site; The Swale SPA and Ramsar site**: Loss of inter-tidal feeding area. Loss of grazing marsh. (Note that these figures do not add up and the

		3.6ha	files have not provided an explanation for the difference). Potential displacement of breeding birds: Shelduck (3 prs), Shoveler (1 pr), Oystercatcher (9 prs), Lapwing (8 prs), Redshank (3 prs)
Lancaster City Council	Morecambe Coastal Defence Works	**11.5 ha**[7]	**Morecambe Bay SAC, SPA and Ramsar site**:
			Phase 6:
		5.5 ha	Loss of sandflat habitat
		1.2 ha	Loss of cobble skear.
			Phase 7:
		2.39 ha	Loss of mudflat and sandflat
		2.4 ha	Loss of natural boulder and cobble skear habitat.
Tarmac Ltd	Arcow Quarry	**1.13ha**	**Ingleborough Complex SAC**:
		0.33ha	Permanent loss of limestone grassland and rubble within the cSAC
		0.2 ha	Permanent loss of limestone grassland, scar and scree in the non-cSAC SSSI
		0.8 ha	Permanent loss of limestone grassland and rubble within the cSAC required for temporary works.

[7] Note that the documentation for Hesketh Outmarsh indicates that compensation for 13 ha of loss at Morecambe is anticipated.

Table 4. Areas of compensatory habitat creation in relation to levels of original habitat losses.

Developer	Development project	Loss of extent (N2K)	Loss of un-designated habitat	Compensation habitat extent
Anglian Water Services	Wing Water Treatment Works	N/A	N/A	96ha (when full)
Associated British Ports	Green Port Hull	8.1ha	N/A	10.5ha (Chowder Ness) 5ha (Alkborough)
	Hull Quay 2005 Container Terminal	4ha	3.5 sub-tidal	10.5ha (Chowder Ness)
	Immingham Outer Harbour	27ha	Not identified?	Welwick (45ha) Chowder Ness (10.5ha) Doig's Creek (3ha)
	Note: the package of compensation measures was developed to meet the needs of both Quay 2005 and Immingham Outer Harbour, and was revised in the light of revisions for Green Port Hull. In the original documentation the combined effects of Quay 2005 and Immingham Outer Harbour were addressed as a single compensation package.			
Defra	Lappel Bank & Fagbury Flats	N/A	22ha 32ha	104ha – Allfleet's Marsh
Dubai Ports World	London Gateway Container Terminal	5ha + change in functionality at Mucking Flats	25ha 68 ha sub-tidal	32ha (site A) 73ha (site x) Additional arable reversion (up to 70 ha) **Note** - a mixture of compensation and mitigation.

Environment Agency	Cley/Salthouse Flood Management Scheme	N/A	N/A	40ha - Hilgay (part of a bigger 65 ha project) based on a need to provide 20ha of reedbed per pair of breeding bitterns
	Hullbridge Tidal Flood Defence Scheme	2.95ha	N/A	7.2ha (but reported ratio of 1:1 in Article 6(4) reporting form.
	Humber Estuary Flood Risk Management Strategy	379ha	N/A	286 ha in stages over 50 years. Compensation at Paull Holme strays was 4:1 for direct habitat loss and 2:1 for loss to coastal squeeze.
	Pett Frontage Tidal Flood Defence Scheme	3.1ha	N/A	6.1ha (9ha total site) - Rye Harbour
	Portchester Castle to Emsworth Flood Risk Management Strategy	35.5ha	N/A	35.5ha - Medmerry
Harwich Haven Authority	Approach channel deepening	16.5ha	N/A	16.5ha (included 12.5 ha as a precaution against mitigation measures not starting to work in the first five years).
Highways Agency	A249 Iwade to Queensborough road improvement scheme	3.9ha	N/A	22ha - Chetney
Lancaster City Council	Morecambe Coastal Defence Works	11.498ha	N/A	52ha - Hesketh Outmarsh
Lafarge-Tarmac Ltd	Arcow Quarry	1.13ha	N/A	8.5ha - Moughton

Timelines and criteria/indicators relating to functionality

3.23. The concept of habitat functionality is gradually evolving, and may evoke different interpretations from different practitioners. For the purposes of this analysis, the concept of functionality is confined to some very simple parameters:

i. Whether the compensation habitat broadly equates to other habitats within the designated sites and to the habitat that was lost. It provides a similar service to the organisms that underpin the reasons for site designation.

ii. Whether as a consequence of creating the new habitat similar proportions of target organisms reside within the compensation site as elsewhere on the designated site.

iii. Whether there is an inter-relationship between the compensation site and the designated site that neutralises the negative impacts of the development project.

3.24. Using these simple criteria, expressions of functionality effectively equate to:

- The extent of habitat created, compared to that lost.
- The nature of the habitats that evolve, in terms of NVC community or biotope.
- The numbers of key target organisms (birds in the case of SPAs) utilising the site.

3.25. Environmental Impact Assessment to support a development proposal generally involves quantification of what will be lost, or how particular changes may lead to a change in the numbers of particular organisms inhabiting a given area of designated/undesignated habitat. It will normally cover a wider range of issues than those strictly affecting Natura 2000 interest. In a few cases, such as London Gateway, considerable attention has been paid to the inter-relationship between un-designated and designated inter-tidal habitat and to the differing roles performed by particular mudflats. In general, however, such relationships have not been considered. Re-creation of functionality therefore needs to be viewed in the context of the defined impacts of a development on the functionality of the affected site / interest features.

3.26. The simple descriptions identified in paragraphs 3.23. and 3.24. are widely used within the design process for compensation sites and the majority of targets therefore relate directly to the delivery of these functional objectives. As an example, target setting may include the use of physical process models for managed realignment to predict how the compensation site will perform over a particular timeframe. It must be recognised, however, that such predictions are a snapshot of a developing continuum between mudflat and saltmarsh.

3.27. This simple approach to 'functionality' does not reflect any analysis of complex food webs or to a wider inter-play between site attributes. It is fit for purpose, but is complicated by the absence of clear empirical evidence to assist in making predictions of the timescales over which compensation measures may fully replace affected function (at a designated site level).

3.28. For the projects examined (see Table 6 - page 28) the available documentation shows that relatively limited consideration is given to the timescale over which habitat development and any more complex functionality is likely to arise. Some indication of expectations may, however, be taken from monitoring packages. Monitoring commitments vary in duration. Monitoring often ranges between five and 15 years, thus suggesting that full functionality was anticipated to be achieved by the end of the agreed monitoring period.

Management arrangements

3.29. Once consent has been granted, several years may elapse before it can be concluded that the development, combined with compensation and mitigation measures has secured the conservation of the Natura 2000 site network(s). Several of the older cases (Table 7 - page 33) demonstrate the weaknesses of granting consent, including the provision of compensatory measures, without also establishing a reporting and oversight process. Where weaknesses in reporting were detected, a regulators' group does not appear to have been established[8].

3.30. The establishment of a regulators' group[9] can therefore be seen to bring several benefits, most notably:

i. Providing a reporting mechanism with a defined timetable.

ii. Establishing a clear need for the developer to provide feedback to regulators.

iii. Providing a mechanism to ensure that corrective action is taken if problems arise.

iv. Alerting regulators to the fact that there is an ongoing need to engage in a statutory process.

v. Providing the basis for passing on corporate memory because attendance by regulators is required (i.e. if a staff member leaves, there is a prompt to send a replacement).

[8] It should be noted that the documentation for several older cases was incomplete and it is, therefore, possible that this may have had a bearing on this finding.

[9] Regulators' Groups comprise representatives of relevant consenting bodies such as Natural England, the Environment Agency, the Marine Management Organisation, IFCAs and Local Authorities.

vi. Providing the process for signing off the package of measures when they have achieved their defined objectives.

3.31. There are several examples where the absence of a formal reporting mechanism may have contributed to weaknesses in the oversight of progress. For example, monitoring showed that remedial action was needed to address weed development in *Carex divssa* translocations at Chetney. However, there does not appear to be any reporting on whether or not weed control was undertaken and if it was successful.

Document accessibility

3.32. The process of assessing development projects has evolved with time and has been greatly influenced by modern software. Consequently, documents produced for development cases 15 or more years ago mainly only exist in paper archives. Today, documents are supplied to regulators in electronic form, usually as pdfs, and these were more straightforward to obtain.

3.33. For this study, constructing a detailed audit trail for older cases proved to be challenging as datasets are often fragmented. Gaps in the data arise as a result of changes in the documentation of the decision-making and implementation process, file management systems and archiving procedures. More-recent cases are generally better populated but, even here, gaps exist. In a few cases, complete datasets for large modern consents may be available from the Planning Inspectorate website. Unfortunately, the majority of cases in this study are too old to be available in this way.

Monitoring documentation

3.34. Although reports exist for the majority of compensation sites (Table 8 - page 34), they vary in quality and relevance to the defined objectives of compensatory habitat provision. This issue is most notable in the case of projects where compensation forms part of a wider 'biodiversity benefits' project (e.g. Hesketh Outmarsh and Rye Harbour). In these cases, the monitoring reports appear to focus almost entirely on the biodiversity benefits and do not clearly assess the performance of the site in relation to compensation objectives.

3.35. Monitoring data are generally not in the public domain, although some are available on password-protected portals. This meant that where it was not possible to source data from Natural England files, it was generally not possible to secure data by a web-based literature search.

Table 5. Timetables for development of compensation sites.

Development	Project start date	Compensation initiated	Compensation completed	Timescale for compensation functionality
Wing Water Treatment Works	Consent April 2007	2008	2011 (staged over three years)	Assumed to provide staged functionality in line with the habitat creation works timescale.
Hull Quay 2005 Container Terminal	Jan 2005 (consent for revised scheme), but project not initiated).	July 2006	2007	2011 – but only with respect to target for inter-tidal area and invertebrate assemblage. Site does not support overall target for bird numbers. But see IOH.
Immingham Outer Harbour (IOH)	Consent given July 2004. Works – February 2005-April 2006	October 2004 to July 2006 (at three different locations)	2007	Site did not start to provide functionality until some 2 years later and up to one year after construction works at IOH began. Targets for the complete package of sites met by 2011/2012.
Green Port Hull	Consent July 2012 – but project not initiated to date.	July 2006	2007	2011 – but only with respect to target for inter-tidal area and invertebrate assemblage. Site does not support overall target for bird numbers. But see IOH.
Lappel Bank & Fagbury Flats	1988 (Fagbury) and 1994 (Lappel Bank)	July 2006	2007	The habitat creation site (Allfleet's Marsh) exceeded targets set by 2011.
London Gateway Container Terminal	Consent July 2005	Site A.	Site A 2010 Site X yet to be developed.	Site A provides functional inter-tidal habitat. Overall aim was to provide functional habitat within 15 years of initiation of creation schemes.
Cley/Salthouse Flood Management	2007?	2009	2014	No indication from available information that the site provides functional compensation as of 2014.

Scheme				
Hullbridge Tidal Flood Defence Scheme	2002	2002?	2003?	Predicted to be within 5 years of habitat creation, but no monitoring documentation available to indicate whether this is the case.
Humber Estuary Flood Risk Management Strategy	2000 - ongoing	2003 (PHS), 2006 (Alkborough)	Ongoing	Monitoring data indicate that the Paul Holme Strays site formed a functional part of the estuary by 2010.
Pett Frontage Tidal Flood Defence Scheme	2001-2002 and ongoing	2005 (Rye Harbour Farm)	Ongoing	Functionality anticipated as 10 years post creation. But habitat creation site not directly linked to area of impact and functionality in this context therefore questionable.
Portchester Castle to Emsworth Flood Risk Management Strategy	Strategy approved Sep 2012	September 2011	Sep 2013	Functional, inter-tidal habitat would be expected to develop in less than 10 years. This would be well in advance of the majority of inter-tidal losses that would occur through implementation of the policies set out in the Portchester to Emsworth Strategy.
Harwich approach channel deepening	1998-2000 and 2004	1998	November 2000	Monitoring indicated that the site was functioning and achieving set objectives by 2008.
A249 Iwade to Queensborough road improvement scheme	2001?	2002?	2002?	Monitoring indicates that the compensation site provided functionality by 2006.
Morecambe Coastal Defence Works	2003?	2006	2008	Site provides functioning saltmarsh habitat, but this is a different habitat type (inter-tidal sandflat) to that lost to the defence works.
Arcow Quarry	Consent 2004	2005	2006?	2011 - translocation of stripped grassland

				appears to provide similar function to impacted areas (note, this is mitigation and not compensation).

Table 6. Objectives and indicators used to determine ecological function for the compensation sites examined.

Development	Objectives / Indicators to describe success / function
Wing Water Treatment Works	Indicators of the success of the compensation measures relate to numbers of waterbirds using the new habitats. Long-term waterfowl counts for the whole reservoir, specific counts in the western part of the reservoir, and detailed counts in the mitigation/compensation areas are monitored. Waterfowl abundance is taken as an indicator of overall habitat functionality.
Hull Quay 2005 Container Terminal	A set of objectives are defined for the three compensation sites (Welwick, Chowder Ness and Doig's Creek) that seek to achieve the maximum ecological potential of the sites in connection with both Quay 2005 and Immingham Outer Harbour. These objectives cover aspects such as habitat quality (largely defined through invertebrate abundance / species composition and vegetational characteristics), habitat area and bird usage. (See Immingham Outer Harbour).
Immingham Outer Harbour	The Environmental management and monitoring plan defines a set of objectives for the three compensation sites (Welwick, Chowder Ness and Doig's Creek) that seek to achieve the maximum ecological potential of the sites. They are designed to address the impacts of both Immingham Outer Harbour and Quay 2005: • '*The creation of inter-tidal habitats with the ability to provide feeding habitat for in excess of 800 (peak mean over 5 years) feeding water birds with typical species In the following relative proportions: 60% dunlin; 20% black-tailed godwit; 10% redshank and 10% other bird species delivered through the creation of inter-tidal habitats at Welwick and Chowder Ness and enhancement of inter-tidal habitat at Doig's Creek.* • *In addition to the targets detailed in the legal agreement there is an additional target to create 0.4ha of saltmarsh at Welwick to replace the area that will be lost as a result of the construction of the scheme.*' In addition, • '*Creation of at least 11.3ha of new grassland habitat to offset losses, including:*

	transplantation of stone parsley to new flood bank at Welwick; and plant replacement hawthorn hedge/scrub at Chowder Ness • *Provision of at least 11.3ha grassland as suitable habitat for a range of farmland birds, potentially including BAP species such as skylark, linnet and reed bunting.*'
Green Port Hull	See Hull Quay 2005.and Immingham Outer Harbour as this project was dealt with by compensation provided for these projects and is covered in that section.
Lappel Bank & Fagbury Flats	'*The targets against which the success of the compensation scheme will be assessed are that the site should be capable of supporting the following:* • *An assemblage of roosting waterbirds, comprising, on a 5-year mean peak basis, at least 3600 waterbirds in similar proportions to those historically supported by Fagbury Flats, in particular ringed plover, grey plover, dunlin and turnstone; and* • *An assemblage of feeding waterbirds, comprising, on a 5-year mean peak basis, at least 2800 waterbirds in similar proportions to those historically supported by Lappel Bank and Fagbury Flats, in particular shelduck, dunlin and redshank.* *In addition, the proposed realignment site should, where practicable, deliver the necessary habitat characteristics that provide the opportunity for the full assemblage of waterbirds to feed and roost within the site, that is:* *i. Soft inter-tidal mudflats;* *ii. Saltmarsh – this should be higher saltmarsh generally suitable for roosting waterbirds;* *iii. A range of islands with appropriate capping material i.e. shingle, cockles and mud, to provide suitable habitat for roosting waterbirds; and* iv. *Limited disturbance – for example, through the prevention of wildfowling, casual access and speed boating on or over the inter-tidal areas created.*'
London Gateway Container Terminal	'At Sites A and X to create a minimum of 74ha of inter-tidal mudflats to provide alternative feeding habitat for displaced wintering waterfowl. Sites A and X, in combination with northern Mucking Flats, continue indefinitely to support an appropriate assemblage of wintering waterfowl at low tide. Sites A and x, in combination with northern Mucking Flats, the necessary inter-tidal habitat to

	support such an assemblage of wintering waterfowl - at least 7900 birds, made up of, in particular, avocet, dunlin and black-tailed godwit in similar proportions to those supported by North Mocking during the winters of 1999/2000 to 2002/2003 (considered in the context of the wider population trends). The target for the overall assemblage have been derived from low water count data for the four winter periods 1999/2000 to 2002/2003 Within 15 years of the breach of the existing seawalls, the sites are of sufficient quality to qualify for designation as an extension to the Thames Estuary and Marshes SPA. In addition, the compensation measures will provide a habitat to support fish populations of not materially less abundance at the port reclamation site than pre-construction although it is agreed that there is no precise data which clearly determines the existing abundance against which to compare. In addition to use all reasonable endeavours to manage coastal grazing marsh at Great Garlands Farm and the Northern Triangle to provide feeding. roosting and loafing habitat for teal and wigeon that potentially form part of the Thames Estuary and Marshes SPA assemblage. The target against which success of the mitigation will be assessed shall be that peak winter counts of 150 teal and200 wigeon are recorded in these combined areas. [Also 'to use all reasonable endeavours to further manage and enhance the area of the Northern Triangle (see plan) and to manage a minimum of 40ha of good quality coastal grazing marsh to offset the loss of 40 ha of coastal grazing marsh, a UK Biodiversity Action Plan habitat, to the construction of the Logistics Centre and the Port (in-combination).'] classed as mitigation but part of the overall compensation package.
Cley/Salthouse Flood Management Scheme	Unclear as to whether specific indicators have been developed. The measure of functionality appears to be strictly confined to the establishment of sufficient habitat to support two pairs of breeding bittern.
Hullbridge Tidal Flood Defence Scheme	No. The only functionality indicator appears to be confined to the development of 2.95ha of saltmarsh.
Humber Estuary Flood Risk Management Strategy	Targets were quantitative combining the effects of direct habitat loss and of coastal squeeze (total 23.76 ha of which 12.56 ha should be mudflat and 11.2 ha saltmarsh). Species composition of plants and in-fauna was to be correlated with middle estuary assemblages. In addition, a series of targets were set for bird usage.

	At least 30 feeding wintering waterbirds, including Redshank, dunlin, shelduck and curlew. In addition, at least 12 roosting wintering waterbirds: golden plover must be present. The project was also intended to offset impacts of other works within the flood risk management strategy but is caveated by the statement: *'Other urgent works schemes must receive planning permission and consent through the Habitat Regulations, before ascertaining whether compensatory habitat is required. A decision can then be taken as to whether suitable habitat is available at Thorngumbald. A process for determining compensatory requirements for other damaging flood defence schemes and whether habitat at Thorngumbald can be used will be agreed by the ESG (subject to approval of the approach at a national level.)*'
Pett Frontage Tidal Flood Defence Scheme	Indicators do not appear to have been identified. However, it appears that agreement was reached that the definition of vegetation of stony banks would include all communities that develop on bare shingle.
Portchester Castle to Emsworth Flood Risk Management Strategy	A key objective is given as the creation of 183ha of inter-tidal habitat, including mudflat, saltmarsh and transitional grassland. However, it is not known whether there are specific indicators relating to ecological function which underlie this overarching objective.
Harwich approach channel deepening	'*To create 4ha of inter-tidal habitat (of which no more than 30% should be saltmarsh) to replace the habitat lost due to the immediate effect of the change on tidal range, within 2 years of the commencement of the deepening.* *To prevent, through the immediate reintroduction of sediment into the system for as long as the channel is maintained', the annual loss of 1.7ha of inter-tidal (mean springs) (plus 1.1ha from the l994 dredge') and 3.3ha of inter-tidal (mean neaps) (plus 2.2ha from the I994 dredge) due to increased rates of erosion; where inter-tidal should be considered to represent a combination of habitats that sustain the form and function of the system.* *To create 12.5ha of inter-tidal habitat (of which no more than 30% should be saltmarsh) as soon as possible, but not later than 5 years from commencement, to mitigate habitat losses that could occur before sediment replacement measures can be expected to be fully effective.*'
A249 Iwade to	To provide habitat for the following breeding bird species in at least the members of pairs

Queensborough road improvement scheme	indicated: Shelduck, 3 prs; Shoveler, lpr; Coot, lpr; Oystercatcher, 9 prs; Lapwing, 8 prs; Redshank, 3 prs; Skylark, 15 prs; Yellow Wagtail, 3 prs. To provide habitat for the wintering bird species in at least the number of individuals indicated: - Lapwing 400 birds So far as is consistent with (a) and (b) above, to foster the development of a sward with a species composition and structure which approaches as closely as possible those of original grazing marsh that has not been subjected to cultivation, herbicide or fertiliser treatment. So far as is consistent with (a) and (b) above, to encourage the survival and spread of *Carex divisa*. (e) so far as is consistent with (a) and (b) above, to develop an invertebrate fauna in the ditches and over the pasture similar in composition to that found on original gazing marsh not subject to nutrient enrichment or pollution.
Morecambe Coastal Defence Works	The scoping report for the Hesketh Outmarsh realignment highlights a wide spectrum of objectives. These objectives include a contribution towards BAP objectives (this element was funded by the RSPB) as well as the provision of habitat to compensate for the loss of 13 ha of inter-tidal habitat at Morecambe Bay. This report also clearly shows that the majority of the habitat creation was expected to be vegetated, but that measures taken to create saline lagoons would also be incorporated.
Arcow Quarry	No specific indicators appear to have been set.

Table 7. Arrangements for regulators groups to facilitate management and reporting.

Developer	Development project	Regulators' group?	
		Yes	No
Anglian Water Services	Wing Water Treatment Works	x	
Associated British Ports	Hull Quay 2005 Container Terminal	x	
	Immingham Outer Harbour	x	
	Green Port Hull	x	
Defra	Lappel Bank & Fagbury Flats	x	
Dubai Ports World	London Gateway Container Terminal	x	
Environment Agency	Cley/Salthouse Flood Management Scheme		x
	Hullbridge Tidal Flood Defence Scheme		x
	Humber Estuary Flood Risk Management Strategy	x	
	Pett Frontage Tidal Flood Defence Scheme		x
	Portchester Castle to Emsworth Flood Risk Management Strategy	x	
Harwich Haven Authority	Approach channel deepening	x	
Highways Agency	A249 Iwade to Queensborough road improvement scheme		x
Lancaster City Council	Morecambe Coastal Defence Works		x
Tarmac Ltd	Arcow Quarry	x	

Table 8. Availability/adequacy of monitoring documentation.

Developer	Development project	Monitoring reports
Anglian Water Services	Wing Water Treatment Works	Yes[10]
Associated British Ports	Hull Quay 2005 Container Terminal	Full
	Immingham Outer Harbour	Full
	Green Port Hull	Full
Defra	Lappel Bank & Fagbury Flats	Full
Dubai Ports World	London Gateway Container Terminal	Partial[11]
Environment Agency	Cley/Salthouse Flood Management Scheme	No[12]
	Hullbridge Tidal Flood Defence Scheme	Limited
	Humber Estuary Flood Risk Management Strategy	Full
	Pett Frontage Tidal Flood Defence Scheme	Limited
	Portchester Castle to Emsworth Flood Risk Management Strategy	No[13]
Harwich Haven Authority	Approach channel deepening	Full
Highways Agency	A249 Iwade to Queensborough road improvement scheme	Full
Lancaster City Council	Morecambe Coastal Defence Works	Limited
Tarmac	Arcow Quarry	Limited

[10] Note: Although there has been ongoing weekly monitoring of bird usage by LRWT within the compensation site and Anglian Water has completed a five-year post-construction monitoring exercise, there has been no opportunity to test the effectiveness of the compensation under extreme low water conditions.
[11] A summary document has been provided, but the full range of monitoring that has taken place has not been made available to this study.
[12] Note: The site has been regularly monitored by NWT during construction, but it is not yet fully inundated. Consequently, the development of reedbed habitat is currently limited and the monitoring is not yet relevant to the key conservation outcomes.
[13] Note: this site was breached in 2013 and there has not been sufficient time to generate and disseminate relevant monitoring data.

4. Findings - post-construction performance of compensation sites

4.1. The timescale over which individual habitat creation projects have been developing is extremely variable. As much as 15 years has elapsed since the creation of the Trimley managed realignment site, whereas the Medmerry realignment was undertaken in 2013, and two sites have yet to be completed (Hilgay and Site X). It is, therefore, important to consider sites in the context of their age and state of development.

4.2. Annex 1 reports the combined results of site visits and of monitoring outputs from individual projects.

4.3. The analysis in this section therefore focuses on overall messages that can be drawn from experience to date.

Gaps between project impacts and compensation site design objectives

4.4. Design objectives for the majority of sites broadly reflect the range of damaging impacts of the development projects. In three cases, the choice of compensation site and the outcomes to date are at variance with the predicted impacts:

i. Hilgay. This site should provide freshwater wetland capable of supporting two pairs of breeding bittern (displaced by water chemistry changes at Cley-Salthouse). It forms part of the Wissey Wetland Creation Project, which is a combined initiative between the Environment Agency, Norfolk Wildlife Trust and Natural England to create new wetland habitats adjacent to the River Wissey. The programme will also restore some of the wetland habitats that were present in the Fens prior to widespread drainage for agriculture. There are therefore a number of wider biodiversity benefit objectives for this scheme, over and above the compensation package under consideration. The site lies a considerable distance from Cley-Salthouse and is not near any other designated site. There have been a number of delays which mean that the site had not been fully inundated by spring 2014, nine years after the impacts commenced. It should, therefore be expected that a further period of time will elapse before reedbeds suitable for bittern are fully established.

ii. Hesketh Outmarsh. Habitat at Morecambe Bay was sandy upper inter-tidal with cobble skear[14] within an SAC, SPA and Ramsar site. Hesketh

[14] In Morecambe Bay outcrops of glacial deposits (known locally as skear) are exposed, forming a mixture of boulders of varying sizes that form reef-like habitat of importance to feeding waders. Skear is a sub-feature of Habitat 1160 Large Shallow Inlets and Bays.

Outmarsh was chosen as the most viable option for creating new sandy inter-tidal habitat to replace inter-tidal sandflats lost to new coastal defences at Morecambe Bay. The replacement site is adjacent to an SPA and Ramsar site. Thus, even if suitable habitat develops, there might be a reduction in the extent of SAC habitat. This was factored into the extent of habitat creation at Hesketh, which involved a ratio of four ha of habitat creation for every one ha of loss. Much of Hesketh Outmarsh has developed into saltmarsh. Although there is some unvegetated inter-tidal habitat (see figure 2, below), this is unlikely to amount to 52 ha (the area identified as replacement habitat). The reasons for this shortfall are: the sediment type at Hesketh is sandy mud or muddy sand rather than pure sand; there has been no quantification of bare muddy or sandy habitats; and the site has already become saltmarsh except where there are channels.

Figure 2. Breach at Hesketh Outmarsh, one of the main areas within the site that is likely to form sustainable inter-tidal sandy and muddy habitats

iii. Rye Harbour. This site should provide compensation for temporary and permanent loss of annual vegetation of drift lines and perennial vegetation of stony banks caused by a range of new flood management measures between Pett Levels and Rye Harbour. The compensation site, however, is inland and involves later successional stages than those affected by the flood management scheme.

Does the conservation interest of the compensation site meet design objectives?

4.5. In general, compensation sites are broadly consistent with their design objectives. All meet the requirement to compensate for the loss of area within

the boundaries of the designated site. Some, such as Chetney and Trimley, clearly meet all design parameters and appear to replicate lost habitat.

4.6. Evidence from a number of sites suggests that the success and longevity of mudflat habitat creation is very dependent on site specific circumstances and characteristics. Although similar mudflat habitat can be created in the short-term, this may not be possible in the longer term (Mazik *et al*., 2010; Morris 2013). Reporting for ABP's compensation sites on the Humber indicated that the range and abundance of in-fauna was broadly consistent with that of true mudflats within two to three years. Sediment accretion at other sites, including Chowder Ness and Welwick, shows that progression towards saltmarsh can be very rapid, especially where there is a high suspended sediment load. Under these circumstances, it is clear that some sites will gradually change towards biotopes that do not meet the original design parameters.

4.7. Evidence from the Trimley managed realignment site provides some reassurance that mudflats may be created over a longer time-frame. This site lies adjacent to an estuary in which suspended sediment loads are considerably lower than those in the Humber and, although there has been a gain in mudflat elevation, this is not sufficient for extensive saltmarsh development, which is largely confined to the most sheltered locations. Suspended sediment levels alone may not be the whole answer, however, as it is clear that Allfleet's Marsh (Wallasea Island) is quickly gaining elevation and isolated clumps of *Spartina anglica* are developing beyond the area of deliberate saltmarsh creation. A similar situation exists at Stanford Wharf (Mucking) where, after just two years, isolated patches of *S. anglica* have developed along the margins of the site.

4.8. At Hilgay, there have been substantial delays in undertaking the habitat creation work, even though the change to management at Cley-Salthouse took place nine years ago. The wet winter of 2013/14 delayed its completion and the site is soon to be inundated. Delays in the development of the compensation site, mean that it is not yet possible to determine whether it will meet the design objectives. However, this must be qualified by the fact that creation of new reedbed is a well-tested science (e.g. White, 2004) and there is high confidence that suitable replacement habitat will result.

Is the habitat type provided 'like-for-like'?

4.9. In the majority of cases, the objectives set for the compensation site were either 'like-for-like' or a suitable replacement for certain key functional parameters, such as the provision of reedbeds with patchy open water suitable for breeding bittern. There are, however, notable disparities between some design objectives and the resulting outcomes. This is most noticeable within two sites on the Humber Estuary, where the objectives set for realignments at Chowder Ness and Welwick focussed primarily on creation of inter-tidal mud. The pace of saltmarsh evolution at these two sites has been rapid and they are now substantially vegetated (see paragraph 4.6 above).

4.10. It should be noted that there are substantial variations in the time that has elapsed since individual habitat creation projects were completed. This is most obvious at Hilgay where the project engineering was at its final stage when visited in 2014, and at Site X (London Gateway) where the engineering had yet to be completed at the time of the site visit. Managed realignment sites have been shown to evolve according to local wave climates and sediment availability (Morris, 2012, 2013). It is our opinion that the form and function of many, if not all, realignment sites in 2014 is unlikely to represent the final stage of habitat evolution.

4.10. There are two cases where the compensation site differs substantially from the impact site (Table 9 - page 40):

i. Hesketh Outmarsh. Habitat at Morecambe Bay was sandy upper inter-tidal with skear within an SAC, SPA and Ramsar site (see 4.4. ii above). The compensation site is predominantly muddy sand and has very largely reverted to saltmarsh.

ii. Rye Harbour. The impact of the flood management measures was primarily upon drift-line and early successional stages of shingle habitats (see 4.4. iii above). The compensation site is inland and involves later stages of shingle vegetation.

4.11. There are very specific reasons for the disparity between impacts and design objectives for compensation at these two sites:

i. Both cases involve flood risk management measures to safeguard large numbers of people and property. Thus, the imperative reasons of over-riding public interest were on grounds of human safety and welfare.

ii. Drift-line and shingle communities require a suitable wave energy environment often associated with storms and suitable sediment supply. Re-creating these conditions is dependent upon finding a suitable location where the combination of waves, shingle supply and un-designated coastline coincide within the proximity of an existing designated site. Such sites are extremely rare or entirely absent, making this a habitat that is unlikely to be re-creatable in any but the most exceptional circumstances.

iii. Sandy habitats occur on the open coast where wave energy disperses finer sediments. Managed realignment sites, meanwhile, are sheltered with a lower wave energy environment that favours finer sediment deposition such as silts and clays. Careful assessment of the coastline between Liverpool and the Scottish borders concluded that there were no obvious locations that could be realigned to create sandy habitat, as

potential realignment sites all lay within sheltered situations that would have resulted in high level saltmarsh[15].

4.12. Whilst they do not fully replicate lost habitat, the compensation packages for both developments are part of bigger biodiversity projects. These projects are comparatively large (in extent), with the potential to contribute significantly to the Natura 2000 network.

4.13. In addition, the Environmental Impact Assessment (EIA) for Green Port Hull recognises that there will be a loss of sub-tidal muddy estuarine habitat. As such, this will lead to the loss of extent within Habitats Directive Annex I Habitat HD1130 'Estuaries', but will not affect other qualifying habitats within the Humber Estuary SAC. The resulting compensation is inter-tidal rather than sub-tidal. This approach is logical because re-creation of sub-tidal habitat is extremely difficult (if not impossible) using conventional techniques. Evolution of realignment sites leads, predominantly, to saltmarsh with some mudflat and occasionally small extensions of sub-tidal habitat where creek systems develop. It would, therefore, be unrealistic to expect any other habitat to arise from realignment, even if it included the creation of a sub-tidal area by excavating part of the site to a much lower level. In biological terms, although there will have been a loss of biological productivity from sub-tidal habitat, valuable functional productivity will develop in the inter-tidal habitat created by realignment. Whilst it will not be entirely similar, it should perform valuable comparable role in maintaining the estuarine ecosystem.

4.14. In the majority of inter-tidal habitat creation programmes, the intention was clearly to replicate habitats as far as was practically possible. In the case of the Defra project at Allfleet's Marsh (Wallasea Island), parts of the site were deliberately engineered to allow saltmarsh to develop at an early stage. Elsewhere, sites were predicted to form a mixture of saltmarsh and mudflat, in order to provide feeding habitat for migratory waterfowl. It is apparent from the available evidence however, that less attention was paid to the specific requirements of 'like-for-like' habitat creation where losses involved complete sections of mudflat that were gradually exposed over the full tidal cycle.

4.15. Morris (2013) discusses the problem of creating inter-tidal habitat as a direct replacement for lost habitat. This analysis argues that habitat lost to major port developments involves a much wider range of physical attributes (Figure 3, page 41) that may be relevant to maintaining migratory waterfowl populations. In particular, it emphasises that lost inter-tidal mudflats were gradually exposed over the falling tide, providing waterfowl with an ongoing food resource (many such birds follow the falling tide). The process of rising and falling tides may be very significant during periods of extreme heat and cold because they buffer the benthic assemblage against some of the

[15] Note, this exercise in looking for possible compensation sites was conducted by English Nature staff, including one of the authors of this report (RKAM). There is no surviving documentation and this report of process, therefore, derives from personal recollections.

extreme conditions. This issue requires further detailed research before absolute conclusions can be drawn about the relative merits of a realignment mudflat and a 'natural' mudflat.

Table 9. Comparisons between habitat loss and re-creation at two sites where loss and replacement are not 'like-for-like'.

Impact site	Habitat Loss	Adjacent to Compensation site	Habitat created
Morecambe Bay SAC, SPA, Ramsar Site	Inter-tidal sand Skear	Ribble & Alt SPA & Ramsar Site	Inter-tidal mudflats & sandflats Saltmarsh habitats.
Dungeness SAC Dungeness to Pett Level Special Protection Area & pRamsar Site	Shingle habitat (general)	Dungeness SAC Dungeness to Pett Level Special Protection Area & pRamsar	Perennial vegetation of stony banks
	Annual vegetation of drift lines		
	Perennial vegetation of stony banks		

Consideration of geographic location within compensation provision

4.16. In almost all cases, the audit trail recording the way in which particular compensation sites were chosen is weak. This lack of information means that it is not possible to link particular choices of sites with wider geographical considerations, such as whether the location was the best in terms of delivering functional habitat, or the most convenient because it could be acquired at a realistic price. It is noteworthy, however, that the majority of compensation sites are near the point of damage and adjacent to the designated site (Table 10 - page 42).

4.17. There are three examples where the compensation site was not adjacent to the same Natura 2000 site: Defra's compensation for Lappel Bank and Fagbury Flats; compensation for Morecambe coastal defences; and compensation for the Cley-Salthouse flood management scheme.

4.18. Although the audit trail for the Morecambe case could not be retrieved, there is sufficient detail in the documentation for the other two projects to be sure that the final choice of site was undertaken according to a rigorous process of

analysis (Field *et. al*., 1998; Banks *et al*., 2003[16]; Environment Agency, 2005). Critical considerations include the possible size of compensation sites, the practicality of undertaking necessary engineering and its geographic location, with the nearest possible practical site being chosen. These various exercises were comprehensive and the final choice of site was the best possible option.

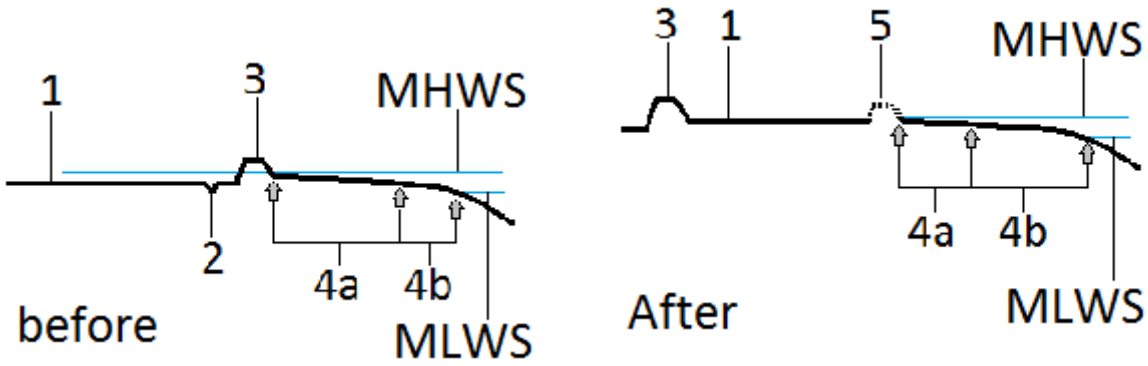

Figure 3. Diagrammatic explanation of the position of managed realignment in relation to 'natural' inter-tidal in front of the sea wall (reproduced from Morris, 2013). MHWS= Mean High Water Spring Tide; MLWS = Mean Low Water Spring Tide

Left, before breaching, **Right** after breaching and sedimentation.
1 = elevation of the realignment before breaching and after breaching and sedimentation.
2 = borrow-dyke behind original sea wall.
3 = sea wall.
4a = elevation of inter-tidal primarily replicated in realignment at time of breach and after sedimentation.
4b = elevation of inter-tidal not replicated in the realignment.
5 = original sea wall that has been breached and is disintegrating.
Comparison between the pre-and post breach scenarios shows how the extent of potential and actual inter-tidal replication changes in favour of the uppermost elements of inter-tidal habitat.

[16] Note: a comprehensive site evaluation report was prepared for Defra during the process of choosing a compensation site for Lappel Bank/Fagbury Flats. The document was not available to us and, therefore, the contents cannot be quoted.

Table 10. Juxtaposition of compensation sites with designated sites.

Developer	Development project	Proximity to impact site		
		Adjacent to the same site	Different site	New site
Anglian Water Services	Wing Water Treatment Works	Yes		
Associated British Ports	Hull Quay 2005 Container Terminal	Yes		
	Immingham Outer Harbour	Yes		
	Green Port Hull	Yes		
Defra	Lappel Bank & Fagbury Flats		Yes	
Dubai Ports World	London Gateway Container Terminal	Yes		
Environment Agency	Cley/Salthouse Flood Management Scheme			Yes
	Hullbridge Tidal Flood Defence Scheme	Yes		
	Humber Estuary Flood Risk Management Strategy	Yes		
	Pett Frontage Tidal Flood Defence Scheme	Yes		
	Portchester Castle to Emsworth Flood Risk Management Strategy			Yes
Harwich Haven Authority	Approach channel deepening	Yes		
Highways Agency	A249 Iwade to Queensborough road improvement scheme	Yes		
Lancaster City Council	Morecambe Coastal Defence Works		Yes	
Tarmac Ltd	Arcow Quarry	Yes		

Capacity of compensation sites to adapt to future change

4.19. There are three key questions in respect of the sustainability of compensation sites in light of potential future change:

i. Do the compensation measures have the capacity to be adapted to unfolding circumstances in the future?

ii. Are compensation sites resilient in the face of sea level rise, climate change and other pressures?

iii. Are compensation sites likely to be sustainable for at least 50 years?

4.20. Assessment of the potential resilience of compensation sites is dependent upon the nature and location of the habitat created. The study sites comprise 11 inter-tidal sites, one grazing marsh, two freshwater wetlands and one limestone grassland. Each has particular attributes that need to be explored separately.

Managed realignment sites

4.21. Most of the compensation sites examined for this study lie in the coastal zone and, as a result of climate change, these can be expected to be the subject to the twin pressures of sea level rise and increased storminess (UKCIP, 2009). In addition, there has been a long-term question over the availability of adequate sediment supplies to coastal localities. For example Bird (1985) notes “Sandy beaches are perceived to be eroding along a substantial proportion of the World’s coastline. This has been estimated to be 70% over the last one hundred years”. In estuary systems in eastern England there is a particular need to allow inter-tidal habitats to keep pace with rising sea levels and a lack of sediment is a critical strategic issue.

4.22. Sites in southeast England where inter-tidal habitats have been created by realignment are arguably more robust than those immediately in front of seawalls, especially on exposed coastlines:

i. They provide a sink of suspended sediments that ultimately raise land levels to the point where saltmarsh habitat develops.

ii. Where banks are realigned, a large area of potential saltmarsh is created. Once sufficient elevation has been gained and saltmarsh habitat evolves, it starts to act as a brake on wave energy and reduces wave energy reaching the new sea wall, thus helping to add to the resilience of the sea wall.

iii. Depending upon the location within the estuary, the realignment site may start to erode, causing saltmarsh to retreat. Where erosion does occur, this will release sediment in the process. This sediment forms part of background levels that help to allow saltmarshes to continue to gain elevation as sea levels rise (French and Burningham, 2003).

iv. Conversely, in many British east coast estuaries, saltmarsh forms a narrow strip adjacent to the sea wall. As it erodes, the sediment it

releases is exported to the estuary unless a new sink is created (as is achieved by managed realignment).

4.23. Realignment by increasing the area of saltmarsh helps buffer the impact of wave energy. This in turn leads to a greater resilience within the system as a whole. A parallel situation exists in the case of natural breaches that have led to a variety of new inter-tidal habitats, especially on the east coast of England. These 'unmanaged realignments' form a considerable amount of the remaining saltmarsh habitat in some estuaries in Essex and Suffolk (Burd, 1992, 1994; Garbutt & Wolters, 2008). They provide a useful analogue that shows how managed realignment sites evolve over time.

4.24. It is, therefore, important to consider inter-tidal habitat evolution in terms of a full cycle of development. Under 'natural' coastal evolution in the face of sea level rise, saltmarshes and mudflats will migrate inland; a process described as 'rollover' (see Allen, 1990; Pethick, 2000) (see Figure 4a. page 45). Construction of flood banks limits the coast's ability to respond to ‘rollover’ in the face of sea level rise and, hence, mudflats and saltmarsh erode - a process described as 'coastal squeeze’ (e.g. Doody 2004). Creating a realignment site partially restores the potential for the coast to adapt to change. In doing so it helps restore the functionality present before the creation of saltmarsh enclosing seawalls. Sedimentation within the realignment site leads to saltmarsh development over a variable time-frame (Morris, 2013; Garbutt & Wolters, 2008). It should not be assumed, however, that this saltmarsh will remain *in situ* indefinitely. The key to this is the sediment budget. If this is positive in a given wave energy environment suitable for saltmarsh development, accretion is likely. A neutral budget may allow the habitat to remain in situ. A negative budget will probably result in erosion. Sea level rise will push the system into an erosional phase in due course and, so, mudflats and, eventually, sub-tidal habitat will result (Figure 4b, page 45).

4.25. During this evolutionary cycle, the ecological function of realignment sites within estuaries will change. During the early stages, mudflats will be created. These are the habitats that are usually the objectives for compensation, but they are transitory and, ultimately, saltmarsh will normally develop. There are exceptions, as illustrated by natural breaches in the Alde-Ore and Blyth (Suffolk) estuaries (Morris, 2012). Evidence around the English coast shows how realignment sites will eventually evolve to the point where breached seawalls degrade and cease to offer effective wave protection. At this point, saltmarsh within the site may start to erode to re-form mudflat and to 'trickle feed' sediment back into the system. This is an essential part of coastal evolution, but it takes time.

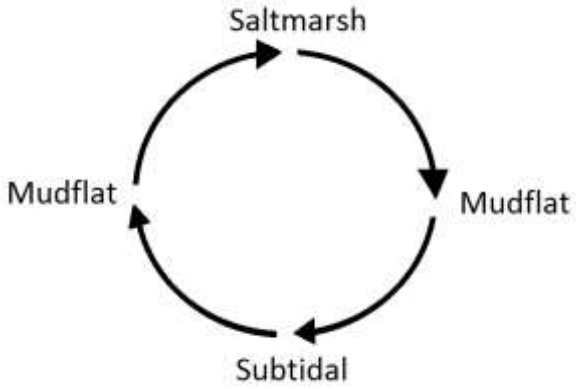

Figure 4a. Natural cycle of coastal evolution in the face of sea level rise. As sea levels rise, they fill a void (accommodation space) which, provided that there is sufficient sediment, ultimately develops into mudflat and then saltmarsh. As sea levels rise further, existing saltmarsh is eroded and the resulting sediment is re-distributed inland to create new mudflats and saltmarsh. Some of the original footprint will eventually become sub-tidal as the sea progresses landwards

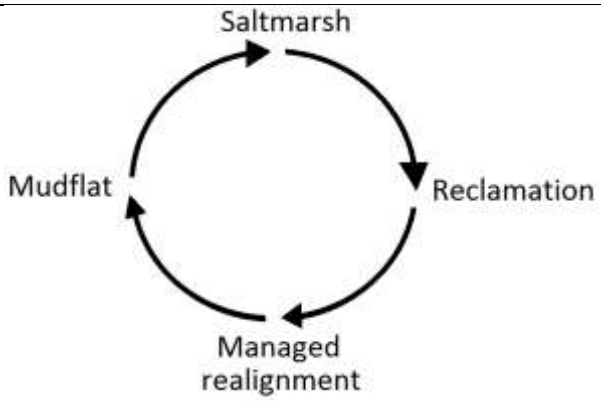

Figure 4b. Where former saltmarsh has been 'reclaimed', the capacity of the coast to evolve is restricted. Realignment creates a new void that creates a sediment sink. Provided that there is sufficient sediment, the void will fill with sediment and will become saltmarsh. At this point, the 'natural' cycle between saltmarsh and sub-tidal habitat will follow (figure 4a) until sea levels overwhelm the new habitat.

Figure 4. Representations of the cycles involved in progressive sea level rise under 'natural' circumstances (i.e. in the absence of seawalls) and where managed realignment has been implemented.

4.26. Timescales for sea wall decay are uncertain and the evidence from current realignments is not well-documented. Key factors are the material that forms the wall, the degree to which it is fronted by saltmarsh, levels of wave protection currently in place, and levels of exposure to wave energy. However, it can be seen that there is a combination of internal erosion (Pethick *et al*., 2009; Morris, 2012) and external erosion, as illustrated in Figure 5 (page 46). The remains of former seawalls within the Blyth Estuary point to considerable resilience in some places, but other seawalls may rapidly disappear. For example, former walls are little more than raised points in the saltmarsh matrix at Lion Creek on the Crouch Estuary (Essex).

4.27. It must, therefore, be assumed that the geometry of all managed realignment sites will change over time. Current (unpublished) evidence from managed and unmanaged realignments points to this being a slow process that will give sites considerable sustainability, extending well beyond 50 years. Quite how long cannot be predicted, but they will face the same pressures as the habitats for which they are compensating. Habitat ceded to development

would also have been subject to coastal squeeze and would have had a finite future. Critical factors will include actual changes in sea levels, changes in wave climates, levels of available suspended sediment and available accommodation space.

Figure 5. Erosion of the former sea wall at Trimley, Stour & Orwell Estuary, Suffolk.

4.28. In summary, evolution of managed realignment sites is a continual process that is dependent upon a wide range of forcing factors. As a consequence, the inter-tidal habitat that is created will be sustainable in a broad sense, but the relative proportions of mudflat and saltmarsh will usually continue to change.

Coastal grazing marsh

4.29. The grazing marsh at the Chetney compensation site lies behind seawalls and, as such, is highly dependent upon the maintenance of these walls. Assuming that there is a commitment to maintaining the seawalls, and water supply to the site does not change, there is no reason to doubt its future sustainability.

4.30. The Chetney Peninsular lies within the Medway Estuary and is therefore covered by the Medway Estuary and Swale Shoreline Management Plan (Halcrow, 2010). Options for this section (E4.20) include managed

realignment. Should it be concluded that the current defences cannot be maintained, or that it is desirable to realign the defences, this compensation site could be replaced by inter-tidal habitat. Should a decision be taken either to realign or not to maintain the seawall, it would be necessary to re-create grazing marsh habitat elsewhere.

4.31. The apparent success of the Chetney compensation site suggests that breeding and wintering bird habitat within grazing marsh can be re-created. The results for invertebrate and plant assemblages are less conclusive. Further investigation and comparison with grazing marsh ditches elsewhere around the Medway Estuary is needed to establish whether these assemblages are comparable.

4.32. Translocation of *Carex divisa* clearly shows that this is possible, but it also indicates that more research is needed to establish how to re-create grazing marsh sward in which this plant occurs extensively and not simply confined to a few patches of translocated plants.

4.33. A far greater conundrum exists in the case of invertebrate assemblages associated with grazing marsh ditches. Monitoring of the Chetney compensation site confirms that many water beetles will readily colonise re-created habitat, provided there are nearby donor sites. Recent expansion in the range of several dragonfly species also shows how some other mobile species can readily adapt to changing opportunities (identified in Morris *et al*. 2006). There can be far less certainty about the potential of other organisms to recolonise, as there are no data to support an interpretation. For example, very little is known about the likely mobility of many molluscs and if these prove to be comparatively immobile the fate of other associated organisms such as the snail-killing flies (Sciomyzidae) must also be questioned. This is a major research gap that requires urgent attention if substantial areas of Ramsar-designated grazing marshes are to be lost.

Freshwater wetlands

4.34. Both the Rutland Water and Hilgay sites are highly engineered and rely upon a supply of freshwater being maintained. Both are managed by Wildlife Trusts and form part of important wildlife assets.

4.35. The crucial long-term issue concerning habitats that are sustained by management intervention involves funding. Costs of maintaining and replacing control structures can be extremely high, and there can be no guarantee that these will be forthcoming precisely when intervention is required. This is especially the case for reedbeds, which gain extent, both laterally and in elevation. Growth in the extent of reedbeds will lead to loss of open water and creation of drier conditions in which willow *Salix* and alder *Alnus glutionosa* scrub gains a foothold. Major mechanical intervention is usually required in these circumstances.

4.36. It may therefore be concluded that both Rutland Water and Hilgay are sustainable, provided there is ongoing management intervention. Any funding

shortfall will inevitably have a knock-on effect on the degree to which these sites meet their design objectives.

Limestone grassland

4.37. Grasslands are a relatively ephemeral habitat that result from long-term management as pasture for grazing animals. Once grazing pressure is lifted they will rapidly turn into scrub and woodland. Grassland management is therefore entirely reliant upon continuity of management and upon suitable grazing stock. In addition, stocking levels can have a significant bearing upon sward structure; hence the attention given to this issue in Higher Level Stewardship Agreements between Natural England and landowners. Long-term sustainability of the Moughton site is therefore wholly dependent upon an agreed grazing regime.

4.38. Many upland habitats are predicted to be particularly vulnerable to the direct effects of climate change (Harrison *et al*., 2001). However, calcareous grassland has been shown to be relatively resilient to climate change (Duckworth, Bunce & Malloch, 2000; Grime *et al*., 2008), with older grasslands being more resilient than those in earlier successional stages (Grime *et al*., 2000; Carey, 2013). Climate envelope modelling suggests that there could be a potential increase in the climate space for many calcareous grassland species in the UK, although their spread would be limited by the availability of suitable substrates (Harrison *et al*., 2006). Factors such as fragmentation, under- or over-grazing and nutrient enrichment are likely to have a greater impact on calcareous grassland than the direct impacts of climate change, at least in the short term. In the medium term, climate change could alter the economics of grazing in relation to other land uses.

Arrangements for control and management of compensation sites

4.39. Once consent is granted for the development project and (possibly separately) for the compensation site, there are a number of factors that will have a bearing on its long term viability. It is unlikely that nature conservation management sits amongst a developer's core business commitments, and consequently control of compensation sites may pass to a third party, either as a tenant or freeholder. Each case is different and therefore each is discussed separately but an 'at-a-glance' assessment is provided in Table 11 (page 56).

4.40 Very little documentation was available to assist in assessing the effectiveness of management arrangements. In some cases the precise details of management arrangements do not appear to be readily available (e.g. Chetney). The most comprehensive monitoring outputs that we have seen involve managed realignment sites and simply report the outcomes of the monitoring. Only in one case (Chetney) was a recommendation for management action identified. Consequently it has not been possible to assess the effectiveness of management arrangements apart from occasional anecdotal information.

Anglian Water Services, Wing Water Treatment Plant - Rutland Water compensation areas

4.41. The site is owned by Anglian Water Services and its conservation interests are managed by Leicestershire & Rutland Wildlife Trust.

4.42. A monitoring protocol was designed to assess the impacts and effectiveness of the mitigation/compensation measures. Wildfowl counts will continue in perpetuity as part of the ongoing conservation management of the Rutland Water Nature Reserve by Leicestershire & Rutland Wildlife Trust. Anglian Water Services have yet to decide whether to extend the five-year monitoring programme for macro-invertebrates, macrophytes and water quality - to which they were conditionally committed following completion of the mitigation/ compensation works in 2009.

Associated British Ports (ABP), Green Port Hull & Quay 2005 Container Terminal - Chowder Ness and Welwick compensation sites

4.43. Green Port Hull is the final stage in a series of consent applications to expand the Port of Hull. Consent was first granted for Quay 2005 Container Terminal but the site was not developed. The original compensation package was the package for Immingham Outer Harbour and the two projects share common compensations sites. There is therefore a direct relationship between all of the ABP developments.

4.44. The compensation includes an 11ha managed realignment at Chowder Ness (inner Humber Estuary). Six hectares of this habitat provides compensation for the loss of habitat and function attributed to the Green Port Hull as per the original Quay 2005 development. The remaining five hectares provides compensation (in part) for the Immingham Outer Harbour (IOH) development (see paras 4.48.-4.50.). A further 5ha of inter-tidal habitat will be created at the existing Alkborough managed realignment site through enhancement of an existing component of the site and modification of management measures. In effect, the compensation has been developed before the development has taken place because all of the compensation sites (for Quay 2005 and Immingham Outer Harbour) were created before the consent for Green Port Hull had been granted.

4.45. Chowder Ness is owned by Associated British Ports. There are no immediate plans to transfer ownership. Alkborough is mainly owned and managed by the Environment Agency (although ABP own a small part of this site), but via consultation with a management group comprising the Environment Agency, Natural England, North Lincolnshire Council, English Heritage, ABP and Lincolnshire Wildlife Trust.

Associated British Ports (ABP), Immingham Outer Harbour - Chowder Ness and Welwick compensation sites + Doigs Creek

4.46. In July 2004, ABP was granted a Harbour Revision Order (HRO) for the construction of the Immingham Outer Harbour. Compensation for the resulting inter-tidal habitat loss involved managed realignment schemes at Welwick, Chowder Ness and blocking the sluices at Doig's Creek (mitigation).

4.47. The Compensation Management and Monitoring Agreement (CMMA) includes a formal review after five and 10 years. Implementation of the CMMA and the performance of the sites to deliver the requisite compensation is overseen by an Environmental Steering Committee (ESC), comprising Associated British Ports, Environment Agency, Natural England, DfT, Cefas, Local Authority, RSPB, Yorkshire Wildlife Trust and Lincolnshire Wildlife Trust.

4.48. At the moment, both Chowder Ness and Welwick are owned and managed by ABP. No decision has been made on possible future management arrangements. Doigs Creek lies within the curtilage of the Port of Grimsby and is only accessible through the port.

Dubai Ports World, London Gateway Container Terminal - compensation sites A and X

4.49. It was predicted that the development of the container terminal at London Gateway would lead to a combination of direct loss of undesignated habitat, indirect loss of designated habitat and functional changes to designated habitat. The compensation package for the overall development therefore sought to address both the losses and functional changes. Two compensation sites were identified, originally listed as 'Site A' and 'Site X'. Site A is on the north bank of the Thames and is adjacent to Mucking Flats at Stanford Le Hope, just upstream from the port development. Site X lies on the south bank of the Thames on Cliffe Marshes. It involves an area of land that had already been undergoing arable reversion under North Kent Marshes Environmentally Sensitive Area (ESA) funding. A commensurate area of arable reversion is therefore included in this project to offset these additional losses which had become functional wildfowl habitat but had not been designated.

4.50. The Mucking realignment site (Site A), breached in 2010, is now a functional mudflat. It is managed by the RSPB under a five-year agreement with London Gateway. The Cliffe site (Site X) has been sterilised and protected species (Predominantly water voles) have been translocated. Flood defences have yet to be built and the site is being maintained free of protected species by an active trapping programme. This site remains within the direct control of London Gateway and no formal arrangements have been made for its ultimate management – although this is likely to be by a local landowner.

Environment Agency, Cley/Salthouse Flood Management Scheme - Hilgay compensation site

4.51. The need for compensatory habitat results from a decision by the Environment Agency to discontinue management of the shingle bank at Cley-Salthouse on the north Norfolk coast. As a result, it is expected that the

shingle bank will roll inland and that the extent and water chemistry of wetlands on the landward side will become unsuitable for the existing population of two pairs of breeding bittern. It was agreed that a compensation site capable of supporting two pairs of bittern was needed.

4.52 The site is still under construction as part of a larger 'Wissey Wetland Creation Project' - an Environment Agency, Norfolk Wildlife Trust and Natural England initiative to create new wetland habitats adjacent to the River Wissey. In addition to replacing bittern habitat, they will also replace coastal reedbed and grazing marsh that will be lost to sea level rise over the next several decades. The programme will also restore some of the wetland habitats that were present in the Fens prior to widespread drainage for agriculture. The Norfolk Wildlife Trust will manage the site for the Agency in perpetuity.

Environment Agency, Hullbridge Tidal Flood Defence Scheme, Brandyhole compensation site

4.53 This project preceded the use of CHaMPs as a strategic way of determining the nature conservation implications of flood management strategies on the coast. It involved a small section of the Blackwater Estuary at Hullbridge where the existing tidal flood defence clay embankment would be raised and widened, leading to the loss of narrow a strip of inter-tidal habitat.

4.54 A managed realignment site was secured at nearby Brandyhole. Covered by a Section 106 agreement[17] with Rochford District Council, it forms part of the consent for the flood defence works. The site is owned and managed by Blackwater Wildfowling Association. The managed realignment site comprises a mixture of saltmarsh and dry grassland that may become inundated as sea level rises. Scrub is invading the grassland area and the site would benefit from active management to remove this. This was noted in the 2007 monitoring report (Wild Frontier Ecology Ltd, 2007) but no recommendations appear to have been made.

Environment Agency, Humber Estuary Flood Risk Management Strategy - Paull Holme Strays compensation site

4.55. Paull Holme Strays, originally referred to as Thorgumbold, lies at a point on the estuary where it was extremely difficult to maintain the existing sea wall. It was a logical realignment site because there was a substantial area of rising ground to the rear, and it should have been possible to realign using a minimum of new sea wall. A sea wall was built in front of the rising ground (reason not recorded in the available documentation), resulting in a larger and ongoing seawall management commitment than might otherwise have been the case.

[17] Planning obligations under Section 106 of the Town and Country Planning Act 1990 (as amended), are commonly known as s106 agreements. They are a mechanism for ensuring that measures are included to make a development proposal acceptable and can include measures to mitigate or compensate for damaging impacts of a development.

4.56. Paul Holme Strays is one of a series of ongoing or proposed realignments that combine to deliver new habitat before adverse effects on site integrity of the Humber Estuary SAC, SPA and Ramsar Site. The site has been the subject of a wide variety of monitoring studies, including work by PhD students, and there is a substantial literature on its evolution. The Environment Agency own and manage the site.

Environment Agency, Pett Frontage Tidal Flood Defence Scheme - Rye Harbour compensation site

4.57. This project involved temporary and permanent impacts upon the shingle foreshore at Rye Harbour, a SAC designated for, inter-alia, annual vegetation of drift lines and perennial vegetation of stony banks. The impacts involve early successional stages that are dependent upon ongoing coastal processes. A compensation site for these particular attributes could not be found and the chosen site lies inland, upon shingle ridges that have been within an agricultural setting. The habitat creation project therefore effectively involved arable reversion although the topography of the site would suggest that the ridges were less significantly affected by ploughing than elsewhere in the Dungeness/Rye Harbour area.

4.58. This compensation package is part of a much larger habitat creation scheme, largely aimed at meeting BAP targets in conjunction with providing improved flood defences for the town of Rye. The compensation site comprises a mixture of shingle habitat and alluvial soils, and thus the overall extent of the land allocated is larger than the area of shingle habitat created. The site has been fenced and is currently being grazed by goats in an attempt to control woody scrub (especially bramble). Human interference is kept at a very low level to maximise the value of the site for ground-nesting birds. This management is not specifically for the habitat replacement sought in relation to loss of early successional stages but accords with the objectives for the Rye Harbour Nature Reserve, now managed by Sussex Wildlife Trust. Monitoring reports largely focus on these wider objectives and detailed vegetation monitoring ceased several years ago in order to avoid disturbance to ground-nesting birds.

Environment Agency, Portchester Castle to Emsworth Flood Risk Management Strategy - Medmerry compensation site

4.59. The large habitat creation scheme at Medmerry is compensation for the predicted losses arising from implementation of the Porchester to Emsworth Coastal Management Strategy. The total losses and requiring compensation measures are 35.5ha of inter-tidal land for the strategy alone and 91.5ha for the strategy in-combination with other plans or projects.

4.60. The Medmerry scheme was identified and developed as part of the Southern Region Regional Habitat Creation Programme (RHCP). RHCPs are Government's recommended vehicle for delivering strategic habitat compensation and are funded in advance of engineering works that cause damage. The RHCP was established to provide a strategic and proactive approach to enable South East Region to meet its legal and corporate habitat

creation targets resulting from flood and coastal risk management schemes in a structured and efficient way.

4.61. The site was developed by the Environment Agency and day-to-day management will be undertaken by the RSPB, with the objective of the site becoming a RSPB reserve.

Harwich Haven Authority, Channel deepening - Trimley Marshes managed realignment site (compensation site)

4.62. The site is leased by Harwich Haven Authority (HHA) from Trinity College, on a renewable basis until September 2067. A 16.5ha realignment was completed in November 2000. HHA is responsible for the maintenance of the realigned sea wall, as set out in the Environment Agency's consent for the work, but has no obligations to maintain the former sea wall (now breached) to the seaward edge of the site. HHA is also responsible, under the Section 106 Agreement (see footnote 18) made as a condition of the planning consent, for the repair and maintenance of the permissive paths.

4.63. The 1998 CMMA for channel deepening of the Harwich Haven approach in the Stour and Orwell Estuaries SPA required HHA to undertake monitoring at the Trimley compensation site for at least 10 years after creation. The 2001 CMMA for the Trinity III terminal extension required the 1998 monitoring agreement to be extended to include the potential impacts of these works on the compensation site, thereby effectively resetting the end date for monitoring to 2014. HHA's obligation to monitor the site has now expired, although certain aspects of the monitoring will be continued as part of surveys of the wider estuarine system. These include benthic monitoring (on a five-yearly basis) and topographic survey (using LiDAR), bathymetric survey and bird counts. HHA's remaining obligations are to maintain the lease of the site and to maintain the realigned sea wall and permissive paths.

Highways Agency, A249 Iwade to Queensborough road improvement scheme - Chetney compensation site

4.64. The Iwade to Queensborough road improvement scheme crossed grazing marshes close to the bridge to the Isle of Sheppey. In doing so, a strip of grazing marsh adjacent to the road was lost. It was predicted that there would be functional changes on adjacent grazing marsh that could affect numbers of breeding birds, especially waders. Compensation, therefore, focussed of the extent of land needed to support the predicted numbers of breeding birds affected.

4.65. The Chetney site involves arable reversion and creation of new grazing marsh habitat. No detail of the management arrangements for the Chetney site have were made available to us. but a letter from Steve Gilbert (RSPB) to R.J. Harman of Swale Borough Council alludes to a management agreement of 50 years duration with the then owner. The site remains in private ownership and management. This arrangement will presumably continue unless there is a change of ownership or until the discharge of the management arrangement.

Lancaster City Council, Morecambe Coastal Defence Works - Hesketh Outmarsh compensation site

4.66. During the latter stages of upgrading coastal defences at Morecambe, within Morecambe Bay SAC, SPA and Ramsar Site, it was determined that the footprint of the defences and the associated sand recharge would lead to the loss of 10.498ha of inter-tidal sand habitat, including 3.6065ha of cobble skear. The cobble skear loss was mitigated by re-laying this habitat elsewhere within the SAC but there was a need to compensate for the overall loss of extent.

4.67. Subsequent analysis concluded that habitat creation adjacent to the designated site(s) was not possible and that an alternative location in a different Natura 2000 site was the only option. The nearest possible option was the Ribble Estuary (an SPA) where the RSPB was proposing a major realignment at Hesketh Outmarsh. This habitat creation project involved realignment of an area that had been saltmarsh until 1980 and was one of the last areas in England to be enclosed.

4.68 The realignment project was undertaken jointly by the RSPB and Environment Agency, with a contribution towards costs from Lancaster City Council. The land was owned by the RSPB who continue to manage the site today.

Lappel Bank & Fagbury Flats, Defra - Allfleet's Marsh (Wallasea Island)

4.69. The Allfleet's Marsh (Wallasea Island) scheme provides compensation for the loss of inter-tidal habitat resulting from two port developments in the late 1980s and early 1990s. Both cases involve habitat that was excluded from SPA designation: Lappel Bank was excluded from the Medway Estuary and Marshes SPA when it was designated; and Fagbury Flats on the Orwell Estuary, was excluded from the Stour and Orwell Estuaries SPA.

4.70. During construction management of the Allfleet's Marsh site was a joint venture between Defra and Wallasea Farms. Wallasea Farms were responsible for the design and construction of the new seawall and its future maintenance. Defra were responsible for managing the five year post-construction monitoring programme and the original design and construction of the re-alignment scheme. An independent Project Management Team comprising Natural England, the Environment Agency, RSPB and Cefas[18] was set up to oversee the project's environmental quality objectives.

4.71. In 2007, the RSPB were employed by Defra to undertake the day to day management of the site. Subsequently, the RSPB have bought most of the rest of Wallasea Island to create the UK's largest coastal habitat creation scheme, the Wallasea Island Wild Coast Project.

[18] Centre for Environment, Fisheries and Aquaculture Science

Tarmac Ltd., Arcow Quarry - Moughton compensation site

4.72. The quarry owners, Tarmac Northern Ltd (subsequently Tarmac Ltd and Tarmac Roadstone Holdings Ltd), submitted proposals (2002) for the extension/stabilisation of Arcow Quarry, which forms part of the Ingleborough Limestone Complex SAC. In response, Defra required compensatory measures to be put in place to protect the coherence of the Natura 2000 network. In 2004, the Yorkshire Dales National Park Authority (YDNPA) granted consent based on mitigation and compensatory measures cited in the application and subject to completion of a Section 106 agreement (see footnote 18). Separate management plans for the mitigation work within the SAC and for the compensation land were produced. The latter was to be effective for at least 20 years, subject to any variations or amendments.

4.71. In 2010, Tarmac made an application to YDNPA for a 3.5 year extension to quarrying at Arcow. The permission granted (2012) requires quarrying to cease on 30 June 2015 and restoration to be completed by 30 June 2016, followed by a 20 year aftercare programme. A restoration and management scheme was part of the planning condition and prepared as part of the S106 agreement. The new permission and S106 agreement requires monitoring takes place on the compensation land every two years, beginning in July 2013, until at least 2036.

4.72. The compensation land was owned by Tarmac and managed under a tenancy agreement by a third party. The former tenants have since purchased the land and should now be responsible for its management. The owner's farm is subject to an Higher Level Stewardship (HLS) agreement. At the time of this study, access to the compensation site was not possible and, in accordance with the new S106 agreement the new owner appears to now only be responsible for allowing access for monitoring, rather than any continued management prescriptions. The HLS agreement currently in place does however ensure appropriate management.

Has there been a need to modify sites?

4.73. Documents supplied provide a weak audit trail about decision-making where modifications to management might have been highlighted by monitoring or from operational experience. Available documentation suggests that the majority of sites have not required modification, either during construction or subsequently. In general, monitoring reports focus simply upon the biology and morphological evolution of the site and do not highlight management prescriptions. In just one case (Chetney grazing marsh) a need for remedial action was recommended (to control creeping thistles within translocation plots). It has not been possible to determine whether this was followed up.

4.74. If management action has been exercised, it is likely to have been initiated through the Regulator's Group or equivalent management body but visits to individual sites did not identify evidence of remedial action. This is not entirely surprising because nearly all of the sites involve managed realignment, for which very little active intervention is possible or necessary once sea walls

have been breached. We know that minor adjustments to the retaining bunds at Allfleet's Marsh were necessary to allow excess water to drain away (Mark Dixon, pers comm.).

Table 11. Management arrangements for compensation sites.

Developer	Compensation site(s)	Ownership during construction	Post-construction management
Anglian Water Services	Rutland Water	Anglian Water	Leicestershire & Rutland Wildlife Trust
Associated British Ports	Alkborough	ABP	Within area managed by North Lincolnshire Council
	Chowder Ness	ABP	ABP
	Doig's Creek	ABP	ABP
	Welwick,	ABP	ABP
Defra	Allfleet's Marsh, Wallasea Island	Defra	RSPB
Dubai Ports World (London Gateway)	Stanford Wharf (Mucking)	Dubai Ports World (London Gateway)	RSPB (5 year agreement)
	Cliffe Marshes	Dubai Ports World (London Gateway)	Likely to be local landowner
Environment Agency	Hilgay	Environment Agency	Norfolk Wildlife Trust
	Brandy Hole	Blackwater Wildfowlers Association	Blackwater Wildfowlers Association
	Paull-Holme Strays	Environment Agency	Environment Agency
	Rye Harbour	Environment Agency	Sussex Wildlife Trust
	Medmerry	Environment Agency	RSPB
Haven Authority Harwich	Trimley	Trinity College Cambridge	Haven Authority Harwich
Highways Agency	Chetney Marshes	Private landowner	Private landowner
Lancaster City Council	Hesketh Outmarsh	RSPB	RSPB
Tarmac Ltd	Arcow Quarry	Tarmac with lease to private tenant	Ownership transferred to private landowner

4.75. In several cases of managed realignment it is clear that the desired habitat (mudflat) may not be a long-term outcome and that sites will become saltmarsh. In two cases (Trimley and London Gateway sites A and X) there does appear to be an onus on the developer to undertake active intervention to maintain mudflat, but the practical details are not clear. Removing excess sediment has several important practical considerations, including high costs, potential lack of suitable machinery and associated health and safety risks.

Factors that support effective compensation

4.76. Many of the cases examined during this review have largely relied upon good will between developers, statutory agencies and NGOs to produce workable packages well before consent was sought. This is exemplified by port development cases. In other words, the developer accepted that it was impossible to show that the project would not have an adverse effect on site integrity and, therefore, the exceptional tests set out within Article 6(4) of the Habitats Directive would apply[19]. The wording of the Habitats Regulations (HM Government, 1994, 2010) implies that the determination of compensation measures should follow a judgement by the competent authorities that:

- it cannot be ascertained that there will not be an adverse effect;
- that there are no alternative solutions; and
- that there are imperative reasons of over-riding public interest to justify consent for the project.

4.77. In practice, this approach proved un-workable because compensatory measures were only addressed after the application for consent was evaluated. In the absence of a defined compensation package for the competent authority to assess, there would have been a need for further negotiation to develop an acceptable package before a final decision could be taken.

4.78. Work on the concept of Coastal Habitat Management Plans (ChaMPs) (Worrall, 2005) by the Environment Agency and English Nature provided a strategic framework to avoid such a situation in the case of flood risk management. Documentation for the Hullbridge tidal defences project and the Brandyhole compensation site demonstrates the need for this strategic approach. The CHaMPs approach is now subsumed within Regional Habitat Creation Plans, such as the one that forms the basis for the Medmerry compensation site. Its importance as a strategic planning tool is therefore emphasised.

4.79. The UK ports industry worked with English Nature and the RSPB to find a similarly pragmatic and practical approach to major port developments. This

[19] The exceptional tests are transposed into Regulations 62 & 66 of the Conservation of Habitats and Species Regulations 2010

process led to the development of Compensation, Mitigation and Monitoring Agreements (CMMA) (Morris & Gibson, 2007) that were agreed before consent was sought. This ground-breaking and risk-taking approach is now well-established, and should be highlighted as a major advance in port-nature conservation relations during the early stages of understanding how the Habitats Regulations work. It remains a model of positive engagement.

4.80. Key factors that have been identified as leading to positive outcomes have been identified below, brigaded as far as possible under common themes:

General

i. Habitat creation adjacent to the site damaged by the development in question provides the best opportunity to ensure ongoing coherence of both extent and functionality within the designated site.

ii. Habitat creation within strategic frameworks such as flood risk management strategies offers a positive example of delivering compensatory habitat before major losses occur.

iii. CMMAs provide a firm basis upon which to agree key issues and ongoing management arrangements when it is necessary to create compensatory habitat.

iv. Regulators' group meetings have proven to be a good way of ensuring engagement between the agencies and the developer following consent and during the construction and post-construction monitoring period. They also have the potential to over-see the end of project sign-off (although a formal process is needed).

v. Designation of compensation sites helps to confirm that the sites have delivered the objectives set.

vi. Partnerships with nature conservation organisations can provide a mechanism to ensure that the conservation interests of compensation sites are firstly achieved and then maintained in the longer term.

Administration

vii. The Port of Rotterdam's website offers a particularly positive model by making publicly available all of the documentation relating to the development of Rotterdam Mainport (Maasvlakte II).

Site selection

viii. The development of a site selection report, such as that produced for Defra's compensation for Lappel Bank and Fagbury Flats[20], provides a long-term record of the rationale behind the choice of the site and the ratios of loss and replacement.

[20] Note: although not available to this team, RKAM was on the steering group for this project and is aware of the report's existence.

Monitoring

ix. Long-term and comprehensive monitoring by Harwich Haven Authority has generated a sound body of data that complements that collected by other agencies. This has included adjustments to make it possible to combine results to investigate a wider range of environmental parameters pertaining to the Water Framework Directive.

x. Monitoring of the Rutland Water compensation areas has also been exemplary. This has included weekly wildfowl monitoring by Leicestershire & Rutland Wildlife Trust and monthly WeBS counts for the reservoir as a whole. In addition, a five-year monitoring programme (from 2009), focused on macro-invertebrates, macrophytes and water quality.

xi. The Immingham Outer Harbour (and Quay 2005 / Green Port Hull) development has a comprehensive monitoring and management package set out in the Environmental Mitigation and Monitoring Plan and an annual reporting framework. The monitoring protocol is specifically designed to determine whether the compensation measures provide the necessary habitat / ecological function to enable the designated interests of the affected European sites to be maintained. Monitoring work was established prior to the compensation sites being implemented and will be maintained for a minimum of five to10 years (depending on the parameters and need for further management action). When coupled with monitoring work at the development site itself, the total monitoring package provides a good picture of progress in meeting specified targets and any shortcomings that may arise.

Individual sites

xii. The project team involved in selecting and constructing Allfleet's Marsh (Wallasea Island) published a formal account of the design and objectives in a relevant engineering journal (Dixon *et al*. 2008). A further account (Scott, 2007) provides a broader range of information on the development of the project. Some relevant documentation is also available on the internet (Field *et al*., 1998; Banks *et al*., 2003; ABPmer, 2004). A newsletter accessible through a dedicated website has provided public engagement following the breaches to the sea wall [21].

xiii. The Trimley managed realignment site has been included within the re-defined boundaries of the Stour and Orwell Estuaries SPA and Ramsar Site. Simpson *et al*. (2005) published a detailed account of some of the issues and conservation measures surrounding the Harwich Haven Channel Deepening scheme

xiv. Scientific studies of Paull Holme Strays have led to the publication of several important peer-reviewed papers (e.g. Mazik *et al*., 2007, 2010).

[21] http://www.abpmer.net/wallasea/

xv. Environment Agency compensation projects at Paull Holme Strays and Medmerry address existing and predicted losses, thus ensuring compensation is created in advance of losses, in accordance with EU guidance (EEC, 2007/2012).

xvi. Compensation for non-specific 'Estuaries' habitat lost to Green Port Hull was offset by creation of new inter-tidal habitat, as it was considered unfeasible to re-create sub-tidal estuarine habitat. This approach maintained the overall extent of the designated Estuaries feature and provided a workable solution in light of the practical difficulties, which still met compensation objectives.

xvii. Projects that combine compensation measures with wider biodiversity benefits (e.g. Rye Harbour, Medmerry, Hesketh Outmarsh) ensure that funds spent on compensation achieve more than they might otherwise. This reduces the unit costs of both the compensation and the habitat creation.

xviii. Habitat creation at London Gateway's Sites A and X includes a combination of adjacent inter-tidal and freshwater habitat, creating a valuable wildlife and amenity resource (Figure 6 - p61).

xix. By combining the assessments of Immingham Outer Harbour and Quay 2005, Associated British Ports (ABP) made it possible to develop larger compensations sites that deliver more cohesive compensation than a series of smaller individual sites.

xx. The compensation measures at Rutland Water have addressed the potential decrease in habitat for wildfowl due to increased demand-driven drawdown from the reservoir and the impacts of low flow/drought conditions on water level. New lagoons were created to ensure that suitable habitat will continually be available to support those species predicted to be displaced by a reductions in water level.

xxi. Hilgay forms part of the Wissey Wetland Creation project, which is an ambitious programme to create new wetland habitats adjacent to the River Wissey in west Norfolk. In doing so, it has made possible a far larger habitat creation project that accords with a landscape approach to nature conservation. It will bring wider wildlife benefits to the area, and may make the site viable as a designated site in its own right.

Figure 6. Borrow-dyke and disabled access surface at Stanford Wharf (Mucking) (Site A): an example of good design practice that makes use of an engineering feature to provide wildlife, landscape and public access benefits.

Ecological barriers to achievement of design objectives

4.81. The compensation measures studied involve a variety of habitats, some of which are more readily re-created than others. The key habitats affected by development in the case studies are:

i. Inter-tidal sandflats
ii. Cobble skear
iii. Drift line vegetation
iv. Vegetated shingle
v. Inter-tidal mudflats
vi. Saltmarsh
vii. Grazing marsh
viii. Reedbeds
ix. Open fresh water
x. Limestone grassland

4.82. In addition, many of the port-related packages have sought specifically to provide sufficient inter-tidal habitat to support a defined number of over-wintering waterfowl. One package has addressed the need to provide suitable habitat for a variety of breeding birds, especially waders.

4.83. It has been highlighted in paragraphs 4.10-4.11 that, in two cases (Morecambe Bay and Rye Harbour), the design objectives could not deliver 'like-for-like' compensation.

4.84. The reasons for the difficulties at Rye and Morecambe lie in the nature of the habitat that has been lost or damaged and the specific physical and sedimentary processes that determine their occurrence on the coast. Experience has shown that, in purely practical terms, it is not possible to replicate upper inter-tidal sandy and shingle habitats in locations that make any ecological sense. This does not imply that such habitat could not be created under any circumstances, but the physical, economic and biological constraints make it impractical.

4.85. Issues relating to the other habitats are dealt with separately.

Inter-tidal mudflats and feeding migratory waterfowl

4.86. Evidence from several projects shows that, in the short- to medium-term, it is possible to create new inter-tidal mudflat and that these mudflats will support requisite migratory waterfowl numbers. The majority of managed realignment gain elevation and saltmarsh develops at the expense of waterfowl feeding habitat. The rate of change is dependent upon the original elevation of the land behind the sea wall and the volumes of suspended sediment within the adjacent tidal waters.

4.87. Realignment sites on the Humber lie considerably below the elevation of modern saltmarsh sites. Even so, in less than 10 years, accretion has occurred to the point where saltmarsh has developed over large areas (Mazik *et al*., 2010; Morris, 2013). The key influence on this process has been the levels of suspended sediment within the Humber Estuary, which have led to accretion levels of as much as 30cm a year (Richardson, 2004). Evidence from Hesketh Outmarsh shows that, where a site is at broadly the same elevation as the surrounding saltmarsh, it will evolve into saltmarsh very rapidly.

4.88. The Trimley realignment points to the role of site design in determining the likely success of realignment in creating mudflat and a feeding area for migratory waterfowl. Where suspended sediment levels are relatively low, wave energy can be sufficient to regulate accretion rates. Site orientation is, however, critical because in sheltered sites sedimentation rates favour the development of saltmarsh. The Trimley site is orientated so that the breach is facing south-west and allows ingress of prevailing wave energy across a relatively substantial fetch.

4.89. The Allfleet's Marsh (Wallasea Island) site is north-facing in a relatively narrow estuary and is gaining elevation comparatively rapidly where protected by former seawalls. This example shows that, even where suspended sediment levels are relatively low, accretion can be rapid.

4.90. These examples show the constraints on the viability of mudflat creation suitable for providing critical biomass to support migratory waterfowl. Further, they highlight the problems of creating sustainable mudflat that does not evolve into saltmarsh. This has also been encountered in the Elbe Estuary, where compensation for Mühlenbergerloch has rapidly gained elevation and has become vegetated (REMEDE, 2008).

4.91. Although mudflat creation is highly reliant upon a suite of critical physical processes, the habitat created in managed realignment has an important functional role within estuaries and can be seen to develop quickly to the point where there is both a scientific and Natura 2000 interest. Each realignment site contributes substantially to the fabric of the relevant Natura 2000 sites and, as such, increases their resilience to sea level rise, climate change and other environmental perturbations.

Saltmarshes

4.92. Investigations into saltmarsh evolution on managed realignment sites (e.g. Wolters *et al*., 2008), have established that it is relatively straightforward to re-create saltmarsh and that they can have wider biodiversity value (Petillon & Garbutt, 2008). This is achieved by allowing a site to gain elevation naturally by sediment accretion or by artificially promoting suitable elevations. The saltmarsh creation at Allfleet's Marsh (Wallasea Island), provides a very useful indication of how slight variations in the elevation of created habitat influences plant colonisation and the speed of attaining complete plant cover. Other sites, such as those on the Humber and at Hesketh Outmarsh, indicate that vegetation will rapidly establish, provided the required seed sources are available.

4. 93. Although local salinity may affect the way in which the site is colonised, the over-riding influence on the speed and composition of saltmarsh development is the availability of seeds (Erfanzadeh *et al*., 2010). Hence, plant species composition of re-created saltmarsh can be very variable. It is also noteworthy that early colonisation by *Spartina anglica* in Allfleet's Marsh (Wallasea) and at Stanford Wharf (Mucking) has helped to trap sediment and led to the rapid development of saltmarsh.

4.94. Garbutt & Wolters (2008) investigated the composition of saltmarsh resulting from natural breaches at a number of locations in England. Their analysis shows that, whilst saltmarsh will develop quickly, its composition may differ from natural saltmarshes over a period of as much as 100 years, often with a higher representation of *Spartina anglica* than reference sites. This study emphasises that, whilst saltmarsh creation is clearly possible, objective-setting should take account of the long-term process of evolution before a replicate of a natural sward is attained.

4.95. Despite there being obvious differences between recently created and 'natural' saltmarshes, there is no reason to believe that such sites could not be designated within a reasonably short timescale on the basis that they:

- support definable vegetation communities;
- have been actively monitored;
- support the same range of plants and animals that occur elsewhere within the adjacent designated site; and
- contribute to overall functionality of the estuary.

In addition, such sites provide potential refuges for the same assemblages within the wider site that might be subjected to the impacts of coastal squeeze.

Grazing marsh

4.96. The results of one compensation package (Chetney) are insufficient to offer definitive evidence that it is possible to replicate grazing marsh by arable reversion. It seems likely, however, that this might be possible when creating habitat for breeding and migratory waterbirds. Other evidence may be forthcoming from the results of arable reversion schemes such as the North Kent Marshes Environmentally Sensitive Area, but to the best of our knowledge, the results of this programme have never been formally disseminated.

4.97. Translocation of divided sedge *Carex divisa* has shown that it is possible to move blocks of turf containing the plant, and that it will continue to survive at the receptor site. Current evidence suggests that the plant does not, however, readily spread away from translocated blocks and that there is a need to consider additional ways of encouraging this (e.g. by spreading hay containing seeds).

4.98. Key Ramsar site features of grazing marshes include the plant and animal communities within ditch systems. Relatively little is known about processes of re-colonisation and the results of this example do not make a significant advance in the scientific case. It is, however, clear from the invertebrate monitoring report (Andrews-Ward Associates, 2006) that the water beetle fauna and plant communities typical of the ditches have become well-established. Survey data do not appear to cover less mobile taxa, such as the Mollusca and specialist Diptera assemblages (e.g. the Dolichopodidae, Ephydridae and Sciomyzidae).

4.99. On the basis of available monitoring reports and the walk-over visit conducted in May 2014, there would appear to be no reason to prevent future notification of this site.

4.100. Part of the habitat creation at Site X (Dubai Ports World/London Gateway) includes an area of arable reversion to replace ESA arable reversion. The results of this project should help to establish in more detail the ease with which this habitat can be re-created.

Reedbeds

4.101. Habitat creation at Hilgay is nearing completion. Groundwater and recent rainfall have been partially inundated the ditch system and some of the scrapes. Reedbeds are already developing in the storage lagoon and around other scrapes/pools, but are more established in some of the (flooded) ditches. Wildfowl have started to use the newly created scrapes, which will form deep water pools once the site is flooded.

4.102. Reedbed is a relatively straightforward habitat to create. There are numerous examples of reedbed creation elsewhere to support the contention that Hilgay will successfully meet its design objectives. Critical issues include the need for

varying topography and a constant water supply (Sussex Otters and Rivers Project, undated). Examples include RSPB's Lakenheath Fen project and reedbed development within the Barton and Barow Claypits (part of the Humber Estuary SSSI, SPA and Ramsar Site). It follows that, although the Hilgay site has yet to be inundated, there is every reason to believe that it will meet its design objectives.

Open water

4.103. The habitat creation work at Rutland Water is complete. The construction of the first compensation lagoon was completed in 2007, with full inundation in 2008. The construction of the second set of four lagoons and creation of the wet grassland was completed in 2008, with full inundation in 2009. The lagoons are fully inundated and have been since completion of the habitat creation works (Rutland Water has not experienced any significant reductions in water level since this time). The compensation habitats are fully established and are supporting designated wildfowl species.

4.104. This compensation project indicates that open water habitats can be created to compensate for similar loss. This is not a great surprise, as Rutland Water is, itself, a man-made water body and has become sufficiently important that it has been classified as an SPA and listed as a Ramsar site. There are a number of other reservoirs that have achieved similar levels of importance for waterfowl. Consequently, the combined evidence from these reservoirs, together with many other water bodies such as abandoned clay and gravel pits, indicates that open water habitats can be readily re-created provided that the key objective is use by waterfowl.

Limestone grassland

4.105. This single compensation site (Moughton) involved management of similar undesignated grassland in an attempt to improve the sward and generate grassland of an equivalent quality to the lost habitat. It also included translocation of scree habitat within the SAC (mitigation). In the course of this project became clear that the Moughton site changed in site ownership. Inability to make a site visit, and a lack of available site survey information, means that it is not possible to confidently conclude that the site and its ongoing management conforms to the compensation objectives.

Threats to compensation sites

4.106. As far as could be ascertained, there have been no direct threats to any of the compensation sites. It should be noted, however, that the transfer of ownership of the Moughton compensation site to a private landowner has complicated assessment and designation of the site. During this study it became clear that the new owner, whilst previously tied into a S106 agreement, is no longer legally required to continue with the management required to deliver the compensation measures. There is currently a HLS agreement in place on the landholding. We were unable to gain access to the site to assess its performance. Further consideration needs to be given to the

long term management of this site and how it can be achieved under existing arrangements.

Ecosystem service benefits

4.107. This section considers the overall ecosystem service benefits of the compensation schemes. Some of these benefits may already have been provided by the lost habitat but others will be substantially new because they involve larger areas than those that were lost.

4.108. There are several different definitions and classifications of ecosystem services. The UK National Ecosystem Assessment[22] classifies ecosystem services along functional lines, similar to the Millennium Ecosystem Assessment[23], into four categories:

- Provisioning services - the products obtained from ecosystems (e.g. food, fibre, fresh water, genetic resources).
- Regulating services - the benefits obtained from the regulation of ecosystem processes (e.g. climate regulation, hazard regulation, noise regulation, pollination, disease and pest regulation, regulation of water, air and soil quality).
- Supporting services - ecosystem services that are necessary for the production of all other ecosystem services (e.g. soil formation, nutrient cycling water cycling, primary production).
- Cultural services - the non-material benefits that people obtain from ecosystems (e.g. spiritual or religious enrichment, cultural heritage, recreation and tourism, aesthetic experience).

4.109. In addition to providing long term compensation to support the coherence of the Natura 2000 network (e.g. replacement habitat to sustain species' populations), compensation sites also have the potential to deliver a range of services over and above those directly related to nature conservation (see Table 12 - page 68). These include:

- provision of grazing opportunities for livestock (e.g. coastal grazing marsh and limestone grassland);
- provision of fresh water to meet increasing human demand (e.g. from Rutland Water);
- regulation of hazards (e.g. the use on natural systems in coastal flood risk management schemes); and

[22] http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemServices/tabid/103/Default.aspx
[23] http://uknea.unep-wcmc.org/About/ConceptualFramework/MillenniumEcosystemAssessment/tabid/112/Default.aspx

- enrichment of cultural experience (e.g. access to wild space for recreational, touristic and aesthetic reasons) (e.g. see Figure 6 - walkway and borrow-dyke at Stanford Wharf, page 61).

4.110. Coastal habitats, such as saltmarsh and mudflats, play an important role in nutrient cycling (notably carbon, nitrogen and phosphorous). Current understanding of the scale of nutrient cycling within these habitats is, however, imperfect. Better evidence of greenhouse gas fluxes is necessary to determine with precision their role in climate regulation (Shepherd *et al*, 2005; Burdon *et al*., 2013; Beaumont *et al.*, 2014). Nonetheless, it is safe to assume that coastal habitats have an important role to play in carbon storage and sequestration (Thompson, 2008; Burdon *et al*., 2013; Connor *et al*., 2012).

4.111. Beaumont *et al*. (2014) identify the potential value of saltmarsh to Great Britain and provide a model that demonstrates how significant the loss of this habitat may be if sea levels rise as predicted. It is, therefore, possible that managed realignment schemes could enhance carbon storage and sequestration in coastal habitats. It should be recognised, however, that the timescale over which managed realignment sites may attain a comparable level of stored carbon to a natural saltmarsh could be as much as 100 years (Burdon *et al*., 2013). There is also developing evidence that the nature of saltmarsh management may have a small, but detectable, influence on the levels of carbon and nitrogen sequestration in saltmarsh (Ford *et al*., 2013). Current, evidence tentatively points towards nutrient cycling being greater in ungrazed saltmarshes (Ford *et al*., 2012), where slightly higher carbon and nitrogen mineralisation has also been detected (Ford *et al*., 2013).

4.112. Arguably, the most significant ecosystem service benefit of saltmarshes and mudflats is the protection they provide by attenuating wave energy. This was first recognised by Brampton (1992) and has been investigated further by a range of authors (e.g. Empson *et al*., 1997; Möller *et al*., 2001; Möller, 2006). Thus, creation of new saltmarsh by managed realignment provides a tangible benefit that reduces long-term maintenance costs and risks to coastal communities.

Table 12. Key ecosystem services delivered by compensation sites. Note that all deliver services to support the coherence of the Natura 2000 network.

Site	Provisioning services (PS)	Regulating Services (RS)	Supporting Services (SC)	Cultural Services (CS)	Comments
Rutland Water	x		x	x	PS: public water supply CS: nature reserve
Chowder Ness		x	x	x	RS - flood defence, air and water quality SS - Ecosystem function CS - wildlife spectacle recreation
Doigs Creek			x		
Welwick		x	x	x	RS - flood defence, air and water quality CS - wildlife spectacle & recreation
Allfleet's Marsh (Wallasea Island)		x	x	x	RS - flood defence, air and water quality SS - Ecosystem function CS - wildlife spectacle & recreation
Cliffe Marshes (Site X)		x	x	x	RS - flood defence, air and water quality CS - wildlife spectacle & recreation
Stanford Wharf (Mucking) (Site A)		x	x	x	RS - flood defence, air and water quality CS - wildlife spectacle & recreation
Hilgay			x	x	CS: nature reserve
Medmerry		x	x	x	RS - flood defence, air and water quality CS - wildlife spectacle & recreation
Paull Holme Strays		x	x	x	RS - flood defence, air and water quality CS - wildlife spectacle & recreation
Rye Harbour Farm			x		
Trimley		x	x	x	RS - flood defence, air and water quality CS - wildlife spectacle & Recreation
Chetney		x	x		RS - air and water quality

Hesketh Outmarsh		x	x	x	RS - flood defence, air and water quality CS - wildlife spectacle & recreation
Arcow/ Moughton	x		x		PS: livestock grazing

5. Analysis and conclusions

5.1. This analysis is based on 15 case studies, out of a possible 32 English examples, where Article 6(4) of the Habitats Directive has been applied. Most involve coastal habitats and, consequently, the lessons learned mainly apply to broadly analogous cases. The science of habitat re-creation was relatively new, and the literature comparatively weak, when many of these packages were agreed. This study, therefore, provides the basis to secure better outcomes from future situations.

5.2. Headline figures for the extent of compensation against actual losses need to be treated with caution. Some losses occurred at the time of the development; others are predicted to occur subsequently as a consequence of morphological adjustments; and others still are functional changes that may or may not manifest themselves in a long term change to the interest features of the designated sites. In addition, some compensation sites have been developed to take account of loss of supporting habitat adjacent to the Natura 2000 sites(s). A brief analysis of these data are expressed in Tables 13 and 14 (below).

5.3. At the time this study was conducted, two of the compensation sites (Hilgay, London Gateway site X had not been completed and one (Medmerry) had only recently started to become functional. In these cases it is not possible to draw any firm conclusions about their likely trajectory of development. Nevertheless, based on wider experience, they may be expected to form functional habitat that will make a positive contribution to the maintenance of the Natura 2000 network.

Table 13. Summary of losses and predicted losses in case studies

Habitat	Immediate permanent loss of N2k	Temporary loss of N2k	Indirect loss of N2k	Change in functionality	Loss of supporting habitat (undesignated)	Loss of potential habitat gain
Inter-tidal	116.26 ha	3.1 ha	374.6 ha*	60 ha	80 ha	1.4 ha pa^{-1}
Large open water				1 case**		
Freshwater wetlands	3.9			2 cases**	73 ha	
Grassland	1.3 ha					

* Losses mainly predicted coastal squeeze and to possible morphological responses to port developments

** Change in functionality of wetlands relate to possible implications of lowered water levels, saline intrusion and breeding bird displacement.

Table 14. Summary of compensation provision in case studies

	Immediate habitat creation	Projected habitat creation
Inter-tidal	386.8	286*
Large open water	96 ha	
Freshwater wetlands	62	Up to 70 ha
Grassland	8.5	

* Habitat to be created over a period of 50 years to replace loss to coastal squeeze.

5.4. Each compensation case developed under a different set of environmental and practical considerations, and this complexity of circumstances is likely to continue with future cases. It is, therefore, not possible to use a single package as a model for all others. Ratios of damage to re-creation used at the time of the cases considered for this report were determined according to best available science and often in respect of individual situations (e.g. timescale of compensation provision in relation to impacts). Subsequent experience has increased levels of understanding about the ways in which habitat creation can and cannot replace and/or augment the functionality of designated sites.

5.5. There are however a number of generic lessons that have been identified as part of this research. These may provide an important basis for developing a model of 'best practice'. They may also inform future compensatory provision judgements of whether or not the compensation packages agreed actually fulfil the requirements of Article 6(4).

Has compensation been successful?

5.6. In all of the cases examined, measures have been implemented to deliver a defined suite of compensatory habitat creation. Each compensation site is at least as big as the area of habitat lost, and in most cases is bigger. Consequently, the basic issue of loss of extent has been addressed.

5.7. The degree to which the measures have been successful varies. Some, such as Rutland Water, appear to meet all of the design objectives but have not been tested by the circumstances envisaged when the EIA was undertaken. Others were nearing completion at the time of our study (Hilgay for Cley-Salthouse). We were refused access to one site (Moughton for Arcow Quarry) and have been unable to assess the site's progress.

5.8. The majority of the study sites involved managed realignment to create mudflat as feeding habitat for migratory waterbirds. In the majority of managed realignment cases, short- to medium-term results suggest that these sites too will have met their design objectives.

5.9. These realignment sites are, however, comparatively young (in morphological terms). There are numerous older analogues that provide important evidence about the evolution of newly created inter-tidal habitat. Academic studies of such sites show that it is saltmarsh and not mudflat that will be created in the

long-term. This evidence, together with differences in the rate of sedimentation and saltmarsh development, means that there is therefore some uncertainty about the degree compensation sites will meet their design objectives in the longer-term.

Findings: general comments

i. In the 15 cases examined, it can be confirmed that compensation for loss of extent within the Natura 2000 Network in England has been, or is in the process of being delivered.

ii. In all cases, the ratio of loss of extent to replacement habitat achieves a ratio of at least 1:1 and in most cases exceeds this ratio.

iii. Each compensation scheme was influenced by a unique set of environmental and practical considerations and is it not possible to use any one case study as a model for future schemes.

iv. The extent to which compensation schemes have been successful varies when assessed against a number of criteria. In all cases, the key issue of loss of extent has been satisfied.

v. The majority of compensation sites can be expected to meet their design objectives in the short- to medium-term. Academic studies of older realignments show that mudflat within realignment sites normally develops into saltmarsh

vi. Each compensation site is at a different state of evolution and some are still experiencing rapid and significant species and habitat changes.

Data availability

5.10. This study is the first serious attempt to assess the success of compensatory habitat provision for loss of Natura 2000 habitat in England. Nobody has previously attempted to assemble all of the relevant information on this suite of sites and consequently we have the advantage of hindsight in making observations on the audit trail and data availability.

5.11. Throughout this study we identified weaknesses in the ways data had been stored and the degree to which available information was retrievable. In several cases the documentation was substantially incomplete, making the process of assessment very difficult. The need for a reliable audit trail is therefore highlighted.

5.12. Each case was different, and it should be noted that the age of the case may have a bearing on the degree to which information could be located and retrieved. In addition, the process of reporting, both at the stage of EIA and after a project has been consented has evolved. More recent cases were

often better accessible because they had been stored in machine-readable formats and could be supplied electronically.

5.13. Whilst the lack of easy access to pre-consent documentation is unfortunate, it is more worrying if monitoring data cannot be accessed. These data are costly to assemble and have potentially important information to relay to decision-makers. There are several possible reasons for the problems with locating documents:

5.13.1. It was normal practice in English Nature for paper files to be archived in a separate place to bound reports (Tim Collins *pers comm*.). Given the volumes of reports that arrived each year, it is possible that some will have been disposed of whilst rationalising libraries.

5.13.2. Staff turnover has led to later generations of staff being unaware of the significance of particular files or reports. Consequently, documents may have been lost or destroyed during file rationalisation[24] and offices relocations.

5.13.3. Feedback from some Natural England staff was that file weeding policy required files older than 6 years to be shredded. This is not the case.

5.14. We believe that there is more monitoring data available for some cases (e.g. London Gateway) but we were unable to access this either via Natural England or the developer. In some other cases, data were only available via a secure website that was not publicly accessible.

Findings: data availability

vii. The audit trail recording the rationale for particular compensation measures is incomplete. In almost all case studies some relevant information could not be located.

viii. Accessibility and presentation of monitoring data was very variable. This meant that it was not possible to draw consistent conclusions for all sites and detailed comparisons could not be made between sites.

vix. Making monitoring data publicly accessible would facilitate scrutiny by third parties such as researchers.

[24] 'File weeding' is a process that was undertaken on a regular basis as the archive of 'closed' files aged. If the originator of the file was no longer responsible for a particular subject area, it fell to their successor to assess the need to retain documents. From experience (RKAM) the relevance of particular information was not necessarily as apparent to a successor as it might have been to the originator.

Ratios of replacement habitat to lost habitat

5.15. The evidence gathered for this study suggests that the scale of compensation has been broadly commensurate with the objectives set to address the impacts in the case of freshwater and terrestrial habitats. In each case, the design objectives differ, as do the overall compensation objectives.

5.16. There are broadly three types of project, however:

5.16.1. Construction projects in which the footprint of the impact is readily definable. These include the majority of infrastructure projects, including new flood defences that 'advance the line', road schemes and port developments.

5.16.2. Projects that may have a direct footprint impact, but that also result in changes in functionality within a site. This may include proposed changes to coastal management (e.g. at Cley-Salthouse) or possibly physical changes that affect erosion/deposition of sediment (e.g. London Gateway).

5.16.3. Measures to offset impacts arising from past management decisions that will be maintained in future because they are the most cost-effective option (e.g. offsetting coastal squeeze arising from flood risk management measures within long-term estuarine or open coast flood and erosion risk management strategies).

5.17. These three categories can be applied both on land, within freshwater sites and in the inter-tidal environment. The chosen study sites do not include sub-tidal habitat creation, which is potentially a very different technical and environmental challenge for the provision of compensation. Any conclusions drawn from this study should therefore not be applied to the sub-tidal environment without more comprehensive analysis of options.

5.18. In the majority of port development and 'advance the line' flood defence projects, the ratio of compensatory habitat to lost habitat is roughly 2:1, but this has not been applied uniformly. Two cases in which ratios are 4:1 (Morecambe Bay) and 6:1 (A249 Iwade to Queensborough road improvement scheme) involve unusual circumstances and should not necessarily be used as a guide for future projects. They simply illustrate the range of situations considered when compensation schemes are designed.

5.19. Ratios of compensation to loss above 1:1 reflect issues of uncertainty associated with assessment of the likely impacts of development and the ecological response to habitat creation measures. They also take account of anticipated delays in the timescales in which compensation habitat takes to develop replacement functionality.

Findings: ratios of loss to replacement

x. Where habitat was lost to commercial development and new coastal flood defences, roughly a 2:1 ratio has been used. Compensation for coastal squeeze has been based on a ratio of 1:1.

xi. In two cases the ratio of replacement to loss has risen to between 4:1 and 6:1. These involve compensation to address functionality that cannot be resolved by smaller ratios and by compensating for losses at a different Natura 2000 site much further afield.

xii. Ratios of compensation to loss above 1:1 reflect issues of uncertainty, and anticipated delays in the timescales in which compensation habitat takes to develop replacement functionality.

xiii. A simple metric of replacement to loss clearly does not work in inter-tidal situations because there is strong evidence that sustainable mudflats are very difficult to create. More work is needed to arrive at designs for realignment that will result in self-maintaining mudflat.

Habitat creation

Habitat types and compensation objectives

5.20. This study investigated a variety of habitat creation projects that can be brigaded as follows:

- Managed realignment to create mudflats, sandflats and saltmarshes.
- Wetland creation using retaining bunds together with water management structures and pumps to create open water and reedbeds.
- Creation of grazing marsh grassland and ditches.
- Re-creation of perennial vegetation of stony banks.
- Restoration of limestone grassland.

5.21. Objectives for compensation sites are very case specific and therefore no two compensation sites will necessarily involve the same design. This is best illustrated by the two freshwater wetland sites: Hilgay involves creation of reedbeds to support breeding bittern, whereas Rutland Water creates open shallow water to support a range of dabbling ducks. In the case of inter-tidal habitats the objectives primarily concentrate on providing adequate feeding habitat for migratory waterfowl, either compensating for direct losses or for loss of functionality of mudflats.

5.22. Definition of the compensation objectives within the project documentation was very variable. There was often inadequate formal definition of what a successful outcome would look like, although objective setting often provided sufficient definition to assess success in the short- to medium-term. Where compensation was required to support feeding water birds, success criteria were essentially to replicate the assemblage lost in terms of broad numbers and species composition.

5.23. As a consequence it is important to recognise that whilst there will be some generic lessons from a suite of projects, local peculiarities mean that lessons from one case may not be directly inferred for another.

Findings: study sites and objectives

xiv. The range of study sites comprised: inter-tidal mudflat and saltmarsh (10), annual vegetation of drift lines, perennial vegetation of stony banks (1), bare sandy inter-tidal habitat (1), reedbed (1), limestone grassland (1), open freshwater pools (1).

xv. There is scope for refining the descriptions of compensation objectives in future projects.

xvi. Objectives for compensation sites are highly case-specific and are not necessarily directly transferable to new projects.

Habitat creation - practical issues

5.24. Most habitat creation and restoration has been pursued in the terrestrial environment. The concept of habitat creation in terrestrial situations largely involves changes to management to create the desired habitat. Some engineering such as turf or soil stripping may be undertaken, but in general the level of physical interference is small. Much emphasis has been upon grasslands, heathlands and woodlands, and there is an extensive literature on restoration and creation outcomes (see Morris *et al*., 2006). Results are somewhat variable and the time required for habitat creation emerges as one of the most important factors. Even where soil conditions are close to ideal, there is likely to be a lag-time, often measured in decades, before re-created habitat is similar to semi-natural comparators. Unfortunately, there are almost no examples of terrestrial habitat compensation for loss of extent of Natura 2000 in England apart from the Moughton compensation site (Arcow Quarry case) which we were unable to visit to review its progress.

5.25. Almost all of the projects investigated in our study involve more complicated measures than previous habitat creation projects. Many are comparatively large, involving tens or even hundreds of hectares of land in specific locations. Sites often involve prime agricultural land and are therefore extremely expensive to acquire. They have often required significant levels of engineering, such as new flood banks at all of the managed realignment sites, and creation of new freshwater bodies at two sites. As such, they represent a different paradigm to the majority of previous habitat creation experience.

5.26. Creating replacement habitat is highly dependent upon availability of suitable land. This is particularly important in the coastal zone because compensation requires not only land purchase but also expensive engineering to create new flood banks to provide the necessary standard of flood protection (should this be required). The site chosen has to offer the right size, topography and proximity to enable linkage with existing coastal processes. Costs and practical considerations arise where sites are located in close proximity to major infrastructure such as roads, dwellings and water, gas and electricity supplies.

5.27. Detailed studies to identify possible compensation for Lappel Bank and Fagbury Flats were not available to us, but we know they existed (Roger

Morris was a member of the Defra-led team that decided upon Allfleet's Marsh). These studies provide an important lesson because it proved very challenging to find a suitably sized site. After evaluating a wide range of sites, the study originally concluded that a site at Bradwell was most suitable. This site had to be abandoned because of intense local opposition and the risk that consent would either be delayed or refused.

5.28. Apart from logistical and regulatory complications, finding compensation sites may also require unusual physical circumstances: sediments such as sand and shingle only occur under certain conditions where both sediment type and the wave climate coincide. Compensation for the Morecambe Coastal Defence Works exemplifies the challenge of finding suitable land adjacent to the designated site. In this case it was not possible to find a location where suitable wave climates and sandy substrates occurred together in the Morecambe Bay SAC. If there are no places where land availability coincides with suitable coastal processes then it may not be possible to compensate adjacent to the same Natura 2000 site.

Findings: practical considerations

xvii. The choice of compensation sites can be limited by a variety of considerations, including the size of available land parcels, land topography and the presence of dwellings, transport and service infrastructure.

xviii. Many compensation sites to date have involved significant costs, arising from land acquisition and the large scale engineering required.

'Like-for-like' habitat

5.29. The process of securing compensation packages for a sand beach (Morecambe Bay) and early stage perennial vegetation of stony banks (Pett Levels to Rye Harbour) has shown that it is not always possible to secure direct 'like-for-like' habitat creation. Also, provision for loss of sub-tidal habitat at Green Port Hull has shown that there are real challenges to creating new sub-tidal habitat and that this may be amongst the most difficult to replicate without changing existing sub-tidal habitat.

5.30. In addition, several managed realignment projects have shown that sustainable mudflat habitat is difficult to deliver in estuaries with high suspended sediment concentrations. Variations between the rate of saltmarsh evolution in realignments in different estuaries can be seen from the study sites considered in this report. Some, such as those on the Humber and Ribble point to saltmarsh as an inevitable end-point, whereas the Trimley site suggests that there may be circumstances where sustainable mudflat can be created. It is therefore too early to conclude that managed realignment can never be used to re-create inter-tidal mudflats. There are numerous unresolved questions; including the possibility that site size, orientation and geometry, and breach design may have a bearing on the degree to which created mudflat are sustainable. Any new case with a requirement to re-create mudflats will need to carefully consider the site specific circumstances

and characteristics of compensation site options, and provide good evidence that conditions are suitable.

5.31. 'Like-for-like' habitat may be more readily reproduced in some terrestrial and freshwater situations. There is a strong body of evidence that creating reedbed habitat on new sites is possible and that this habitat will ultimately support breeding bittern and other reedbed specialists, if large enough. The Chetney compensation site also shows that certain attributes of grazing marsh habitat, supporting breeding and overwintering waterfowl populations and some invertebrate populations, can be re-created.

5.32. More work is needed before it is possible to conclude with confidence that less mobile taxa can either be translocated or encouraged to spread. The ongoing grazing marsh creation at Site X for London Gateway provides an opportunity for developing a partnership to investigate aspects of colonisation by less mobile taxa, such as divided sedge *Carex divisa*, and populations of invertebrates, such as molluscs and non-flying species.

Findings: like-for-like habitat creation

xix. Annual vegetation of drift lines, perennial vegetation of stony banks, and some inter-tidal muddy and sandy habitats have not been fully replicated at the time of the study and it is believed by the review team that these objectives are unlikely to be met because they rely on very specific coastal processes and sediment conditions.

xx. Whilst in the short-term, mudflat habitat has been created by managed realignment, most case studies point to a long-term evolution into saltmarsh. This observation is reinforced by a variety of published research into saltmarsh evolution.

xxi. It is therefore clear that saltmarsh habitat is largely re-creatable. Published research indicates that it may take many decades before re-created saltmarsh is fully comparable with long-established saltmarshes.

xxii. Where the design objectives for mudflat or sandflat creation have not been met, evidence points to the need to create substantially larger sites.

xxiii. The study has also identified some parts of the country (e.g. the Humber Estuary) where mudflat or sandflat habitat is unlikely to be the long-term outcome of managed realignment.

Functionality

5.33. The review team found that documentation often failed to adequately define functionality and to set clear success criteria against which to devise and execute a monitoring strategy. In the absence of this clear structure, it is inevitable that there will be uncertainty over the point where habitat functionality has been achieved.

5.34. Despite this weakness, recreating mudflat habitat appears to be possible within a relatively short space of time. In some instances, the sites show that there may be a two to three year time lag before recreated inter-tidal habitat supports significant numbers of waterbirds, but even in the first year some functional contribution results. It is difficult to ascertain what effect this time lag may or may not have in terms of the overall coherence of the European site network. Part of the reason for the difficulty in detecting the actual effects from the damaging developments is that they have generally covered a small area, relative to the European site, and there is a lack of long-term monitoring data at sufficient resolution to detect change.

5.35. Inter-seasonal variation in the numbers of migratory waterfowl visiting individual Natura 2000 sites is substantial. This variation makes it very difficult to detect the point at which downward or upward trends in numbers arise. Where detailed monitoring of waterbird assemblages (e.g. on the Stour and Orwell Estuary) has been undertaken, it has not been possible to disentangle the impacts of other pressures from the possible influences of the development.

5.36. Compensatory habitat creation arising from multiple realignment sites within the same estuary appear to have ensured the maintenance of overall functionality of the estuary despite the various developments. This conclusion is based on the benefit arising from the overall extent of mudflat habitat created and that of the saltmarsh as a contribution to the long-term sustainability of inter-tidal habitats within the estuary (see Figure 4, page 43).

5.37. Where development projects affect populations of waterbirds, there is insufficient evidence to show whether habitat creation has helped maintain overall waterbird populations. Evidence from the Cardiff Bay barrage suggests that some displaced waterbirds lose condition and the ability to compete for food in new locations (Burton *et al*., 2006). Monitoring outputs for Harwich Haven Authority's (HHA) approach channel deepening demonstrate the difficulty of separating the effects of one impact from those of other projects and from changing environmental parameters[25].

Findings: functionality

xxiv The science of habitat creation could also be improved by increasing consistency in the approach to predicting the time-scale for compensation to become functionally viable. Clear success criteria would enable more objective assessment of success .

xxv. In the majority of cases there has been a lag between the loss of Natura 2000 habitat and the point where compensation measures have become functionally effective.

[25] In the HHA case a variety of changes in waterfowl populations have occurred, including increases and declines in numbers. None of these changes can be directly attributed to the dredge or to the sediment replacement strategy and linking cause and effect in this case may not be possible.

xxvi. Monitoring has largely concentrated on the compensation site rather than on the whole Natura 2000 site. Consequently, it cannot be ascertained with absolute certainty that there has not been a short-term deleterious effect from individual developments.

xxvii. Inter-seasonal variation in waterbird numbers means that it is extremely difficult to disentangle issues arising from habitat loss and replacement from natural variation.

Monitoring

5.38. Monitoring is an essential part of any development project. Its purpose is threefold:

5.38.1. To confirm predictions made about the net impact of the development and mitigation measures.

5.38.1. To determine whether specific compensation measures perform in accordance with targets/objectives or whether measures require modification in order to meet targets/objectives.

5.38.1. To facilitate assessment of the overall project impact and confirm that the developer has discharged the responsibilities set out in the consent.

5.39. Design of the monitoring package is, therefore, a crucial aspect of the oversight of any compensation project. This study identified a number of weaknesses in monitoring design and delivery:

5.39.1. There is an inconsistent approach to the use of success criteria and indicators that would help regulators determine whether design objectives have been achieved.

5.39.2. Monitoring outputs do not always fully coincide with the original design objectives for the compensation site.

5.39.3. Where compensation is within sites developed for other biodiversity gain, assessment of the delivery of compensation objectives is largely overlooked.

5.39.4. Much of the monitoring data are not in the public domain and cannot be accessed to ensure transparency in decision-making.

5.39.5. Monitoring agreements often involve insufficient timescales to ensure that the site has achieved and retained functionality. For example, predictable evolution of site morphology in the longer term may shift away from original design objectives and may not be detected under five-year agreements.

5.39.6. Processes for signing-off the results of monitoring are weak and it is unclear how any residual concerns will be resolved.

5.39.7. It is unclear how monitoring data have been used to influence site management.

5.39.8 It is unclear how the lessons learned from one case will be used to inform design, implementation and monitoring of subsequent cases.

5.40. Monitoring outputs can be an essential part of compliance with a planning permission or consent. As such, they are potentially of great public interest and, yet, relatively little information is available for public or scientific scrutiny. The reasons behind this lack of visible information are unclear. Monitoring is usually a condition or requirement of a legal agreement. It therefore follows that the findings should be made publicly accessible. This weakness suggests that there is scope for establishing best practice concerning the availability of monitoring data. Making lessons from the study of compensation sites available to a wider audience would also be of great benefit for the design and management of future schemes. It could also benefit the design and implementation biodiversity offsetting that might be undertaken in connection with a wider range of development projects.

Findings: Monitoring

xxviii. Monitoring for longer periods and over wider areas would help to show how compensation sites evolve. It could also show how they influence bird populations, which range over wider geographical areas.

xxix. A peer-reviewed final monitoring report could form the final stage of the consent process. This would provide a clear end to the project and would resolve existing difficulties accessing the results of monitoring. It would also make it possible for future practitioners to use lessons learned to improve compensation site design, decision-making and regulatory processes.

xxx. Making monitoring data publicly accessible would improve transparency in decision-making and would mean that past experience can be used to inform the better regulation agenda.

Long-term sustainability of habitat

5.41. In the case of inter-tidal habitats, there will be a gradual (rate variable) change from mudflat to saltmarsh. Resulting saltmarshes are a recognised adaptation response to sea level rise (Natural England & RSPB, 2014).

5.42. Over time, saltmarsh within a realignment site will start to erode releasing sediment to feed mudflats. Realignments can, therefore, be seen as a strategic way of maintaining sediment supplies and, with it broader functionality of mudflats within an estuary. It is a possible that organic debris from saltmarshes could make a contribution to supporting benthic organisms. Thus, where realignment sites evolve into saltmarsh, the vegetation will contribute to broader functional sustainability.

5.43. In areas with a negative sediment budget, where sea level is rising relative to the land, in exposed locations or during storms saltmarsh may erode and revert to mudflat. This may in turn support migratory waterfowl. It could be argued that managed realignment compensation sites do secure necessary

functionality for migratory waterfowl in the longer term. This is because saltmarsh habitats provide wave attenuation services and contribute organic nitrogen which is required by the invertebrates upon which many waterfowl feed.

Findings: habitat sustainability

xxxi. Recently created inter-tidal habitat is likely to be viable for the foreseeable future, even taking account of the twin pressures of sea level rise and increased storminess.

Scientific interest

5.44. Where a compensation site has been subjected to detailed monitoring, it is likely that there will be a robust body of scientific data to underpin its possible notification as a SSSI/SPA/SAC. Monitoring data provides a detailed description of the evolution of the site's nature conservation interest. The scientific value of the monitoring studies may be greatly enhanced if peer-reviewed studies are published in the academic literature, making the site a known reference site for future analysis.

5.45. As a matter of government policy, compensation sites are treated as though they are already part of the Natura 2000 network (section 118 of the National Planning Policy Framework, 2012). At some stage, however, it may be necessary extend the boundaries of existing Natura 2000 sites to include land provided as compensation for development impacts.

5.46. Using this model as a checklist, this review suggests that the majority of the study sites are worthy of consideration for designation. This analysis works on the basis that sites would need to be notified as SSSIs as well as designated as Natura 2000 sites (Table 15 - page 86). Uncertainties remain over the Hilgay and Moughton sites, and on the basis of this study and progress to date, it is not possible to predict whether or when Site X or Medmerry will satisfy SSSI selection guidelines (although inter-tidal habitats should present few difficulties, if they are large enough).

Findings: scientific interest

xxxii. In all cases, the level of monitoring of compensation sites makes them scientifically important because there are important lessons to be learned from the evolution of the compensation site.

xxxiii. The scientific value of compensation sites would be enhanced if the key findings from monitoring were to be published in the peer-reviewed literature.

Better regulation and delivery

5.47. A key objective of this study was to provide Defra and Natural England with the information it needs to formulate improved working practices, in line with the agendas to streamline and improve regulation. The study highlights a number of areas where there is scope for improvement. These fall into the following categories:

5.47.1. Improved data management and retrieval processes.

5.47.2. Refinements to project design and in particular to monitoring and essential learning feedback loops.

5.47.3. Public accessibility to relevant documents.

5.47.4. Emphasis on follow-up after the main development project has been completed.

5.48. This study, together with our investigation into European case studies (Broekmeyer *et al*., 2015), has demonstrated how opaque the process of assessing and implementing consents has been. It is almost impossible for an interested third party to access relevant information, and extremely difficult for statutory agency and Defra staff to make use of the lessons learned from past cases. In essence, the audit trail is not clear and as a result it has been possible to lose important documentation. When the relevant staff member changes jobs or leaves, all local memory of the files and issues goes with them. At a corporate level, staff departures also lead to substantial loss of corporate memory. Such losses can be vitally important if there is to be long-term engagement to follow the progress of particular compensation cases.

5.49. Problems encountered at the Moughton compensation site illustrate the problem of tracking progress with a compensation site. In the absence of a clear audit trail and tracking system contact with both the developer and the owner/occupier was lost. The importance of securing long-term arrangements for maintenance of compensation sites is also highlighted by this case.

5.50. This study has also shown how weak the feedback loop is between the lessons learned from one compensation site and development of the next one. Although a great deal of expensive monitoring takes place, the documentation is often misplaced or overlooked by subsequent practitioners. Bearing in mind that quite a small number of consultancies are involved in these types of projects, greater corporate memory and learning probably occurs within them, but this is not necessarily to the advantage of Defra or the statutory agencies. It would therefore make sense to ensure that important learning points from individual projects are documented and made available to all parties with an interest in such matters (Defra, statutory agencies, consultants, developers, NGOs, academics and the interested public).

5.51. Difficulties encountered when investigating progress with the Moughton compensation site (Arcow Quarry) highlight an unusual but important risk: the possibility that loss of corporate memory will lead to a compensation site being forgotten or partially forgotten about. At Moughton this appears to have

happened with Natural England, the planning authority and the quarry owners. As such, it illustrates the advantages of agreeing a clear Compensation, Mitigation and Monitoring Agreement, and of establishing a review process to provide the necessary follow-up. It also raises a question about the legal covenants that safeguard such sites and the possible need for more formal safeguards once a site has been created.

5.52. The port-related cases included the establishment of a 'Regulators Group' to provide an interface between the developer, their consultants and statutory bodies whilst the development and compensation package were evolving. The life-span of such groups may vary but they do appear to be a positive way of formalising engagement between the various parties. Involvement of key NGOs such as the RSPB and Wildlife Trusts in such arrangements can also help to maintain open dialogue and transparent decision-making, as well as making use of their expertise and experience.

5.53. This study is a first stage in establishing a more effective knowledge-management regime. Many of the comments in previous sections have highlighted the potential benefits of retaining and disseminating findings from individual projects. A final report, compiled as part of the process in which the compensation package is agreed, would improve the process. This would help to improve the learning process. Furthermore, this approach would help to demonstrate the degree to which the compensation had achieved its objectives and whether the UK Government obligations under the Habitats Directive had been met.

5.54. Compensatory habitat creation differs from general habitat creation because it is expected to deliver a defined set of objectives that have legal ramifications for all concerned. Some developers will have previous experience of such matters, but others will not. There is voluminous guidance on how to create certain habitats such as managed realignment sites (Adnitt *et al*., 2007; Burd, 1995; Leggett *et al*., 2004), but it is arguably geared to nature conservation practitioners. A simple, yet comprehensive guide for developers might therefore help to ensure that prospective developers are familiar with the issues.

5.55. The need for understanding the broader aspects of recreating grazing marsh habitat is becoming increasingly important because many grazing marshes on the Essex and Kent coasts are potential managed realignment sites. This potentially includes the Chetney compensation site. Replacing SPA habitat is a well-established principle in flood risk management but provision for Ramsar interest has not been given the same profile. The National Planning Policy Framework requires that Ramsar interest is treated in the same way as Natura 2000 interest and consequently it is important to understand what is and is not possible, and the timescales over which new habitat might support an analogous assemblage of wetland invertebrates. The arable reversion at Site X (Cliffe Marshes) offers an unparalleled opportunity to investigate this in detail.

Findings: better regulation and delivery

xxxiv. There is considerable scope to improve consistency and transparency in advice and decision-making. This largely involves the need for a clear audit trail of the rationale for particular decisions, when and why they were taken.

xxxv. A checklist of key documents that should be retained for each Natura 2000 compensation case would help to ensure that the audit trail is maintained in the long-term.

xxxvi. There is currently no publicly accessible electronic library of key documents for Article 6(4) cases i.e. a transparent audit trail of decision-making and the entire compensation process. If such a system was in place, public scrutiny would be greatly improved.

xxxvii. The case of compensation for Arcow Quarry highlights the risks to the integrity of the Natura 2000 network where compensation sites have not been formally designated.

xxxviii. Where used, 'Regulators Groups' have proven to be an excellent way of ensuring ongoing dialogue between regulators and developers, and establishing a process to track progress and sign off key stages. Standardised implementation of such an approach might help to avoid some of the historic problems identified in this report.

xxxix. Useful lessons can be learned from individual compensation sites. Evaluations of completed projects, published as reports would greatly improve long-term evolution of site design. Reports should include searchable key words and a brief synopsis of the findings to help to ensure that lessons are learned and embedded in the knowledge-base for both developers and decision-makers.

xl. Although there is ample guidance on how to create certain habitats, there is no clear distinction between general environmental improvement and the specific needs of compensatory habitat provision. A comprehensive yet simple report, setting out the relevant stages in objective setting, site selection and design, monitoring and reporting, could help to improve engagement with developers and to avoid confusion.

Table 15. Analysis of the factors that could assist in determining whether compensation sites could be notified as SSSIs and designated as Natura 2000 sites. The final columns represent the study's conclusions regarding designation possibilities.

Site	Compensation site under development	Compensation site completed	Compensation site > 5 years old	Already within N2k site (mitigation)	Contiguous with damaged N2k site	Contiguous with another N2k site	Detailed monitoring reports	Adequate monitoring reports	Weak monitoring reports	Similar assemblages to those in N2k site	Positive visual appraisal	Appears to merit consideration as SSSI	Current status of site			
													Already designated	Could be designated	Future designation	Uncertain outcome
Rutland Water		x	x		x		x			x	x	x		x		
Chowder Ness		x	x		x		x			x	x	x		x		
Doigs Creek		x	x	x			x			x	x	x	x			
Welwick		x	x		x		x			x	x	x		x		
Allfleet's Marsh (Wallasea Island)		x	x		x		x			x	x	x		x		
Cliffe Marshes (Site X)	x				x							x			x	
Stanford Wharf (Mucking) (Site A)		x			x		x			x	x	x		x		
Hilgay*	x															x
Medmerry*		x													x	
Paull Holme Strays		x	x		x		x			x	x	x		x		
Rye Harbour Farm		x	x		x				x		x				x	
Trimley		x	x		x		x			x	x	x	x			
Chetney		x	x		x			x		x	x	x		x		
Hesketh Outmarsh		x	x		x	x		x		x	x	x		x		
Moughton		x	x		x				x	x						x

***** Sites that are in the early stages of developing functionality and as such they cannot be fully assessed.

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8. Glossary

Term	Acronym	Definition
Adverse affect		Residual negative impacts (after mitigation) upon a site designated under The Habitats Directive, classified under the Wild Birds Directive or listed as a Ramsar Site.
Adverse effects		Residual negative impacts (after mitigation) upon a site or assemblage of organisms.
Alternative solutions		A test within the Habitats Directive to determine whether there are any other feasible ways to deliver the overall objective of the plan or project which will be less damaging to the integrity of the European site affected.
Annual vegetation		Plants that compete their life cycle in a single year and are replaced by a new generation the following year.
Appropriate Assessment		An evaluation of the impacts of a development project on the features of a site designated under The Habitats Directive classified under the Wild Birds Directive or listed as a Ramsar Site, in the context of the site's conservation objectives.
Arable reversion		Management measures that facilitate development of new semi-natural habitat on arable land.
Audit trail		A detailed record of the decision-making process.
Biodiversity offsetting		Measures to yield biodiversity compensation to ensure that when a development damages nature (and this damage cannot be avoided or mitigated) biodiversity interest of comparable value and type will be created. They are different from other types of ecological compensation as they are normally provided for away from the development site, and can often bring together compensation provision from a number of projects. Biodiversity offsetting needs to show measurable outcomes that are sustained over time.
Birds Directive		Properly referred to as the Wild Birds Directive or Directive 2009/147/EC of the European Parliament on the conservation of wild birds (the codified version of Directive 79/409/EEC as amended)

Borrow-dyke		A linear water-body from which material has been excavated to create a seawall (usually landward of the sea wall).
Breach		A physical break in a former sea wall intended to allow the tide to enter a managed realignment site.
Carbon sequestration (natural)		Removal of atmospheric carbon into a natural reservoir in which carbon bound up within organic compounds.
Coastal Defence		A term that encompasses costal structures that provide protection against coastal erosion and flooding.
Coastal Erosion		Progressive loss of foreshores and physical structures as a result of ongoing wave action.
Coastal Habitat Management Plan	CHaMP	A prediction of the likely morphological evolution of a coastal nature conservation site as a result of sea level rise and coastal squeeze that is used to estimate levels of habitat replacement to offset the nature conservation impacts of flood risk management strategies.
Coastal processes		The evolution of the coast in the context of sediment transport, erosion and deposition.
Coastal squeeze		Inter-tidal habitat loss resulting from the high water mark being fixed by a coastal defence whilst the low water mark migrates landwards in response to sea level rise.
Cobble skear		Relict glacial deposits that include boulders of varying size that provide a hardened surface to which marine organisms may become attached or under which other organisms may reside.
Coherence		The maintenance of the extent and function of the Natura 200 network, for which each individual site contributes, to ensure the necessary quality, distribution, extent and range of habitats and species.
Compensation, Mitigation and Monitoring Agreement	CMMA	An agreement between a developer and the statutory (and voluntary) nature conservation bodies that defines commitments to appropriate levels of compensation, mitigation and monitoring.
Compensation		Habitat creation undertaken to replace habitat lost, disturbed or damaged as a consequence of development projects, where such impacts cannot

		be avoided or mitigated. In the context of the EU Habitats Directive, any measure intended to offset the negative effects of a plan or project so that the overall ecological coherence of the Natura 2000 network is maintained.
Consent		Permission granted to undertake a development project.
Dabbling ducks		Ducks that mainly feed at the surface of a water body rather than by diving
Design objectives		The outcomes defined to ensure that a project meets its intended purpose.
Developer		The organisation responsible for putting forward and undertaking a development project.
Diptera		True flies, with one pair of wings and a pair of modified wings 'halteres' that act as turn and bank indicators.
Dolichopodidae		A family of flies, many of which have long legs and are strongly metallic in appearance.
Drift line		The point on the shore where debris carried landward by the sea is deposited on a temporary or permanent basis.
Ecological barriers		Natural biological factors that prevent a particular outcome being achieved.
Ecosystem		A community of living organisms that act in conjunction with abiotic factors (air, water and mineral soil) to create a particular set of conditions.
Ecosystem service		The benefits provided by ecosystems that contribute to the maintenance and quality of human life.
Environmental Impact Assessment	EIA	The process of evaluating the likely beneficial and adverse impacts of a proposed project upon all environmental parameters, taking into account inter-related socio-economic, cultural and human-health impacts.
Electronic library		A facility that allows access to documents stored in their electronic form.
Environmental sustainability		Securing the long term protection of features of the natural environment, normally in the context of some form of potential impact or change, for

		example rates of use of renewable resources, pollution creation, and non-renewable resource depletion. Used in this context as the degree to which the newly created habitat can be sustained in the face of sea level rise and coastal squeeze.
Ephydridae		A family of true flies (Diptera) often referred to as 'shore flies' that are closely associated with exposed muddy environments.
Evolution		The progression from one physical state to another in a sequence of almost imperceptible change.
Extent		The absolute area of a feature. Used in this context to relate to habitat or designated site.
Fish nurseries		Habitat that provides shelter and feeding grounds for juvenile fish.
Flood risk management		Measures to limit the risk of flooding either by saltwater or freshwater intrusion.
Flood risk management strategies	FRMS	A set of objectives and proposed outcomes for limiting flood risk in a given section of coastline (or a river basin).
Freshwater wetlands		Areas of permanently or intermittently flooded land that supports plants and animals that are adapted to particular levels of inundation.
Functionality		The contribution of particular attributes of a site to the maintenance of the features for which it is designated.
Grazing marsh (coastal)		A mosaic of grassland and water-filled ditches that form 'wet fences' to constrain livestock movement.
Groundwater		Water within the soil and rocks that feeds springs, streams and rivers.
Habitat		The environment in which a particular kind of animal or plant usually lives. A term that is often used in the context of a particular environment dominated by certain plants that gives it a distinctive character (more correctly referred to as a biotope).
Habitats Directive Wild Birds Directive also needs adding		Also known as Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora.
Habitats		Transposition of the Habitats Directive and Wild

Regulations		Birds Directive into UK law.
Inter-tidal		The area of land that is uncovered by the tides on a regular basis over the spring-neap cycle.
Invertebrates		Animals without backbones, including *inter-alia* bivalve molluscus, polychaete worms and arthropods including shrimps, crabs and insects.
Legal covenants		A promise to engage in or refrain from a specified action, secured by legally binding documentation.
Like-for-like		Replacement of a particular area of habitat by creating new habitat that is directly analogous to that lost.
Loafing		A period of general inactivity or resting by waterfowl.
Lowest Astronomical Tide		The lowest point in the tidal cycle that can be predicted to occur under average meteorological conditions and under any combination of astronomical condition.
Managed realignment		The process of creating a new sea defence line behind an existing defence line and allowing the area between the two to be inundated by creating holes (breaches) in the outer defences.
Mitigation		Measures to prevent the negative impacts of a development through complete avoidance of impacts or reduction of impacts to an acceptable level. It Can include measures incorporated into the plan/project at the outset that remove any significant effect It should not be confused with compensation, which is undertaken to offset negative effects as a consequence of development projects.
Mollusca		The taxonomic division that embraces, *inter-alia,* slugs, snails sea slugs, octopus and *Nautilus*
Molluscs		Used in this context to embrace slugs and snails.
Monitoring		A process of systematic and purposeful observation to establish how project activities are progressing. It also involves the provision of feedback about the progress of the project to interested parties.
National Planning Policy Framework	NPPF	The NPPF sets out the UK Government's planning policies for England and how these are expected to be applied.

Natura 2000		This is a network of nature protection areas in the territory of the European Union. It is made up of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) designated respectively under the Habitats Directive and Wild Birds Directive.
Organic nitrogen		A term used to describe a nitrogen compound that had its origin in living material.
Peer-review		Independent evaluation of a piece of work by people of similar competence to the authors of the work.
Perennial vegetation		Plants that persist over more than one year. Communities are maintained over ongoing years, even though their absolute composition may change in response to seasonal variations in rainfall and temperature.
Planning Inspectorate		An executive agency of the UK Government that deals with planning appeals, national infrastructure planning applications, examinations of local plans and other planning-related and specialist casework in England and Wales.
Protected species		A species of animal or plant that is protected under UK Law. In the context of this study, these are water voles and great crested newts.
Public Inquiry		An official enquiry into planning applications.
Ramsar site		Wetlands of international importance, listed in accordance with the Ramsar Convention.
Receptor sites		The site that is used to create new habitat.
Regional Habitat Creation Programme	RHCP	A programme established by the Environment Agency to provide a strategic and proactive approach to identifying and addressing potential habitat loss resulting from flood and coastal risk management schemes.
Regulators		Statutory bodies responsible for granting consents.
Restoration		Measures to return degraded habitat to a condition that more closely approximates to a desired state.
Roosting		The process of birds congregating at a particular location to gain safety in numbers whilst resting during high tides or overnight.
Scrape		A shallow depression created to retain water.

Scientific scrutiny		Rigorous challenge by the scientific community to ensure reliable data collection and interpretation.
Sciomyzidae		A family of Diptera known as 'snail killing flies' whose larvae are predacious upon slugs and snails.
Sea level rise		The combination of isostatic adjustment or natural land sinking, combined with the effects of thermal expansion and additional freshwater input from glacial melting.
Secretary of State		The senior politician responsible for a particular Government department.
Sediment sink		The natural conditions under which suspended sediment is deposited and is not immediately re-suspended.
Semi-natural		Habitat that has developed as a result of arable reversion or as a consequence of long-term human intervention in the management of the landscape.
Significant effect		A term used in both Environmental Impact Assessment and in the Habitats Regulations, but with slightly different meanings. In the case of the Habitats Regulations, a 'likely significant effect' is a coarse filter to eliminate inconsequential effects but captures any measurable impacts that could possibly occur. In EIA, significance can be graded from minor to major to reflect a judgment of the magnitude of effect and the sensitivity of the receptor.
Site integrity		The maintenance of a designated site in a state that sustains the habitats and species for which it is designated enabling their full contribution to favourable conservation status across their range, thus ensuring that condition and extent is not compromised.
Special Areas of Conservation	SAC	Sites designated in accordance with the European Council Directive 92/42/EEC (Habitats Directive) for vulnerable and threatened habitats and species listed in the Annexes of the Habitats Directive.
Special Protection Areas	SPA	Sites classified for their endangered and regularly occurring migratory or breeding birds in accordance with European Council Directive 2009/147/EC (Wild Birds Directive).
Site of Special	SSSI	Sites designated under the Wildlife and

Scientific Interest		Countryside Act (1981) as amended, on account of defined scientific interest.
Statutory advisers		Bodies given a defined advisory/consultee remit under legislation. Statutory advisors provide Regulators (or Competent Authorities) with reasoned assessment of the impacts of development projects so that a decision can be made using best available evidence. In England, the statutory advisor for nature conservation is Natural England.
stony banks		These translate in coastal environments to shingle systems.
Sub-tidal		The sea bed below the lowest point of tidal exposure.
Success criteria		The goals, deliverables, scope and requirements for successful completion of a project.
Succession		The process of habitat evolution from pioneer stages through to largely stable 'climax' communities that are regulated by external pressures such as grazing animals or water availability and soil depth.
Taxon (taxa)		A group of one or more populations of an organism or organisms seen by taxonomists to form a discrete unit. For example, the Avocet *Recurvirostra avosetta* is a discrete taxon.
Terrestrial		Land dwelling.
Transitory habitat		A habitat that exists for a short period during the evolution of more stable and advanced conditions.
Waterfowl		Wading birds, ducks and geese.
Wave attenuation		The dampening effects of sub-tidal and inter-tidal surfaces that gradually absorb wave energy through friction.
Wildfowl		Ducks and geese.

Appendix 1. Pro-forma used in assessing compensation measures

Project name	
Developer	
Date of application	
Competent Authority(ies)	
Designated site(s)	

1. Document availability		**Dated**	**Notes**
1.1. Environmental Impact Assessment	Yes/No		
1.2. Maps	Yes/No		
1.3. Appropriate Assessment	Yes/No		
1.4. Compensation, Mitigation and Monitoring Plan	Yes/No		
1.5. Progress reports	Yes/No		
1f. Monitoring reports	Yes/No		
1.6. Regulation 33/35 advice/ Conservation Objectives	Yes/No		
1.7. Article 6(4) form	Yes/No		
1.8. ES/EIA for compensation package	Yes/No		
1.9. Additional notes			

2. Designated sites	

3. Habitat types, species and assemblages affected			
HD Code	**Description**	**Extent (Ha)**	**Impact type (Direct/Indirect/Functionality)**

Assemblage details (SPA)			
Code	**Description**	**Numbers**	
Priority species/Annex I Species			
Code	**Description**	**Details**	
Ramsar interest			
Code	**Description**	**Details**	
Additional notes			

4. Appropriate Assessment

When was effect on integrity determined? Before/after submission for consent (details)

Overall judgement (note separation of decision is relevant)	Cannot ascertain no adverse affect on integrity?	Yes /no	Adverse affect on integrity?	Yes /no
Rationale				
Additional information from EIA of habitat creation				
5. Mitigation/Compensation measures				
Habitat creation (overview of the exact requirements derived through the consenting process)				

Habitat type	Extent (Ha)	Permanent/ temporary	Links to specific impacts
Timescale			

Commencement of habitat creation			**Coincidence with damage impacts**

Was geographic location of loss and compensation factored into the package?	
Rationale for ratios of loss/replacement	
Timescale before it is anticipated that habitat will become fully functional	
Duration of management arrangements	
Who will manage the site	
Who controls the site (now and in future)	

6. Implementation and Management

Reporting process		**Is there a Regulators' Group**	**Yes/no**
date		**Who is involved?**	
date			

Monitoring reports

Period	By whom	Results

7. Additional information

Any corrective action?	

When was this?	
Has it secured its objectives?	
Any subsequent impact from other plans/projects	
Was any impact considered to be an impact on N2k?	

ANALYSIS

		Y/N	Notes
1	Do the compensation measures replace the predicted habitat loss changes at a site level (i.e. the nature of the adverse effect on integrity), thereby securing the coherence of the Natura 2000 network?		
2	Do compensation measures address the structural and functional aspects of site integrity, the related types of habitat and species populations that are affected and the contribution that these elements make to the overall coherence of the Natura 2000 network?		
3	Are losses/alteration to function etc. quantified with respect to key habitats and species using best available knowledge and judgment? How was uncertainty in assessment outcomes and habitat creation built into the measures?		
4	Were the compensation measures designed on the basis of best scientific knowledge and to deliver the ecological functions necessary to support the affected species and habitats? Were criteria/indicators established to describe functionality?		
5	Were the measures clearly defined, feasible and able to operate effectively in protecting the overall coherence of the Natura 2000 network?		
6	Were permits and monitoring plans etc. in place in sufficient time to enable the compensation package to proceed in time in respect to the development proposal (e.g. many compensation schemes also require their own EIA investigations and HRA)?		

7	Have measures been put in place to deal with unforeseen uncertainties (e.g. slow habitat development)?		
8	How do the compensation sites relate to the designated sites in which the impacts occurred or are occurring (i.e. is compensation adjacent to the existing site or at a distance from the designated site)?		
9	How does the compensation relate to the continuity of ecological processes (i.e. in terms of maintaining coherence in respect of the timing of the effects of the consented development)?		
10	Were any additional measures put in place to deal with impacts that could arise in the period before the compensation measures became effective?		
11	Were there predictions or estimates of when re-created habitat would be functional as a compensation site and when did the habitat became functional and maintain overall coherence of the Natura 2000 network?		
12	Was a fit for purpose monitoring package (i.e. to determine the effectiveness of the compensation in relation to the predicted impacts of the works) agreed and, if so, how has the monitoring process been implemented?		
13	Has any modification to the design or implementation been necessary?		
14	Has the compensation site been threatened or compromised by other projects?		
15	Are there any gaps between the design objectives and the final compensation package?		

Appendix 2. Study site data sheets

Data for the following are provided is an separate document (Annex 1):

- Anglian Water Services, Wing Water Treatment Works
- Associated British Ports, Hull Quay 2005 Container Terminal
- Associated British Ports, Immingham Outer Harbour
- Associated British Ports, Green Port Hull
- Defra, Lappel, Bank & Fagbury Flats
- Dubai Ports World, London Gateway Container Terminal
- Environment Agency, Cley/Salthouse Flood Risk Management
- Environment Agency, Hullbridge Tidal Flood Defence Scheme
- Environment Agency, Humber Estuary Flood Management Scheme
- Environment Agency, Pett Frontage Tidal Flood Defence Scheme
- Environment Agency, Portchester Castle to Emsworth Flood Risk Management Strategy
- Harwich Haven Authority, approach channel deepening
- Highways Agency, A249 Iwade to Queensborough road improvement scheme
- Lancaster City Council, Morecambe Coastal Defence Works
- Tarmac, Arcow Quarry