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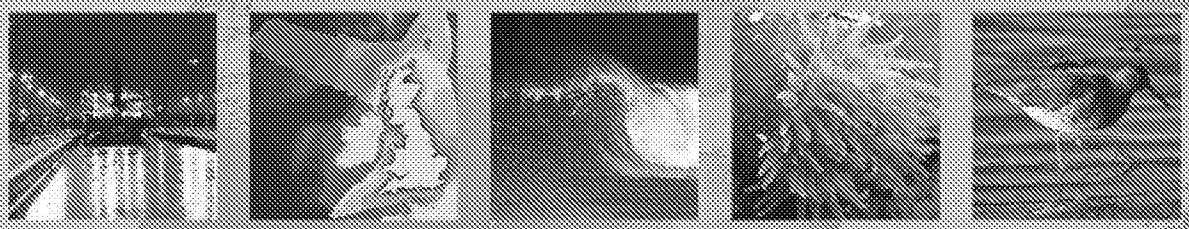
Managed Breach of Shingle Spit at Pagham: Environmental Statement

Volume 2: Appendices

Report R.2446

September 2015

Creating sustainable solutions for the marine environment



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Pagham Parish Council

Managed Breach of Shingle Spit at Pagham: Environmental Statement

Volume 2: Appendices

Date: September 2015

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Appendices

Appendix A

Proposed Design and Modelling Report

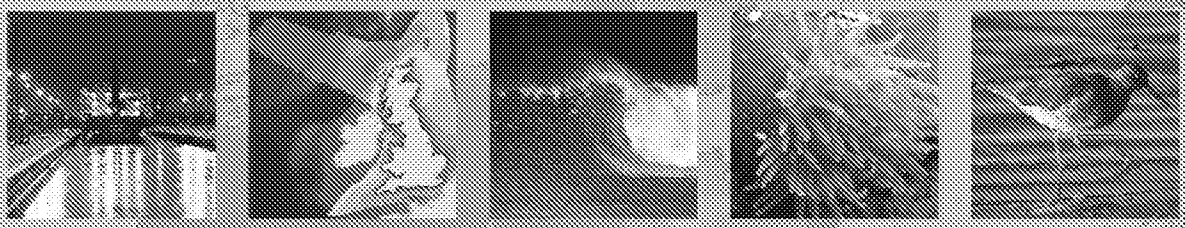
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Managed Breach of Shingle Spit at Pagham: Proposal Design and Modelling Report

Report R.2404

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Managed Breach of Shingle Spit at Pagham: Proposal Design and Modelling Report

Date: June 2015

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Summary

Project Background

Pagham Parish Council (PPC), and its working group the Pagham Flood Defence Steering Group (PFDSG), are proposing to undertake a controlled breach of the shingle spit feature at the mouth of Pagham Harbour, West Sussex. The aim of this proposed shoreline adjustment is to move the coastline towards a more sustainable morphology and address the severe coastal erosion problems that are being experienced on the Pagham Beach.

The erosion problems at Pagham Beach are largely being caused by the 'Church Norton Spit' in front of Pagham Harbour which has grown substantially over the last decade. In recent years, the northern end of this spit has migrated closer towards Pagham Beach and, in this position, it has caused a tidal channel to cut into the beach leading to rapid localised shoreline retreat. The formation of the spit and the tidal channel are also 'locking up' shingle and not allowing it to reach adjacent, and more slowly eroding, sections of the Pagham foreshore via the usual longshore sediment transport pathways.

On behalf of the PPC and PFDSG, ABPmer is undertaking a sequence of evidence-based studies to progressively verify, develop and inform this proposal. This information is intended, ultimately, to inform a planning application for this work. To date, ABPmer has undertaken the following two studies:

- An initial review of options (ABPmer, 2015a) which reviewed the intervention options and identified that the most appropriate approach (in terms of creating a more sustainable shoreline morphology) involves creating a breach through the spit that functions as naturally as possible (i.e. one that allows natural processes to continue operating and avoids introducing artificial features such as cross-shore training wall structures); and
- A scoping study (ABPmer, 2015b) which highlights the Environmental Impact Assessment (EIA) issues that are relevant for this proposal as well as the consent requirements that will be needed to underpin a planning application for it.

Report Objectives

This 'Breach Design Review' is the third report in the sequence of studies that ABPmer is undertaking to inform this proposal. It has been prepared to clarify the detail of the breach design including details about its proposed width, shape, location and about the volume of shingle that will need to be excavated to create a breach and then moved into the existing tidal channel to close it. This report has been prepared to inform discussions with contractors about how the work can be undertaken and at what cost. The results of this work, and the Method Statement agreed with contractors, will then also be used to inform the EIA and consenting work that is needed for this proposal.

This review is not designed to act as an impact assessment for the proposal, as this will be undertaken separately within the formal Environmental Statement (ES). However, to inform the design work, it was necessary to make an initial review of the likely evolution of the breach and its interaction with the wider dynamics environment of Pagham Harbour and Pagham Beach.

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Project Approach

To develop a suitable breach scheme design that will achieve the desired adjustment of the shoreline towards a more sustainable morphology, a range of relevant and interlinked technical studies were carried out. These studies (including empirical and hydrodynamic modelling analyses) were undertaken following best practice and according to standard methods consistent with other projects of a similar nature and with reference to past examples of shingle breaches and the particular environmental conditions that are prevalent in Pagham Harbour at the present time.

No single study has been, or should be, taken in isolation and instead it is necessary to review the full suite of analysis as a full 'tool kit' to help inform expert and objective decision making. The key tasks undertaken for these analyses were as follows:

- Collation of existing data and literature to describe the morphology and hydrodynamics of Pagham Harbour and the Pagham frontage;
- Field surveys to collect extra flow speed information and topographic (bed elevation) readings to address gaps in the data that relate to the present day morphology and hydrodynamics of Pagham Harbour and frontage;
- Integration of the available data to create the most up-to-date 'Digital Terrain Model' (DTM) of Pagham Harbour and frontage;
- A review of the tidal prism volumes in Pagham Harbour (i.e. the volume of water exchanged over a tide) to underpin the subsequent breach design analyses;
- Application of available empirical and mass-continuity breach calculations and a review of the local environment to identify the most suitable breach location and design;
- Computer (numerical) modelling work to describe the baseline hydrodynamic conditions (using the up-to-date DTM described above) to compare them against the changes that are likely to arise from a range of different possible breach configurations; and
- An initial prediction of the future patterns of breach evolution (pending further analysis within the EIA which follows this study) which was, in turn, informed by
  - An inlet stability analysis; and
  - A review of previous projects that have involved breaches through shingle barriers to understand how these 'analogue' examples have functioned.

The results of these studies were used to develop a proposed design and identify the key issues that will be pertinent for contractors implementing the scheme. As described above, the results also provide an initial (pre-EIA) understanding about the extent to which the desired outcome of the project (creating a new harbour inlet within a more sustainable coastal morphology) can be achieved. This initial understanding will be used to inform consultations with key stakeholders during the next EIA stage.

Conclusions and Next Steps

Following all the work undertaken, a proposed breach design has been developed with the following characteristics:

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- A central 40 m channel at a depth of -1.80 mODN which is equivalent to the Mean Low Water (MLW) level and is comparable to the channel bed level of the existing harbour inlet channel[1];
- Side slopes on each side of the breach that will be set at approximately a 1:4 gradient;
- A width of 80 m at tidal elevation of +3.0 mODN level which is approximately at the Highest Astronomical Tide (HAT) level; and
- An excavated volume of around 42,000 m³ (below 3.0 mODN) with an expected additional 10,500 m³ needing to be excavated above the +3.0 mODN elevation.

A suitable proposed location and alignment for this proposed breach has also been selected based on the topography within the harbour; proximity to the tidal channels; the position of the existing training wall; the shape of the spit and the position of the harbour inlet historically. The design is also relatively simple, with a straight alignment, to ensure that contractors can excavate it relatively easily and safely. Once created, the breach is then expected to adjust in alignment and form.

The information presented within this report will now inform the development of a formal project Method Statement which will be prepared by an experienced contractor. For this Method Statement the health and safety of the staff that would work on the project, and public that use the area, will clearly be the paramount considerations. Below this overarching consideration, it will be necessary to determine the most suitable methods for excavating the breach while working within and near to a tidal environment. It will also be important to note that the methods (and timings) for closing the existing tidal channel are as important as the methods (and timings) for opening the new breach. The proposed approach will need to consider how this can be most effectively achieved with the volumes of material excavated.

The project will also bring about a number of short term and longer-term environment changes within an area of national and international conservation importance. The results of the numerical modelling work presented within this report help to understand these changes by describing how conditions are likely to interact with the foreshore. The modelling work indicates, for instance, that the proposed breach design will result in changes to water levels and flow speeds in Pagham Harbour. In particular, a reduction in the high water level within the harbour is indicated after the creation of the breach. The peak water levels will then alter as the breach evolves but are expected to remain within the spectrum of past variability given that the proposal seeks to return the harbour to an historical position.

The significance of these, and other, changes will be evaluated during the subsequent impact assessment and planning application work. This work will, in turn, be informed by: this report; the contractor's Method Statement; and the results of a Scoping review that has been undertaken jointly by the Arun and Chichester District Councils. It should be noted that, following the impact assessment, there may well be a need for mitigation or compensation measures to offset any significant effects on the environment. The most likely effects will be upon nesting terns and/or overwintering birds and as such, offsetting measures may well include constraints on the timing of the works or the need to create/restore shingle habitat in other locations. The requirement for such mitigation or compensation work, and the approaches that could be taken, will be investigated during the EIA work.

---

[1] It should be noted that under the current condition the inlet channel is not fully draining and hence there is typically still water present at low water.

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Acknowledgements

We would like to thank the many people and organisations that have provided helpful advice and support for this breach design review. These have included a number of people and organisations that have freely contributed data, information and advice including the following: Dan Amos and James Bovington (Adur & Worthing Borough Councils); Roger Spencer (Arun District Council); Andrew Colenutt and Travis Mason (New Forest District Council and Channel Coastal Observatory); Uwe Dornbusch (Environment Agency). We would also like to thank Prof. Ian Townend (Independent Coastal Engineer) for providing his expert advice as part of the project team during this study.

ARUN DISTRICT COUNCIL P/93/25/PL

Abbreviations

ABPmer	ABP Marine Environmental Research Ltd
ADC	Arun District Council
ATV	All-Terrain Vehicle
CCO	Channel Coastal Observatory
CDC	Chichester District Council
CD	Chart Datum
DTM	Digital Terrain Model
EA	Environment Agency
GIS	Geographic Information System
HAT	Highest Astronomical Tide
LiDAR	Light Detection and Ranging
MHW	Mean High Water
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLW	Mean Low Water
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
ODN	Ordnance Datum Newlyn
PFDSG	Pagham Flood Defence Steering Group
PPC	Pagham Parish Council
RTK	Real Time Kinematic
UKHO	UK Hydrographic Office

ARUN DISTRICT COUNCIL P/93/25/PL

Managed Breach of Shingle Spit at Pagham: Proposal Design and Modelling Report

Contents

Page

Summary 5

Acknowledgements 8

Abbreviations 9

1. Report Background 13
   - 1.1 Project Background 13
   - 1.2 Report Objectives and Summary Approach 14
2. Data Collation and Field Survey Work 16
   - 2.1 Data Collation 16
   - 2.2 Field Survey Work 18
   - 2.3 Key Supporting Documents 18
3. Development of Digital Terrain Model 20
   - 3.1 Initial DTM Development 20
   - 3.2 Further DTM Development 21
4. Tidal Volumes in Pagham Harbour 23
   - 4.1 Water Levels 23
   - 4.2 Tidal Volume Analysis 23
     - 4.2.1 Hypsometry Assessment 23
     - 4.2.2 Tidal Prism Volume 24
5. Breach Design Development 25
   - 5.1 Breach Design Methods 25
     - 5.1.1 Empirical Approach 25
     - 5.1.2 Mass-Continuity Approach 26
   - 5.2 Developing the Breach Design 27
     - 5.2.1 Breach Location 27
     - 5.2.2 Breach Dimensions 28
6. Breach Design Modelling 29
   - 6.1 Stage 1 'Schematic' Breach Design Modelling 29
     - 6.1.1 Model Results 30
     - 6.1.2 Sediment Mobility Assessment 32
     - 6.1.3 Summary of Breach Design Modelling 33
   - 6.2 Stage 2 'Refined' Breach Design Modelling 33
     - 6.2.1 Breach Design Characteristics 33
     - 6.2.2 Model Results 35

ARUN DISTRICT COUNCIL P/93/25/PL

7. Predictions of Future Breach Evolution 38
7.1 Inlet Stability Assessment 38
7.2 Lessons from Similar Sites 39
7.2.1 Porlock 40
7.2.2 Medmerry 43
7.2.3 Summary 46
8. Conclusions 48
8.1 Overview of the Proposed Breach Design 48
8.2 Interactions with the Environment 48
8.3 Key Considerations for the Next Stages of the Project 49
9. References 50

Appendix

A. Modelling Review of the Proposed Breach at Pagham Harbour

Tables

1. Existing topographic and bathymetric survey data collated 16
2. Standard tidal levels 23
3. Hypsometry assessment results for Pagham Harbour 24
4. Indicative breach widths calculated using the breach design methods 28
5. Results from the breach testing exercises (mean spring tide) 32
6. Estimated potential sediment mobility 32
7. Classification of K_c values 38
8. Results of tidal inlet stability assessment (DTM) 38

Images

1. Church Norton Spit and Pagham Beach 13
2. Nortek current profiler prior to being deployed within Pagham Harbour 18
3. LiDAR elevation map of Pagham Harbour 20
4. Collecting bathymetric data within Pagham Harbour 21
5. Model results for the schematic breach designs (internal channel) 30
6. Model results for the schematic breach designs (centre of breach) 31
7. Indicative preferred/proposed breach design (not to scale) 34
8. Inferred sediment transport around Porlock breach (2011) with photos of the breach (top right) and ebb delta (bottom right) taken in May 2009 42
9. Medmerry breach (27 February 2015) 44
10. Evolution of the Medmerry breach over 1.5 years 46

ARUN DISTRICT COUNCIL P/93/25/PL

Figures

1. Pagham Harbour Location Plan
2. Pagham Harbour Digital Terrain Model
3. Preferred Breach Design Location
4. Channel Slope Profiles
5. Spring Tide Assessment plots – Water Level
6. Spring Tide Assessment plots – Flow Speed

ARUN DISTRICT COUNCIL P/93/25/PL

1. Report Background

1.1 Project Background

Pagham Parish Council (PPC), and its working group the Pagham Flood Defence Steering Group (PFDSG), are proposing to undertake a controlled breach of the shingle spit feature at the mouth of Pagham Harbour, West Sussex (Figure 1). The aim of this proposed shoreline adjustment is to move the coastline towards a more sustainable morphology and address the severe coastal erosion problems that are being experienced on the Pagham Beach.

The proposal was identified and described in outline by ABPmer (2015a) following a review of available options (as previously considered by Royal Haskoning (2014a, 2014b) in consultation with key stakeholders). It is considered, by ABPmer, to be the most appropriate approach for the sustainable management of this shoreline under current conditions because it doesn't seek to introduce new revetments or fixed structures that will combat ongoing coastal change. Instead it will allow the shoreline to continue evolving but from new configuration. This approach is also considered, by ABPmer, to be a suitable 'adaptive management' measure that is in-keeping with the strategic coastal defence objectives for this coast as set out in the Pagham to East Head Coastal Defence Strategy (Environment Agency, 2009a).

The erosion problems observed at Pagham Beach are largely being caused by the 'Church Norton Spit' feature, which has grown substantially over the last decade. This has created an extended inlet channel from the harbour that now runs along the front of the adjacent Pagham Beach foreshore to the east (see Image 1). This extended spit, and increased longshore channel, are exerting erosive pressure on the beach and posing ongoing threats to properties along the frontage.



(Source: John Akerman, 27 February 2015)

Image 1. Church Norton Spit and Pagham Beach

ARUN DISTRICT COUNCIL P/93/15/PL

The evolution of the spit has also resulted in a situation where shingle is not being allowed to enter into the natural longshore sediment transport pathways. Instead, it continues to be 'locked up' within the shingle spit and is not being moved ashore because of the strong flows occurring through the now elongated tidal channel. As a result of this process, the properties up-drift of the sediment transport pathway (at the western end of Pagham Beach) are vulnerable to ongoing erosion and potential flooding.

Whilst necessary intervention measures have been undertaken, in recent years, to protect the properties (and beach) that are threatened from erosion where the tidal channel has formed, these measures are inherently reactive to shoreline changes. As such, these measures are comparatively localised short-term solutions to a wider, ongoing and evolving problem. By contrast, the proposed breaching of the Church Norton Spit offers an opportunity for more sustainable/natural, longer-term, and spatially more extensive, coastal protection improvements for the whole coastal system as well as benefits to human health and site amenity.

On behalf of the PPC and PFDSG, ABPmer is undertaking a sequence of studies to build up the evidence-base required to inform this proposal. These studies are addressing details about its feasibility, its proposed design and its environmental impacts. This information is designed, ultimately, to inform a planning application for this work. To date, ABPmer has completed the following two studies:

- An initial review of options (ABPmer, 2015a) as noted above which reviewed the intervention options and identified that the most appropriate coastal management approach at this location would involve creating a breach through the spit that is as natural as possible (i.e. one that allows natural processes to continue operating and avoids introducing an artificial features such as cross-shore training wall structures); and
- A scoping study (ABPmer, 2015b) which highlights the Environmental Impact Assessment (EIA) issues that are relevant for this proposal as well as the consents requirements that will be needed to underpin a planning application for it.

This Breach Design Review is the third report in the sequence of studies. Further details about the objectives and approach of this study are set out in the following sections.

1.2 Report Objectives and Summary Approach

The primary objective of this report is to determine a suitable design for the proposed managed breach of the shingle spit at Pagham (i.e. one that will achieve the desired adjustment of the shoreline towards a more sustainable morphology and, therefore, help alleviate the erosion problems on Pagham Beach). To inform this design work, it was necessary to make an initial review of the likely evolution of the breach and its impacts on the functioning of both Pagham Harbour and the Pagham Beach frontage. Therefore, a secondary outcome of this review is to provide an initial (pre-EIA) understanding about the effects of the proposal and the extent to which the desired outcome of the project can be achieved. This information can then be used to inform consultations with key stakeholders, about the project, during the next EIA stage.

ARUN DISTRICT COUNCIL P/93/15/PL

This report is not, however, intended to act as an impact assessment review for the proposal, as this will be undertaken separately, and in greater detail, within the formal Environmental Statement ES that will be prepared for this proposal (ABPmer, in prep).

A key part of this investigation involved the application of a series of empirical and hydrodynamic models to refine the scheme design, and establish the likely changes that will occur from the present (evolving) condition and the proposed breach scenario(s). The findings of this work were interpreted using expert judgement and were evaluated in the context of past analogue examples in order to provide a robust interpretation of the results.

In order to achieve these objectives, this report has been structured into the following sections which encompass the tasks that were undertaken:

- Data Collation and Field Survey Work (Section 2);
- Development of Digital Terrain Model (Section 3);
- Review of Water Levels and Tidal Prism Volumes (Section 4);
- Breach Design Development (Section 5);
- Breach Design Numerical Modelling (Section 6);
- Predictions of Future Breach Evolution (Section 7); and
- Conclusions (Section 8).

ARUN DISTRICT COUNCIL P/93/25/PL

2. Data Collation and Field Survey Work

2.1 Data Collation

The development of a suitable breach design (that will achieve objectives described previously) needed to be underpinned by available data describing the topographic, bathymetric and hydrodynamic conditions of the environment. This was required to: inform the modelling work, assist with developing a conceptual understanding of physical processes at Pagham Harbour and to ascertain historical changes that have occurred.

For Pagham Harbour and the adjacent beach there is already an extensive amount of available data including information collated under, or held by: Environment Agency (EA), Southeast Strategic Regional Coastal Monitoring Programme, Adur and Worthing Council and the Channel Coastal Observatory (CCO). Therefore the first step for this study was to collate this data and identify any key gaps that might exist.

In the first instance available topographic and bathymetric data was collated to describe the morphology of the environment both now and historically. A list of key datasets collated for this project is provided within Table 1, whilst a summary is provided below:

- Light Detection and Ranging (LiDAR) Data (2001 to 2014);
- Topographic Real Time Kinematic (RTK) GPS Data (2007 to 2009);
- Topographic All-Terrain Vehicle (ATV) Laser Scan Data (2012 to 2015);
- Photogrammetric Data (2003 to 2007); and
- Bathymetric Survey Data (2006 and 2014).

Table 1. Existing topographic and bathymetric survey data collated

Date	Spatial Coverage	Data Type	Survey Method
Summer 2001	Pagham Harbour	Baseline	1:3000 Photogrammetry
10/03/2003	Selsey to Brighton	Baseline	1:3000 Photogrammetry
23/04/2004	Inner Owers to Pagham	Profile	1:3000 Photogrammetry
05/07/2004	Inner Owers	Bathymetric	Single Beam
06/07/2004	Pagham Harbour	Bathymetric	Single Beam
22/08/2004	Inner Owers to Pagham	Baseline	1:3000 Photogrammetry
05/11/2004	Inner Owers	Bathymetric	Single Beam
22/04/2005	Pagham Harbour	Baseline	1:3000 Photogrammetry
27/05/2005	Inner Owers to Pagham	Profile	1:3000 Photogrammetry
17/09/2005	Inner Owers	Profile	1:3000 Photogrammetry
19/09/2005	Pagham Harbour	Profile	1:3000 Photogrammetry
27/10/2005	Inner Owers to Pagham	Profile	1:3000 Photogrammetry
10/04/2006	Pagham Harbour	Baseline	1:3000 Photogrammetry
12/06/2006	Inner Owers to Pagham	Profile	1:3000 Photogrammetry
08/09/2006	Inner Owers to Pagham	Profile	1:3000 Photogrammetry
10/10/2006	Pagham Harbour	Bathymetric	Single Beam
03/11/2006	Inner Owers	Bathymetric	Single Beam
08/12/2006	Selsey to Pagham	Baseline	LiDAR

ARUN DISTRICT COUNCIL P/93/15/PL

Date	Spatial Coverage	Data Type	Survey Method
30/01/2007	Pagham Harbour	Baseline	LiDAR
02/03/2007	Pagham Harbour	Baseline	1:3000 Photogrammetry
27/09/2007	Inner Owers	Profile	RTK GPS
08/10/2007	Pagham Harbour	Profile	RTK GPS
06/01/2008	Selsey to Brighton	Baseline	LiDAR
31/01/2008	Pagham Harbour	Baseline	LiDAR
12/03/2008	Pagham Harbour (Post Storm)	Profile	RTK GPS
02/09/2008	Inner Owers	Profile	RTK GPS
14/10/2008	Pagham Harbour	Profile	RTK GPS
11/11/2008	Pagham Harbour (Post Storm)	Profile	RTK GPS
16/12/2008	Pagham Harbour (Post Storm)	Profile	RTK GPS
31/01/2009	Pagham Harbour	Baseline	LiDAR
24/05/2009	Inner Owers	Profile	RTK GPS
20/08/2009	Pagham Harbour	Profile	RTK GPS
01/12/2009	Selsey to Pagham	Baseline	LiDAR
13/05/2010	Pagham Harbour	Baseline	LiDAR
11/10/2010	Pagham Harbour	Baseline	LiDAR
03/02/2011	Selsey to Pagham	Baseline	LiDAR
28/09/2011	Selsey to Pagham	Baseline	LiDAR
08/03/2012	Selsey to Pagham	Baseline	LiDAR
05/09/2012	Selsey to Pagham	Baseline	ATV Laser Scan
29/10/2012	Inner Owers to Pagham (Post Storm)	Baseline	ATV Laser Scan
26/11/2012	Pagham Harbour IN	Survey	ATV Laser Scan
30/11/2012	Pagham Harbour OUT	Survey	ATV Laser Scan
26/02/2013	Selsey to Pagham	Baseline	ATV Laser Scan
12/03/2013	Pagham Harbour	Baseline	LiDAR
10/09/2013	Selsey to Pagham	Baseline	ATV Laser Scan
08/01/2014	Pagham Harbour (Post Storm)	Baseline	ATV Laser Scan
20/02/2014	Selsey to Pagham	Baseline	ATV Laser Scan
30/03/2014	Pagham Harbour	Baseline	LiDAR
15/09/2014	Selsey to Pagham	Baseline	ATV Laser Scan
25/11/2014	Pagham Harbour Inlet Channel	Bathymetric	Single Beam
27/01/2015	Selsey to Pagham	Baseline	ATV Laser Scan

In addition to this information further data was then also collated to describe the historical and baseline hydrodynamic conditions including:

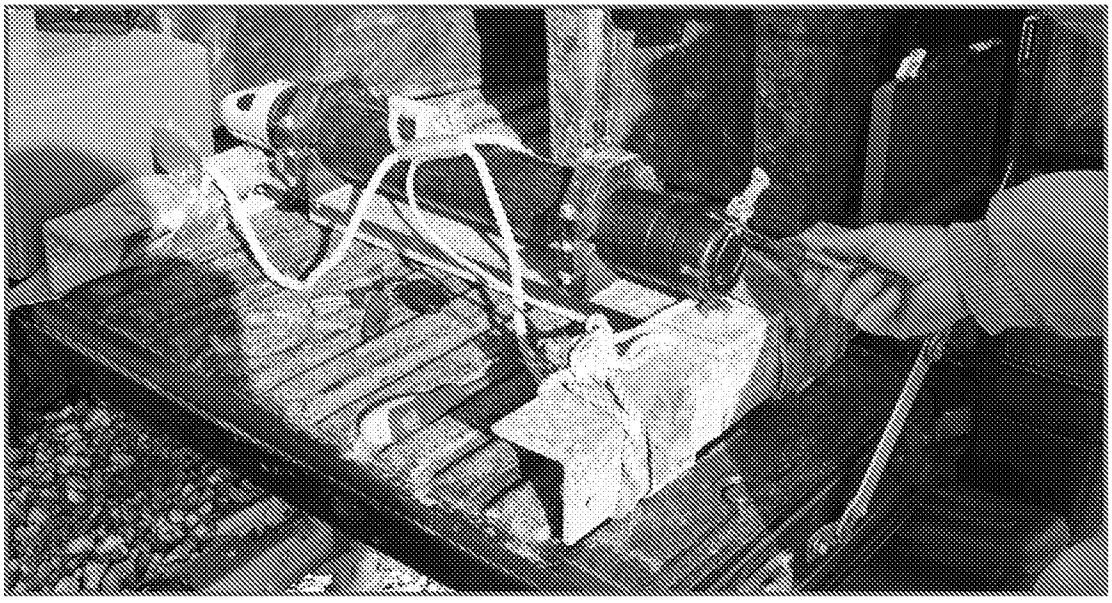
- Rustington Wave Buoy Data (2003 to 2015);
- Pagham Outfall Tide Gauge Data (2002 to 2015);
- Aerial Photographs (various); and
- Historical charts, maps and drawings.

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2.2 Field Survey Work

Following a detailed review of the data presented in Section 2.1, a number of data gaps were identified within the harbour (and along the inlet channel). Specifically, insufficient data was available to allow the appropriate calibration and validation of a hydrodynamic model for Pagham Harbour. In order to address some of these data gaps, ABPmer undertook bespoke surveys between the 5 March 2015 and 14 March 2015. These surveys comprised the following:

- The deployment and recovery of a Nortek Current Profiler (see Image 2) within the main internal channel (adjacent to the training wall) in order to collect water level, flow speed and flow direction data on both spring and neap tides. Two separate surveys were undertaken to describe conditions at two locations within the primary Pagham Harbour drainage channel. The positions of these deployments are shown in Image A1 (see Appendix A); and
- A GPS topographic survey in order to determine bathymetry within both the main internal channel and the adjacent secondary channel (i.e. to the south-west). Further information regarding this survey is provided in Section 3.2.



(ABPmer, March 2015)

Image 2. Nortek current profiler prior to being deployed within Pagham Harbour

2.3 Key Supporting Documents

For this study, further information was also provided by a variety of studies and assessments that have already been undertaken for Pagham Harbour, particularly with respect to the ongoing evolution of the spit and the potential necessity for coastal defence works. These key studies provide a vital context for this analysis and include the following:

ARUN DISTRICT COUNCIL P/93/15/PL

- Pagham Coast Defence Study – Geomorphological Assessment (Royal Haskoning, 2009);
- Pagham Beach Coastal Defence Project – Environmental Report (Royal Haskoning, 2013);
- Pagham Harbour Beach Management Plan Report (Worthing Borough Council, 2014);
- Geomorphological advice in respect of Pagham Spit, West Sussex (Orford, 2009, 2013 and 2014);
- Potential future development of the Church Norton Spit at Pagham (Dornbusch, 2014); and
- Coastal erosion associated with a tidal inlet: Pagham, West Sussex (Barcock and Collins, 1991).

ARUN DISTRICT COUNCIL P/93/15/PL

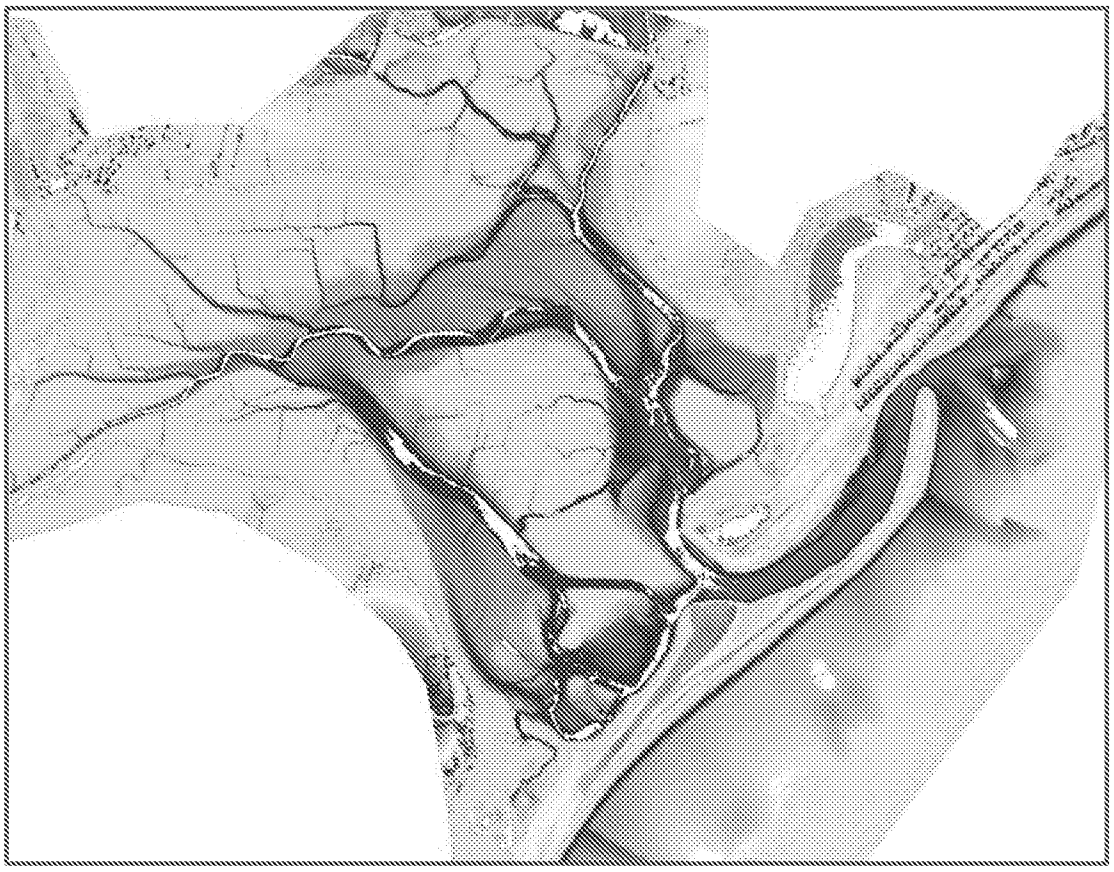
3. Development of Digital Terrain Model

Following the collation of available data, the key next stage in the development of a suitable breach design involved the creation of an up-to-date digital terrain model (DTM) using a Geographic Information System (GIS). The DTM provides the bathymetric grid for subsequent numerical modelling but is also important for calculating key parameters such as the tidal prism within the harbour (i.e. the volume of tidal exchange through a full tidal cycle as dictated by the morphology of the inlet).

3.1 Initial DTM Development

As a first stage in the DTM creation process, an initial DTM for Pagham Harbour was developed using a combination of the most up-to-date existing data (see Table 1). Datasets were integrated together using the ArcGIS 10.2 'Mosaic to New Raster' tool, which created one seamless DTM with the most recent data taking precedence over the older data.

The base of the DTM was created using LiDAR data for the whole of Pagham Harbour (recorded on 30 March 2014 by EA). The LiDAR data was gridded at 1 m resolution, thus providing a detailed representation of the intertidal morphology within the harbour (Image 3).



(Environment Agency, March 2014)

Image 3. LiDAR elevation map of Pagham Harbour

ARUN DISTRICT COUNCIL P/93/25/PL

This intertidal information was further enhanced by data collected during the most recent All-Terrain Vehicle (ATV) Laser Scan survey (recorded on 27 January 2015 by Adur and Worthing Council), which was integrated into the DTM. This dataset consisted of 1.47 million elevation points and provided the most recent data describing the morphology of the Church Norton Spit feature and entrance to the harbour (including Pagham Beach). This data was also gridded at 1 m resolution, utilising an intricate mask that followed the exact outline of the data supplied to ensure that the topographic data was represented accurately.

In addition to these topographic (intertidal) areas, the DTM also required bathymetric (subtidal) data to describe the nearshore region, the inlet channel and internal harbour channels. The nearshore region is described using data recorded during a single beam bathymetric survey in 2006[2], which extends to approximately 1 km offshore of MLW. Within the inlet channel, data was collected at the distal end of the spit during a single beam survey (recorded on 25 November 2014 by EA) using a remotely operated Arc boat (Sontec RiverSurveyor). However, no bathymetric data was available for the inner sections of the inlet channel and within the internal harbour channels.

3.2 Further DTM Development

Although a large amount of existing topographic and bathymetric data was available to the study, considerable data gaps were identified within the subtidal channels during the creation of the DTM. In order to address some of these data gaps, ABPmer collected additional bathymetric data through a bespoke GPS topographic survey that was undertaken on the 5 March 2015 and 14 March 2015 (see Image 4).



(ABPmer, March 2015)

Image 4. Collecting bathymetric data within Pagham Harbour

[2] A more recent bathymetric survey was undertaken in the nearshore region in 2011, however, this data is subject to data quality/accuracy issues and has been excluded from this study.

ARUN DISTRICT COUNCIL P/93/15/PL

For this survey, ground elevation readings were taken across transects along a 150 to 200 m section of the main channel, adjacent to the existing training wall, and across the entrance to the secondary south-western channel. The location of the area covered by the ABPmer survey work is provided in Figure 2.

The data gaps in this section of the harbour were considered to be most critical, primarily due to the proximity of the potential breach design, but also due to the 'branching' nature of the primary and secondary internal channels. Based upon the available bathymetric data, depths were estimated elsewhere along the inlet channel (i.e. between the site of the ABPmer topographic survey and area where single beam survey records had been taken), and through the immediate nearshore region to connect with the 2006 bathymetric dataset.

Due to safety and accessibility issues, bathymetric data was not collected within the smaller internal channels across the rest of Pagham Harbour. As such, depths within these channels were interpolated based on the lowest elevations that were available for the adjacent areas in the 2014 LiDAR dataset. This methodology was considered to be most appropriate and in keeping with previous studies (James Bovington, Pers. Comm., March 2014).

During the process of estimating and interpolating channel morphologies for areas where no data was available, it is likely that the depths of these channels were slightly underestimated particularly within the more dominant channels. This is, in turn, likely to underestimate the full tidal prism values for the harbour and add an element of confidence to the analyses of breach stability as undertaken later in this review (see next section).

These new datasets (including the estimations) were also integrated into the DTM using the ArcGIS 10.2 'Mosaic to New Raster' tool, thus providing the most up-to-date and accurate DTM available for Pagham Harbour. This finalised DTM, including the relevant data sources, is illustrated in Figure 2.

ARUN DISTRICT COUNCIL P/93/25/PL

4. Tidal Volumes in Pagham Harbour

When developing the proposed breach design, it is important to have a clear understanding about the volume of tidal water that will pass through the breach on spring and neap tides. Therefore, to clarify these volumes, the water levels at the harbour were reviewed, and a tidal volume (prism) analysis was undertaken. This analysis will assist in the development of an appropriate breach design, specifically providing input parameters to allow an assessment of inlet (breach) stability. Further details about the analysis, and the values obtained, are presented in the following sections.

4.1 Water Levels

Tides at Pagham Harbour are macro-tidal in nature, experiencing a mean spring and neap tidal range of approximately 4.85 m and 2.40 m, respectively. These values are an average of the standard tidal levels presented for Selsey Bill and Pagham in Table 2, the locations of which are further along the coast to the south-west and north-east of the harbour. Some minor discrepancies between these standard tidal levels have been identified in previous studies (e.g. Royal Haskoning, 2009; Worthing Borough Council, 2014), however, the values presented in Table 2 are those most recently provided by the UK Hydrographic Office (UKHO, 2014).

Table 2. Standard tidal levels

Tidal Level		Selsey Bill (M12) (mODN)	Pagham (M12A) (mODN)	Pagham Harbour (mODN)
Highest Astronomical Tide	HAT	2.80	3.05	2.93
Mean High Water Springs	MHWS	2.30	2.55	2.43
Mean High Water	MHW	1.75	1.90	1.83
Mean High Water Neaps	MHWN	1.20	1.25	1.23
Mean Sea Level	MSL	0.00	-0.50	-0.25
Mean Low Water Neaps	MLWN	-1.10	-1.25	-1.18
Mean Low Water	MLW	-1.70	-1.90	-1.80
Mean Low Water Springs	MLWS	-2.30	-2.55	-2.43
Mean Spring Tidal Range (MHWS – MLWS)		4.60 m	5.10 m	4.85 m
Mean Neap Tidal Range (MHWN – MLWN)		2.30 m	2.50 m	2.40 m
Note: The tidal levels presented for Pagham Harbour are an average of those for Selsey Bill and Pagham.				

(Source: UKHO, 2014)

4.2 Tidal Volume Analysis

4.2.1 Hypsometry Assessment

Based upon the tidal levels for Pagham Harbour provided in Table 2, a hypsometry assessment of water volume within the harbour has been undertaken. This assessment effectively identifies the volume of water between a specific elevation (e.g. MHWS) and the topography (taken from the DTM), the results of which are provided in Table 3.

ARUN DISTRICT COUNCIL P/93/25/PL

Table 3. Hypsometry assessment results for Pagham Harbour

Tidal Level	Elevation (mODN)	2D (m²)	Surface (m²)	Volume (m³)
MHWS	2.43	2,657,989	2,677,965	2,800,841
MHW	1.83	1,732,061	1,744,395	1,400,765
MHWN	1.23	1,028,944	1,034,059	593,222
MSL	-0.25	64,463	64,580	14,653
MLWN	-1.18	6,700	6,714	2,418
MLW	-1.80	634	634	67
MLWS	-2.43	0	0	0`
Please note that the area and volume values are expressed to nearest 1m² or 1m³ based on GIS analysis. This implies a higher level of accuracy than is possible with the data available and also it should be emphasised there will also be an inherent variation in these levels due to large number lunar, environmental and climatic factors.				

The tidal hypsometry reflects the fact that the topography (bathymetry) within the harbour is predominantly elevated above MSL (-0.25 mODN). As a consequence the volume of water below MSL only accounts for approximately 0.5% of the total volume at MHWS. This volume will be limited to the deeper internal harbour channels, with the majority of the harbour drying out towards low water.

4.2.2 Tidal Prism Volume

Given the hypsometry assessment results presented in Table 3, the tidal prism volumes of Pagham Harbour can be calculated. For example, the spring tidal prism is equivalent to the MHWS volume (2,800,841 m³) minus the MLWS volume (0 m³). As such, the tidal prism values for Pagham Harbour are as follows:

- Spring Tidal Prism (MHWS-MLWS): 2,800,841 m³;
- Mean Tidal Prism (MHW-MLW): 1,400,699 m³; and
- Neap Tidal Prism (MHWN-MLWN): 591,000 m³.

Importantly, these tidal prism values deliberately encompass the harbour area only and do not include the volumes within the now extended inlet channel. This inlet would be blocked and would not have any functional effect on the tidal prism once the proposed managed breach scheme has been implemented.

These tidal prism volumes results are based on the most up-to-date DTM available for this study (described in Section 3.2), which recognises that the depths within the internal harbour channels will be slightly underestimated. As such, these tidal prism volumes will be marginally lower than the 'actual' volumes.

ARUN DISTRICT COUNCIL P/93/25/PL

5. Breach Design Development

Based on the information collected and the tidal prism and hypsometry volumes calculated, this section identifies the appropriate location and dimensions of a suitable breach. The aim of this work is to create a new inlet into the harbour which is as stable as possible while also recognising that it will evolve and change over time as has been the case historically at this site.

In the context of the dynamic environment (and especially the mobile nature of the shingle within which this inlet will be created), the aim is to create a design that accommodates the flows and also has sufficient jetting (scour) potential to keep the inlet clear of material transported into the breach; without destabilising (eroding) the breach itself. Whilst the majority of this material is derived from offshore sources, e.g. Kirk Arrow Spit and the Inner Owers shingle banks, transport across the Pagham Harbour frontage is predominantly driven by nearshore littoral (longshore) drift processes (ABPmer, 2015a).

The breach design methods are described in Section 5.1 below and the overall process of breach design (including identifying the location and dimensions) is set out in Section 5.2.

5.1 Breach Design Methods

As part of the design process for the proposed managed breach of the Church Norton Spit, a variety of methods/calculations have been employed by ABPmer to provide an indication of realistic breach dimensions (i.e. width and depth) given a range of input parameters (e.g. tidal prism and hypsometry). These methods can be broadly categorised into two types as follows:

a. Empirical approach – this is based on understanding how past case-example breaches have evolved and especially the lessons they provide about the relationship between the cross-sectional area and the tidal prism; and
b. Mass-continuity approach – this is based on more site-specific examination of the pattern of tidal flows through a proposed breach which is, in turn, influenced by the particular topography of the site.

5.1.1 Empirical Approach

Empirical relationships make use of data from existing case study sites to obtain estimates of breach width or cross-sectional area from other parameters. This method assumes that the case studies used are in an equilibrium state. One of the simplest relationships is between the minimum cross sectional area of a breach (inlet) and the tidal prism of a site. This is given by the following form:

$$A_E = CP^n \quad (1)$$

Where:

A_E = Breach (inlet) cross sectional area (m^2)
P = Tidal Prism (m^3)
C and n = constants derived from regression equations

ARUN DISTRICT COUNCIL P/93/15/PL

This form of equation is the most widely used approach to determine the cross-sectional area of a breach. The C and n constants vary depending on the forcing processes, and so the choice of appropriate constants must be determined from regression analysis incorporating a large number of inlets of similar characteristics.

The most applicable empirically derived constants for this method are those by Hume and Herdendorf (1993), where C = 0.0004 and n = 0.9128. These values were calculated using a variety of open embayment, elongated embayment and inlet/estuary case studies. Despite limitations associated with this method (because it doesn't account for the specific hydrodynamic and morphodynamic conditions of a site), it can be used to provide an indication of how the cross-sectional area of a breach varies depending on the tidal prism. This is particularly useful when data is limited (e.g. sediment properties, tidal inundation period etc.) as it provides a quick and easy method of obtaining an approximate breach cross sectional area.

The cross-sectional area versus tidal prism relationship method has, however, been further developed by Hughes (2002). The method assumes that the maximum discharge (per unit width) through a breach is in equilibrium with depths across the minimum cross-section. This is represented as:

$$A_E = \left\{ \frac{W^{1/9}}{[g(S_s-1)]^{4/9} d^{1/3} T^{8/9}} \right\} P^{8/9} \qquad (2)$$

Where:

A_E	=	Breach (inlet) cross sectional area (m²)
W	=	Inlet width (m)
g	=	Gravitational acceleration
S_s	=	Sediment specific gravity
d	=	Median grain diameter (m)
T	=	Tidal period (s)
P	=	Tidal Prism (m³)

This method takes account of the tidal period, mean grain diameter, specific gravity as well as the tidal prism. Therefore, this method is considered to be more robust than using the Hume and Herdendorf (1993) constants.

Whilst other simplistic empirical methods for determining appropriate breach cross sections (and widths) also exist (e.g. Burd et al., 1994), the Hume and Herdendorf (1993) and Hughes (2002) methods are considered more relevant to this study. Like Pagham Harbour, these methods are typically derived from case studies in non-cohesive (i.e. sand and shingle) rather than cohesive (mud and clay) environments.

5.1.2 Mass-Continuity Approach

The mass-continuity approach involves a closer examination of the site-specific physical conditions than the empirical methods discussed in the preceding section. This approach uses the mass-continuity equation to relate the changing volume of water within the site throughout the tide (i.e. the hypsometry), with the flow rate into and out of the site. By constraining the maximum flow rate as the maximum velocity before erosion of the bed material occurs, the required cross-sectional area of the breach (ensuring no erosion) can be determined.

ARUN DISTRICT COUNCIL P/93/25/PL

There are several assumptions attributed to this method as follows:

a. The sediment type is relatively uniform;
b. The topography across the site is relatively uniform, with negligible surface gradients; and
c. The frictional effects of the flow are negligible (although these effects can be accounted for).

A comparison of estimated against measured breach widths (from sites where the seawall has historically failed) was undertaken by Townend (2008), which found that the mass-continuity approach under-predicted the breach width. However, Townend (2008) further concluded that the mass-continuity approach was preferable to the empirical methods as it accounts for different hydrodynamic and morphodynamic conditions of the site, whilst the accuracy of the estimates is determined by data availability. It should be recognised though that both the empirical and mass-continuity methods presented should not be used in isolation, but importantly, they should be used as part of a wider 'tool kit' to assist in the development of a suitable breach design.

5.2 Developing the Breach Design

5.2.1 Breach Location

When choosing an appropriate location for a potential breach against the objectives of the project, many factors need to be taken into consideration, such as the topography within the harbour, proximity to the tidal channels and the ability for the harbour to inundate and drain under normal conditions (i.e. over a tidal cycle).

Given the topography of Pagham Harbour, with a centralised main channel adjacent to the existing training wall, breaching through the spit at this central location is considered to be the most appropriate option. It is proposed that the material excavated from the breach would be side-cast into the inner section of the existing inlet channel, thus closing this extended channel, whilst also providing a new north-eastern bank for the harbour inlet; effectively extending the end of the training wall into the proposed breach. Breaching at a centralised location would replicate a similar scenario seen in 1978, after which time the harbour inlet (and channel) was relatively stable for a period of circa 40 years recognising that some regular shingle maintenance activities were undertaken (ABPmer, 2015a).

A centralised breach design allows for an effective exchange of tidal volume through the inlet, whilst also offering a relatively simple and achievable engineering solution. The breach would also avoid the significant volume of material locked within both the spit to the south-west and the more expansive tidal delta found to the north-east, thus considerably reducing the volume of translocated shingle and associated construction costs. The breach will, however, be subject to some morphological evolution with time, in which the inlet is likely to develop towards a more natural form. In doing so, the orientation of the inlet and channel may turn slightly anticlockwise (i.e. towards the north-east), allowing for a more natural sinusoidal channel shape through the spit.

ARUN DISTRICT COUNCIL P/93/25/PL

5.2.2 Breach Dimensions

The next stage of developing a breach design is to identify a suitable depth and width (cross-sectional area) of the breach, allowing the site to effectively inundate and drain, whilst being sufficiently wide and deep to ensure that it forms a stable configuration; given the flow regime through the breach and the critical erosion thresholds of local sediments.

Based upon the bathymetric data collected during the ABPmer GPS topographic survey (described in Section 3.2), the depth of the existing harbour inlet channel in proximity to the proposed breach location is around -1.80 mODN; although the channel can be slightly deeper in localised pockets. As such, this value is considered as an appropriate sill level (depth) for the proposed breach, allowing sufficient drainage from the harbour over the ebb tide. Coincidently, a sill level of -1.80 mODN is equal to the MLW tidal level within the harbour (see Table 2).

Using the breach design methods described in Section 5.1, the likely minimum and maximum breach widths have been calculated. These values are provided in Table 4. The range of widths determined by each method take into consideration variations in the tidal prism (i.e. spring, mean and neap) and sediment characteristics (where this is an input parameter).

Due to the nature of the gravelly material found across the spit and within the inlet channel, predominantly supplied through longshore transport, the calculations have assumed the D_{50} will typically range between 0.01 m (10 mm) and 0.05 m (50 mm); although both finer and coarser fractions of material will also be present in the spit. Furthermore, it is important to note that the breach widths provided in Table 4 assume a schematic rectangular breach, rather than an 'engineered breach' with appropriate side slopes.

Table 4. Indicative breach widths calculated using the breach design methods

Method	Approach	Sill Depth (mODN)	Minimum Breach Width (m)	Maximum Breach Width (m)
Hume & Herdendorf (1993)	Empirical	-1.80	48	198
Hughes (2002)	Empirical	-1.80	10	46
Townend (2008)	Mass-continuity	-1.80	37	65

The indicative breach widths calculated using the various design methods indicate absolute minimum and maximum widths of 10 m (Hughes, 2002) and 198 m (Hume & Herdendorf, 1993), respectively. These values are useful for deriving the range of potentially suitable widths based on the available breach calculations. However, this is a wide range and it is necessary to draw upon experience to refine this and identify the most realistic options.

Based upon previous case studies (e.g. Medmerry and Porlock) and expert technical opinion, it is concluded that the extremes of this range, while they provide a level of sensitivity testing to the analysis, are likely to be unrealistic. Instead the centre of this range (between 37 and 65 m), as indicated by the Townend (2008) method, is likely to appropriate breach width below MHWS.

ARUN DISTRICT COUNCIL P/93/25/PL

6. Breach Design Modelling

The breach design calculations described within the preceding section provide a good initial indication of suitable breach dimensions and show that a width of between 37 and 65 m below MHWS is likely to be most appropriate at this location. However, this should only be considered as an initial step in the breach design process and a 'multiple tool kit' approach should be adopted to provide confidence in the analysis.

To take this analysis forward, a MIKE21 FM numerical hydrodynamic model was developed for Pagham Harbour in order to assist in the optimisation of a suitable breach design; thus providing additional confidence and allowing a range of different breach designs to be tested. In this model, a domain was created using both triangular and quadrangular model elements (mesh) to describe the study area, with bathymetric data interpolated into the model from the DTM; described in Section 3. This mix of triangular and quadrangular elements allows for a more accurate representation of the breach and internal channels, which had been previously adopted in the model studies for the successful Medmerry managed realignment scheme (ABPmer, 2014).

The model is then driven at the boundary by a water level time-series dataset, extracted from ABPmer's regional English Channel model. Calibration and validation of the model has been achieved against ABPmer spring and neap tide survey data (see Section 2.2) and Environment Agency tidal gauge data (recorded at Pagham Rife) at the back of the harbour; i.e. to achieve a good representation of the present day (baseline) scenario.

In order to represent a breach within the model, the model mesh was adapted to create a new channel (breach) through the existing shingle spit. The width and depth of this channel could be varied, depending upon the design of the breach to be tested, whilst the existing inlet channel was infilled adjacent to the breach. Any changes to the model were localised to the proposed managed breach location, with no modifications made to the wider domain. Full details of the hydrodynamic model are provided in Appendix A.

The model was used to examine tidal exchange through a variety of breach designs, and in identifying changes to the hydrodynamics of the harbour (i.e. water levels and flow speeds) between the present day and a proposed managed breach of the shingle spit. This work was done in two logical stages. Firstly an initial schematic (rectangular) breach shape was tested (see Section 6.1) then based on the information obtained and more realistic and 'refined' breach (shaped with more natural side slopes and a recognition as to how the breach will function and how it can be most efficiently excavated) was trailed through the modelling process (see Section 6.2).

6.1 Stage 1 'Schematic' Breach Design Modelling

For this initial analysis, a number of schematic (rectangular) breach designs were initially tested in order to understand the likely influence of a breach on the hydrodynamic conditions within the harbour and through the breach (inlet) channel. These schematic designs were principally

ARUN DISTRICT COUNCIL P/93/25/PL

determined based upon the outcomes of the breach design method analysis (described in Section 5.2.2), with a sill level of -1.8 mODN and breach widths of 40 and 60 m, respectively[3].

An additional 80 m wide breach was also tested, in order to consider a breach of a similar width to the internal channel (adjacent to the training wall). The breach (inlet) channel for each scenario was aligned with the existing training wall, as detailed in Section 5.2.1.

6.1.1 Model Results

Outputs from model testing of the schematic breach design indicated that water levels and flow speeds (depth-averaged) within the breach channel, and across the harbour, vary considerably between each scenario. Image 5 presents the differences in the water levels and flow speeds within the centre of the internal channel (approximately half way along the training wall) between the breach scenarios and the baseline condition.

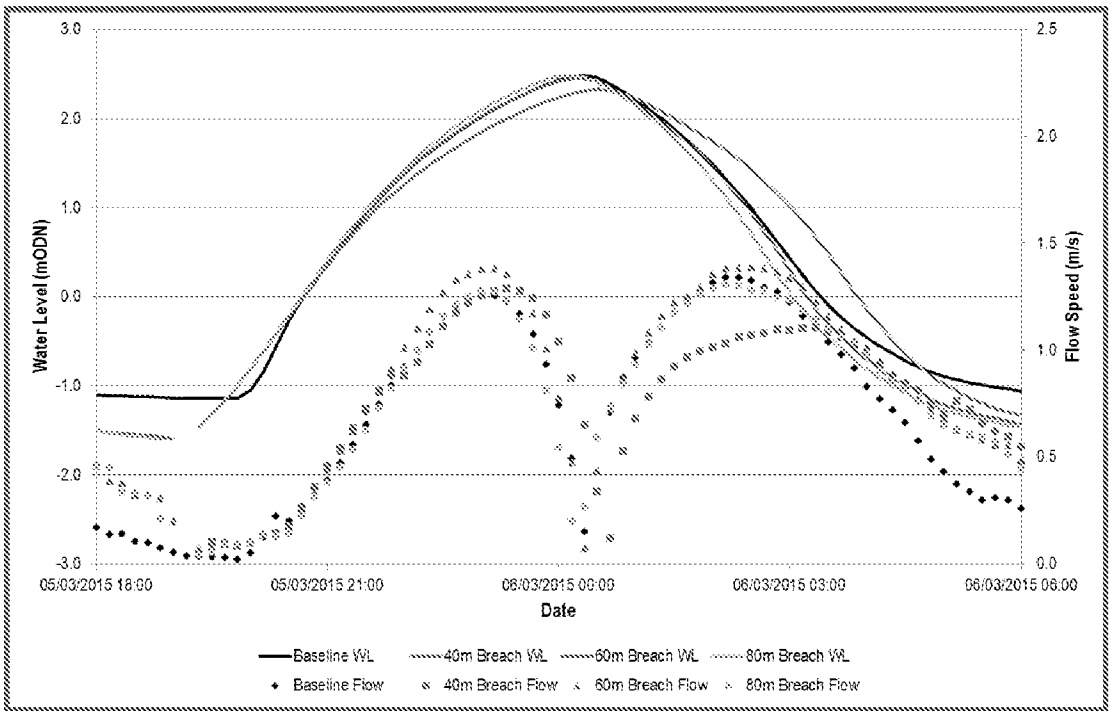


Image 5. Model results for the schematic breach designs (internal channel)

It can be seen within the Image 5 plot that the high water level and flow speeds with the 60 and 80 m breaches are similar to that presently experienced under the existing conditions at the site. However, in each case, there is a change (lowering) of the low water levels as a result of a bathymetric change between the baseline and scheme scenarios and a more efficient drainage of the harbour.

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[3] As the model that has 10 m grid cells, the values of 40m m and 60 m are designed to equate to the preferred range of 37 m and 65 m that were identified from the preceding analysis in Section 5.

ARUN DISTRICT COUNCIL P/93/15/PL

Conversely, the smaller 40 m breach appears to constrain tidal exchange between the harbour and coast, resulting in a skewed tidal curve within the harbour. As a result, the high water level within the harbour, under this narrow schematic breach scenario, is reduced by approximately 0.16 m on a mean spring tide (compared to the baseline), with a prolonged ebb (draining) phase. Furthermore, the skewing of the tidal curve considerably alters the balance of flow speeds experienced within the internal channel, potentially promoting increased sediment transport of coarser material (i.e. sand and gravel) on the flood tide at this location. These results, therefore, indicate that the flood and ebb tides are in balance for the wider breaches but that the narrower channel constraints the tide to reduce the exchange and tidal penetration into the harbour.

Model results extracted from a point within the centre of the breach channel, shown in Image 6, further emphasise both the similarities and differences between the 40, 60 and 80 m schematic breach scenarios. One of the key similarities between the scenarios is the ebb dominance of tidal flows through the breach channel, both in respect to duration and magnitude. However, increased ebb dominance can be clearly seen with the narrowing of the breach (i.e. the 40 m breach compared to the 60 m and then the 80 m scenario).

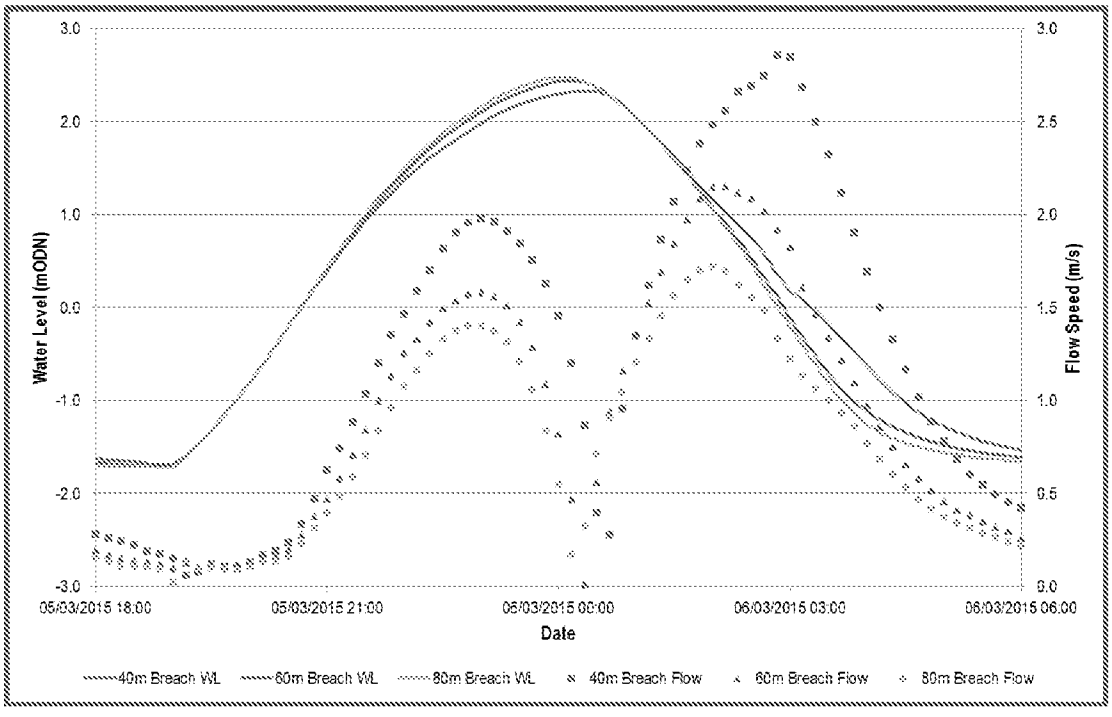


Image 6. Model results for the schematic breach designs (centre of breach)

From the model, the peak depth-averaged flood and ebb flow speeds, and the mean flow speed, within the centre of the breach, have been provided in Table 5 for each breach-size scenario. These values are indicative of flows through the respective breaches, however, slightly higher flows are present in the outer section of the breach channel; which would increase the potential for sediment mobility.

ARUN DISTRICT COUNCIL P/93/25/PL

These flows, generated by tidal exchange at the Pagham Harbour entrance, have been shown, historically, to be effective in interrupting littoral drift at the harbour entrance (Royal Haskoning, 2009). The ebb dominance of the breach channel means that material moved into the channel via littoral drift will be subject to 'flushing' over the ebb tide, thus likely forming a significant ebb tidal delta.

Table 5. Results from the breach testing exercises (mean spring tide)

Breach Width (m)	Cross Sectional Area of Breach (m2)*	Peak Flood Flow Speed (m/s)	Peak Ebb Flow Speed (m/s)	Mean Flow Speed (m/s)
40	169.0	1.97	2.85	1.17
60	253.5	1.57	2.15	0.87
80	338.0	1.40	1.72	0.71
*Values are provided for the cross sectional area between the sill level and MHWS.				

6.1.2 Sediment Mobility Assessment

A high-level assessment of sediment mobility has been undertaken for the schematic breach designs based upon data extracted for a mean spring and neap tides within the centre of the breach channel. This assessment identifies the percentage of time for which bed shear stresses (BSS) within the channel (due to currents only) are sufficient to mobilise a particular material type (e.g. fine gravel); using standard methods described in Soulsby (1997). The results of this assessment are provided in Table 6. It is worth highlighting that the potential effect of waves on sediment mobility has not been taken into account within this assessment, as it is considered that an ebb tidal delta will provide the breach channel with considerable protection from wave activity.

Table 6. Estimated potential sediment mobility

Breach Width (m)	Coarse Sand (1mm)	Fine Gravel (5mm)	Medium Gravel (10mm)	Coarse Gravel (25mm)	V. Coarse Gravel (50mm)
40	85%	59%	47%	21%	6%
60	78%	50%	37%	12%	0%
80	73%	45%	26%	0%	0%
The mobility calculations are based on an assumed gravel bed, which is defined as having a roughness height (Z_0) of 3mm (Soulsby, 1997). Mobility % relates to the percentage of a mean spring tidal cycle.					

It is apparent from Table 6 that bed shear stresses (induced from tidal currents) within the breach channel are sufficiently high to mobilise a range of material types. The results indicate that there is potential for some movement of sand and fine gravel over the flood tide (i.e. into the harbour) under each breach scenario. However, much of this will be deposited within the breach channel itself or within the internal channel (adjacent to the training wall). This material would then be subject to flushing over the ebb tide, feeding the ebb tidal delta.

By contrast, the mobilisation of medium to very coarse gravel fractions will largely be constrained to the ebb tide, when flow speeds are greatest. This being said, larger breaches will struggle to flush gravel larger than 25 mm from within the breach channel, with any such transport limited to the largest spring tides (if at all). The model results also identify that during

ARUN DISTRICT COUNCIL P/93/25/PL

neap tides, the potential for sediment mobility along the breach channel is greatly reduced, with mobilisation restricted to sands and fine gravels (i.e. less than 5 mm) predominantly during the ebb tide. As such, larger material may be deposited within the breach channel over neap tides, although much of this will be flushed during the following spring tides.

6.1.3 Summary of Breach Design Modelling

Following this review of 'schematic breach designs', it is concluded the proposed managed breach of the shingle spit at Pagham would be best achieved through a breach larger in dimension than the 40 m schematic design, but slightly smaller than the 60 m design. This would help ensure that tidal exchange through the breach is sufficient to maintain existing water levels within the harbour, whilst keeping flow speeds through the breach high enough to maximise sediment mobility.

The 80 m breach is considered to be too large, with insufficient flows to keep the breach (inlet) channel sufficiently clear of larger material fractions (i.e. medium to very coarse gravels) throughout a spring-neap tidal cycle. As such, a suitable breach design is ideally expected to have a cross-sectional area (below MHWS) of approximately 200 to 250 m^2. Further analysis to identify a suitable refined design is presented in the following section.

6.2 Stage 2 'Refined' Breach Design Modelling

Based upon the information presented in the previous sections, ABPmer has sought to develop a 'refined', 'realistic' and, therefore, 'proposed' breach design for the managed breach of the shingle spit at Pagham. This more realistic breach needs to have a more natural morphology (e.g. with appropriate side slopes) that integrates more effectively with the local hydrodynamic regimes whilst also recognising the issues for contactors having to excavate this breach in situ.

This refined design, as developed and detailed in Section 6.2.1, has been tested using the hydrodynamic model in order to understand the likely influence of a breach on the hydrodynamic conditions within the harbour, through the breach (inlet) channel and along the Pagham Beach frontage. The results from the hydrodynamic modelling are presented in Section 6.2.2.

6.2.1 Breach Design Characteristics

The developed of the refined breach design takes account of the findings from the testing undertaken for the schematic breach designs, and then further considers the requirement for appropriate side slopes (rather than vertical banks) to account for natural physical processes and engineering constraints.

As described in Section 5.2.1, it is considered that the most appropriate location to breach through the spit will be adjacent to the main internal channel, following an alignment with the existing training wall. More specifically, the north-eastern edge of the proposed breach channel (at HAT) would be aligned with and follow the angle of the seaward end of the training wall through the shingle spit. The breach, with respect to its width, would then be cut in a south-west direction along the Church Norton Spit.

ARUN DISTRICT COUNCIL P/93/25/PL

With respect to developing the preferred/proposed breach shape and dimensions, the schematic review concluded that the breach should be larger than the 40 m but slightly smaller than the 60 m. To achieve this width on average (while also recognising the suitable side slopes are required and the breach will have to be narrower at its base than at its upper elevations) it is proposed that the breach should comprise a central base 40 m channel with a uniform sill depth of -1.8 mODN but have an 80 m in width at +3.0 mODN. Each side of this channel would then slope upwards to +3.0 mODN (approximately HAT) with an approximate angle of 13.5˚, equivalent to a circa 1:4 slope ratio.

Based upon these dimensions, the cross-sectional area of the breach (below MHWS) has been calculated as being approximately 243 m², therefore, within the expected range described in Section 6.1.3. Above HAT there is less emphasis on the breach design, in which the side slopes can be made steeper and in a bid to reduce excavation volumes. An indicative cross-section of the preferred/proposed breach design is illustrated in Image 7, whilst the proposed location of the breach is detailed in Figure 3.

In order to determine realistic slope angles for the breach, analogues have been drawn from the existing inlet channel, where the slopes typically vary between a 1:2 and 1:10 slope ratio depending on the depth, width and orientation of the channel (see Figure 4). In the area of the proposed breach, the steeper slopes tend to have a ratio in the order of 1:3 to 1:5, which is in-keeping with the proposed design. Furthermore, various technical sources suggest that the angle of repose for wet gravel (pebbles) is approximately 30˚, therefore the proposed slope angle should be sufficiently stable.

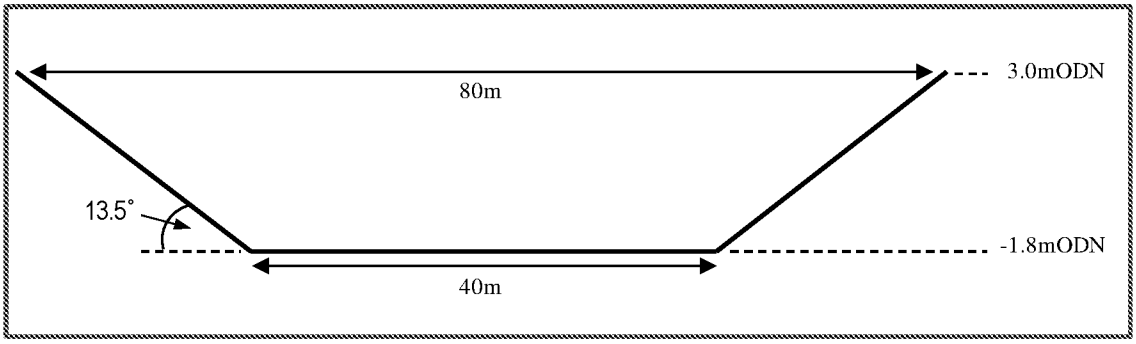


Image 7. Indicative preferred/proposed breach design (not to scale)

It is envisaged that material excavated from the breach would be stockpiled on the spit, before being used to infill (bund) the inner end of the existing inlet channel; prior to breaching. Where possible, it would be appropriate to use coarser material fractions (i.e. medium to very coarse gravels) on the outer section of the bund adjacent to the breach, as this will minimise the likelihood of scour.

Based upon the dimensions of the breach presented above, it has been calculated from the DTM that circa 42,000 m³ of material will be excavated from the breach (below 3.0 mODN) with an expected additional 10,500 m³ being excavated above 3.0 mODN. Given these large volumes of material, along with the proposed breach channel being more hydraulically efficient

ARUN DISTRICT COUNCIL P/93/25/PL

than the existing channel, it is considered unlikely that the existing inlet will re-open post infilling.

Whilst the breach design presented here is the preferred design, this design will be dependent upon any health and safety, time and access constraints during the excavation and infilling works. Separately to this document, the chosen contractor will confirm the methodology (design plan) for achieving the proposed works and identify any risks where necessary.

6.2.2 Model Results

In order to initially assess the effect of the preferred breach design on the hydrodynamic regime, both within Pagham Harbour and along the Pagham Beach frontage, the modelling results for the scheme and baseline (present day) have been compared. For simplicity, the comparison of water levels and depth-averaged flow speeds have been provided as time-series plots at key locations for a mean spring tide, illustrated in Figures 5 and 6. The differences that arise between the scheme and baseline conditions are discussed below.

The model results identify that in the near-shore region, adjacent to the proposed new harbour inlet (breach), water levels are not expected to be noticeably affected through the tidal cycle, except near low water when some harbour drainage influence is indicated (Point 1, Figure 5). Flow speeds in this area will, however, be substantially increased due to the tidal exchange with the harbour (Point 1, Figure 6). Additionally, the tidal signal at this location will become more similar to an estuarine/harbour environment, with distinctive flood and ebb tidal flows.

Peak flows on a mean spring tide are predicted to reach approximately 0.8 and 2.0 m/s on the flood and ebb tide, respectively, thus indicating strong ebb dominance. The model results indicate that the maximum extent of any measureable change outside the harbour (i.e. above 0.1 m/s) will occur no further than 650 m from the breach. In contrast, neap flow speeds at this location are not predicted to exceed 0.4 m/s on either the flood or ebb tide, with little sign of tidal dominance; in respect to both time and speed. Furthermore, as the ebb tidal delta develops with time from the mouth of the harbour, flows are likely to become more constrained along the ebb tidal channel (or along multiple channels).

Within the centre of the breach (inlet) channel (Point 2, Figure 5), no comparison can be made between the baseline and scheme water levels, as this area was previously occupied by the spit. This being said, the scheme water levels identify some retardation of the tide compared to that outside the harbour (Point 1), controlled by tidal exchange through the breach. Flow speeds through the centre of the breach channel identify an ebb tidal dominance, with flood and ebb flow speeds reaching approximately 1.75 and 2.30 m/s, respectively (Point 2, Figure 6).

The model results further indicate that this ebb dominance is increased in a seaward direction along the breach channel, whilst across the width of the breach channel, flow speeds are considerably reduced over the side slopes. Given these flow speeds, sediment mobility within the centre of the channel will be very similar to those calculated for the 40 to 60 m schematic breach scenarios in Section 6.1.2, with lesser mobility (sediment transport) across the slopes of the breach channel; thus reducing the likelihood for slope erosion and instability.

ARUN DISTRICT COUNCIL P/93/25/PL

Over neap tides, flow speeds through the centre of the breach channel are typically no greater than 0.7 m/s, with no distinct flood or ebb tidal dominance. These reductions in flow through the breach clearly illustrate that sediment mobility, particularly of coarser material (i.e. gravels), will be largely restricted to spring tides.

Inside Pagham Harbour, the model results for Points 3 to 7 (Figures 5 and 6) clearly illustrate that the proposed breach design will result in small changes to water levels and flow speeds, compared to the baseline scenario. Changes identified are largely attributed to a small phasing difference in the tide across the harbour and a small reduction in HW, estimated to be approximately 0.05 to 0.06 m over a mean spring tide (less than 0.02 m over neap tides).

This reduction in HW will have implications for the habitats within the harbour which will need to be assessed but it is inherently beneficial with respect to flood risk, effectively lessening any potential for flooding to properties surrounding the harbour, i.e. those at Pagham. The flood risk is also a product of surge activity as well as the standard tidal signal and this aspect too will need to be assessed within the EIA.

This reduction in high water levels occurs because of the flow speed 'throttling effect' through the breach which would occur, deliberately, under the preferred design to increase breach stability. If the breach was considerably larger, (e.g. with a 60 to 80 m base width) then there would be a lesser change to HW; as seen in the schematic breach tests. However, the breach would then be less stable and it would also need considerably more material to be excavated. This, in turn, would make it much more complex to implement (with safety and cost implications).

It is relevant that these anticipated changes in water levels from the proposed breach design are indicative of the initial condition following the excavation work. Any natural readjustment of the breach and inlet channel that occurs as the influences of natural processes take over following the excavation is likely to either increase HW (if the breach widened/deepened) or decrease HW (if the breach narrowed). Such changes will be in keeping with the range of conditions experienced previously given the range of morphologies that have previously existed at the site and the water levels continue to be highly variable and an inherent function of the natural dynamic of the environment in the future.

Changes to flow speeds across the harbour are predominantly characterised by slight reductions on both the flood and ebb tide, with these changes decreasing away from the harbour entrance (largely becoming negligible). Furthermore, the model results indicate that there is no overall impact to tidal dominance along the internal channels and across the intertidal areas within the harbour.

Importantly, due consideration must also be given to the Pagham Beach frontage, where the existing inlet channel has caused considerable erosion to the beach; with the properties becoming vulnerable to future erosion and flooding. Flows along this channel are presently greatest at the distal end of the spit, where the channel is re-orientated seawards around the spit due to the constraint placed on the channel by the groynes and shoreline. The modelling results tend to suggest that the peak flood and ebb depth-averaged current speeds within this

ARUN DISTRICT COUNCIL P/93/25/PL

channel presently reach 0.75 and 1.40 m/s over a mean spring tide[4], respectively (Point 8, Figure 6). However, much higher speeds occur within the surface waters, during large spring tides and in localised areas not sufficiently resolved by the model (i.e. in the vicinity of the rock groynes).

Following implementation of the proposed managed breach, and the associated infilling of the existing inlet channel (at the harbour end), flow speeds within this distil end of the spit would be greatly reduced. The model results predict that peak flow speeds on a mean spring will be in the order of 0.30 m/s, whilst neap flows will not exceed 0.15 m/s. Given these changes, caused by the reduction in tidal prism afforded to the channel following its closure to the harbour, flow speeds will be insufficient to erode gravel sized material; requiring approximately 0.8 m/s and greater (for coarser fractions). As such, the considerable erosion pressure currently placed on the Pagham frontage by the spit and inlet channel will rapidly ease.

In the absence of the strong tidal flows along the closed existing channel, the head of the spit feature down-drift (north-east) of the breach will no longer be subject to migration constraints placed upon it by the channel. As such, under continued wave action and littoral drift processes, the distal end of the spit is likely to close (reconnect) with the Pagham Beach; forming an enclosed lagoon behind the spit. Over time, the material within the spit is likely be winnowed out through ongoing coastal processes, providing a large supply of material to the Pagham frontage and further down-drift.

Should the preferred breach design not be achieved, as described in Section 6.2.1, differences in the hydrodynamic conditions through the breach (inlet) channel and in the harbour are likely to arise from that described above. Should the contractor achieve a considerably smaller design prior to breaching taking place, it is envisaged that flow speeds through the breach (inlet) channel will be greater than those predicted. This would lead to scour potential during the natural adjustment of the breach.

Also, under this scenario, tidal levels within the harbour will be subject to increased retardation; similar to that identified for the schematic 40 m breach design, discussed in Section 6.1.1. Whilst this will have some short-term influences on the hydrodynamic and sedimentary regime along the breach channel and within the harbour, self-adjustment of the breach to an improved morphological equilibrium state will likely be achieved over a full spring tidal cycle; i.e. the breach will be subject to some natural erosion to increase its cross-sectional area.

[4] The model results have been amended at the initial stages of the flood tide (shown by dashed lines) to remove an artificial result, caused by wetting/drying issues associated with hydrodynamic modelling around LW.

ARUN DISTRICT COUNCIL P/93/25/PL

7. Predictions of Future Breach Evolution

7.1 Inlet Stability Assessment

Following its excavation, the stability of the tidal inlet (breach) will be primarily determined by the balance between the rate of sediment supply to the inlet and the flows through the inlet (both tidal and fluvial). Wave action will transport sediment alongshore to the inlet (i.e. littoral drift), acting to close the inlet through deposition within the channel, while flows through the breach will act to erode sediment and hence maintain the inlet cross-sectional area.

An empirical relationship was derived by Bruun & Gerittsen (1960) between the tidal prism and the total sediment transport into the inlet by longshore drift. Gao & Collins (1994) refined this method to also include freshwater flows, although Pagham Harbour is not characterised by significant fluvial input. The outputs from this calculation are then interpreted using the Bruun & Gerittsen (1960) stability criteria, shown in Table 7.

Table 7. Classification of K_c values

Ratio Value	Stability Conditions	
$150 < K_c$	Good conditions, good flushing, minor bar formation	Very High Stability
$100 < K_c < 150$	Less good, offshore bar is more pronounced	High Stability
$50 < K_c < 100$	Rather large bar by entrance, but usually a channel through the bar	Moderate Stability
$20 < K_c < 50$	Typical 'bar by-passer' - storm events provide flushing	Low Stability
$K_c < 20$	Very unstable inlets, mainly just overflow channels	Unstable

Using the spring, mean and neap tidal prisms determined from the DTM in Section 4.2, an inlet stability assessment has been undertaken for Pagham Harbour. In order to account for variations in littoral drift along the harbour frontage, the assessment has considered a range of drift values between 10,000 and 76,000 m³/yr.

These values have been ascertained from previous studies, as described in the ES (ABPmer, in prep), and consider both the present and historical littoral drift rates observed along this coastline in a net north-easterly direction (i.e. from Selsey Bill towards Pagham Harbour). This pathway is determined by the predominant wave direction, which arrives from the south-west and south, albeit with periodic episodes of lesser energetic wave activity from the south-east (Royal Haskoning, 2013). Recent analysis undertaken for this study for the period 2003 to 2014 suggests that the annual drift potential along the coast has varied between approximately 12,000 and 38,000 m³/yr, thus in keeping with previous studies. The results from this inlet stability assessment are provided in Table 8 (colour coded to Kc thresholds).

Table 8. Results of tidal inlet stability assessment (DTM)

Tide	Stability Conditions as indicated by drift potential (m³/yr)					
	10,000	20,000	30,000	42,000	50,000	76,000
Spring	280.08	140.04	93.36	66.69	56.02	36.85
Mean	140.07	70.03	46.69	33.35	28.01	18.43
Neap	59.08	29.54	19.69	14.07	11.82	7.77

ARUN DISTRICT COUNCIL P/93/15/PL

The tidal inlet stability assessment clearly identifies that the stability of the breach is highly dependent upon the tidal volume exchange (prism) and volume of littoral drift material. The assessment has predicted that the breach will be stable during spring tides, with a lessening degree of stability under considerable drift rates (i.e. above 30,000 m³/yr).

In contrast, the breach is predicted to be unstable during neap tides when littoral drift rates exceed 20,000 m³/yr. However, these results do not consider the potential for increased sediment mobility within the breach (inlet), achieved by throttling tidal flows through a narrower breach (particularly on the ebb tide); as is the case with the preferred breach design.

Importantly, there is no evidence to suggest that the inlet has ever closed (infilled) naturally in the past, with historical closures being the result of human intervention. As such, it is predicted that during periods of lesser volumes of littoral drift, the breach (and channel) is likely to remain relatively stable and located in a similar position to the design position, albeit with some self-adjustment. However, during periods of increased littoral drift, bypassing of the inlet is likely to occur, which will result in the formation of a spit rather than the closure of the breach. This process of spit formation, rather than breach (inlet) closure, would be in-keeping with historical evidence, particularly that seen of the past 10 to 15 years.

7.2 Lessons from Similar Sites

When designing any coastal project, and seeking to understand its functionality, it is always beneficial to review previous examples of similar projects and to capture the lessons that have been learned from them. This is especially true for projects (such as the proposed breach of the spit at Pagham Harbour) where there are multiple influencing factors with interactions that can be very difficult to model. In such cases understanding past 'analogues' is, therefore, an additional and valuable scheme verification process.

In this instance the best analogue of spit evolution and breach morphology is actually the frontage at Pagham Harbour itself. This is because this frontage has not existed in a fixed shape but has instead exhibited a variable morphology over time often having breaches of varying sizes and also, rarely, occurring as a closed shingle barrier. Therefore understanding how these past configurations have responded over the last decades and centuries will provide the best indication about how a future managed breach should be designed and how it is likely to function. With this consideration in mind, these historical changes will be examined in greater detail within the subsequent ES.

There are, however, other useful examples of manmade or natural breaches that have been made as part of previous managed realignments or from unmanaged flood events. The stability, shape and evolution of such breaches, where they have been made deliberately for managed realignments, has been reviewed by Nikolaou (2012). This useful review has identified examples where the breaches have been comparatively small and have eroded over time to accommodate the flows of water through them and reach an equilibrium form (e.g. Freiston on the Wash or Hesketh Out Marsh in the Ribble Estuary). They also include examples of breaches that have been made deliberately large to accommodate flows and have remained stable or even accreted over time (Allfleet's Marsh, in the Crouch Estuary).

ARUN DISTRICT COUNCIL P/93/15/PL

These examples of past managed realignment breaches, and the empirical and mass-continuity models for defining breach shapes that have been developed from them, have informed the preceding breach design analysis (while always recognising the distinct characteristics of the environment at Pagham, with its predominantly mobile coarse-grained sediment (shingle and sand)). In the majority of cases these breaches have, however, occurred through relatively fixed sea walls with consolidated clay/mud sediments. By contrast, there are relatively few examples of projects that have specifically involved creating, or allowing the formation of, breaches through shingle barriers. Two key examples are as follows:

- Porlock (Exmoor Coast, Somerset): This involved a 'natural' breach of a shingle spit barrier that occurred during a storm event in 1996. It is often referred to as an unmanaged realignment although the breach was foreseen and allowed to occur in its own time through a deliberate process of non-intervention; and
- Medmerry (Selsey Peninsula, West Sussex): This was a deliberate managed realignment that was undertaken by the Environment Agency and involved the first deliberate excavation of a breach through an open coast shingle barrier in the UK. For this project, a new 7 km-long sea wall was constructed at the back of the site and, following the breaching work, 330 ha of new coastal habitat (183 ha intertidal) was created in front of these walls. ABPmer played a lead role in designing the breach and developing the wider scheme in collaboration with the Environment Agency project team (ABPmer, 2010, Environment Agency 2010).

These projects have each involved breaches through coastal shingle barriers and, in both cases, the breaches have remained in place (18 years in the case of Porlock and 20 months for Medmerry to date). To underpin the present breach design study, further details about these schemes including their background and the post-implementation changes that occurred, are reviewed below.

7.2.1 Porlock

Background

The Porlock site is located on the North Somerset Coast on the south bank of the Severn Estuary. It is an area of formerly low-lying farmland that is fronted by a 5 km-long coastal gravel barrier and was once the longest continuous such bank on the UK west coast of the (JNCC, 2007). In October 1996, a major storm-induced breach occurred in the bank which resulted in the hinterland becoming flooded by tidal waters.

This project is often cited as being an 'unmanaged realignment' because the breach was not deliberately created as would be the case for a managed realignment. Instead the breach was left to develop without intervention. However, it should be noted that unmanaged realignment is not the same as 'accidental' or 'unforeseen' because the risk of flooding was recognised on this site by the National Trust as the landowner. In this case, a clear management decision was taken to not continually rework the bank to prevent inundation of the land behind (as had been done for the previous two centuries).

ARUN DISTRICT COUNCIL P/93/25/PL

This was likely to have been prompted by gradual material depletion in the shingle barrier over time which meant that it was increasingly challenging to keep reshaping the bank. Therefore a decision was made, in the early 1990s to discontinue the active management and allow the coast to adapt naturally in keeping with the National Trust's management principles for their coastal land holdings.

This development at Porlock provided a valuable indication about how breaches naturally-formed and, owing to the uniqueness of the site, a number of studies have been undertaken since. These include studies by Orford (2003) and Bray and Duane (2001) which have informed this review.

Post-breach bank and breach evolution

The barrier at Porlock was orientated parallel to the predominant waves (swash-aligned), with a relatively low net easterly drift rate. In its previous (artificially reworked) form, the shingle was present as a heightened and steepened barrier beach. On the 28 and 29 October 1996, its crest was over-washed and the hinterland flooded. These processes pushed the crest into the back of the barrier area in the form of wash-over fans.

The breach was then formed, as is often typical in unmanaged breaches, by the falling tide as the waters which had overtopped the barrier drained from the site. This process, and the subsequent tidal exchanges at the breach, rapidly cut a tidal drainage channel into the clay substratum (bed). The channel exhibited then a rapid and progressive headward erosion over a distance of more than 180 m. Through this process the channel became long and deep enough to fully drain the site on each tide.

Four months later, in February 1997, a series of major wave events helped to reconsolidate the beach ridge at a new position, some 15 to 25 m landwards of its previous site. Since 1999 there have only be slight changes in the gravel ridge, with this lack of movement and the natural restructuring of the ridge into a broader, lower feature suggesting longer-term stability. However, the barrier is predicted to continue retreating as a result of wave run-up during extreme events, which is likely to increase in the future owing to both sea level rise and possible increases in storminess.

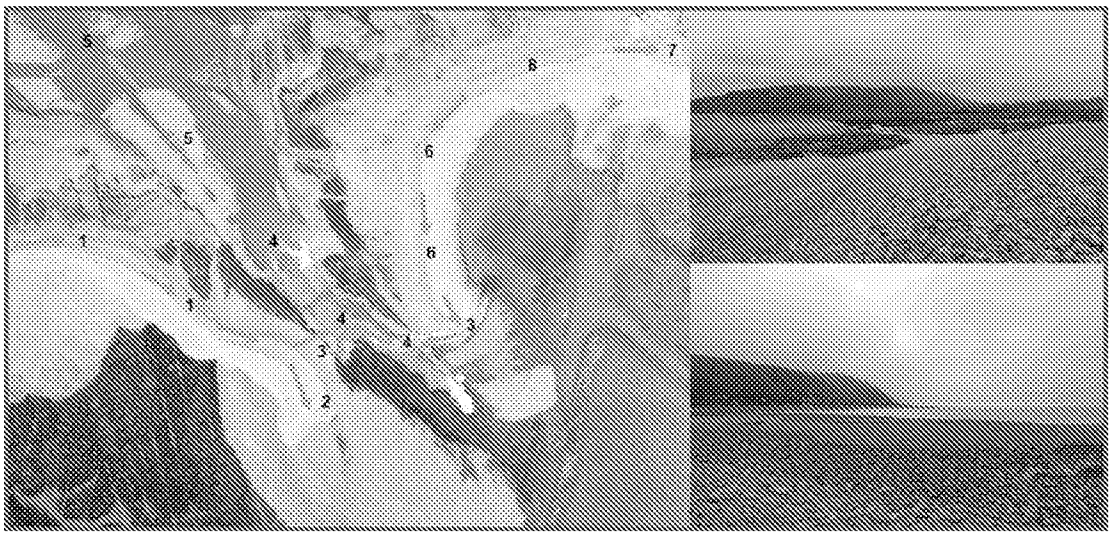
The channel that formed in the breach had an invert elevation of approximately 2.0 mODN, with mean high water springs and neaps of 5.0 and 2.6 mODN, respectively. The breach in the gravel barrier is now approximately 80 m wide, whilst the deeper channel in the breach is approximately 15 m wide. The plan area of the site is approximately 50 ha, however, unfortunately no information is available on the tidal prism of the site.

The formation of the breach at Porlock altered the pattern of shingle movement along this part of the coast from a relatively simple net easterly drift to a more complex dynamic. This is because the breach now forms a sediment transport boundary which prevents the continuous drift along the barrier. In addition, it has also resulted in a drift reversal (switch in net drift direction over a short length of the barrier) and a zone of drift divergence on the eastern side of the breach.

ARUN DISTRICT COUNCIL P/93/25/PL

Gravel spits have formed inside the site along the sides of the channel, with gravel being transported along the banks into the site from both sides of the breach. The spit on the western side (which is the 'up-drift' side because shingle is mainly being transported from west to east) is accreting and partially encroaching on the breach channel. The spit on the eastern side (i.e. down-drift of the prevailing shingle transport pathway) is migrating landward and depleting. The net effect of these is that the breach is tending to migrate slowly eastward, the same direction as the drift.

A proportion of the gravel which is transported into the channel within the breach is flushed seaward to a small ebb tidal delta located on the lower foreshore, this delta acts to store gravel which would otherwise remain part of the barrier; a schematic of the sediment transport around the breach is shown in Image 8. The development of the spits within the channel strongly inhibits any wave penetration through the breach and into the site behind.



(Source Transport Map Bray and Duane 2001, Photos by ABPmer)

Image 8. Inferred sediment transport around Porlock breach (2011) with photos of the breach (top right) and ebb delta (bottom right) taken in May 2009

The gravel barrier continues to function as a coastal defence structure, although now that it is a more natural barrier it is much more responsive to the forcing and adjusts its form to achieve the optimum wave energy dissipation. The main adjustments which have occurred are a recession of the bank and a widening and flattening in the profile of the bank. It is important to note that the natural breach occurred during the period when the profile was adjusting from being a steepened artificial form to a wider, flatter form. The possibility exists that other parts of the barrier which are undergoing this change in form could be prone to breaching. However this has not occurred after 18 years.

Based on the estimated drift rates it appears that the drift volume is insufficient to naturally close up the existing breach. The channel in the breach will continue to intercept drift along the barrier which will continue to feed the ebb tidal delta.

ARUN DISTRICT COUNCIL P/93/25/PL

7.2.2 Medmerry

Background

The Environment Agency Medmerry project was the involved the first managed realignment to involve making a deliberate breach through a shingle bank. The breach design work was undertaken by ABPmer following the key principles and analytic techniques that have been applied for this Pagham breach design review. The Medmerry work also drew upon past case examples and made particular reference to the lessons that had been learned from the Porlock site, as described above.

There are a great many similarities between Medmerry and Porlock both in terms of the conditions that prevailed before the breach and the response that were observed afterwards. The similarities are as follows:

- They are fronted by gravel/shingle that needed to regularly reworked to prevent inundation of the land behind (at Medmerry this was done by the Environment Agency on an annual basis, at a cost of around £300,000/year);
- This regular reworking resulted in an artificially heightened and steepened barrier profile;
- There had been gradual depletion of the shingle over time, owing to the limited natural gravel inputs to the systems;
- All or part of the shingle barrier is swash aligned, with relatively low net drift rates along the frontage (getting an accurate drift volume at Medmerry was difficult because of the previous artificial reworking but it was estimated at between 2,800 m^3/yr and 12,500 m^3/yr (ABPmer, 2010)); and
- Both sites are subject to limited long period wave events in addition with more locally generated wind waves.

Medmerry does, however, differ from Porlock in a number of key areas. Firstly, it is a much larger site (330 ha as opposed to 50 ha) with a larger tidal prism (700,000 m^3). It is also in a more wave-exposed coastal location with a much larger fetch and a greater exposure to prevailing south-westerly winds. Also there is a lower tidal range at the Medmerry site. These characteristics are relevant for understanding how the breach and barrier evolved after the completion of the managed realignment. However the post-implementation evolution of the breach has, so far, also been very similar to the pattern that had been observed at Porlock. This is considered further in the following section.

Post-breach bank and breach evolution

The breach at Medmerry was excavated over a series of days in September 2013 and after it was completed, the shingle bank and the breach entrance evolved and adapted to the new hydrology. This evolution, and certainly the rapidity of the change observed, was substantially influenced by the sequence of major southerly storms that occurred during the following 2013/14 winter. Based on past experience at this site, these storms would certainly have formed a natural breach (at a similar location to the one that was created by the Environment Agency) and would have flooded the hinterland and resulted in widespread damage. The fact

ARUN DISTRICT COUNCIL P/93/15/PL

that this damage did not occur reinforces the value of this project as a flood protection scheme in the first instance, as well as being a major habitat creation project.

The evolution of the breach and barrier has been monitored in detail by the CCO on behalf of the Environment Agency. To date, the CCO has carried out 16 laser scanning surveys which describe the breach topography between from August 2013 to March 2015. This covers the period before, during and after the breach excavation.

Over this period, the shingle barrier beaches on both sides of the breach have shown an anticipated landward movement and the bank has relaxed to a shallower profile as was observed at Porlock. There are clear sediment fans inside the site behind the main fronting barrier and these fans are often much larger where they lie immediately behind old redundant groyne features as these structures cause wave energy reflection and promoted localised shingle erosions and shingle out-washing into the site.

From the experience at Porlock it is during this period of profile readjustment (from its managed form to a natural form) that the natural breach occurred at Porlock and it was expected that this would be the period when the barrier was arguably most at risk of breaching. This process has occurred faster than the anticipated due to the winter 2013/14 storm sequence but now that it has reached a more natural form it is likely to be more effective at dissipating wave energy. This barrier is likely to be more stable but may also continue migrating in a landward direction while broadening its profile. This evolution will continue to be monitored by CCO and the Environment Agency.

Over the 21 months (to June 2015) since the work was completed (and notwithstanding the sequence of storms) the breach has remained open (see Image 9). There have been clear shingle movements, with the breach developing to a distinctive new morphology, with shingle spit features extending into site on both the east and the west side.



(Source: John Akerman, 27 February 2015)

Image 9. Medmerry breach (27 February 2015)

ARUN DISTRICT COUNCIL P/93/15/PL

One of the most distinctive physical changes to have occurred at the Medmerry breach is the extension of a shingle spit into its eastern side. This process of shingle development mirrors the change that occurred at Porlock where there was also a relatively large accretion of shingle in the up-drift section of the breach. At Medmerry this up-drift spit has grown and transgressed landward and, in doing so, has migrated into the path of an internal channel that had been excavated and connected to a former freshwater dyke to accommodate tidal flooding and draining on the eastern side of the Medmerry site.

As the shingle cut into the drainage channel it forced the channel to divert and follow a more north-westerly direction away from the breach in contrast to its original south-westerly direction alignment. This effect occurred as the shingle material moving in from the south exerted pressure on the more erodible channels forcing this migration. This effect will have been influenced by both the shingle movements (often storm induced) and by the relatively low tidal volumes occurring through the diverted channel.

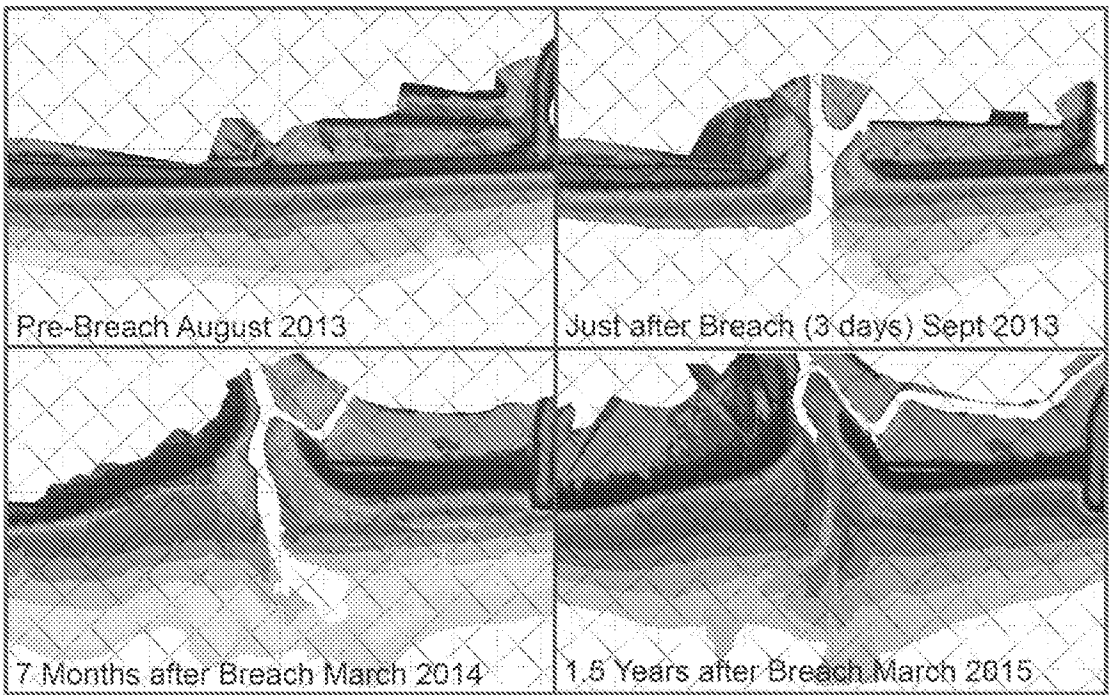
In recent months there appears to be more gravel on the lower foreshore around the inlet channel, especially to the east of the inlet channel. This may represent the early stages of an ebb tidal delta formation in keeping with the behaviour of the Porlock breach. The evolution of the Medmerry breach over the past 1.5 years is illustrated in Image 10.

While some of the details about the functioning of the Medmerry breach have yet to be confirmed through monitoring, its similarity with Porlock means that it is functioning in many of the ways that were originally predicted (ABPmer 2010). In particular gravel is being transported from the east and west sides of the breach into the channel within the breach. The spit located on the updrift side (east) is extending into the breach channel, while the spit on the downdrift side is receding landward. It may be that sediments are also starting to be transported seaward where they could accumulate in a small ebb tidal delta.

Erosion of the bed immediately inside the breach was also anticipated to occur to improve the flooding and draining of the site. This was expected to be in the form of headward erosion from the breach and this has occurred along the channel running the east immediately behind the site which was influenced by the spit migrating into the site. This process may be occurring in other smaller channels across the site. However, the main channel to the north-west was deliberately excavated to be wide and deep enough to ensure stability and maximise tidal conveyance into and out of the site.

In general, there are many similarities between the smaller and comparatively wave-sheltered Porlock site and the much larger and more exposed Medmerry site. It appears though that the pace of evolution of the breach channel, gravel barriers and tidal delta is much greater at Medmerry than it was at Pollock. This greater speed of change at Medmerry may be due to the larger tidal prism and/or because there is an greater focus of wave action at the shoreline due to the smaller tidal range on the south coast when compared to the Bristol Channel (Malcolm Bray, Portsmouth University, Pers. Comm.).

ARUN DISTRICT COUNCIL P/93/25/PL



(Source: CCO & Environment Agency unpublished data)

Image 10. Evolution of the Medmerry breach over 1.5 years

7.2.3 Summary

In summary the evidence from these two analogue projects indicates how breaches through shingle barriers can remain stable under a range of conditions. This provides further reassurance from the analyses undertaken in this document that a proposed breach at Pagham can remain open once created. At Pagham the tidal prism is much larger at Pagham (2.7 million m^3) than it is at Medmerry (nearly 0.7 million m^3) and this large volume will be a key factors in helping to maintain the Pagham Breach. The fact that the Medmerry Breach reduced in size from a maximum width of 100 m to around 50m width through the migration of the shingle spits also gives a further indication that the proposal to create a starting breach design of 40-60 m in width on average is appropriate.

It is recognised that no two case examples are the same on the coast and that there are distinct differences between Porlock, Medmerry and Pagham. Porlock was a natural breach that included the formation of a central clay channel, Medmerry also involved the excavation of a central clay channel and these channels will each help to stabilise these respective breaches. Pagham is not the same because the channel base is likely be shingle rather than clay (unless substantial base channel scouring occurs) especially in the short term and that would create a tendency for instability. However, the Pagham inlet also has a training wall on its landside (unlike the other case examples) which will help to focus flows and maintain breach position and flow directions.

ARUN DISTRICT COUNCIL P/93/25/PL

The key consideration here is that these case examples help provide support to the evidence presented in this report and these case examples are one element in the wider tool kit that has been applied for this study. In particular, it is notable that, because Medmerry has remained open and stable it has proved the value of the techniques that were applied to its design (ABPmer, 2010). These techniques are essentially the same as those used for this Pagham Breach review study. Furthermore, the best case example evidence in this case (as noted at the start of Section 7.2) is Pagham Harbour itself which has remained breached throughout most of its history.

ARUN DISTRICT COUNCIL P/93/25/PL

8. Conclusions

8.1 Overview of the Proposed Breach Design

For this review, a range of data analysis techniques and interpretation tools have been used to derive a suitable design for the proposed managed breach at Pagham Harbour. This work has been informed by the development and application of a hydrodynamic model to investigate the potential impact of a managed breach through the shingle spit at Pagham. Following all the work undertaken to date, a suitable breach design has been identified would have the following characteristics:

- A central 40 m channel at a depth of -1.80 mODN which is equivalent to the Mean Low Water (MLW) level and is comparable to the channel bed level of the existing harbour inlet channel;
- Side slopes on each side of the breach that will be set at approximately a 1:4 gradient;
- A width of 80 m at tidal elevation of +3.0 mODN level which is approximately at the Highest Astronomical Tide (HAT) level; and
- An excavated volume of around 42,000 m³ (below 3.0 mODN) with an expected additional 10,500 m³ needing to be excavated above the +3.0 mODN elevation.

A proposed location and alignment for the breach have also been selected based on the topography within the harbour; proximity to the tidal channels; the position of the existing training wall; the shape of the spit and the position of breach historically. The results of the computer modelling work also describe how conditions will interact with the foreshore and indicate that the proposed breach design will have very little impact on water levels and flow speeds in Pagham Harbour.

8.2 Interactions with the Environment

The results of the modelling demonstrate that the proposed breach (or 'harbour inlet') will allow a relatively unconstrained tidal exchange into the harbour, maintaining existing water levels, whilst maximising flow speeds through the breach. Increased flow speeds through the breach (and channel) will increase the potential for sediment mobility through 'flushing', thus reducing the likelihood of material accumulating in the breach.

Along the Pagham Beach frontage, where the existing inlet channel has caused considerable erosion to the beach, the proposed breach design (including the associated infilling of the existing inlet channel) will greatly reduce flow speeds. Therefore, flow speeds within the remaining section of channel will be insufficient to erode gravel sized material, thus removing the considerable erosion pressure currently placed along this frontage. In the absence of the strong tidal flows along the closed existing channel, the distal end of the spit will close (reconnect) with the Pagham Beach. Over time, the spit will provide a large supply of material to the Pagham frontage and further down-drift.

ARUN DISTRICT COUNCIL P/93/25/PL

In the future, the stability of the proposed breach is highly dependent upon the tidal prism within the harbour and the volume of littoral drift material. It has been assessed that the breach (inlet) will remain stable during spring tides, with a lessening degree of stability under high drift rates. The stability of the breach is, however, reduced over neap tides. That being said, there is no evidence to suggest that the Pagham Harbour inlet has ever closed (infilled) naturally in the past, with historical closures being the result of human intervention. As such, it is predicted that during periods of lesser volumes of littoral drift, the breach (and channel) is likely to remain relatively stable.

During periods of increased littoral drift, bypassing of the inlet is likely to occur, which will result in the formation of a spit (as seen over the past 10 to 15 years) rather than the closure of the breach. This hypothesis is further validated by evidence taken from relevant coastal analogues at Medmerry and Porlock, where both man-made and natural breaches through shingle spit barriers have remained relatively stable with time.

8.3 Key Considerations for the Next Stages of the Project

The results presented within this report provide a design verification for the proposed breach of the Church Norton Spit. They indicate, pending further review and assessment work, that a breach can be introduced with the aim of achieving the core project objectives. As described above, these objectives are to create a sustainable/natural, longer-term, and spatially more extensive, coastal protection improvement for the whole coastal system as well as providing benefits to human health and site amenity.

This information presented in this document can now be used to inform the development of a formal project Method Statement which will need to be developed by an experienced contractor. For this Method Statement the health and safety of the staff that would work on the project, and of the public that might use the area, will clearly be the paramount consideration. Below this overarching consideration, it will be necessary to work out the most suitable methods for excavating the breach while working within and near to a tidal environment. It will also be important to note that the closure of the existing tidal channel is as important as the opening of the new breach. The proposed approach will need to consider how this can be most effectively achieved with the volumes of material excavated.

The project will also bring about a number of short term and longer-term environment changes within an area of national and international conservation importance. The significance of these will be evaluated during the subsequent impact assessment and planning application work. This work will, in turn, be informed by: this report, the contractor's Method Statement and the results of a Scoping review undertaken jointly by the Arun and Chichester District Councils.

It should be noted that, following the impact assessment, there may well be a need for mitigation or compensation measures to offset any significant effects on the environment. The most likely effects will be upon nesting terns and/or overwintering birds and as such as offsetting measures may well include constraints on the timing of the works or the need to create/restore shingle habitat in other locations. The requirement for such mitigation or compensation work, and the approaches that could be taken, will be investigated during the EIA work.

ARUN DISTRICT COUNCIL P/93/25/PL

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Figures



Extent of Church Norton Spit in January 2015

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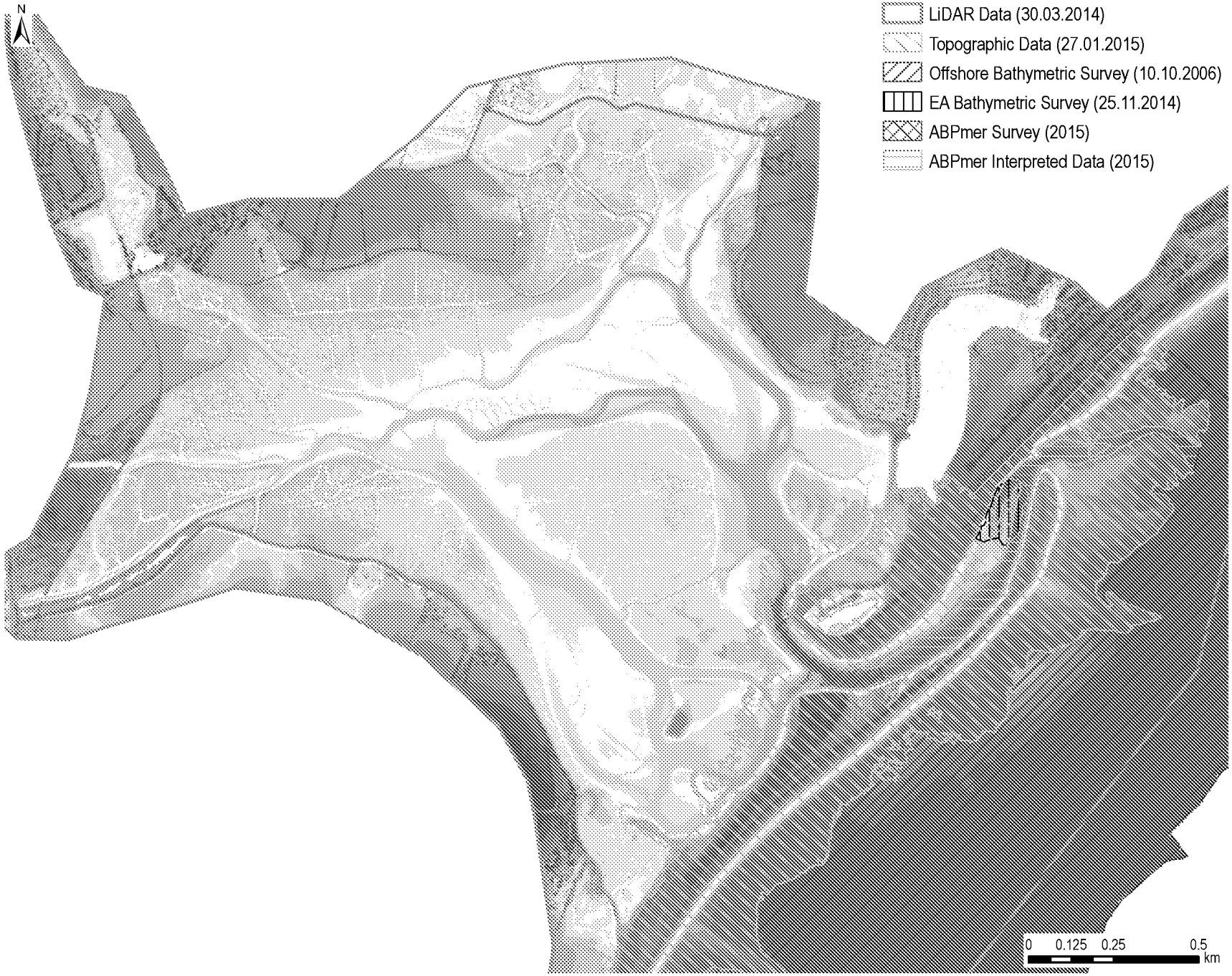
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Pagham Harbour Location Plan

Figure 1



Digital Terrain Model

Elevation (mODN)

- < -2.00
- -1.99 to -1.50
- -1.49 to -1.00
- -0.99 to -0.50
- -0.50 to 0.00
- 0.00 to 0.50
- 0.50 to 1.00
- 1.01 to 1.50
- 1.51 to 2.00
- 2.01 to 2.50
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- > 6.50

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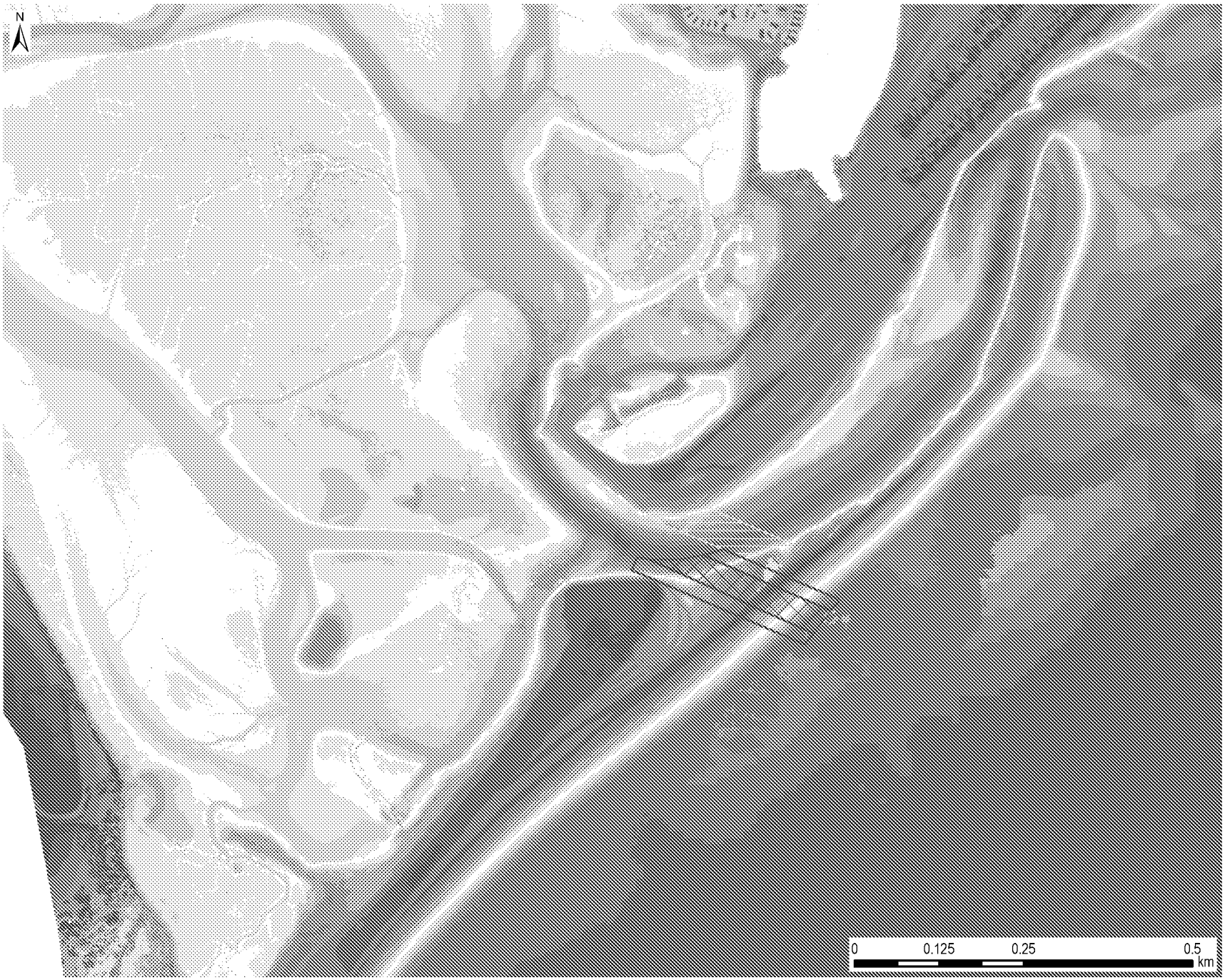
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Pagham Harbour
DigitalTerrain Model

Figure 2



40m Wide Base Channel

Breach Side Slopes

Proposed Infill with Excavated Material

Digital Terrain Model

Elevation (mODN)

- < -2.00
- -1.99 to -1.50
- -1.49 to -1.00
- -0.99 to -0.50
- -0.50 to 0.00
- 0.00 to 0.50
- 0.50 to 1.00
- 1.01 to 1.50
- 1.51 to 2.00
- 2.01 to 2.50
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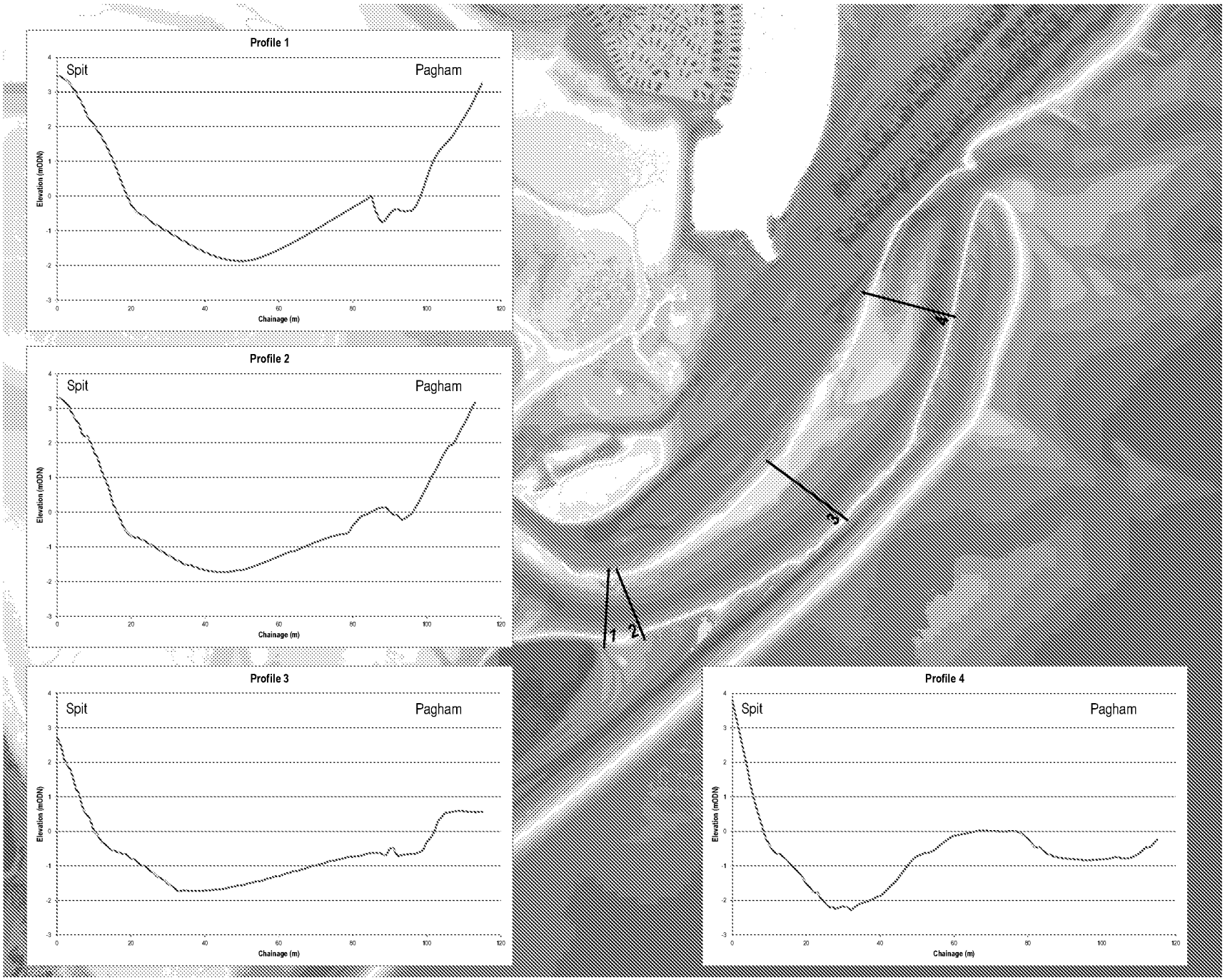
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Preferred Breach Design and Location

Figure 3



Profiles

Digital Terrain Model

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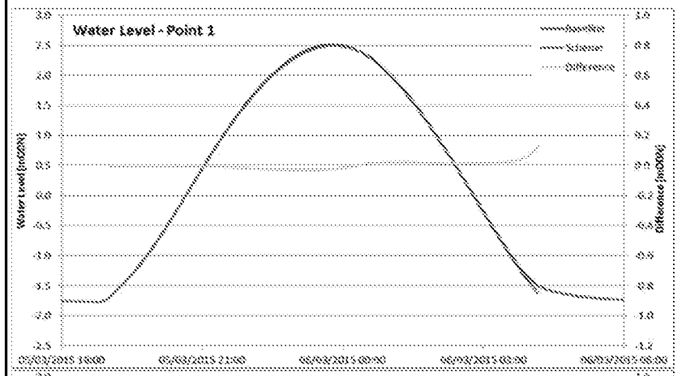
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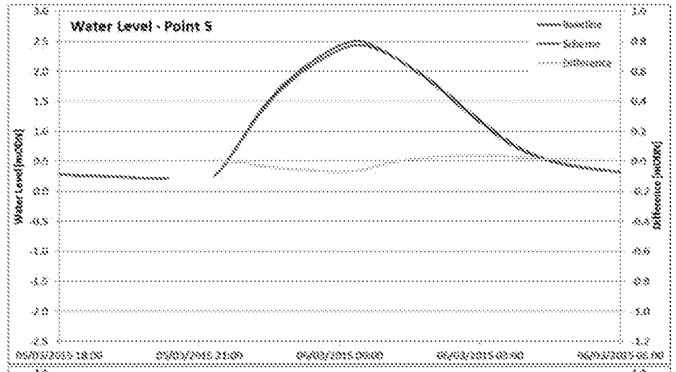
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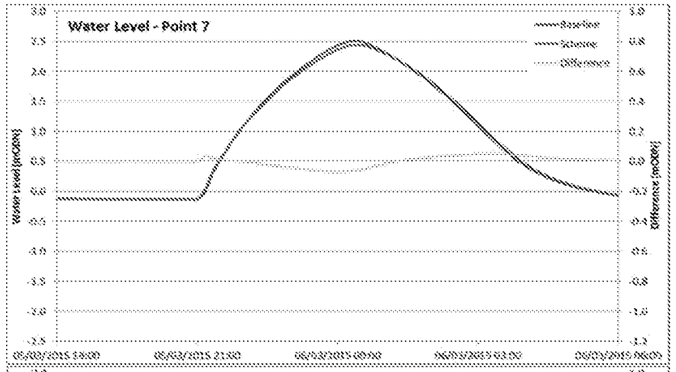
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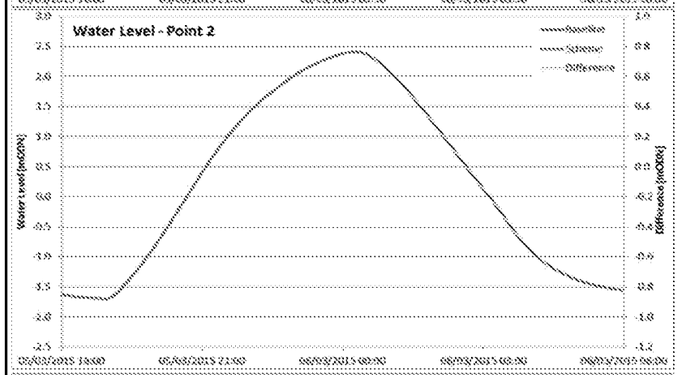
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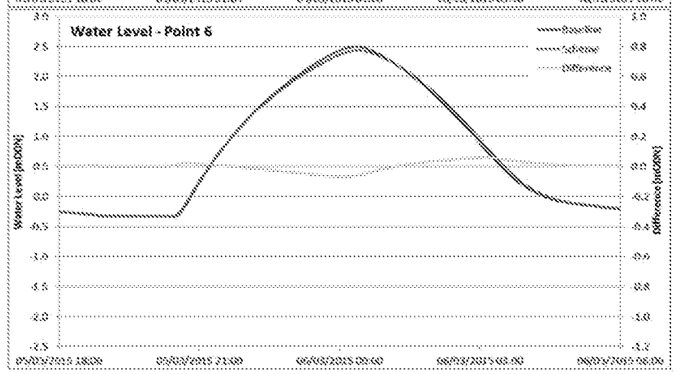
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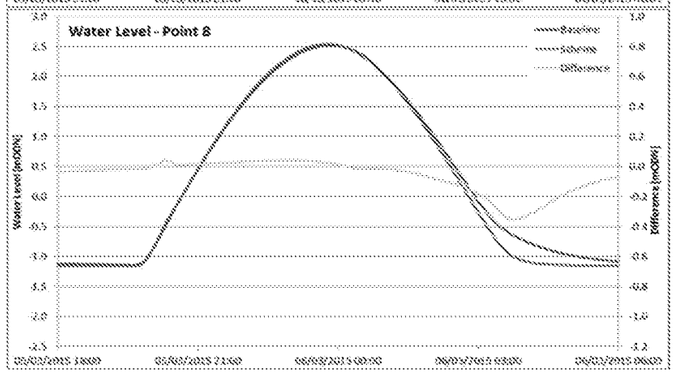


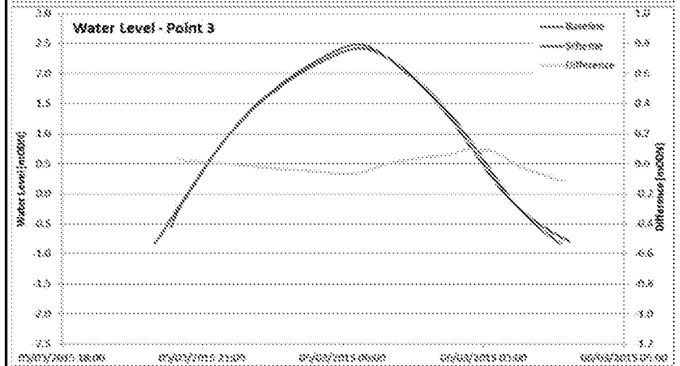


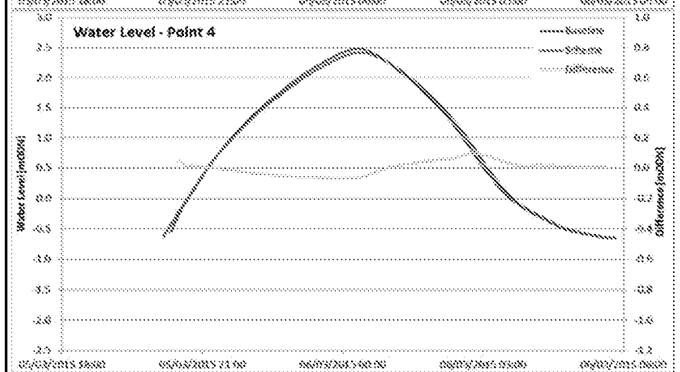


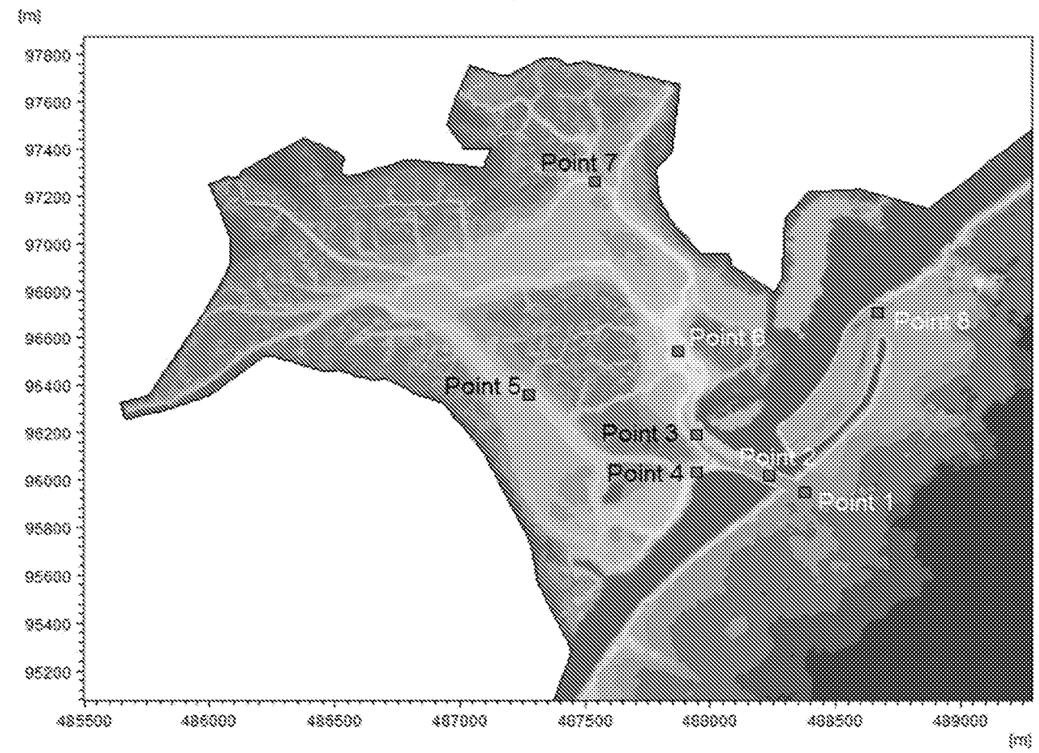












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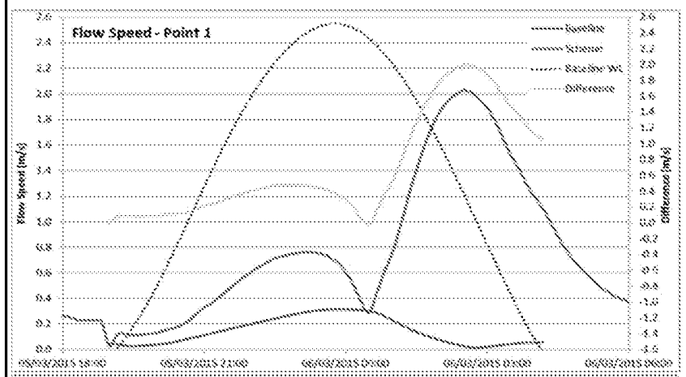
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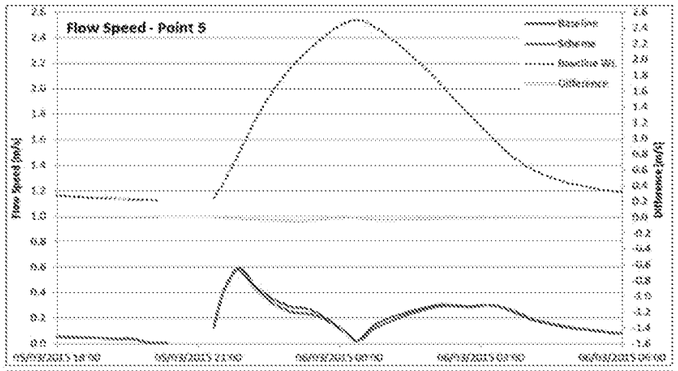
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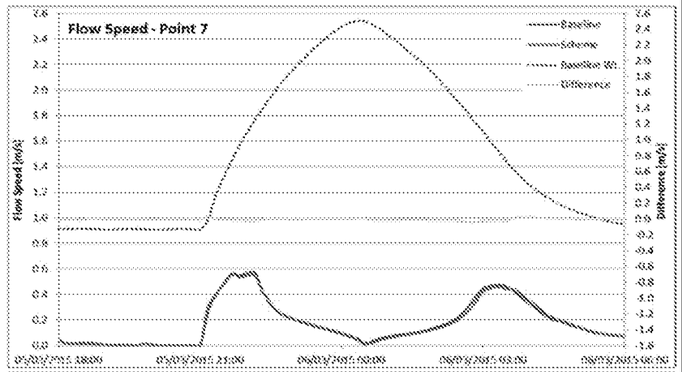
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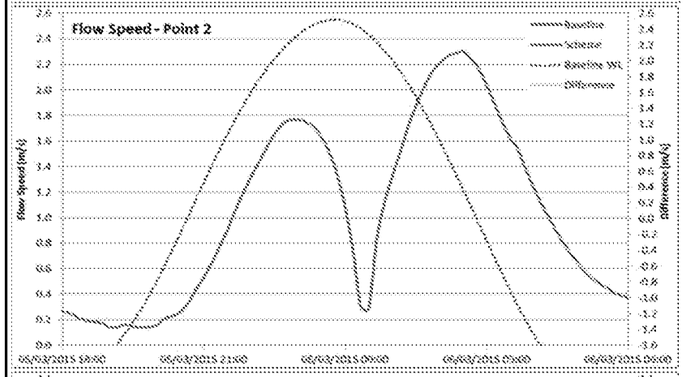
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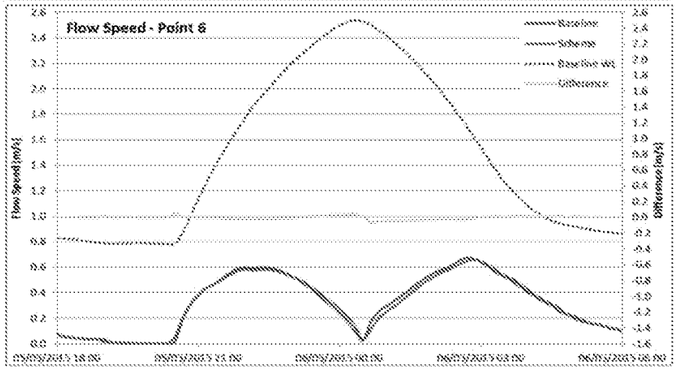
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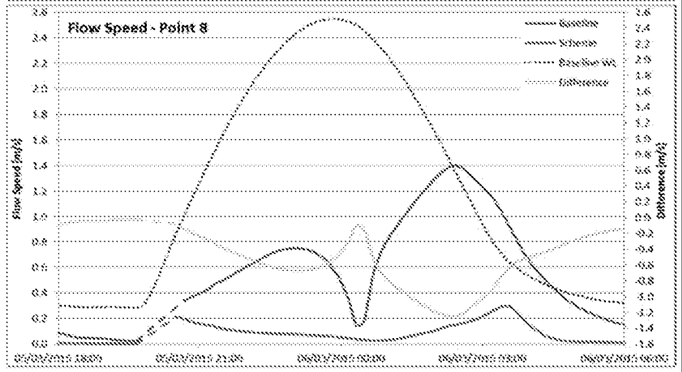


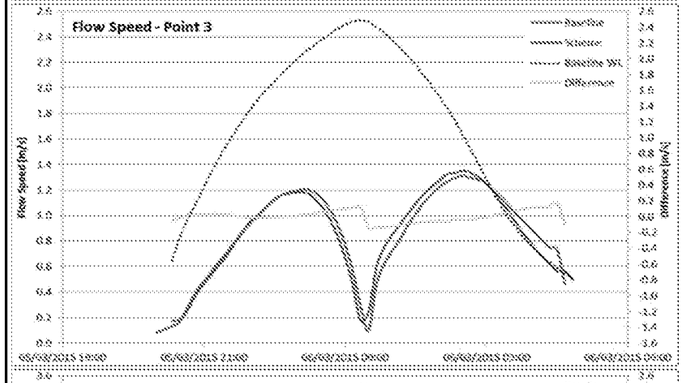


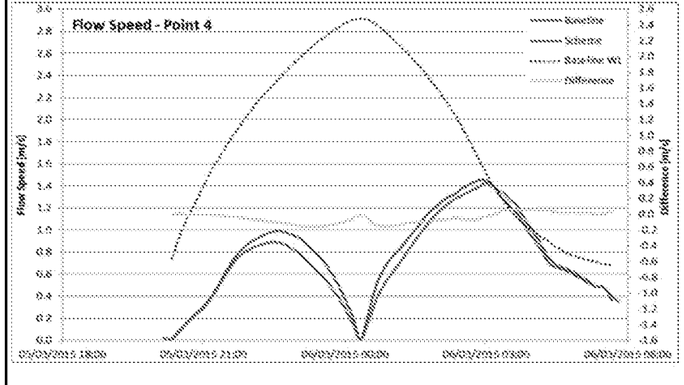


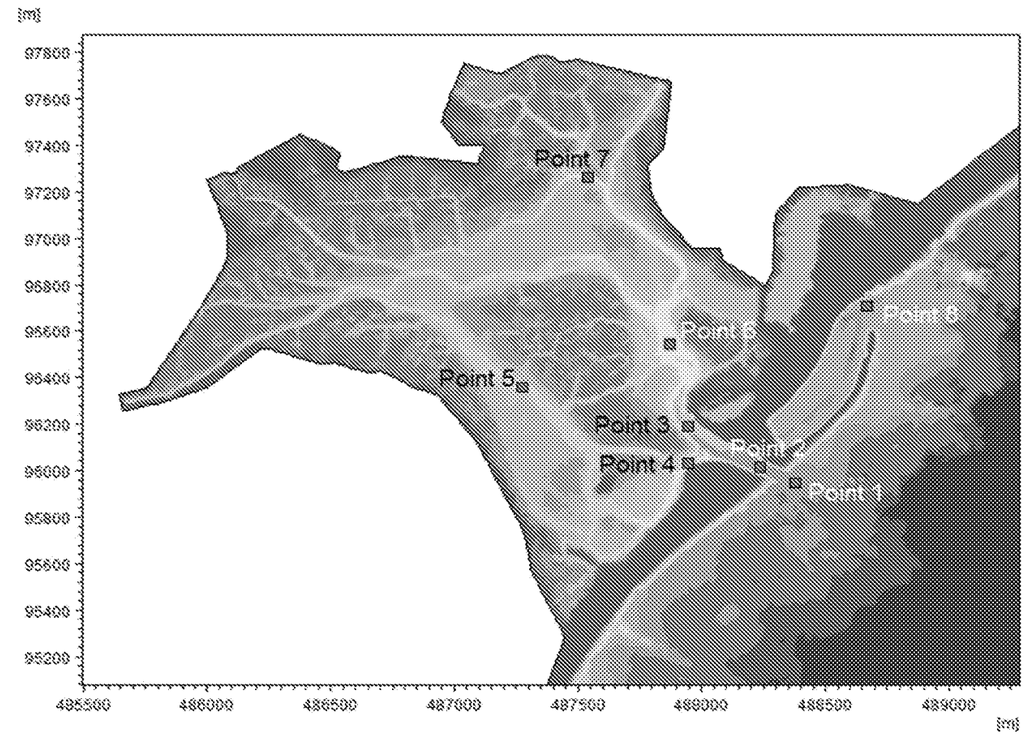












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PaghamSpring Assesment Plots.xlsm			
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Marine Environmental Research

Spring Tide Assessment Plots - Flow Speed

Figure 6

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Appendix A

Modelling Review of the Proposed Breach at Pagham Harbour

ARUN DISTRICT COUNCIL P/93/21/PL

A. Modelling Review of the Proposed Breach at Pagham Harbour

A.1 Model Introduction

A.1.1 Background to Model Development

The hydrodynamic model that was required for this study was developed from an existing MIKE21 FM model that ABPmer had previously been created for the Environment Agency. This preceding model was developed and used to inform the design and impact assessment that was needed prior to the implementation of the Medmerry Managed Realignment project (ABPmer, 2010). This established model was not only used prior to the Medmerry breaching work but it was also later upgraded and re-run after the breaching was completed as part of investigations into the post-breach evolution of the Medmerry site (ABPmer, 2014a).

Both versions of the preceding model were shown to be valid representations of the environment through a detailed statistical assessment of tidal elevations, depth-averaged current speeds and associated directions. This was proven for both the far field and in close proximity to the managed realignment breach.

The representation of the internal channels and the breach were significantly improved during the post-breach evolution modelling, employing the use of quadrangular elements within the flexible mesh (triangular) design. This created a model that presented the interaction of drainage within individual channels very effectively, and informed adaptations to the scheme design to improve the internal drainage of lagoons and pools on the site. The lessons learned from this modelling work, especially about efficiently resolving channels within tidal inlets, have been applied to the development of the Pagham Harbour model of the present review.

Further background details about the development of the Medmerry model are presented in the preceding reports (ABPmer 2010 and 2014a).

A.1.2 Upgrading and Tailoring the Model for Pagham Study

For this review of the Pagham Breach Design, and to inform the subsequent assessment of the proposed Pagham Spit intervention, this model was extensively upgraded in order to fully represent Pagham Harbour and the local geomorphological features. To achieve this, the latest available bathymetry within the Pagham Harbour and coastal area were initially interpolated into the model from the Digital Terrain Model' (DTM) that was developed as part of this study (see Section 3). Then the hydrodynamic model was adapted so that it was more focused on representing the channels within and into Pagham Harbour along with the area surrounding the shingle spit.

Within the model, a combination of triangular and quadrangular model elements was used to describe the study area and to develop the 'Model Mesh'. A detailed view of the updated model mesh used in this study, showing these model elements is presented in Image A1. The approach, of using both triangular and quadrangular elements, is important for adequately describing the flooding and draining characteristics of the site. The quadrangular elements were introduced particularly to represent key

ARUN DISTRICT COUNCIL P/93/25/PL

channels, and significant linear features such as sections of the shingle spit and adjoining beach. They are also an effective method of resolving the narrow channels towards the back of Pagham Harbour.

To further upgrade the original model for this Pagham Harbour study, the boundary water-level time-series data was updated so that the model could run over a period that corresponds with the field survey data collection (see Section 3). The boundary data was taken from ABPmer's regional English Channel model (as was the case for creating the original Medmerry model). Local tidal levels and ranges for Pagham Harbour, as calculated in Section 4.1 are provided in Table A1.

Table A1. Reference water levels for the study area

Tidal Level		Pagham Harbour (mODN)
Highest Astronomical Tide	HAT	2.93
Mean High Water Springs	MHWS	2.43
Mean High Water	MHW	1.83
Mean High Water Neaps	MHWN	1.23
Mean Sea Level	MSL	-0.25
Mean Low Water Neaps	MLWN	-1.18
Mean Low Water	MLW	-1.80
Mean Low Water Springs	MLWS	-2.43
Mean Spring Tidal Range (MHWS – MLWS)		4.85 m
Mean Neap Tidal Range (MHWN – MLWN)		2.40 m
Note: The tidal levels presented for Pagham Harbour are an average of those for Selsey Bill and Pagham.		

A.2 Model Verification

To demonstrate that a modelling tool appropriately represents real-world conditions within Pagham Harbour, a model calibration verification process was undertaken whereby the model outputs were compared to other, often measured, datasets. In the first instance it was confirmed that the wider performance of the model in areas offshore from Pagham had not changed from the original model.

Following this initial check, a formal model verification exercise was undertaken to ensure that the model is capable of reproducing the hydrodynamic processes that were also observed by the separately collected measured data in situ. To make this comparative test, key field datasets, both collected in Pagham Harbour, were used for comparison with the model. These were:

- The ABPmer survey data, collected on a spring and neap tide in the main channel, (adjacent to the training wall) as described in Section 3.2, and
- The gauged water level data at Little Welbourne as provided by the Environment Agency.

The site locations for these data sources are shown on Image A1 and further details about the model verification process are presented below in Sections A2.1 and A2.2.

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A.2.1 Verification Against Survey Data

During the ABPmer surveys, measurements of water level, flow speed and direction were recorded for an individual spring tide (13 hours) and two consecutive neap tides (20 hours). Recordings were taken over night on 5/6 March 2015, and 14/15 March 2015 for spring and neap conditions respectively. Images A2 to A5 show the variation of the modelled and surveyed water levels, flow speeds and flow direction through time for the spring tide survey and neap tide survey.

The water levels compare very well between the modelled and measured data, with the model matching the measured level of high water (HW) on a spring tide (Image A2). The spring tide in question can be considered approximate to a Mean High Water Spring (MHWS) tide, stated as 2.43 mODN (Table A1).

The measured values of low water (LW) are not consistent for successive LW periods, displaying a 0.2 m difference during the period of deployment (Image A2). The model compares well with the second LW period (approx. 6am on 6 March 2015), with the possibility of an additional volume of water draining from the site (possibly from additional fresh water inputs to the harbour) causing the asymmetric patterns of LW.

Measured flow speeds are seen to peak at just below 1.5 m/s, for both the flood and ebb phases of the spring tide. Image A3 shows that the general patterns of flow speed and direction through the tide compare well between measurements and the model. Modelled speeds are consistently higher than measured speeds however, with ebb flow speeds comparing more favourably than flood flow speeds.

To verify the compatibility between the modelled outputs and recorded field data, basic statistical comparisons of modelled and measured water levels and flows were undertaken. The results of this are presented in Table A2. These show that for the spring tide, water levels provide a match against between the modelled and measured height at HW. Typically, modelled speeds are 0.2 m/s higher on the flood tide, and 0.1 m/s on the ebb tide.

For neap tides, Image A4 demonstrates that the model and measured data have a very close match throughout the tide, with the flood, HW and ebb phases of the tide comparing well. The height of HW is greater than the value for a Mean High Water Neap tide (Table A1).

The precise location of the instrument on the neap tide is unknown because it was tampered with and moved after deployment. Therefore the period of LW on the neap tide is of questionable certainty, which could explain why measured levels stop recording half an hour before the model dries out (Image A4). Additionally, it would be expected that the survey instrument would not record robust measurements in shallow water.

Peak flow speeds on the neap tide are approximately 0.5 m/s, and compare favourably with the modelled values (Image A5). However, the surveyed directions of flow over the tide appear to rotate slowly as the tide rises and falls, as opposed to the strong rectilinear change in direction observed in the model.

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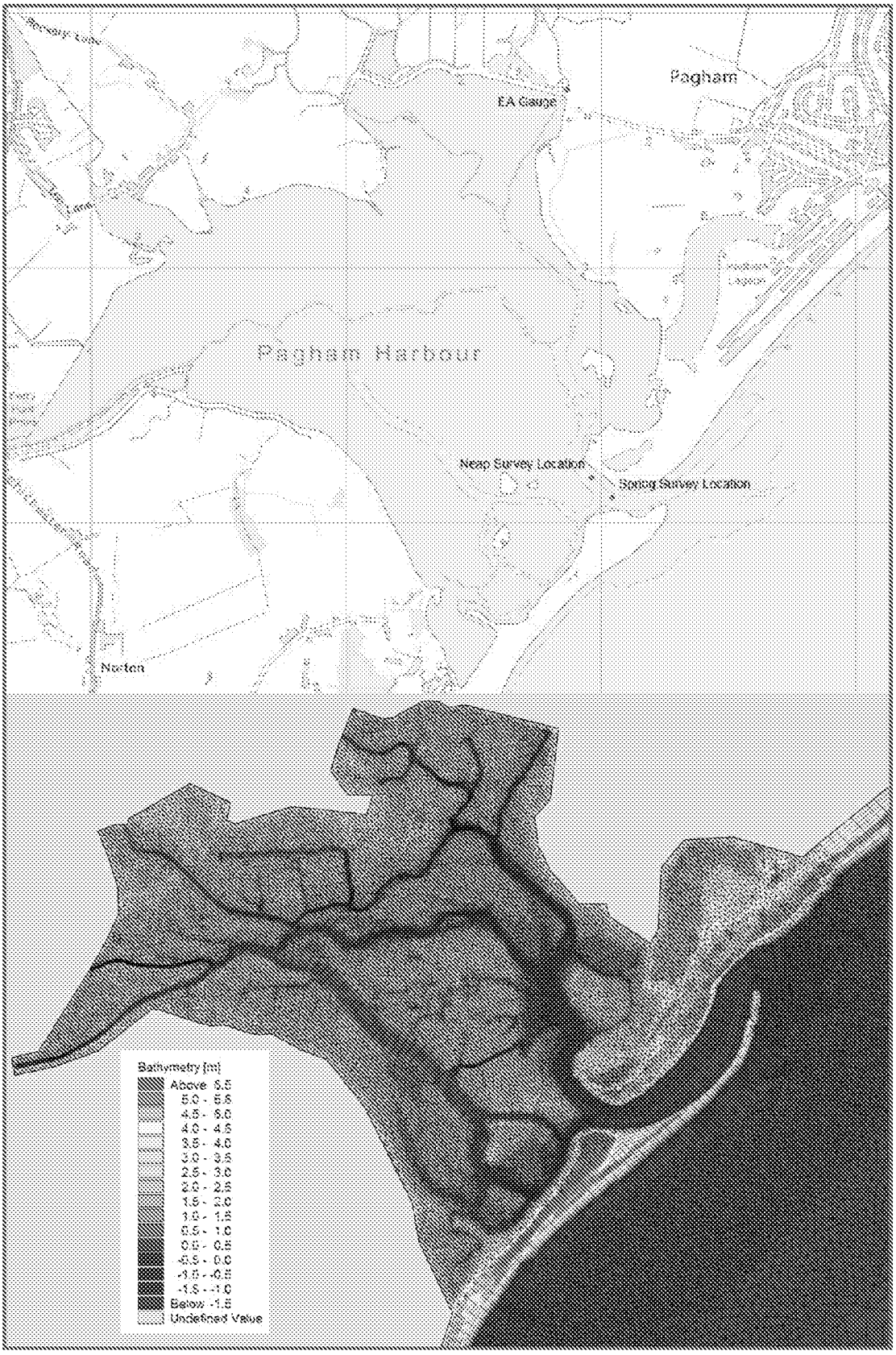


Image A1. Survey data locations and model mesh

ARUN DISTRICT COUNCIL P/93/25/PL

ABPmer maintain an internal guidance document for model calibration and validation, in which acceptable statistical guidelines and thresholds are stated for the comparison of modelled and measured datasets (ABPmer, 2014b). Against the guidelines set out in ABPmer (2014b), the model compares very well. In a coastal (and non-estuarine) setting the guidance aims for peak water levels to be within ±0.1 m and 15 minutes, a threshold that is met comfortably for both the spring and neap tides.

With regards to flow speeds, the guidance seeks for peak speeds to be within ±0.2 m/s. All comparisons for spring and neap tides fall within this threshold. Within the guidance note, thresholds and an associated quality index are provided for peak flow speeds. Flow speeds that are within 0.05 m/s are described as 'very good', those within 0.1 m/s are classed as 'good', while flows within 0.2 m/s classed as moderate.

All peak ebb flows in Table A2 are seen to be classed as 'good', with those on the neap tides classed as 'very good'. The peak flood flow on the second neap tide is also classed as 'very good', while the flood flow on the spring and first neap tide are classed as 'moderate'. Overall this represents an excellent standard of comparison, meeting all thresholds set in the guidance document.

Table A2. Difference in water level and flow speeds on the spring and neap surveys

Parameter	Spring Tide	Neap Tide (1)	Neap Tide (2)
Difference in water level at HW (modelled - surveyed)	0.00 [m]	0.01* [m]	-0.03* [m]
Difference in flow speed at measured time of peak flood flow speed (modelled - surveyed)	0.19 [m/s]	0.13 [m/s]	0.04 [m/s]
Difference in flow speed at measured time of peak ebb flow speed (modelled - surveyed)	0.09 [m/s]	0.04 [m/s]	0.00 [m/s]
*Datum of neap survey data is estimated and based on modelled levels.			

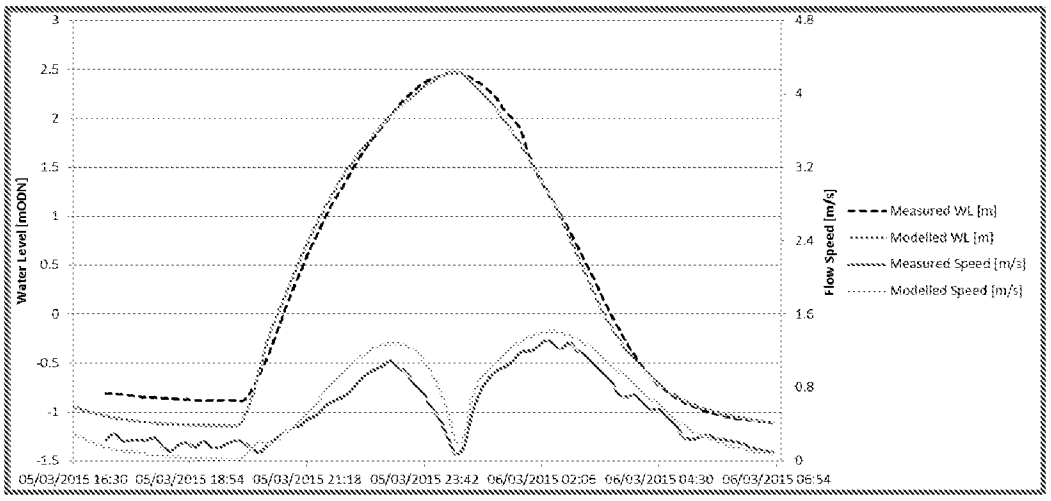


Image A2. Spring tide modelled and surveyed water level and flow speed

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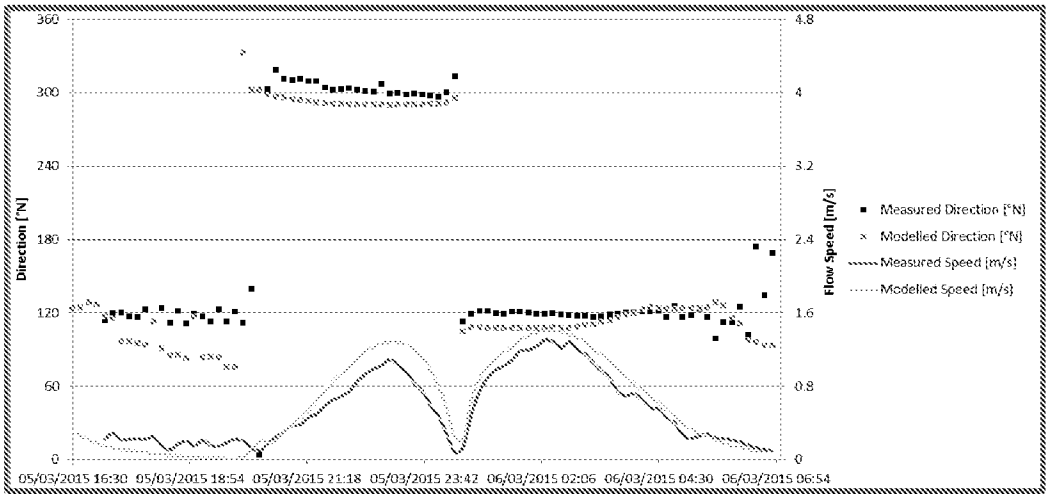


Image A3. Spring tide modelled and surveyed flow direction and flow speed

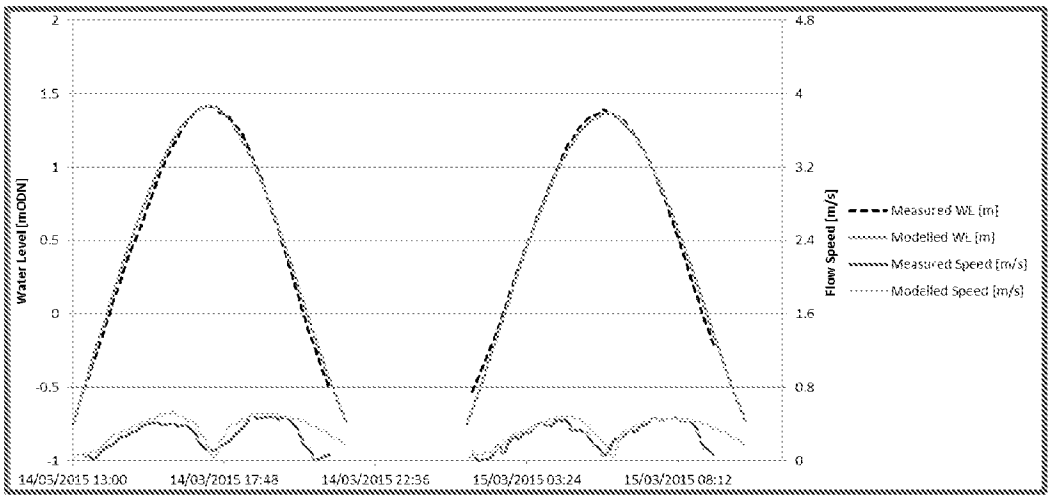


Image A4. Neap tide modelled and surveyed water level and flow speed

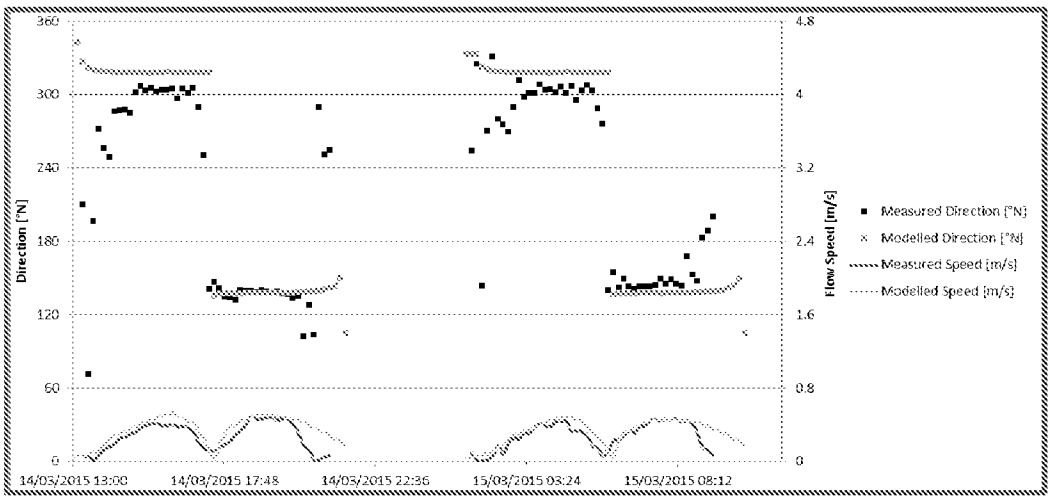


Image A5. Neap tide modelled and surveyed flow direction and flow speed

ARUN DISTRICT COUNCIL P/93/15/PL

A.2.2 Verification against Environment Agency Gauge Data

The comparison of the modelled levels against the Environment Agency's gauged data at the north east corner of the site is shown in Figure 6. The location of the gauge is on the harbour side of the bund holding the outfall from Pagham Rife, close to Little Welbourne (Image A1). Modelled values are from a location in the channel leading up to the sluice structure adjacent to the gauge. Through personal communication with the Environment Agency it was understood that there is uncertainty surrounding the datum level for the gauge data at Pagham Harbour, with internal work ongoing to determine its true height. Despite this the stated datum of the gauge was used in this study.

The phasing and height of the tide compare well on both spring and neap tides. The overall range on spring and neap tides also compare well, with a consistent positive offset on the measured data of approximately 0.2 m at HW. LW values from the Environment Agency suggest the gauge has dried out and may also be influenced by flows from Pagham Rife, and are in the order of 0.25 m lower than measured values.

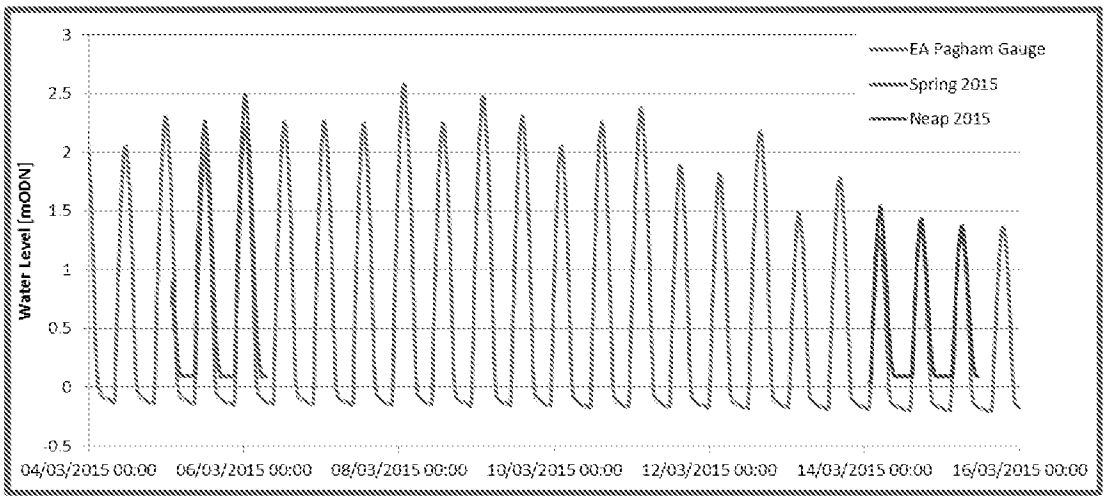


Image A6. Modelled and measured water levels at the Environment Agency gauge

A.2.3 A Note on Model Accuracy and Uncertainty

The focus of the model development and verification exercise has been to replicate the measured survey data from within the main channel. It is assumed that achieving a good match between the modelled and measured water levels, the total exchanged volume of water on each tide should also compare well.

Uncertainty due to the total depth of channels within the harbour remains, as bathymetry data is provided by remote survey (LiDAR). However, manual edits to deepen a number of the key channels has been a calibration parameter, and used when it was deemed necessary to increase the volume of water drawn into the harbour.

ARUN DISTRICT COUNCIL P/93/25/PL

'Downstream' of the survey locations, towards the present terminus of the shingle spit, uncertainty in the bathymetry data remains due to the highly dynamic nature of the bed in that area. During the calibration process manual edits to remove the shingle deposits on the northward edge of the channel and a 30 m shortening of the tip of the shingle spit were performed to achieve the best possible calibration against the measured data.

A.3 Baseline Characterisation from the Model

Following the development and verification of the model, it was run to describe the baseline conditions within the harbour in advance of further analyses to describe the effects of the proposed breach. The results of this analysis are presented in Figures A1 to A3.

Appendix A shows a series of images depicting hourly output from the model over a spring tide. Each plot displays flow speeds (with vectors) around the entrance to Pagham Harbour, at time steps in sequential steps relative to HW, such that output covers HW-6 hours to HW+5 hours (12 hours in total).

Flow speeds are shown to be at their highest at the distal end of the spit and in the narrow section of the channel, close to the training wall, before the divergence of the two channels into Pagham Harbour. Highest flow speeds are seen on the ebb tide, between HW+2 hours and HW+3 hours.

The flooding of the site occurs gradually though the tide, with the majority of the site inundated an hour before HW. The majority of the site remains inundated until HW+1, where after intertidal areas become present in the plots. At LW, features of a delta at the end of the spit are observable offshore (eastward) of the spit (HW-6, HW-5 & HW+5). The draining of the site is seen to split into 3 to 4 separate channels.

A.4 Adaptations for Scheme Assessment

To fully represent the post-construction breach, the model mesh was adapted to guide the quadrangular elements describing the main channel along the path of the new breach. This was done to optimise the representation of the new channel, and to help maintain the simulation efficiencies associated with the quadrangular elements. The same method used to develop the baseline mesh was used for the scheme assessment mesh (Image A7).

Any changes to the mesh are localised, and do not have any modifications to the wider domain, and thus does not compromise the calibration of the baseline mesh.

The central channel into Pagham Harbour is made up of eight quadrangular elements across the channel. This number was unchanged for scheme representation so as to limit changes to the mesh to the location of the breach. The entire scheme was represented within these eight elements (from values prescribed at nine nodes across the channel) from breach base to the crest of the side slopes.

ARUN DISTRICT COUNCIL P/93/25/PL

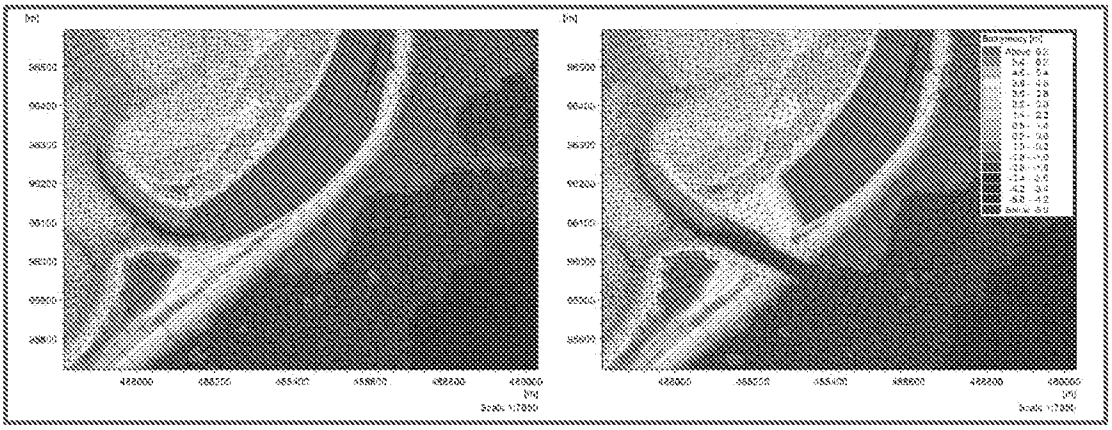


Image A7. Detail of the baseline (left) and scheme (right) model mesh at the breach

A.5 Conclusions about model suitability

An adapted version of ABPmer's Medmerry Managed Realignment model, as developed to fully represent Pagham Harbour, has been shown to calibrate very well against local field data within Pagham Harbour. The model mesh has been developed to represent the harbour through a combination of triangular and quadrangular elements which help improve representation of internal channels and aid computational efficiency. To adequately represent the proposed scheme breach, an adapted version of the model mesh was constructed to fully represent the constructed channel.

A.6 References

ABPmer, 2014a. Medmerry Managed Realignment: Review of Post-breach Tidal Flooding and Draining. ABP Marine Environmental Research Ltd, Report for Jacobs and the Environment Agency Report No. R. 2273.

ABPmer, 2014b. Numerical Model Calibration and Validation Guidance. ABP Marine Environmental Research Ltd, File Note R/1400/112.

ABPmer, 2010. Medmerry Managed Realignment: Coastal and Hydrodynamic Modelling Report – Phase 2. ABP Marine Environmental Research Ltd, Report for Jacobs and the Environment Agency No. R. 1606.

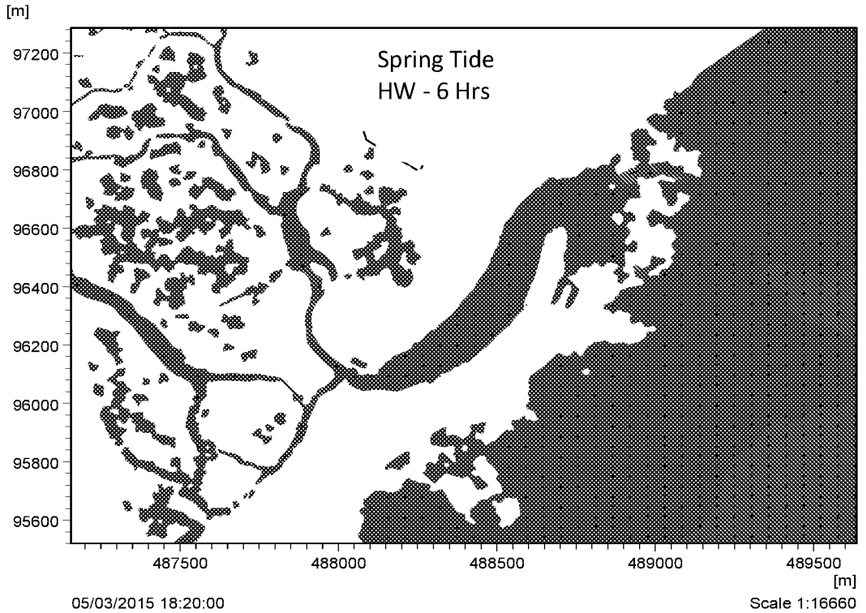
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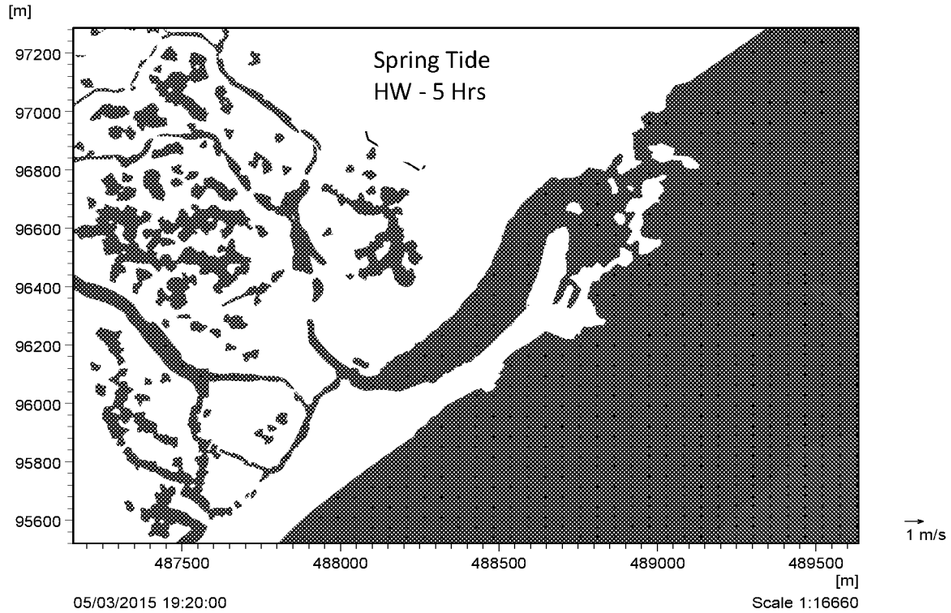
Appendix Figures

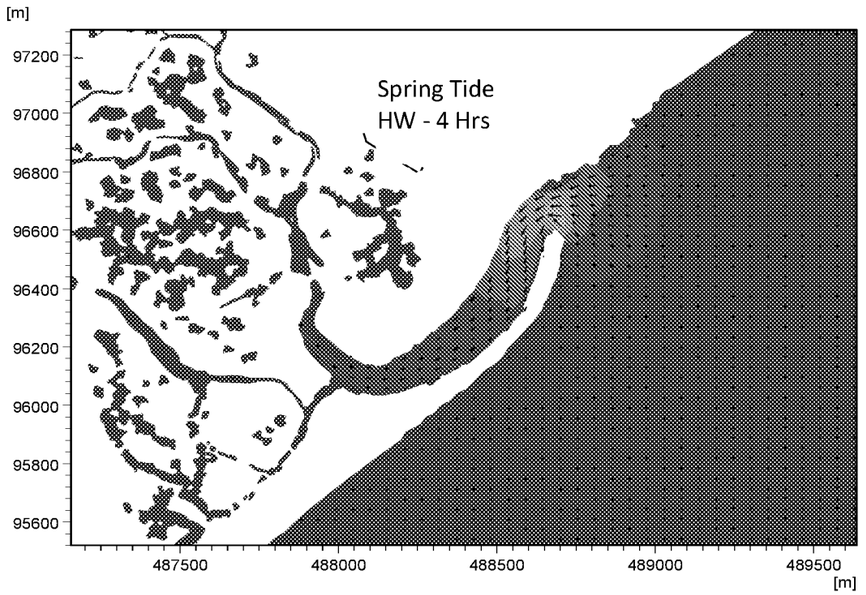
A1. Spring Tide Baseline plots – Flow Speed (A)
A2. Spring Tide Baseline plots – Flow Speed (B)
A3. Spring Tide Baseline plots – Flow Speed (C)

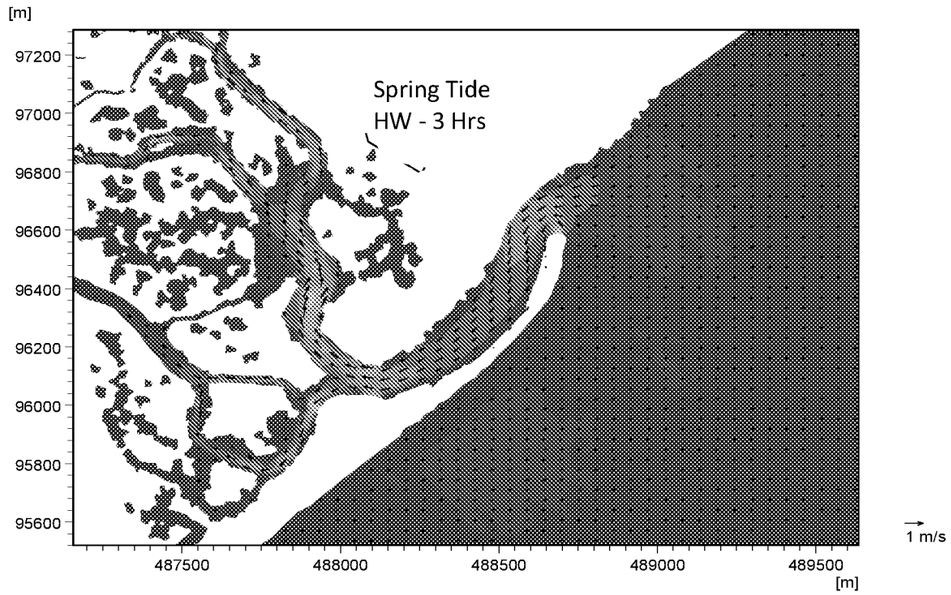
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Current speed [m/s]

	Above 1.80
	1.65 - 1.80
	1.50 - 1.65
	1.35 - 1.50
	1.20 - 1.35
	1.05 - 1.20
	0.90 - 1.05
	0.75 - 0.90
	0.60 - 0.75
	0.45 - 0.60
	0.30 - 0.45
	0.15 - 0.30
	0.00 - 0.15
	-0.15 - 0.00
	-0.30 - -0.15
	Below -0.30
	Undefined Value

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Scale		n/a	
QA		REW	
PaghamSpringTidalAtlas.xlsm			
Produced by ABPmer			



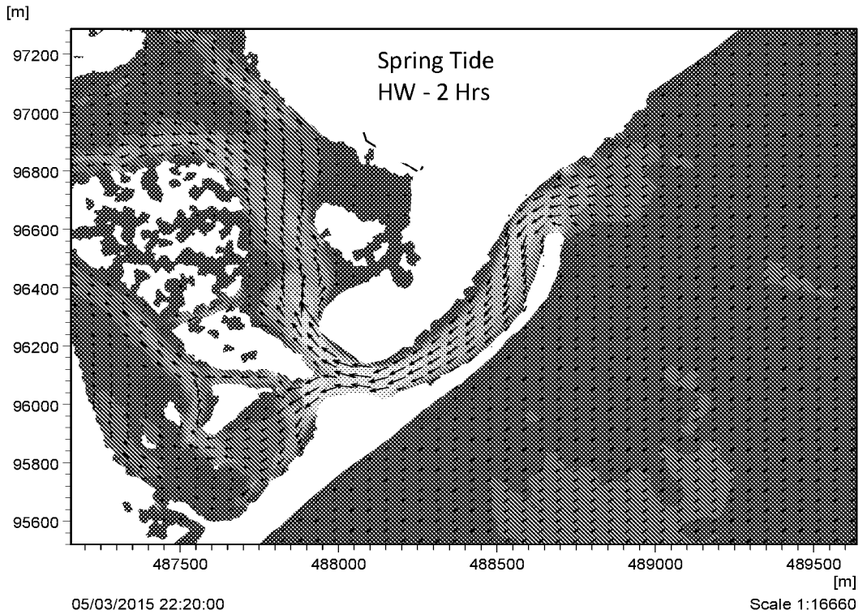
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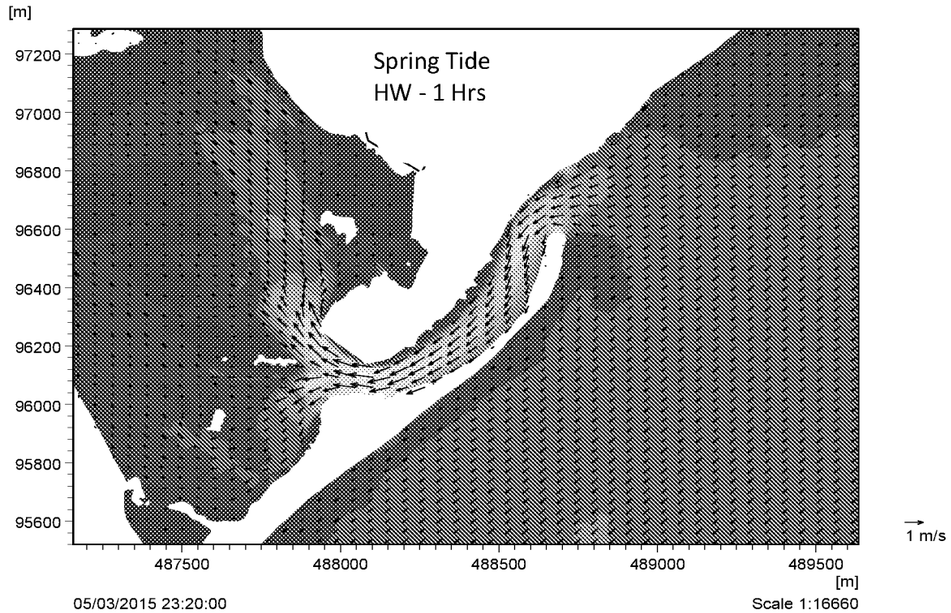
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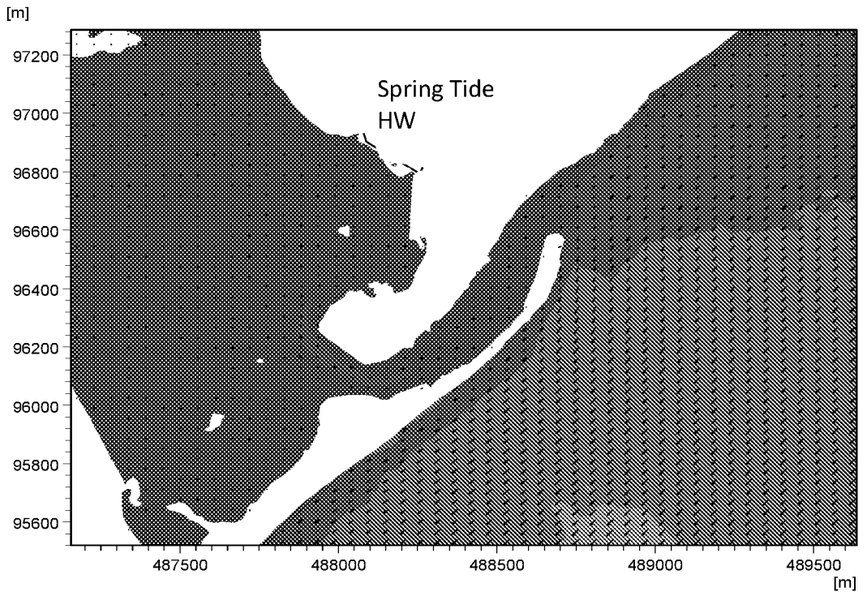
Spring Tidal Atlas - Baseline Flow Speed (A)

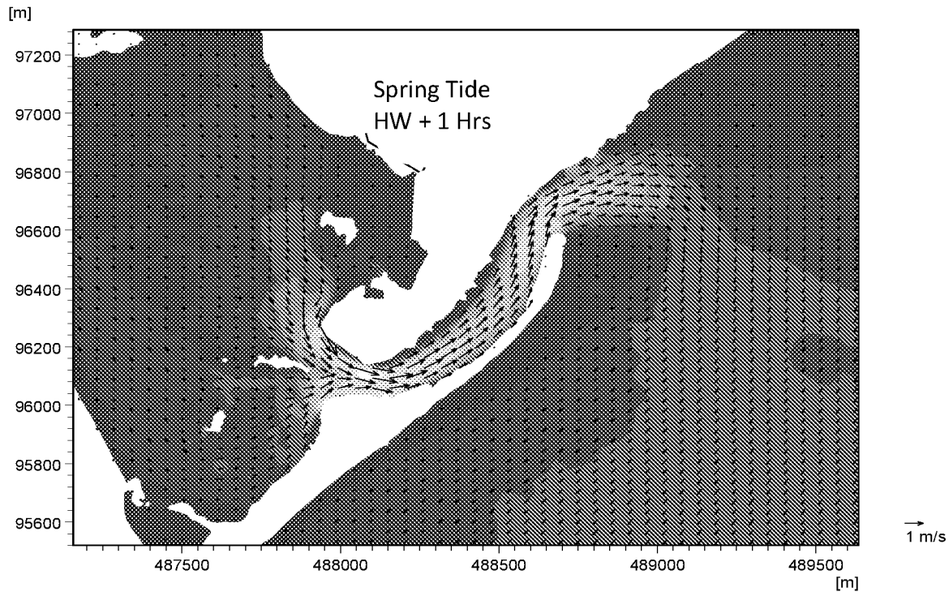
Figure A1

ARUN DISTRICT COUNCIL P/97/15/PL









Current speed [m/s]

- Above 1.80
- 1.65 - 1.80
- 1.50 - 1.65
- 1.35 - 1.50
- 1.20 - 1.35
- 1.05 - 1.20
- 0.90 - 1.05
- 0.75 - 0.90
- 0.60 - 0.75
- 0.45 - 0.60
- 0.30 - 0.45
- 0.15 - 0.30
- 0.00 - 0.15
- -0.15 - 0.00
- -0.30 - -0.15
- Below -0.30
- Undefined Value

Date	By	Size	Version
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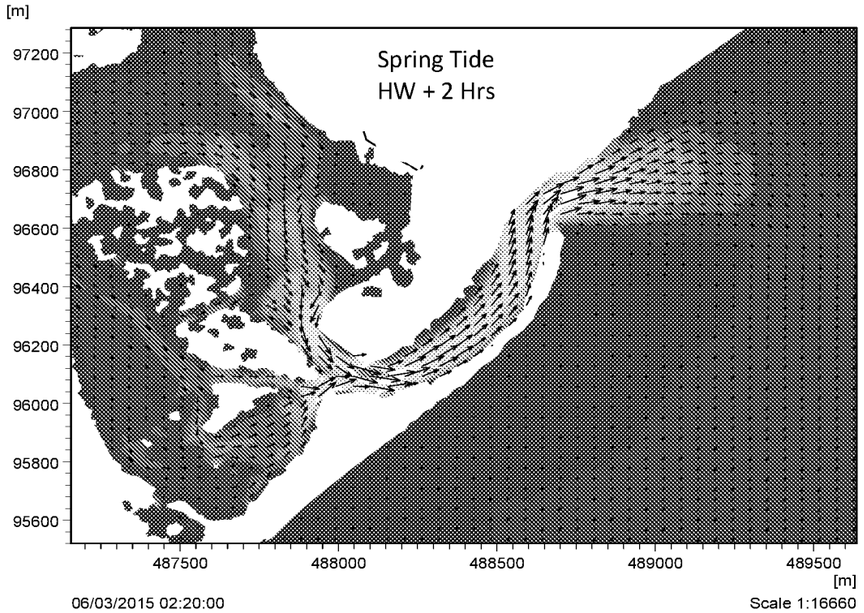
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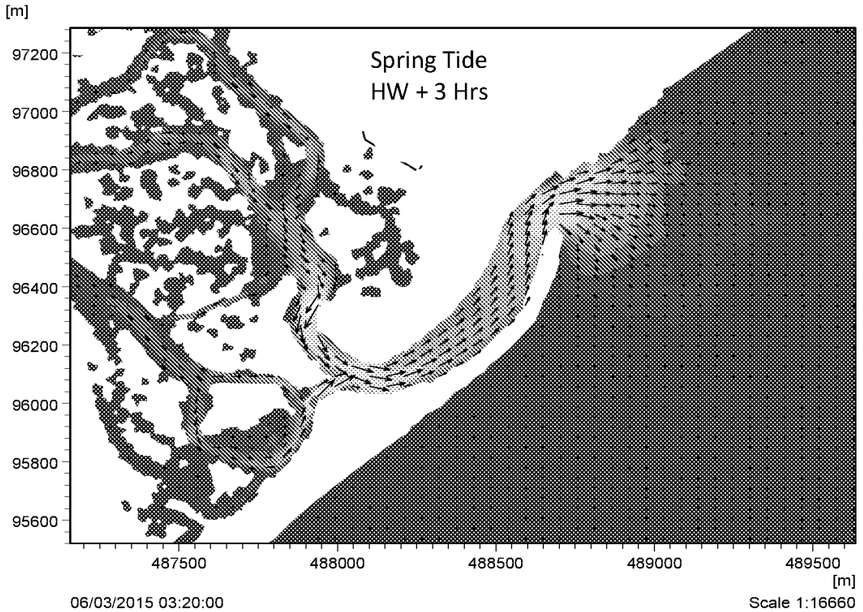
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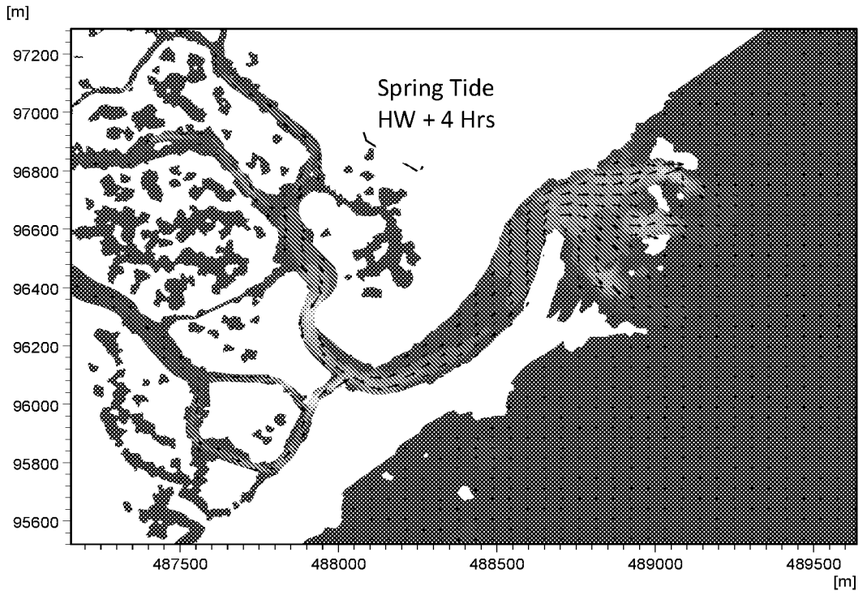
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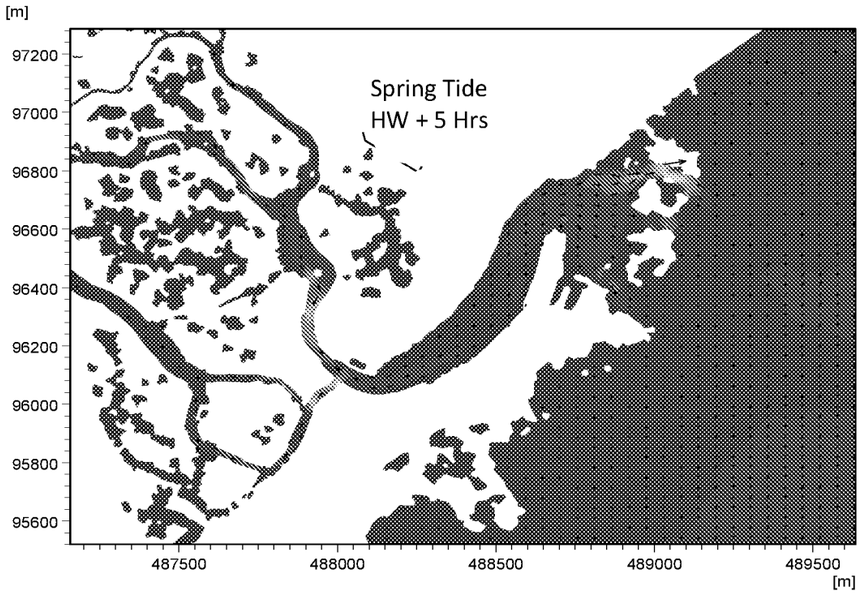
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Current speed [m/s]

Above	1.80
1.65 -	1.80
1.50 -	1.65
1.35 -	1.50
1.20 -	1.35
1.05 -	1.20
0.90 -	1.05
0.75 -	0.90
0.60 -	0.75
0.45 -	0.60
0.30 -	0.45
0.15 -	0.30
0.00 -	0.15
-0.15 -	0.00
-0.30 -	-0.15
Below	-0.30
Undefined Value	

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PaghamSpringTidalAtlas.xlsm			
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Spring Tidal Atlas - Baseline Flow Speed (C)

Figure A3

Appendix B

Scoping Consultation Log

Managed Breach of Shingle Spit at Pagham: Environmental Statement

Volume 2: Appendices

Contents

Page

B. Scoping Consultation Log 3

ARUN DISTRICT COUNCIL P/93/25/PL

B. Scoping Consultation Log

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
James Kenny, Chichester District Council	06/05/2015	Archaeology	1	It should be possible to return the breach to where it was in the late 1990s without impacting on any archaeological interest. In the circumstances the inclusion of archaeology in any EIA would not be necessary.	No action.	NA
Steve Dommett, Chichester District Council	12/05/2015	Noise	2	While I agree that the 600m distance to residents will afford a degree of flexibility from a noise point of view, I was not able to determine how the shingle might be transported and what the full extent of the working hours might be in order to accommodate tides. These issues should be clarified in due course as notwithstanding the distance afforded by the location of the breach site, I have no doubt that heavy vehicle movements at the extremes of the day could cause consternation to local residents.	Contractors with significant experience of undertaking beach movement operations (including experience of excavating breaches through the shingle barrier at Medmerry) have been consulted on the proposed methodology for the project. The main access routes, project programme and proposed construction methods have been included in the ES. Given that the proposed project will strongly benefit the coastal flood protection and recreational and amenity value of the beach to the local community at Pagham, it is considered unlikely that the movements of a small number of construction plant (limited to the Pagham side of the harbour), which are limited to the start and end of the construction programme, will cause any inconvenience or annoyance.	3.2

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Emma Winchester, Environment Agency	08/05/2015	Flood risk	3	We are satisfied with the scope of the report and recommendations for further assessment areas to be included in the Environmental Statement. We advise that a Flood Risk Assessment will need to be submitted for this proposal.	The proposed breach of the spit will provide an appropriate level of flood risk protection over a relatively short timescale (a least 8 years) in comparison to proposals for 'hard' coastal defence works. Given the nature of these changes it is not considered appropriate or proportionate to undertake a full FRA. The ES, however, discusses the benefits of the proposed project in terms of flood risk along Pagham Beach and the implications of the changes to flood risk within Pagham Harbour which would inform a FRA if necessary. Further consultation with the Environment Agency will be required as part of the implementation of the scheme, the securing of funding and flood defence consenting which will confirm anything beyond what is provided within the ES which will be required.	6.3.5
Emma Winchester, Environment Agency	08/05/2015	Fisheries	4	We also recommend that the Sussex Inshore Fisheries Conservation Authority (IFCA) is consulted on this proposal	We have consulted with the Sussex IFCA. A copy of the Scoping Report has been sent and opportunity for comment provided. No response has been received as yet.	NA

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Greg Tomlinson, Marine Management Organisation	22/05/2015	Marine licence	5	The responsibilities of the MMO include the licensing of construction works, deposits and removals in the marine area by way of a marine licence. Marine licences are required for deposits or removals of articles or substances below the level of mean high water springs, unless a relevant exemption applies. It is acknowledged in the report that the proposed works will require a licence from the MMO under Part 4 of the MCAA 2009.	It is recognised that a Marine licence will be needed for this work. To progress this issue, the MMO (Greg Tomlinson) was consulted with during the course of the impact assessment process. It was agreed that the licence application should be progressed subsequent to the submission of the planning application. This will help to ensure that an integrated approach to the planning process is adopted in keeping with Coastal Concordat principles (see below).	NA
Greg Tomlinson, Marine Management Organisation	22/05/2015	Coastal Concordat	6	The MMO recognises there is some overlap between the geographical jurisdiction of the MMO and the local planning authorities (i.e. between MHWS and mean low water) and would welcome the opportunity to further discuss ways of workings aligned to the principles of the Coastal Concordat for England (https://www.gov.uk/government/publications/a-coastal-concordat-for-england).	Possible ways of streamlining the application and consultation process have been put forward to the MMO.	NA
Greg Tomlinson, Marine Management Organisation	22/05/2015	Consultation	7	The MMO notes the proposed works are within or adjacent to the Pagham Harbour Site of Special Scientific Interest (SSSI), Pagham Harbour Marine Conservation Zone (MCZ) and Pagham Harbour Special Protection Area (SPA). Should the applicant wish to seek a detailed scoping opinion from the MMO, they should engage directly with us and submit a scoping request on the MMO's online Marine Case Management System (https://marinelicensing.marinemanagement.org.uk/).	A scoping request was submitted directly to the MMO (an approach was subsequently agreed involving engagement post planning as described above).	NA

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	8	Natural England's advice is that this proposal has the potential to negatively impact on a number of key features of both international and national importance; principally these are the SPA and Ramsar bird interest features and their supporting habitats and SSSI geomorphological interest.	Noted. These issues have been given particular consideration throughout the scheme design and assessment processes.	NA
Angela Marlow, Natural England	15/05/2015	Habitats Regulations Assessment (HRA)	9	If adverse effects on site integrity are concluded, under Article 6(4) of the Habitats Directive, the proposal must follow the tests of 'no alternatives' and 'imperative reasons of overriding public interest' in order to obtain permission.	Following a thorough assessment it has been concluded that the possibility of an adverse effect cannot be excluded on the basis that the scheme once completed will be subject to the dominant effects of natural processes and there is some uncertainty as to future site evolution. As a consequence, further information to support the tests of 'no alternatives' and inform the preparation of an IROPI case has been provided in the ES. In addition, an HRA signposting document has been included as an Appendix to the ES.	2.1, 2.2, Appendix C
Angela Marlow, Natural England	15/05/2015	Designated sites and features	10	The EIA also needs to consider the SSSI geomorphological interest feature of the site (i.e. the Church Norton spit itself). This should consider both the impacts arising from breaching of the spit and the longer term implications of management options that may restrict the coastal processes required to re-establish the geomorphological interest and how this affects this SSSI features in accordance with the CROW Act (Section 28G of The Wildlife and Countryside Act (1981) (as amended)) which imposes a duty on all government and public bodies, including Local Planning Authorities to conserve and enhance the special interest features of SSSIs.	Noted. The assessment of the impacts of the scheme on the spit has taken account of these considerations. The Legislation and Policy Appendix acknowledges the duty placed on all government and public bodies under the CROW Act.	8.2.1, 8.2.4, 8.2.7, 8.2.11, Appendix E

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	11	Consideration should also be given to both the achievability and uncertainty of the proposal, due to the intervention being within a dynamic coastal system. Various scenarios may result after the breach and these may pose a risk of significant negative impacts on the conservation features of a number of designations. The main risks are likely to be the loss of little tern habitat, changes to the intertidal habitat within the harbour, the potential closure of the harbour and the SSSI geomorphological interest. These risks need to be assessed within the EIA and any proposal mitigation measures need to be set out.	A discussion on the uncertainty associated with the proposed project and also other alternatives have been included in the ES. The potential impacts on designated sites and features, including any necessary mitigation measures, have been assessed in the relevant receptor chapter of the ES.	2.2, 6.3 and 8.2
Angela Marlow, Natural England	15/05/2015	Change in Scope	12	Should the proposal be amended in a way which significantly affects its impact on the natural environment then, in accordance with Section 4 of the Natural Environment and Rural Communities Act 200, Natural England should be consulted again.	Noted. Natural England has been kept informed of any developments that have been made during the assessment process. As part of that process, a stand-alone breach design report was issued (June 2015) that described the proposal in greater detail based on the technical and modelling work undertaken. This updated description is based on the original design principles and the proposal was not altered significantly.	NA
Angela Marlow, Natural England	15/05/2015	General	13	Schedule 4 of the Town & Country Planning (EIA) Regulations 2011, sets out the necessary information to assess impacts on the natural environment to be included in the ES.	These requirements are signposted in the Consents, Approvals and Policy Guidance Chapter of the ES.	4.3
Angela Marlow, Natural England	15/05/2015	Cumulative and in-combination	14	It will be important for any assessment to consider the potential cumulative effects of this proposal, including all supporting infrastructure, with other similar proposals and a thorough assessment of the 'in combination' effects of the proposed development with any existing developments and current applications. A full consideration of the implications of the whole	A cumulative and in-combination assessment chapter is included in the ES.	10

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				scheme should be included in the ES. All supporting infrastructure should be included within the assessment.		
Angela Marlow, Natural England	15/05/2015	EIA Methodology	15	Natural England advises that the potential impact of the proposal upon features of nature conservation interest and opportunities for habitat creation/enhancement should be included within this assessment in accordance with appropriate guidance on such matters. Guidelines for Ecological Impact Assessment (EcIA) have been developed by the Chartered Institute of Ecology and Environmental Management (CIEEM) and are available on their website.	The impact assessment process that has been followed is based on a standard analysis methodology which was developed from a range of sources, including the Institute of Ecology and Environmental Management's (IEEM) Guidelines for Ecological Impact Assessment in the UK (IEEM, 2006).	5
Angela Marlow, Natural England	15/05/2015	Policy	16	The National Planning Policy Framework sets out guidance in S.118 on how to take account of biodiversity interests in planning decisions and the framework that local authorities should provide to assist developers	A review of the NPPF is included in an Appendix to the ES and the proposal is considered to be in-keeping with the principles of NPPF which directs planning decisions to give full weight to sustainable development. Altering the shoreline towards a more sustainable morphology with associated benefits for coastal protection and amenity value of the beach are central to this proposal. The effects on the ecology have also been given full consideration.	2.3, Appendix E
Angela Marlow, Natural England	15/05/2015	Designated sites and features	17	The ES should thoroughly assess the potential for the proposal to affect designated sites. European sites (e.g. designated SACs and SPAs) fall within the scope of the Conservation of Habitats and Species Regulations 2010. In addition, paragraph 118 of the NPPF requires that potential SPAs, possible SACs, listed or proposed Ramsar sites, and any site identified as being necessary to compensate for adverse impacts on classified,	The importance of this aspect has been recognised throughout the design and assessment process including through regular consultation with Natural England. A review of the effects on internationally protected sites that	8.1, Appendix C

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				potential or possible SPAs, SACs and Ramsar sites be treated in the same way as classified sites.	fall within the scope of the HRA is included in an Appendix to the ES.	
Angela Marlow, Natural England	15/05/2015	Designated sites and features	18	Under Regulation 61 of the Conservation of Habitats and Species Regulations 2010 an appropriate assessment needs to be undertaken in respect of any plan or project which is (a) likely to have a significant effects on a European site (either alone or in combination with other plans or projects) and (b) no directly connected with or necessary to the management of the site. Should a Likely Significant Effect on a European/Internationally designated site be identified or be uncertain, the competent authority (in this case the Local Planning Authority) may need to prepare an Appropriate Assessment, in addition to consideration of impacts through the EIA process. The EIA needs to consider construction, operational and decommissioning impacts.	It has been agreed with Natural England that the project will have a 'likely significant effect' as defined under the Habitats Regulations. Therefore an Appropriate Assessment (AA) will be required. To inform the preparation of the AA, an Information for an Appropriate Assessment "signposting document" has been included as an Appendix to the ES. This directs the competent authority(ies) to the locations within the assessment documentation where the information needed to produce an AA can be obtained.	Appendix C
Angela Marlow, Natural England	15/05/2015	Designated sites and features	19	Pagham Harbour SSSI The special interest of the SSSI are not all listed in the scoping report text or in Table 1 of the report (which should be titled 'qualifying features of conservation designations of Pagham Harbour' rather than 'Marine components of the qualifying features of the Pagham Harbour designated sites').	All terrestrial and marine features are now included in the description of the Pagham Harbour SSSI in the ES	8.1, Appendix F
Angela Marlow, Natural England	15/05/2015	Designated sites and features	20	Of particular note is that the geomorphology interest and SSSI bird interest (over and above the SPA bird features) are missing from this table, these features are of key interest for the assessment of this proposal. Our advice would be that the EIA provides a full list of the interest features for all designations and then lists those that are screened out and why, and then completes a full assessment on those likely to be affected.	A table listing all the interest features of all designations in Pagham Harbour has been included in the ES. This table includes a column that describes whether the features have been scoped in or out of the assessment and on what basis.	8.1

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	21	Further information on the SSSI and its special interest features can be found at www.magic.gov. The ES should include a full assessment of the direct and indirect effects of the development on the features of special interest within Pagham Harbour SSSI and should identify such mitigation measures as may be required in order to avoid, minimise or reduce any adverse significant effects.	An assessment of the direct and indirect effects of the proposed project on SSSI features is included in the ES.	8.2
Angela Marlow, Natural England	15/05/2015	Designated sites and features	22	SSSI Geomorphology interest feature Pagham Harbour provides the best documented example of a double spit system made of shingle in England (i.e. a location which has two spits, one from either side of the harbour). The fact that the Pagham spits are made up of shingle has allowed clear ridges to form, these provide excellent examples of how such features have grown historically. This has provided significant information to the science of coastal geomorphology to enable an understanding of how spits develop and change.	Noted. This has been recognised in the coastal geomorphology baseline in the Nature Conservation and Ecology Chapter of the ES. The historic and more recent evolution of the spit is described in detail in the Physical Environment and Coastal Protection Chapter.	6.2.6, 8.1.7
Angela Marlow, Natural England	15/05/2015	Designated sites and features	23	In addition, in terms of the active processes Pagham currently shows a truly exceptional rapid extension of its western spit that has not been seen elsewhere in England in the last 60 years (and possibly longer); this illustrates the ongoing geomorphological importance of the site in a national context. Full details of the geomorphological SSSI interest are contained in the SSSI citation.	See response to comment 22.	6.2.6, 8.1.7
Angela Marlow, Natural England	15/05/2015	Designated sites and features	24	The initial breach through Church Norton spit would result in damage to the geomorphology of the SSSI. Although the lack of hard structures is positive, the position of the breach and any requirements for future management to retain it in situ, increases the impact. Conservation of the geomorphological interest requires that dynamism of the spit systems is retained. Currently the scoping report does not provide certainty around how this could be achieved.	The future evolution of the site and effects on the geomorphological interest features are assessed in the ES .	6.3.1, 6.3.3, 8.2.1, 8.2.4, 8.2.7

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	25	The assessment with regards to the geomorphology needs to consider: - Assessment of how the breach through the spit to create a new channel in the location suggested would impact the geomorphological interest features of the SSSI in accordance with the CROW Act to conserve and enhance, and predict (using best available evidence and expert opinion) how the geomorphology is likely to respond.	The assessment on the geomorphological interest feature has taken account of the CROW Act.	6.3.1, 6.3.3, 8.2.1, 8.2.4, 8.2.7
Angela Marlow, Natural England	15/05/2015	Designated sites and features	26	- A key unknown with the current proposal is whether maintenance would be required to keep the newly created channel open. This is a key issue as it affects how and whether the geomorphological interest features of the spit can be expected to recover with time (either in whole or in part).	Once the existing channel is closed and the new breach is created, natural processes will take over and no ongoing management of the site (e.g. maintaining the breach position) is proposed. However, one subsequent breach intervention has been included as part of the proposal as a contingency should the breach close. Breach closure would result in the loss of the spit features and therefore we consider such an intervention to be in keeping with the requirements of the CROW Act.	6.3.1, 6.3.3, 8.2.7, 8.2.11
Angela Marlow, Natural England	15/05/2015	Designated sites and features	27	- If no hard structure is put in place and management of the breach is not carried out (allowing the spit to regrow) then the impact on the geomorphological interest could likely be viewed, to a certain extent, as temporary.	Agreed.	8.2.7
Angela Marlow, Natural England	15/05/2015	Designated sites and features	28	- If continued maintenance of the breach is needed (e.g. through dredging the harbour channel and keeping it in the same place) this would be viewed as a permanent (as long as maintenance is in place) loss of the geomorphological interest of the site.	See response to comment 26.	6.3.3, 8.2.7, 8.2.11

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	29	- Impacts of both construction and operation need to be considered.	Noted.	8.2
Angela Marlow, Natural England	15/05/2015	Designated sites and features	30	- Mitigation of any impacts may include the potential removal of any redundant hard structures from the harbour that currently prevent the site from responding to coastal processes.	No proposals for removing redundant hard structures from the harbour are currently included as part of the proposed project.	NA
Angela Marlow, Natural England	15/05/2015	Designated sites and features	31	- Monitoring and evaluation of the evolution of the spit post breach (e.g. low tide LiDAR), could also form mitigation for the impacts on this special scientific interest.	Agreed, post breach monitoring is included as mitigation for adverse effects on the SSSI feature.	8.2, 11.2
Angela Marlow, Natural England	15/05/2015	Designated sites and features	32	- The report needs to appreciate the dynamic nature of the spit and that it is likely to breakdown at some point and that the sediment supply at Pagham will change in time. This needs to be recognised and taken into account when considering management options for both the preferred option and any alternatives. Consideration of both certainty and timescales of any intervention should be set out.	The level of certainty and longevity of the alternative options in terms of providing coastal protection is evaluated in the Consideration of Alternatives section of the ES. The changes to the shingle spit during operation and the changes in the supply of sediment are considered in the ES.	2.2, 6.2.8, 6.3.1, 6.3.3, 8.2.7
Angela Marlow, Natural England	15/05/2015	Designated sites and features	33	- It is not very clear to us that using the examples of Porlock and Medmerry are useful parallels as the conditions at these sites differ from Pagham.	Porlock and Medmerry are useful analogues because they involved man-made/natural breaches through shingle barriers. They are thought to be the best examples of such in the UK. They offer guidance on the scientific relationships that exist between littoral drift and tidal prism to help understand how such breaches can remain stable. Medmerry is also a precedent for showing how the application of these scientific	6.2.6 and Appendix A

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
					principles can then lead to a successful project being implemented (and Medmerry was also different from, but built upon, the lessons at Porlock). They are not analogues for this proposal in all respects. No such parallel is believed to exist at another location (Natural England has been separately asked for any such examples that they might be aware of). The best analogue is the vast range of morphologies that have existed in Pagham Harbour itself in the past and that has been reviewed in detail in Chapter 6. Further details about Medmerry and Porlock are also contained in the Breach Design Report in Appendix A	
Angela Marlow, Natural England	15/05/2015	Designated sites and features	34	Other SSSI features - The palaeobotanical GCR interest (GCR No. 764 - Bognor Regis) extends from SZ 889979 to SZ 934987, and includes the entire frontage, eastward of the easternmost the groynes at Pagham. While this would seem to be away from the breach proposals, this interest could easily be damaged by vehicles tracking along the foreshore at low tide and therefore should be considered and scoped out if appropriate.	The main access to the site will be from the east on the Pagham side of the harbour but will not overlap with the palaeobotanical GCR interest of GCR 764 Bognor Regis. However, the palaeobotanical interest of Pagham Harbour RIGS has been scoped into the assessment.	3.2, 8.1, 8.2.1, 8.2.4, 8.2.7
Angela Marlow, Natural England	15/05/2015	Designated sites and features	35	In addition, the area of the proposed breach is through an extensive area of shingle habitat. Wider damage to shingle habitat (both to vegetation and geomorphology) during construction and transportation of shingle on both Church Norton and Pagham Beach should be assessed. The EIA needs to	These impact pathways have been included in the assessment.	8.2

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				assess both the construction impacts and the operational impacts on the SSSI habitats and other features including SSSI bird species that might be impacted.		
Angela Marlow, Natural England	15/05/2015	Designated sites and features	36	Pagham Harbour Marine Conservation Zone The proposal has the potential to directly or indirectly affect the features of the Pagham MCZ. The application will therefore require an assessment under Section 126 of the Marine and Coastal Access Act 2009 to determine whether there is any significant risk of the proposal hindering the conservation objectives of the MCZ (Section 5 of the Designation Order). The assessment will need to consider the significance of impacts to the [three] MCZ features. The MCZ assessment should refer to the conservation advice package as produced by Natural England under Section 127 (1) of the Marine and Coastal Access Act 2009. https://www.gov.uk/conservation-advice-for-marine-protected-areas-how-to-use-site-advice-packages	The advice is not currently available for this site on the website but we understand that these are currently being produced. An MCZ assessment is included as an appendix to the ES.	Appendix G
Angela Marlow, Natural England	15/05/2015	Designated sites and features	37	We have previously supplied to the consultants a map of the survey results and the verification report for the DeFolin's Lagoon snail.	This map has been incorporated into the ES.	8.1.4
Angela Marlow, Natural England	15/05/2015	Designated sites and features	38	DeFolin's lagoon snail may be impacted through direct reduction in numbers (if they use that area or are in the vicinity); reduction in the distribution/extent of the population (if they use that area or are in the vicinity); together with associated indirect impacts on supporting or potentially supporting habitat (loss of, or alteration from optimum conditions).	The effects of the loss of, and change to, habitat for DeFolin's lagoon snail within the development footprint during construction has been assessed in the ES and MCZ assessment appendix.	8.2.3, 8.2.5, 8.2.9, Appendix G
Angela Marlow, Natural England	15/05/2015	Designated sites and features	39	Opening up the harbour to more direct wave action could potentially threaten the seagrass beds via changes in energy/exposure (tidal scour); sedimentation rate (sediment scour); and water quality (i.e. turbidity).	The effects on seagrass beds of changes brought about by the proposed project post construction have been assessed in the ES and MCZ assessment.	6.3.4, 8.2.9, Appendix G

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	40	We do not consider that the lagoon shrimp would be a concern as current evidence indicates it is located in the Ferry Pool Lagoon.	Agreed. This interest feature has been scoped out of the ES and MCZ assessment.	8.1.2, Appendix G
Angela Marlow, Natural England	15/05/2015	Designated sites and features	41	Pagham Harbour Special Protection Area (SPA) and Ramsar site Natura 2000 network site conservation objectives are available on our internet site http://publications.naturalengland.org.uk/category/6490688940899216 (see annex 1)	These sites have been screened into the assessment.	8.1.2, Appendix C
Angela Marlow, Natural England	15/05/2015	Designated sites and features	42	In this case the proposal is not directly connected with, or necessary to, the management of a European site. In our view it is likely that it will have a significant effect on internationally designated sites and therefore will require assessment under the Habitats Regulations. We recommend that there should be a separate section of the ES to address impacts upon European and Ramsar sites entitled 'Information for Habitats Regulations Assessment' this should address the following issues:	Noted. Article 6 of the Habitats Directive requires an appropriate assessment if there is a likely significant effect. The HRA is the term for the whole process of determining whether there will be a LSE or adverse effect on site integrity. An appendix signposting all the necessary information for an AA is included in the ES.	Appendix C
Angela Marlow, Natural England	15/05/2015	Designated sites and features	43	Potential impacts on the SPA and Ramsar bird interest features, to include increased disturbance, loss of little tern habitat, potential changes to the habitat available within the inner harbour to wintering and breeding birds through more direct tidal action and the risk of closure of the harbour.	These impact pathways have been included in the assessment.	6.3.4, 8.2.2, 8.2.5, 8.2.6, 8.2.8, 8.2.9, 8.2.10, 8.2.11, Appendix C
Angela Marlow, Natural England	15/05/2015	Designated sites and features	44	The proposal has the potential to adversely affect the integrity of the SPA with regard to both the breeding (little terns and common terns) and the overwintering birds in the inner harbour.	Impacts on both breeding and overwintering birds are discussed in the assessment.	8.2.2, 8.2.5, 8.2.6, 8.2.8, 8.2.9, 8.2.10, 8.2.11 Appendix C

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	45	Detailed comments on the SPA bird features - breeding little terns - The little terns with growing success continue to nest along the Church Norton spit.	Detailed accounts of the current and past breeding success of Little Terns (and other species) have been included in the baseline.	8.1.5
Angela Marlow, Natural England	15/05/2015	Designated sites and features	46	- Little terns are extremely vulnerable to disturbance and predation from a range of factors (humans, dogs, near-shore recreation and natural predators), such that the only regularly successful breeding colonies in England are those where these factors are actively managed. Such management generally requires some combination of site wardening, physical access restrictions, and predator control or diversionary feeding.	Noted. A scientific review on the vulnerability of Little Terns to predation,= and disturbance have been included as part of relevant pathways. Active management techniques are also reviewed in an appendix.	8.2.2,8.2.10, Appendix L
Angela Marlow, Natural England	15/05/2015	Designated sites and features	47	- The proposal would likely increase the level of disturbance by people, their dogs and predators, as the material used to block the channel would provide more direct access onto the spit from Pagham Beach. As this location receives many more visitors than the Church Norton spit potentially management measures may be required to control this increase in disturbance.	The potential impact on birds as a result of disturbance due to more direct access on to the Spit has been assessed. A range of mitigation measures are proposed to minimise disturbance.	8.2.10, 11.2
Angela Marlow, Natural England	15/05/2015	Designated sites and features	48	- Consideration should be given to potentially negative impacts that may result from the breach position, as this potentially opens the harbour up to increased marine recreation activities such as boating which may also result in an increase in disturbance to the bird interest features.	The potential disturbance impact of changes in accessibility into the harbour during operation has been assessed.	8.2.10
Angela Marlow, Natural England	15/05/2015	Designated sites and features	49	- As the disconnected spit moves away under longshore drift (timescale to be confirmed in the EIA), loss of nesting habitat for little tern would occur.	Loss of nesting habitat for Little tern due to future shoreline evolution has been assessed.	8.2.8
Angela Marlow, Natural England	15/05/2015	Designated sites and features	50	- The suggested approach to offsetting the impacts upon breeding little terns is to create new habitat in the form of isolated gravel islands in the harbour or recharge existing islands. Again, the results of such actions may be considered unpredictable - they would benefit the little terns only if the little terns found them suitable and chose to use them. Experience at this and other sites indicates that it is quite likely that any such	Noted. A review of the factors to consider when designing tern islands has been undertaken including the risk of competition and predation.	Appendix L

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				new habitat would be colonised by other tern species (e.g. common terns and Sandwich tern) and/or gulls, which would outcompete little terns, preventing them from settling or displacing any birds that had attempted to settle, but could also take eggs and nestlings which would represent a considerable additional predation pressure upon any remaining little terns.		
Angela Marlow, Natural England	15/05/2015	Designated sites and features	51	- Furthermore, following the CJEU ruling in the Briels case, there may be issues as to whether the creation of habitat for SPA features within the site fabric of the SPA can be regarded as 'mitigation' under the Habitats Directive (currently there is no UK specific case law on this point although CJEU case law is binding). Rather it may be considered as 'compensation', an option which is available only after following the 'no alternatives' and 'imperative reasons of overriding public importance' tests under Article 6(4) of the Habitats Directive.	The implications of the Briels case and Natural England's advice have been considered in this assessment. Information to support the alternatives and IROPI tests under Article 6(4) of the Habitats Directive are provided in the ES and Information for an Appropriate Assessment Signposting Appendix. Proposals for compensatory habitat within the site fabric of the SPA are also provided.	2.1, 2.2, 11.2, Appendix C
Angela Marlow, Natural England	15/05/2015	Designated sites and features	52	- Therefore the consideration of alternatives for preventing erosion of Pagham Beach is likely to be a key issue in this HRA and EIA. Comparison between the preferred option and alternatives need to consider the certainty, risk, sustainability and longevity of each proposal in relation to the interest features of the designated site. Clear indication should be provided on the benefits and risks with supporting evidence in managing this current issue in a dynamic system	Noted, this information is provided in the Consideration of Alternatives Section of the ES.	2.2
Angela Marlow, Natural England	15/05/2015	Designated sites and features	53	Detailed comments on the SPA/Ramsar overwintering and breeding bird features within the harbour - The position of the proposed breach has the potential to change the physical conditions of Pagham Harbour due to more direct influence of the sea through tidal inundation and wave action, potentially increasing the tidal prism of the harbour. This	These impact pathways have been included in the assessment.	6.3.4, 8.2.9

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				may result in impacts on the supportive intertidal habitats (e.g. change in type, extent and erosion impacts) that supports both overwintering and breeding birds. These potential changes will need to be assessed.		
Angela Marlow, Natural England	15/05/2015	Designated sites and features	54	- If there is a credible risk that the mouth of the harbour may close as a result of this intervention, this would lead to the removal of the harbour from tidal influence and potentially lead to a significant changes in the abundance and availability of invertebrate and fish populations. Such changes would be likely to have a significant effect upon the SPA water birds populations, and we advise that appropriate assessment may be unable to exclude the potential for an adverse effect upon the integrity of the site.	The risk of the tidal inlet channel closing as a result of the proposed project has been assessed. This risk also exists under the baseline situation and the potential effects this would cause to nature conservation features are considered as a future baseline scenario in the ES. A review of the positive and negative impacts associated with the alternative option of artificially closing the channel has also been included in the consideration of alternatives section of the ES.	2.2, 6.3.1, 8.1.9, 8.2.11
Angela Marlow, Natural England	15/05/2015	Designated sites and features	55	- Similarly, the abundant plant resources used by foraging birds are also likely to be affected, albeit on a somewhat longer timescale. The availability of these plants, through changes in the tidal cycle and lack of exposure, could, however, result in more rapid change.	The impacts of the closure of the harbour tidal inlet on birds have been considered in the ES.	8.1.9
Angela Marlow, Natural England	15/05/2015	Designated sites and features	56	- Breeding bird population would also be impacted, through habitat changes resulting from closure, and an increased potential for ground predators and disturbance factors (e.g. human activity) to reach nesting locations if access restrictions as a result of tidal movements are removed.	The impacts of the closure of the harbour tidal inlet on birds have been considered in the ES.	8.1.9
Angela Marlow, Natural England	15/05/2015	Designated sites and features	57	- The EIA needs to consider the potential risk around closure occurring and in the event of this occurring what actions would be taken to remedy this.	The risk of the tidal inlet channel closing as a result of the proposed project has been assessed. The	3.2.7, 6.3.1, 8.2.11

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
					likelihood of the tidal inlet closing is highly unlikely. However, one subsequent breach intervention has been included as part of the proposal as a contingency in the event of this occurring.	
Angela Marlow, Natural England	15/05/2015	Designated sites and features	58	Possible/draft marine SPA extension for foraging TernsThe possible/draft new marine Solent and Dorset Coast SPA will cover the foraging activity for little Sandwich and common tern species designated at the adjacent qualifying breeding tern SPA colonies and will be formally consulted on later this year. This designation will require consideration in relation to a plan/project at or within proximity of the respective breeding SPA colony. However, the possible/draft new marine SPA extension is not expected to add any further requirements to this assessment as these should already be considered due to Pagham Harbour's SPA designated tern species.	Reference is made to draft marine SPA extensions in the report.	8.1.5
Angela Marlow, Natural England	15/05/2015	Designated sites and features	59	In general terms, given the features is foraging terns; impacts would be those that prevent terns directly from foraging (disturbance); or indirectly (prey availability or loss of habitat supporting prey). Disturbance and prey availability would be a seasonal consideration given they only forage in this area in the breeding season; however supporting habitat would require consideration year-round.	Disturbance impacts and changes to habitat/prey for foraging terns have been assessed.	8.2.5, 8.2.6, 8.2.9, 8.2.10
Angela Marlow, Natural England	15/05/2015	Designated sites and features	60	2.3 Regionally and locally important sitesThe EIA will need to consider any impacts upon local wildlife and geological sites. Local sites are identified by the local wildlife trust, geoconservation group or a local forum established for the purposes of identifying and selecting local sites. They are of county importance for wildlife or geodiversity. The ES should therefore include an assessment of the likely impacts on the wildlife and geodiversity interests of such sites. The assessment	A description of locally important wildlife and geological sites and features is included in the ES. The key interest features that could potentially be affected by the proposed project have been scoped into the assessment.	8.1.2, Appendix F

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				should include proposals for mitigation of any impacts and if appropriate, compensation measures. Contact the local wildlife trust, geoconservation group or local sites body in this area for further information.		
Angela Marlow, Natural England	15/05/2015	Designated sites and features	61	Pagham Local Nature Reserve (LNR) - the EIA needs to consider the environmental and nature conservation interest value of the LNR to the many tens of thousands of people who visit the site each year and the potential effect the proposal may have on this.	The impacts on the environmental and nature conservation interest value of Pagham Harbour are assessed in the Nature Conservation and Ecology Chapter of the ES. Taking account of proposed mitigation measures and compensation, the overall impacts are not considered to be of a scale that would significantly affect visitor numbers to the nature reserve.	8.2, 11.2
Angela Marlow, Natural England	15/05/2015	Designated sites and features	62	2.4 Protected Species - Species protected by the Wildlife and Countryside Act 1981 (as amended) and by the Conservation of Habitats and Species Regulations 2010The ES should assess the impact of all phases of the proposal on protected species (including, for example, great crested newts, reptiles, birds, water voles, badgers and bats). Natural England does not hold comprehensive information regarding the locations of species protected by law, but advises on the procedures and legislation relevant to such species. Records of protected species should be sought from appropriate local biological record centres, nature conservation organisations, groups and individuals; and consideration should be given to the wider context of the site for example in terms of habitat linkages and protected species populations in the wider area, to assist in the impact assessment.	A review of all protected species that occur in the study area is included in the ES.	8.1.4, 8.1.5, 8.1.6

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Angela Marlow, Natural England	15/05/2015	Designated sites and features	63	The conservation of species protected by law is explained in Part IV and Annex A of Government Circular 06/2005 Biodiversity and Geological Conservation: Statutory Obligations and their impact within the Planning System. The area likely to be affected by the proposal should be thoroughly surveyed by competent ecologists at appropriate times of year for relevant species and the survey results, impact assessments and appropriate accompanying mitigation strategies included as part of the ES.	The results of past and present surveys that have been undertaken on protected habitats and species in the study area are included in the ES.	8.1.1
Angela Marlow, Natural England	15/05/2015	Designated sites and features	64	In order to provide this information there may be a requirement for a survey at a particular time of year. Surveys should always be carried out in optimal survey time periods and to current guidance by suitably qualified and where necessary, licensed, consultants. Natural England has adopted standing advice for protected species which includes links to guidance on survey and mitigation. https://www.gov.uk/protected-species-and-sites-how-to-review-planning-proposals#standing-advice-for-protected-species	See response to comment 63.	8.1.1
Angela Marlow, Natural England	15/05/2015	Designated sites and features	65	2.5 Habitats and Species of Principal Importance The ES should thoroughly assess the impact of the proposals on habitats and/or species listed as 'Habitats and Species of Principal Importance' within the England Biodiversity List, published under the requirements of S41 of the Natural Environment and Rural Communities (NERC) Act 2006. Section 40 of the NERC Act 2006 places a general duty on all public authorities, including local planning authorities, to conserve and enhance biodiversity. Further information on this duty is available in the Defra publication 'Guidance for Local Authorities on Implementing the Biodiversity Duty'.	A list of S41 species and habitats that overlap with the study area is included in an Appendix to the ES. Information regarding the NERC Act 2006 is included also.	Appendix E, Appendix F
Angela Marlow, Natural England	15/05/2015	Designated sites and features	66	Government Circular 06/2005 states that Biodiversity Action Plan (BAP) species and habitats, 'are capable of being a material consideration….in the making of planning decisions'. Natural	See response to comment 65. The S41 list contains species and habitats of principal importance	Appendix E, Appendix F

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				England therefore advises that survey, impact assessment and mitigation proposals for Habitat and Species of Principle Importance should be included in the ES. Consideration should also be given to those species and habitats included in the relevant Local BAP.	which occur in England. These are all the habitats in England that were identified as requiring action in the UK BAP and which continue to be regarded as conservation priorities in the subsequent UK Post-2010 Biodiversity Framework.	
Angela Marlow, Natural England	15/05/2015	Designated sites and features	67	Natural England advises that a habitat survey (equivalent to Phase 2) is carried out on the site, in order to identify any important habitats present. In addition, ornithological, botanical and invertebrate surveys should be carried out at appropriate times in the year, to establish whether any scarce or priority species are present. The Environment Statement should include details of: - Any historical data for the site affected by the proposal (e.g. from previous surveys); - Additional surveys carried out as part of this proposal; -The habitats and species present: -The status of these habitats and species (e.g. whether priority species or habitat); -The direct and indirect effect of the development upon those habitats and species; -Full details of any mitigation or compensation that might be required.	No specific habitat survey has been undertaken at this site in view of the large amount of existing information and previous survey work that is already available to describe the baseline habitats and species in the ES. The direct and indirect effects of the proposed project on these habitats and associated species are included in the ES. Details of proposed mitigation and compensation are also included. It is also envisaged that further monitoring will be conducted as part of the scheme's implementation (should it be consented)	8.1, 8.2, 11.2, 11.3
Angela Marlow, Natural England	15/05/2015	Designated sites and features	68	The development should seek if possible to avoid adverse impact on sensitive areas of wildlife within the site, and if possible, provide opportunities for overall wildlife gain.	The proposed mitigation and compensation to avoid adverse impacts (or the uncertainty regarding impacts) is included in the ES. Opportunities for biodiversity enhancement measures are also explored.	11.2, 11.3
Angela Marlow,	15/05/2015	Designated	69	The record centre for the relevant Local Authorities should be	See response to comment 65.	Appendix F

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Natural England		sites and features		able to provide the relevant information on the location and type of priority habitat for the area under consideration.		
Angela Marlow, Natural England	15/05/2015	Designated sites and features	70	2.6 Contacts for Local Records Natural England does not hold local information on local sites, local landscape character and local or national biodiversity priority habitats and species. We recommend that you seek further information from the appropriate bodies (which may include the local records centre, the local wildlife trust, local geoconservation group or other recording society and a local landscape characterisation document).	Local information has been requested from local groups (e.g. RSPB nature reserve, Sussex Wildlife Trust, Friends of Pagham and Sussex Geodiversity Partnership) and included in the relevant sections of the ES.	8.1, Appendix F
Angela Marlow, Natural England	15/05/2015	Designated Landscapes and Landscapes Character	71	3. Designated Landscapes and Landscapes Character Landscape and visual impacts Pagham Harbour is not covered by any nationally designated landscape, so Natural England will not advise on impacts to landscape. The European Landscape Convention places a duty on Local Planning Authorities to consider the impacts of landscape when exercising their functions.	In the context of the dynamic nature of this environment, and the continual landscape changes which are typical of it, landscape changes brought about by the proposed project are not considered to be significant and this topic has been scoped out of the ES.	5.5.2
Angela Marlow, Natural England	15/05/2015	Designated Landscapes and Landscapes Character	72	Heritage Landscapes You should consider whether there is land in the area affected by the development which qualifies for conditional exemption from capital taxes on the grounds of outstanding scenic, scientific or historic interest. An up to date list may be obtained at www.hmrc.gov.uk/heritage/ibsearch.htm and further information can be found on Natural England's landscape pages.	There is no land in the area affected by the development which qualifies for conditional exemption from capital taxes on the grounds of outstanding scenic, scientific or historic interest. The nearest tax-exempt land is in Chichester according to the website link provided.	NA
Angela Marlow, Natural England	15/05/2015	Access and Recreation	73	4. Access and Recreation Natural England encourages any proposal to incorporate measures to help encourage people to access the countryside for quiet enjoyment. Measures such as reinstating existing footpaths together with the creation of new footpaths and bridleways are to be encouraged. Links to other	Public access has been scoped out of the EIA. However, this is a project that has been led by the community and they in turn have offered to provide volunteer support	5.5.2

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				green networks and, where appropriate, urban fringe areas should also be explored to help promote the creation of wider green infrastructure. Relevant aspects of local authority green infrastructure strategies should be incorporated where appropriate.	for the initiative and for the mitigation works that will be required as part of the proposal. It is hoped that this proposal will allow the community to re-engage with and enjoy their environment rather than viewing it as a threat.	
Angela Marlow, Natural England	15/05/2015	Access and Recreation	74	Consideration should be given to the potential impacts from this proposal on the ability of people to access the site, to enjoy quiet recreation and have access to nature, both during construction and after the breach.	Public access has been scoped out of the EIA. The impacts of the proposed project on marine recreation have been assessed in the ES.	5.5.2, 9.2
Angela Marlow, Natural England	15/05/2015	Access and Recreation	75	Rights of Way, Access land, Coastal access and National Trails The EIA should consider potential impacts on access land, public open land, rights of way and coastal access routes in the vicinity of the development. The National Trails website www.nationaltrail.co.uk provides information including contact details for the National Trail Officer. Appropriate mitigation measures should be incorporated for any adverse impacts. We also recommend reference to the relevant Right of Way Improvement Plans (ROWIP) to identify public rights of way within or adjacent to the proposed site that should be maintained or enhanced.	There are no CRoW Open access land (heathland, downland and registered common land) or National Trails in the study area. The effects on public rights of way have been scoped out of the EIA (see response to comment 73). We have reviewed the West Sussex County Council ROWIP. However, this does not specify which public rights of way are to be maintained. None of the public rights of way within the study area are proposed to be enhanced.	5.5.2
Angela Marlow, Natural England	15/05/2015	Climate Change Adaptation	76	5. Climate Change Adaptation The England Biodiversity Strategy published by Defra establishes principles for the consideration of biodiversity and the effects of climate change. The ES should reflect these principles and identify how the development's effects on the natural environment will be influenced by climate change, and how ecological networks will be maintained. The	As the proposed project seeks to address existing and anticipated coastal erosion problems over a period of 20 years (because making predictions beyond this timeframe is not feasible), longer-term issues	5.8, 11.3

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				NPPF requires that the planning system should contribute to the enhancement of the natural environment 'by establishing coherent ecological networks that are more resilient to current and future pressures' (NPPF Para 109), which should be demonstrated through the ES.	associated with climate change and sea level rise have not been reviewed in detail. These issues will instead need to be considered on an ongoing basis as part of the continuing process of adaptive management.	
Angela Marlow, Natural England	15/05/2015	Cumulative and in-combination	77	6. Cumulative and in-combination effects A full consideration of the implications of the whole scheme should be included in the ES. All supporting infrastructure should be included within the assessment.	See response to comment 14.	10
Angela Marlow, Natural England	15/05/2015	Cumulative and in-combination	78	The ES should include an impact assessment to identify, describe and evaluate the effects that are likely to result from the project in combination with other projects and activities that are being, have been or will be carried out. The following types of projects should be included in such an assessment, (subject to available information):A. existing completed projects;B. approved but uncompleted projects;C. ongoing activities;D. plans or projects for which an application has been made and which are under consideration by the consenting authorities; andE. plans and projects which are reasonably foreseeable, i.e. projects for which an application has not yet been submitted, but which are likely to progress before completion of the development and for which sufficient information is available to assess the likelihood of cumulative and in-combination effects.	See response to comment 14.	10
Tom Day, Chichester District Council	14/05/2015	Nature conservation and Ecology	79	The scoping report broadly covers the range of ecological topics that should be addressed. However, under the 'impact pathways list' (Section 6.1), I would like to see one addition. Under Nature Conservation and Ecology- Operational Phase, the only long term loss, or change to, habitat to be considered is shingle. This is the most important habitat to be affected by the proposal certainly, but changes to the hydrology could lead to long-term	Agreed, the post-construction effects on habitats within Pagham Harbour from changes to the tidal environment have been included as an additional impact pathway (number 17) in the ES.	8.2.9

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				changes in other habitats within the Harbour, in particular mudflats and saltmarsh. These are to be considered under temporary effects during construction phase (Section 6.1, point 13), but not any permanent impacts.		
Steve Gilbert, RSPB	16/04/2015	General Comment	80	1. We have had the advantage of seeing the draft the comments provided by Natural England, and note that these provide a comprehensive review of the implications of the various statutory designations relevant to the site. We do not propose to repeat these here.	Noted.	NA
Steve Gilbert, RSPB	16/04/2015	General Comment	81	2. Subject to the additional comments below, we consider that the Scoping Report sets out a useful set of parameters for the Environmental Impact Assessment (EIA) and that it correctly identifies the significant environmental issues that will need to be addressed.	Noted.	NA
Steve Gilbert, RSPB	16/04/2015	Habitats	82	3. We consider that the EIA should give consideration to any long term loss of or change to intertidal habitats within the harbour (notably saltmarsh and mudflats) and not just loss of or change to, shingle habitats, as currently stated in Section 6.1 point 15.	See response to comment 79.	8.2.9
Steve Gilbert, RSPB	16/04/2015	Cumulative and in-combination	83	4. Linked to this, consideration should be given to any in-combination effects between the proposed breach and current and/or planned erosion risk management projects within the harbour, for example proposed works at and in the vicinity of Sidlesham.	See response to comment 14.	10
Steve Gilbert, RSPB	16/04/2015	Birds	84	5. If there is any significant possibility that the proposed breach could become a causal factor in a subsequent closure of the harbour to tidal influence then the consequences (particularly, but not exclusively, for overwintering waterfowl interests) should be within the scope of the EIA.	The potential risk of closure as a result of the proposed project has been assessed. In addition, the effects of a potential closure on nature conservation interest features have been considered as part of the future baseline scenario (given that the low risk of closure	6.3.1, 8.1.9, 8.2.11

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
					already exists under present conditions).	
Steve Gilbert, RSPB	16/04/2015	Birds	85	6. The Scoping Report rightly identifies potential impacts upon breeding little terns (a SPA interest feature) as a key factor to be addressed by the EIA. In giving consideration to any measures that might be undertaken to offset negative impacts on this feature, the implication of the Briels judgement in the ECJ need to be accounted for. This case appears to indicate that the provision, for example, of shingle islands within the SPA for breeding terns would be treated as a compensatory measure for an adverse impact, rather than mitigation reducing or eliminating any such impact.	See response to comment 51.	11.2.2
Tessa MacIntyre, Sidlesham Parish Council	20/05/2015	Physical Processes and Habitats	86	Although the North Sea surge of last year was an abnormal event, it illustrates the increased vulnerability of the Pagham Harbour shoreline to inundation from the sea. Local warming and associated rising sea levels, combined with an increase in more extreme weather conditions, raises a question as to whether a harbour opening, giving the sea direct access into the harbour, may increase this vulnerability. Wave action energy may not dissipate until it reaches the shore and erosion may result. Additionally, there may be destruction of the current mud flats and the associated drainage channels, a number of which are 'main river' and the primary exit routes for drainage water from Sidlesham.	The effects of the proposed project on tidal, wave and sedimentary dynamics in Pagham Harbour have been assessed. However, as the proposed project seeks to address existing and anticipated coastal erosion problems over a relatively short time period, longer-term issues associated with climate change and sea level rise have not been reviewed in detail. These issues will instead need to be considered on an ongoing basis as part of the continuing process of adaptive management.	5.8, 6.3.4, 11.3
Tessa MacIntyre, Sidlesham Parish Council	20/05/2015	Physical Processes and Habitats	87	Overall, water levels within the harbour and the speed at which the harbour fills and empties may have impacts on the shore and the mud flats in terms of their ecology and habitat value as the erosion and disposition regime alters. The spring tidal range of 5.1m of Pagham are macro-tidal in nature and it is evident that	The proposed project is predicted to result in some small changes to water levels and flow speeds inside Pagham Harbour. These changes are described in the Physical	6.3.4, 8.2.9

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				currently the range is higher outside the harbour than within, indicating that at present the entrance is restricting the tidal flow. This may alter with a direct sea entrance producing higher tides in the harbour.	Processes and Coastal Protection Chapter of the ES. The implication of these changes to habitats is assessed in the Nature Conservation and Ecology Chapter of the ES.	
Tessa MacIntyre, Sidlesham Parish Council	20/05/2015	Physical Processes	88	The proposal will rely on the 'jet effect' of water leaving the harbour to scour out and maintain the new cut. There will not be any protection by training walls. There is a question therefore as to whether natural processes will rapidly cause the entrance to again be deflected.	The future evolution of the site following the breach is described in detail in the Physical Processes and Coastal Protection Chapter of the ES.	6.3.1, 6.3.3
Tessa MacIntyre, Sidlesham Parish Council	20/05/2015	General Comment	89	For Sidlesham, consideration should also be taken as to the situation, should the entrance completely close (the 1909 position with just a sluice draining Pagham Lagoon). There could be major implications for Sidlesham with the silting up of the harbour and even the possibility of completely dry land areas forming. There would be a need to retain and re-establish the main river channels (ditches) to give drainage access to the sea and then through the shingle spit/beach shoreline.	The likelihood of the tidal inlet closing following the proposed breach is highly unlikely. It is less likely to occur than under present conditions and if it were to occur it would more easily re-open than if the existing spit and inlet closed. Despite this, one subsequent breach intervention has been included as part of the proposal as a contingency in the event of this occurring.	3.2.7, 6.3.1, 8.2.11
Dominic Smith, West Sussex County Council	27/04/2015	Transport	90	While West Sussex County Council (WSCC), in its capacity as the Local Highway Authority (LHA), would not provide direct comment on any Environmental Impact Assessment it would be able to assist in the verification of transport data i.e. proposed vehicular movements.	Noted. A Transport Statement has been prepared as an Appendix to the ES.	Appendix I
Dominic Smith, West Sussex County Council	27/04/2015	Transport	91	It is understood that the proposal will have a limited impact on the local network, with vehicular movements generated through site set up and demobilisation and the movement of staff. The LHA would recommend that a transport statement be submitted	See response to comment 90.	Appendix I

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				as part of any application setting out the anticipated vehicular movements and means of vehicular access.		
Dominic Smith, West Sussex County Council	27/04/2015	Transport	92	The LHA requests that the impact on the highway network be considered as part of a Transport Statement/Assessment to cover, but not be limited to, the following.	See response to comment 90.	Appendix I
Dominic Smith, West Sussex County Council	27/04/2015	Transport	93	Information regarding content and the need for assessment can be found within the WSCC Transport Assessment Methodology at the following link. This provides guidance on establishing baseline transport conditions and appropriate means of assessing the impact of development proposals. http://www2.westsussex.gov.uk/roadsandtransport/WSCC%20Transport%20Assessments%20-%20Guidance%20on%20Methodology%20for%20Developers.pdf	See response to comment 90.	Appendix I
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Procedural matters	94	The proposal in its current form involves development that would take place on land within both Chichester and Arun Districts and, as explained by Karl Roberts in his email to you of 17 April 2015, any subsequent planning application will need to be submitted to both local planning authorities.	Noted.	NA
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Proposed development	95	For the avoidance of doubt this Opinion is based on the description of works set out at section 1.3 of the submitted Scoping Report (SR) dated April 2015. With regard to the descriptions of development set out at Schedule 2 to the Regulations the proposal comprises 'Coastal work to combat erosion' which is included at its paragraph 10(m). Further, given Pagham Harbour's designation as both a SSSI and Special Protection Area, the site lies within a 'sensitive area' as defined by the Regulations. Both LPA's agree that the proposal is likely to have significant effects on the environment by virtue of factors such as its nature, size and location. Consequently, whilst you have not sought a screening opinion under the Regulations, both LPAs agree that the proposal does comprise EIA development within the meaning of the Regulations.	Noted.	NA

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Proposed development	96	It is noted that the Scoping Report clarifies that the nature and extent of proposed works may evolve as a result of subsequent studies and modelling. Whilst such changes are unlikely to necessitate a change to the Opinion set out below, you may wish to re-consult both LPAs should it become evident that the nature of the proposal is to change materially.	The position of the proposed breach and channel infill remain the same. There have been some minor modifications to the orientation of the breach. However, these changes have not materially changed the nature of the project.	3.1
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	97	Legal requirements in respect of the content and form of Environmental Statements (ES) are set out at Schedule 4 to the Regulations; these are summarised in Natural England's scoping response. Furthermore, guidance on, amongst other things, the content of an ES and the Scoping process is set out in the National Planning Practice Guidance.	The legal requirements in respect to the content and form of the EIA have been met in accordance with Schedule 4 of the Town and Country Planning (EIA) Regulations.	4.3
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	98	Before adopting an Opinion Regulation 13(6) requires an authority to take into account the following factors:a. the specific characteristics of the particular development;b. the specific characteristics of development of the type concerned; andc. the environmental features likely to be affected by the development.	Noted, this information has been included in the ES.	3, 6, 7, 8, 9, 10
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	99	When taking into account the requirements of the Regulations, the content of the NPPG and the consultation responses received it is considered that the submitted Scoping Report does serve to identify the environmental constraints relevant to the site and its locality. Further, it is agreed that the SR highlights a number of the likely significant environmental effects of the development together with appropriate recommendations for their further assessment in order to inform the content of the ES. It is also noted that the SR identifies the various other consent regimes relevant to the proposal along with an acknowledgement that information sufficient to enable the LPAs to carry out Marine Conservation Zone and Habitats Regulation Assessments must be submitted.	Noted.	NA

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	100	Consequently, it is confirmed that the ES should address the environmental impacts listed at paragraph 1.6.3 of the SR in the manner set out in its subsequent sections (2 to 5)	Noted.	NA
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	101	Having confirmed that the submitted Scoping Report may form the basis of the Environmental Statement, the ES must also address and/or take into account the matters set out in Sections 2 – 4 below:	Noted.	NA
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	102	2. Natural England's response to the Scoping request The attached response includes detailed comments in respect of the range of issues that should be addressed by the ES including advice in respect of a number of matters that are either not covered or given little emphasis in the submitted Scoping Report. You will note that a number of the issues raised by Natural England and also referred to by the RSPB and both responses should be carefully considered in conjunction with one another.	See responses to comments 10 to 78 and 80 to 85 above.	NA
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	103	Whilst it is confirmed that all of the matters raised in Natural England's response should be addressed in the ES, it is considered appropriate to highlight the following issues which require particularly careful attention: • the implications of the need (if necessary) to consider the 'no alternatives' and 'imperative reasons of overriding public interest' tests of the Habitats Directive	See response to comment 9.	2.1, 2.2, Appendix C
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	104	• the need to fully consider the immediate and longer term implications of the proposal in terms of the geological interest feature of the SSSI	See response to comment 10.	8.2.1, 8.2.4, 8.2.7, 8.2.11, Appendix E

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	105	• the need to consider the inherent uncertainty that inevitably accompanies any proposal involving intervention in a dynamic coastal system	See response to comment 11.	2.2, 6.3 and 8.2
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	106	• the need to consider the cumulative and in-combination effects of the development. Consideration of in-combination effects should include, but not necessarily be restricted to, the current and/or planned erosion risk management projects within the Harbour that are referred to by the RSPB in its response	See response to comment 14.	10
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	107	• the need to take into account the implications of the Briels CJEU ruling in terms of what might be correctly considered to comprise 'mitigation' under the Habitats Directive	See response to comment 51.	2.1, 2.2, 11.2, Appendix C
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	108	In view of the nature of the comments in its response you may consider it prudent to further discuss your intentions with Natural England before progressing the proposal.	Further discussion with Natural England has been undertaken as required during the assessment phase of the EIA. This has included a meeting on 16 June 2015 to discuss their scoping response in more detail.	NA
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	109	3. Additional matters Alongside consideration of the matters identified by Natural England, the following issues should be addressed in the ES:- (i) The ES should fully explore the implications of the 'do nothing' scenario	The future evolution of the site in the absence of the proposed project (i.e. the future baseline scenario) has been assessed in the ES. The "do nothing" option is not considered a viable alternative in the ES as it is not in keeping with the principles of adaptive management for the shoreline.	2.2, 6.2.8.

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	110	(ii) The Scoping Report correctly highlights that there is uncertainty in respect of the potential range of eventualities following the carrying out of the proposed breach and the subsequent side-casting. It is therefore important that, as far as is reasonable, the ES explores the range of possible scenarios – including the potential for the natural re-filling of the breach and the harbour closing - with reference to verifiable evidence and modelling. It is likewise important to explain how any such uncertainty will be managed in the future (any by whom).	The various potential future scenarios that could result from the proposed project have been predicted and the consequences to potential receptors have been assessed in the ES.	3.2.7, 6.3.1, 6.3.3, 8.2, 11.3.
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	111	(iii) With regard to coastal processes, there appears to be an initial emphasis in the Scoping Report on potential impacts at the Harbour entrance and to the coast to its north-east. It is, however, important that potential impacts on the western end of the Church Norton Spit and the coastline beyond (to the south-west) are also fully explored – in this regard please see the consultation response of the CDC Senior Engineer	The impacts of the proposed project on these areas have been considered in the ES.	6.3.1
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	112	(iv) With regard to the 'Nature Conservation and Ecology - Operational Phase' subsection of Section 6.1 of the SR the only long term loss, or change to, habitat to be considered is 'shingle'. Whilst shingle is arguably the most important habitat to be affected by the proposal, changes to hydrology could lead to long-term changes to other habitats within the Harbour, in particular mudflats and saltmarsh. These are considered as temporary effects during construction phase (section 6.1, point 13), but such impacts could be permanent.	See response to comment 79.	8.2.9
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	113	(v) It is assumed that the excavated material will be sufficient to block the existing channel and that there will be no need to import material or remove it from elsewhere on the spit. If this is not the case then the consequences of any shingle importation/redistribution in terms of the conservation and ecology and the physical/hydrodynamic environment should be clarified in the ES. Similarly, the consequences of any temporary	These is no need to import material or remove additional material from elsewhere on the spit to infill the existing channel. The consequences of temporary stockpiling on underlying habitat are considered in the nature	8.2.1

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
				stockpiling of shingle material should, if relevant, be addressed.	conservation and ecology assessment in the ES.	
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	114	(vi) Section 1.6.4 of the SR refers to matters that might be 'screened out' of the ES. The NPPG clarifies that the ES should indeed focus on the likely significant environmental impacts, and it is accepted that the impacts listed at Section 1.6.4 are unlikely to be significant within the meaning of the Regulations. Having said that, the NPPG also clarifies that, rather than excluding such matters from the ES, they 'need only very brief treatment to indicate that their possible relevance has been considered'. Consequently, whilst some of these issues – for example in the highway and noise implications (see CDC EHO's response attached) during the course of the works - will require only a 'light touch' in the ES, they should not be omitted altogether. Such matters should, however, be dealt with more comprehensively in separate assessments to be submitted in support of the planning application	A review of the scoped out issues is provided in the ES. In addition, a transport statement is included as a separate Appendix in support of the planning application.	5.5.2, Appendix I
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	115	(vii) In terms of flood risk, it is noted that the underlying purpose of the works is to reduce the risk posed to properties at Pagham beach. However, the potential for increased risk to property and land fronting onto the harbour (i.e. fronting onto the 'internal' harbour shoreline) should also be addressed. As referred to by the Environment Agency in its response, the planning application should be accompanied by a Flood Risk Assessment.	The effects on coastal protection in Pagham Harbour are considered in the ES both as a result of the proposed project alone and in-combination with other projects. See response to comment 3 in relation to the need for a full FRA.	6.3.5, 10
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	116	4. Marine Management Organisation Please note that due to an administrative error in the LPA's scoping consultation process it has only been possible for the MMO to provide a high level response at this stage. You will, however, note the MMO's offer to provide a detailed scoping opinion should you wish to obtain one. If you do decide to liaise directly with the MMO then I would be grateful if you could provide both LPAs with a copy of any correspondence.	See responses to comments 5 to 7 above. We have discussed the matter with the MMO and decided in this instance not to seek a separate scoping opinion from the MMO as the timescales of provision of an opinion would have been after the proposed timescales for the	NA

ARUN DISTRICT COUNCIL P/93/15/PL

Consultee	Date	Topic	Comment Number	Comment	Action/Response	Section of Environmental Statement (ES)
					submission of the planning application (and marine licencing application).	
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	117	Other consent regimes As referred to above the proposed works will, alongside planning consent, need permission under various other consenting regimes. If planning permission were to be granted then this would be without prejudice to the need to separately gain those consents. You are advised to contact the relevant consenting bodies at an early stage in order to ascertain their requirements.	Noted.	4
Joanna Bell, Chichester District Council and Karl Roberts, Arun District Council	28/05/2015	Scoping Opinion of Chichester and Arun District Councils	118	Planning application supporting documentsInformation about national and local planning application validation criteria can be found on the Chichester and Arun District Council websites. Reference is made above to the particular need for information in respect of noise, highways and flood risk matters and the attached consultation responses also provide further indications as to those consultees' expectations. If you are in any doubt as to the nature of information required to support the application then you should contact the LPAs for further advice.	See responses to comments 2 to 3 and 90 to 93 above.	NA

ARUN DISTRICT COUNCIL P/93/15/PL

Appendix C

Information for an Appropriate Assessment Signposting Document

Managed Breach of Shingle Spit at Pagham: Environmental Statement

Volume 2: Appendices

Contents

Page

C. Information for an Appropriate Assessment Signposting Document 3
C.1 Introduction 3
C.2 Designated Sites that Could be Directly or Indirectly Affected 4
C.3 Need for a Habitat Regulations Assessment 5
C.4 Information on the Need for the Proposed Development 6
C.5 Project Description 7
C.6 Consultation with Stakeholders 7
C.7 An Understanding of the Designated Features, Conservation Objectives and Favourable Condition Target 8
C.8 Baseline Description of Relevant Interest Features 9
C.9 Impacts to Relevant Interest Features 9
C.10 Mitigation and Monitoring 9
C.11 In-combination Effects with Other Plans or Projects 10
C.12 Integrity of the European Marine Site 10
C.13 Alternatives 13
C.14 Imperative Reasons of Overriding Public Interest 13
C.15 Compensation 13
C.16 References 14

Tables

C1. Conservation objectives for Pagham Harbour SPA 8
C2. Favourable condition table for the Pagham Harbour SPA 11

Images

C1. Summary of the key stages comprising a HRA 4

ARUN DISTRICT COUNCIL P/93/25/PL

C. Information for an Appropriate Assessment Signposting Document

C.1 Introduction

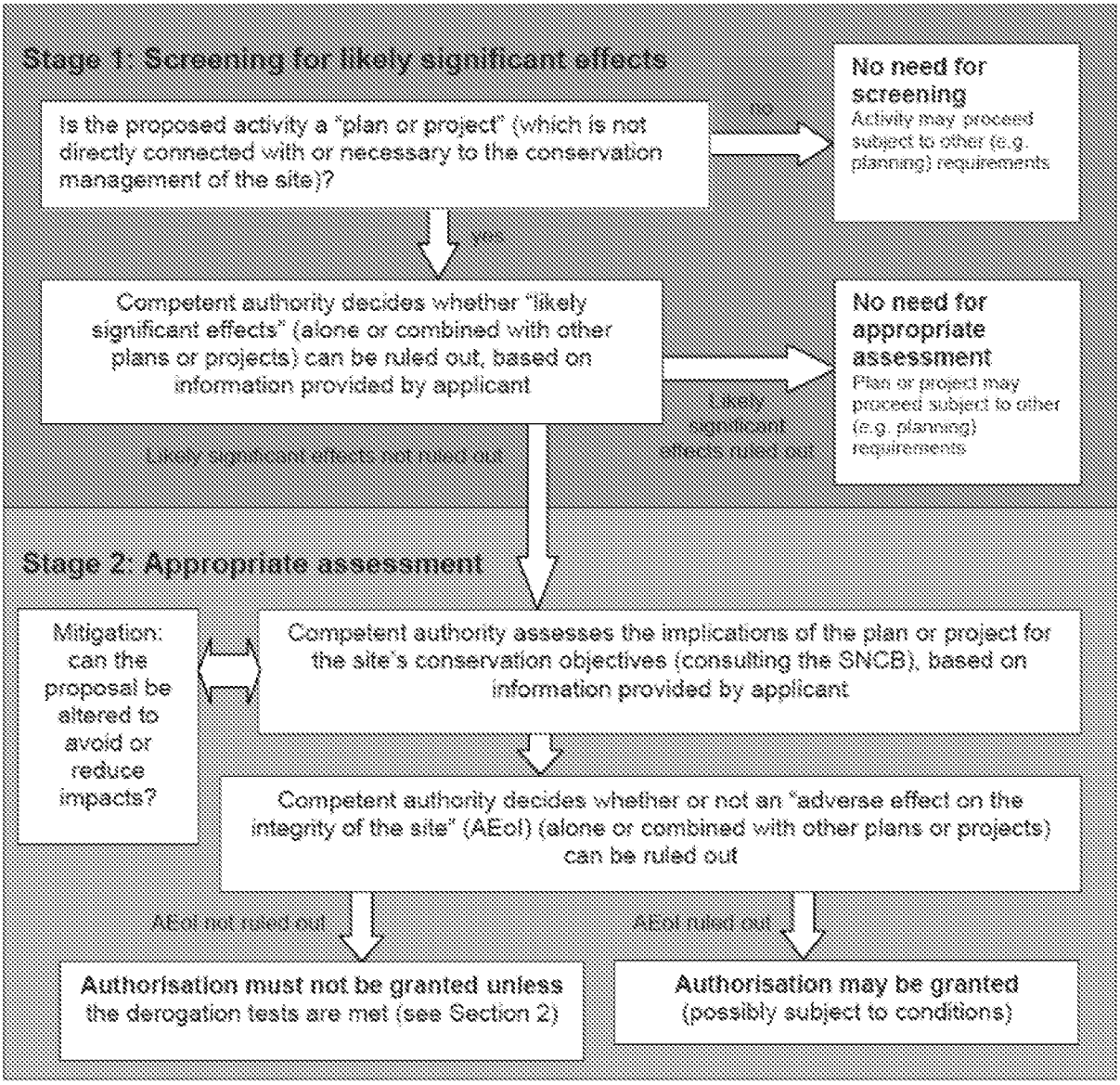
This appendix provides information to support an Appropriate Assessment (AA) for the proposed controlled breach of the shingle spit feature at the mouth of Pagham Harbour and infill of adjacent channel (hereafter referred to as "the proposed project"). It identifies, under relevant subject headings, those sections within the Environmental Statement (ES) and any relevant supporting documentation that contain the information needed by the Competent Authority(ies), in this case jointly Chichester District Council (CDC) and Arun District Council (ADC), to determine whether the proposed project is likely to have a significant effect on European Marine Sites and to produce an AA, if required. It is designed to serve the following functions:

1) Avoid unnecessary repetition of information. The information required for an Environmental Impact Assessment (EIA) and a Habitats Regulations Assessment (HRA) often overlap and it is considered good practice to avoid replication of this information. Therefore, where comprehensive data and descriptions already exist in the main ES, cross-references to these sources of relevant information are made here.
2) Add new information that is specific to implementation of Regulation 61 of the Habitats Regulations. In those instances where information is needed by a Competent Authority to produce an AA but is not available in the ES (and any relevant supporting documentation) then such additional information has been included here.
3) To act as an auditable checklist of AA information. This appendix is designed to provide a confirmatory checklist, which ensures that all the relevant information that is needed for an AA is provided.
4) To assist the Competent Authority and its consultees. The overall aim of this document is to provide a concise and readable document that will make it easier for the Competent Authority(ies) to consult on, and produce, an AA.

In producing this appendix, it is recognised that the scope of the HRA can vary on a case-by-case basis, however the information provided is considered to represent most, if not all, the detail required and follows the key stages within the relevant Habitats Regulations Guidance (Defra, 2012). These key stages are shown in Image C1.

This appendix seeks to provide the information needed by the relevant Competent Authorities (CDC and ADC) to undertake an Appropriate Assessment. In compiling this information, the starting point has been advice provided by the relevant Statutory Nature Conservation Body (SNCB), in this case Natural England, under Regulation 35(3) of the Conservation of Habitats and Species Regulations 2010 (hereafter referred to as the "Habitat Regulations") for the Pagham Harbour Marine Site (English Nature, 2001) and the Conservation Objectives published by Natural England in 2014. It has also taken into consideration the specific views on the proposed project expressed by key stakeholders, namely Natural England.

ARUN DISTRICT COUNCIL P/93/25/PL



(Source:Defra, 2012)

Image C1. Summary of the key stages comprising a HRA

C.2 Designated Sites that Could be Directly or Indirectly Affected

The requirements of the EC Habitats Directive (92/43/EEC) have been transposed into UK legislation through the Habitats Regulations. These Regulations define SACs and SPAs as European Sites. In addition, Paragraph 118 of the National Planning Policy Framework requires that potential SPAs, possible SACs, listed or proposed Ramsar sites, and any site identified as being necessary to compensate for adverse impacts on classified, potential or possible SPAs, SACs and Ramsar sites be treated in the same way as classified sites. These sites are referred to hereafter as European/Ramsar sites.

ARUN DISTRICT COUNCIL P/93/25/PL

The proposed project overlaps with the Pagham Harbour SPA and Ramsar site. Impacts on these European/Ramsar sites could therefore be via both direct and indirect pathways.

The proposed project is also located approximately 4km from the Medmerry Managed Realignment compensatory site (see Figure 8.1 in the main ES). There is unlikely to be a significant effect on this site given that there is no connectivity with the hydrodynamic and/or ecological changes brought about by the proposed project. This compensatory site has therefore not been screened into the HRA.

The possible/draft marine Solent and Dorset Coast SPA is proposed to cover the foraging activity for Little, Sandwich and Common Tern species designated at the adjacent qualifying breeding tern SPA colonies along the Solent and Dorset Coast. The proposal for this new nature conservation site is currently being finalised with formal consultation planned for 2015. Once Government initiates public consultation on this site, it will need to be formally included in an HRA where a plan or project overlaps or is within proximity of the respective breeding SPA colony. Natural England in their scoping response has advised that this possible/draft marine SPA extension is not expected to add any further requirements to the assessment (see Appendix B of the main ES).

C.3 Need for a Habitat Regulations Assessment

As the proposed project is located within, and has the potential to directly and/or indirectly affect Pagham Harbour SPA and Ramsar site, CDC and ADC, as Competent Authorities, need to take account of the Habitats Regulations, taking appropriate advice from Natural England. Consultation with Natural England has confirmed the view that an AA is required for this project under Regulation 61(1) of the Habitats Regulations. Regulation 61 states that:

> "A competent authority, before deciding to undertake, or give any consent, permission, or other authorisation for a plan or project which:
>
> (a) is likely to have significant effect on a European site or a European offshore marine site (either alone or in combination with other plans or projects); and
>
> (b) is not directly connected with or necessary to the management of the site
>
> must make an appropriate assessment of the implications for the site in view of that site's conservation objectives".

Further guidance on undertaking an AA is provided in Natural England's 'Habitats Regulations Guidance Note (HRGN 1; English Nature, 1997).

The decision as to whether a HRA is required or not is the assessment of 'Likely Significant Effect', or LSE (Image C1), which is recognised by Natural England as being a 'coarse filter' or statement that the anticipated effects of the proposal will be more than trivial, i.e. that the anticipated changes resulting from a proposal have the potential to impact on an interest feature of a European/Ramsar Site. It does not automatically follow that an impact will occur, or that the impact would be significant, with a decision of LSE being purely an indication of the need for an AA. The interpretation of the term significant under

ARUN DISTRICT COUNCIL P/93/15/PL

the Habitats Directive in England is therefore different to its use under the EIA Directive, with LSE in the Habitats Directive effectively analogous to a Screening Decision under EIA. Early consultation with Natural England as regards to LSE and the basis for the assessment has been undertaken, to ensure that the issues to be addressed in the HRA are highlighted at an early stage.

Further information on the requirements of a HRA is included in Section 4.4 of the main ES report.

C.4 Information on the Need for the Proposed Development

A comprehensive description of the proposed project's rationale is presented in Section 2.1 of the main ES.

The main aims of the proposed project are to move the coastline towards a more sustainable morphology[1] and address the coastal erosion, amenity and human health problems presently being experienced along the adjacent Pagham Beach.

The proposed project represents a 'soft' solution to these problems because it seeks to mimic a process (i.e. breaching of the spit) that has happened naturally in the past and is likely to occur in the longer-term future (though probably not within the next decade). However, it does this in a predictable and controlled way to address immediate problems and also buy time for the ongoing adaptive management of this coastline.

The main erosion problems at Pagham Beach are largely being caused by the growth of the 'Church Norton Spit' in front of Pagham Harbour. Over the last decade, this spit and the Pagham Harbour tidal inlet channel have extended northwards along Pagham Beach; and this has caused/allowed the inlet channel to cut into the beach leading to rapid localised shoreline retreat. The formation of the spit, tidal channel and its fronting 'ebb delta' feature are also 'locking up' shingle and not allowing it to reach the more slowly eroding sections of the Pagham foreshore via the usual sediment transport pathways.

The proposed managed breach of Church Norton Spit is designed to alleviate the problems arising in a proactive manner that works with natural coastal processes and then also allows these processes to continue being the dominant factor influencing the coastline. Compared to alternatives (as described further below in Section C.13), this approach can achieve more natural, cost-effective, and spatially extensive, coastal protection improvements as well as benefits to human health and site amenity.

A further benefit arises from the fact that it is very much a 'community project'. It was the local community who originally emphasised the need for it and have continued to be supportive of it as the design has been developed. This proposal will inherently help the community to re-engage with the environment on their doorstep rather than viewing it as a threat to homes on the beach. Members of the community have also volunteered to play an active role in the management of the environment

[1] i.e. one that is more natural, self-maintaining, requires less frequent and costly intervention and has a wider range of social ecological and economic benefits than alternatives (in keeping with the principles of sustainable development as directed by the National Planning Policy Framework (NPPF)).

ARUN DISTRICT COUNCIL P/93/25/PL

following the implementation of such a measure. Thus the potential exists for greater coherence between the needs of the environment and the community.

In addition, the proposed breach is expected to be slightly more stable when compared to the existing tidal inlet position and is predicted to allow for a marginally improved tidal exchange in the harbour. Also, in the unlikely event that the new breach closed, it is likely to be more easily re-opened than if the current spit and inlet closed up. Thus, while environmental effects will occur from this proposal that are reviewed in detail within this assessment (and mitigation/compensation measures identified where relevant) there will be inherent long term environmental benefits associated with this scheme (e.g. for water quality and ecology) in terms of greater assurances that the tidal functioning of Pagham Harbour will be maintained.

C.5 Project Description

A detailed description of the scheme is provided in Section 3.1 of the main ES.

It is proposed that the managed breach would be excavated where the harbour mouth/inlet was located throughout much of the latter part of the 20th century (although this position has been highly variable). This is considered to be the best position for creating a more stable breach because it will most efficiently accommodate the ebbing tides as they flow from the harbour. These flows are influenced by a man-made training wall at the western end of the Pagham foreshore and the breach has been carefully positioned relative to this training wall to take advantage of the channel meander that is directed by the angled training wall. The excavated shingle will then be used to locally infill the existing tidal channel. The locations of the proposed breach and channel infill are shown on Figure 2.2 of the main ES.

Once created, the breach is expected to adjust in alignment and form as a result of natural processes. The short and longer term morphological development of the breach is described in Section 6.3 of the main ES. Once the existing channel is closed and the new breach is created, natural processes will take over and no ongoing management of the site (e.g. maintaining the breach position) is proposed. However, one subsequent breach intervention has been included as part of the proposal as a contingency in the unlikely event that the breach should close.

C.6 Consultation with Stakeholders

Relevant consultations with a wide range of stakeholders have been carried out throughout the period of the EIA from appraisal of alternative options through to scoping and preparation of ES. These have involved a number of meetings with CDC, ADC, Natural England, the Environment Agency and the Royal Society for the Protection of Birds (RSPB). A Scoping Report for the proposed project was submitted to CDC and ADC in April 2015 (ABPmer, 2015). The scoping opinion provided by CDC and ADC and individual responses from statutory consultees is provided in Appendix B of the main ES. Actions and/or responses arising from each of these comments, signposting to the relevant section of the ES where relevant are also provided.

ARUN DISTRICT COUNCIL P/93/25/PL

C.7 An Understanding of the Designated Features, Conservation Objectives and Favourable Condition Target

Further information about the qualifying criteria and interest features of the Pagham Harbour SPA and Ramsar site is provided in Appendix F of the main ES. The Conservation Objectives for Pagham Harbour SPA as set out in Natural England's Regulation 35(3) advice for the Pagham Harbour Marine Site (English Nature, 2001) and more recently published by Natural England in 2014 are presented in Table C1. The sub-features, attributes and target condition for Pagham Harbour SPA are included in Table C2. There are no specific Conservation Objectives or favourable condition table provided for the Pagham Harbour Ramsar site and therefore these have been assumed to be the same as those set out for Pagham Harbour SPA.

Table C1. Conservation objectives for Pagham Harbour SPA

Criteria	Qualifying Features	Conservation Objectives (English Nature, 2001)	Conservation Objectives (Natural England, 2014)
Article 4.1 - Internationally important populations of the regularly occurring Annex 1 bird species	A151 Philomachus pugnax; Ruff (Non-breeding) A193 Sterna hirundo; Common tern (Breeding) A195 Sterna albifrons; Little tern (Breeding)	Subject to natural change, maintain the following in favourable condition*: Mudflat and sandflat communities Shallow water over intertidal areas (with permanent water channels) Saltmarsh Shingle for roosting	With regard to the SPA and the individual species and/or assemblage of species for which the site has been classified (the 'Qualifying Features'), and subject to natural change; Ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring; The extent and distribution of the habitats of the qualifying features The structure and function of the habitats of the qualifying features The supporting processes on which the habitats of the qualifying features rely The population of each of the qualifying features, and, The distribution of the qualifying features within the site.
Article 4.2 - Internationally important populations of regularly occurring migratory bird species	A046a Branta bernicla bernicla; Dark-bellied brent goose (Non-breeding)	Subject to natural change, maintain the following in favourable condition*: Mudflat and sandflat communities Saltmarsh Shallow water over intertidal areas	

* For a detailed definition of how to recognise favourable condition see Table C2.

ARUN DISTRICT COUNCIL P/93/25/PL

C.8 Baseline Description of Relevant Interest Features

Details of the existing condition of relevant interest features and sub-features are addressed in the ES under the following categories:

- Marine and Coastal Habitats (Section 8.1.3 of the main ES);
- Benthic Invertebrates (Section 8.1.4 of the main ES);
- Ornithology (Section 8.1.5 of the main ES).

C.9 Impacts to Relevant Interest Features

Table C2 describes the potential effects of the proposed project on the targets that have been set for the Pagham Harbour SPA interest features and cross-refers to the relevant sections of the ES. The significance of the effects, proposed mitigation measures and residual effects are described. This EIA significance judgement is different to the Habitats Regulations significance (as described above in Section C.3) but is considered to be a valuable guide to assessing the effect of the proposed project on the Conservation Objectives and favourable condition targets. The targets are intended to define the desired condition of a sub-feature's attribute, taking into account fluctuations due to natural change. Assessing the predicted effects of the proposed project in relation to the targets enables the potential effect on favourable condition and hence on the designated status of these sites to be determined.

C.10 Mitigation and Monitoring

Table C2 presents any mitigation measures i.e. measures that have been incorporated into the design of the scheme or the proposed methodology for the construction phase to minimise potential impacts as far as possible.

Where effects are identified as either 'insignificant' or 'minor/tolerable' significant (under the standardised definitions of impact significance that are applied within the EIA) then no specific mitigation measures are considered to be necessary. However, in some instances where such impact levels are identified, relevant impact verification monitoring is proposed as best practice and these are included in Table C2. Where greater effects have been predicted to be of 'moderate' or 'major' significance, appropriate mitigation measures have been identified in detail in Section 11 of the main ES and are summarised in Table C2.

Tables C.2 also concludes the significance, under the EIA process applied, of the residual impact (i.e. the impact remaining following mitigation) followed by an initial assessment of the implication of the predicted impact on the relevant favourable condition target.

ARUN DISTRICT COUNCIL P/93/25/PL

C.11 In-combination Effects with Other Plans or Projects

Other plans, projects and activities that could potentially result in a cumulative and in-combination effect with the proposed project have been reviewed in Section 10 of the main ES. The only other projects that have been scoped into the cumulative and in-combination assessment are the current defence works in the eastern part of the harbour and the future defence works at the Ferry Pumping Station and Sidlesham. The potential overlap of the effects of the proposed project and other projects with the receptors that have been scoped into the EIA were identified and assessed.

C.12 Integrity of the European Marine Site

In a HRA it is necessary to determine whether the project or plan would adversely affect the integrity of the European/Ramsar site in view of the site's Conservation Objectives. The integrity of a site has previously been defined as the coherence of its ecological structure and function, across its whole area that enables it to sustain the habitat, complex of habitats and/or the levels of populations of the species for which it was classified (DETR, 1994). An adverse effect on integrity is likely to be one which prevents the site from making the same contribution to favourable conservation status for the relevant feature as it did at the time of its designation (English Nature, 1997).

The decision on whether integrity is affected will be made by the Competent Authorities (CDC and ADC) with advice from Natural England. However, to assist this decision, Table C2 includes information about the potential effect on the relevant Conservation Objectives and favourable condition targets.

Where it cannot be demonstrated that a project will not have an adverse effect on site integrity (AEOI), or there is insufficient certainty of an avoidance of an adverse effect, the proposed project can only proceed if it can be demonstrated that there are no more suitable (less damaging) alternatives (Section C.13) and that there are Imperative Reasons of Over-riding Public Interest (IROPI) sufficient to justify the proposed project (Section C.14).

In certain circumstances, the Secretary of State may be required to ensure that adequate compensation, usually in the form of replacement habitat, has been provided to protect the overall coherence of the Natura 2000 network (Section C.15)

ARUN DISTRICT COUNCIL P/93/25/PL

Table C2. Favourable condition table for the Pagham Harbour SPA

Summary of Natural England Objectives (English Nature 2001)					Summary of EIA Findings Following EIA Significance Criteria			Initial Conclusions on Favourable Condition Target
Criteria	Qualifying Features	Sub-feature	Attribute	Target	Potential Effect	Mitigation/Monitoring	Significance of Residual Impact	
Internationally important populations of regularly occurring Annex I species	A151 Philomachus pugnax; Ruff (Non-breeding) A193 Sterna hirundo; Common tern (Breeding) A195 Sterna albifrons; Little tern (Breeding)	Mudflat and sandflat communities, saltmarsh, sand and shingle, shallow coastal water.	Disturbance (feeding and roosting areas).	No significant reduction in numbers or displacement of birds, attributable to human disturbance from an established baseline.	Minor to moderate (Sections 8.2.6 and 8.2.10).	Construction works will avoid the breeding bird season and fencing will be used to minimise potential disturbance impacts during operation (Section 11.2.1). Community will provide active involvement in management measures (Section 11.2.3).	Insignificant.	Any potential reduction or displacement of birds following the application of mitigation measures will be temporary/ minimal and will not result in a significant change in favourable condition.
			Extent and distribution of habitat.	No decrease in extent from an established baseline.	Insignificant to moderate (Sections 8.2.1, 8.2.2, 8.2.4, 8.2.5, 8.2.7, 8.2.8 and 8.2.9).	Given the increasing uncertainty over time in future predictions, a new isolated island habitat will be created within the harbour as compensation (Section 11.2.2). In addition, evaluation of LiDAR monitoring for a period of up to 8 years post breach (i.e. covering the minimum lifespan of the project in terms of coastal defence protection) will validate the predictions in the ES (Section 11.3).	Insignificant to minor.	Any change in extent and distribution of supporting habitat will be small to negligible following the provision of compensatory habitat and will not result in a significant change in favourable condition.
			Absence of obstruction to viewlines.	No increase in obstructions to existing viewlines.	Not applicable (N/A).	-	-	-
		Saltmarsh, sand and shingle.	Vegetation Characteristics.	Vegetation height throughout the areas used for roosting and nesting should not deviate significantly from an established baseline, subject to natural change.	Minor (Section 8.2.4).	Access routes will be via an agreed route to minimise access footprint and cause the least damage to vegetated shingle (Section 11.2.1).	-	Any change in vegetation height will be temporary/ minimal and will not result in a significant change in favourable condition.
		Mudflat and sandflat communities Saltmarsh (feeding habitat).	Food availability.	Presence and abundance of food species during the breeding period should not deviate significantly from an established baseline, subject to natural change.	Insignificant to minor (Sections 8.2.5 and 8.2.9).	-	-	Any change in the presence and abundance of food species will be temporary/ minimal and will not result in a significant change in favourable condition.
		Shallow coastal water over intertidal area (and permanent water channels).	Food availability.	Presence and abundance of food species during the breeding period should not deviate significantly from an established baseline, subject to natural change.	Insignificant (Sections 8.2.5 and 8.2.9).	-	-	Any change in the presence and abundance of food species will be temporary/ minimal and will not result in a significant change in favourable condition.

ARUN DISTRICT COUNCIL P/93/25/PL

Summary of Natural England Objectives (English Nature 2001)					Summary of EIA Findings Following EIA Significance Criteria			Initial Conclusions on Favourable Condition Target
Criteria	Qualifying Features	Sub-feature	Attribute	Target	Potential Effect	Mitigation/Monitoring	Significance of Residual Impact	
Internationally important populations of regularly occurring migratory species	A046a Branta bernicla bernicla; Dark-bellied brent goose (Non-breeding)	Mudflat and sandflat communities, saltmarsh.	Disturbance (feeding and roosting areas).	No significant reduction in numbers or displacement of birds, attributable to human disturbance from an established baseline, subject to natural change.	Minor (Sections 8.2.6 and 8.2.10).	-	-	Any potential reduction or displacement of Dark-bellied Brent Geese will be temporary/ minimal and will not result in a significant change in favourable condition.
			Extent and distribution of habitat.	No decrease in extent from an established baseline, subject to natural change.	Insignificant to minor (Sections 8.2.5 and 8.2.9).	-	-	Any change in extent and distribution of supporting habitat will be temporary/ minimal and will not result in a significant change in favourable condition.
			Absence of obstruction to viewlines.	No increase in obstructions to existing viewlines, subject to natural change.	Not applicable (N/A).	-	-	-
		Mudflat and sandflat communities (feeding habitat).	Food availability.	Presence and abundance of food species should not deviate significantly from an established baseline, subject to natural change	Insignificant to minor (Sections 8.2.5 and 8.2.9).	-	-	Any change in the presence and abundance of food species will be temporary/ minimal and will not result in a significant change in favourable condition.
		Saltmarsh.	Food availability.	Presence and abundance of food species should not deviate significantly from an established baseline, subject to natural change	Insignificant (Sections 8.2.5 and 8.2.9).	-	-	Any change in the presence and abundance of food species will be temporary/ minimal and will not result in a significant change in favourable condition.
		Shallow coastal water.	Disturbance in feeding and roosting areas.	No significant reduction in numbers or displacement of birds, attributable to human disturbance from an established baseline, subject to natural change.	Minor (Sections 8.2.6 and 8.2.10).	-	-	Any potential reduction or displacement of Dark-bellied Brent Geese will be temporary/ minimal and will not result in a significant change in favourable condition.
			Extent and distribution of habitat.	No decrease in extent from an established baseline, subject to natural change.	Insignificant (Sections 8.2.5 and 8.2.9).	-	-	Any change in extent and distribution of supporting habitat will be temporary/ minimal and will not result in a significant change in favourable condition.

ARUN DISTRICT COUNCIL P/92/25/PL

C.13 Alternatives

Under Article 6(4) of the Habitats Directive, a plan or project can only proceed provided there are no feasible alternative solutions to the plan or project which are less damaging to the affected European/Ramsar sites. In this case none of the alternative options meet all the objectives of the project and are not feasible alternatives (see Section 2.2 of the main ES). The proposed project achieves all the required goals for cost-effective coastal protection (as described in Table 2.1 of the main ES) but has the added benefit that it will create a breach morphology that is marginally more stable and less likely to close than the alternative. Thus, it helps with protecting the Pagham Harbour SPA and Ramsar site from closure (a concern that has been expressed by Natural England within the SPA Site Improvement Plan (Natural England, 2014)).

C.14 Imperative Reasons of Overriding Public Interest

Under Article (4) of the Habitats Directive, a plan or project can only proceed provided there are "imperative reasons of overriding public interest" (IROPI) that justify the plan or project despite the environmental damage it will cause. This requires consideration of the different elements of the term IROPI and the objectives of the proposed project (see Section 2.1 of the main ES):

- Imperative: the proposed project is urgently required to provide the necessary public safety and human health benefits;
- Overriding: the larger and longer term coastal defence and other benefits served by the proposed project is considered to outweigh the uncertainty over the potential risk of harm to the integrity of the European/Ramsar site; and
- Public Interest: a public benefit will be delivered to the local residents of Pagham Beach Estate as well as the wider community. Furthermore, the project is consistent with the recommended Adaptive Management measure for this part of the coastline and, as such, is in keeping with the objectives of the Pagham to East Head Coastal Defence Strategy.

C.15 Compensation

In order to account for the uncertainty of whether there will be an adverse effect on site integrity as a result of the proposed project, a new isolated island habitat will be created for these SPA features within the harbour. Following the Court of Justice of the European Union (CJEU) ruling in the Briels case, there may be issues as to whether the creation of habitat for SPA features within the site fabric of the SPA can be regarded as 'mitigation' under the Habitats Directive. Currently there is no UK specific case law on this point although CJEU case law is binding. Rather it may be considered as 'compensation', an option which is available only after following the 'no alternatives' and 'imperative reasons of overriding public importance' tests under Article 6(4) of the Habitats Directive (see Sections C.13 and C.14).

Further details of the proposed compensation are provided in Section 11.2 of the main ES.

ARUN DISTRICT COUNCIL P/93/25/PL

C.16 References

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ARUN DISTRICT COUNCIL P/93/15/PL

Appendix D

Construction Maps Provided by Mackley

Managed Breach of Shingle Spit at Pagham: Environmental Statement

Volume 2: Appendices

Contents

Page

D. Construction Maps Provided by Mackley 3
D.1 Introduction 3

Sketches

1. Pagham Spit Breach – Location Plan & Access Routes
2. Pagham Spit Breach – Site Access Routes
3. Pagham Spit Breach – Step 1 – Temporary Sheet Piles for Access
4. Pagham Spit Breach – Step 2 – Landward Breach Excavation & Initial Fill
5. Pagham Spit Breach – Step 3 – Seaward Breach Excavation, Stockpile & Fill
6. Pagham Spit Breach – Step 4 – Central Breach Excavation, Stockpile & Dam Fill
7. Pagham Spit Breach – Step 5 – Completed Breach & Dam.

ARUN DISTRICT COUNCIL P/93/25/PL

D. Construction Maps Provided by Mackley

D.1 Introduction

Mackley, an engineering contractor with extensive experience of undertaking beach works along the south coast, has provided an outline project methodology for the proposed project. This method is presented in Section 3.2 of the Environmental Statement (ES). The following sketches in support of this methodology are included in this appendix:

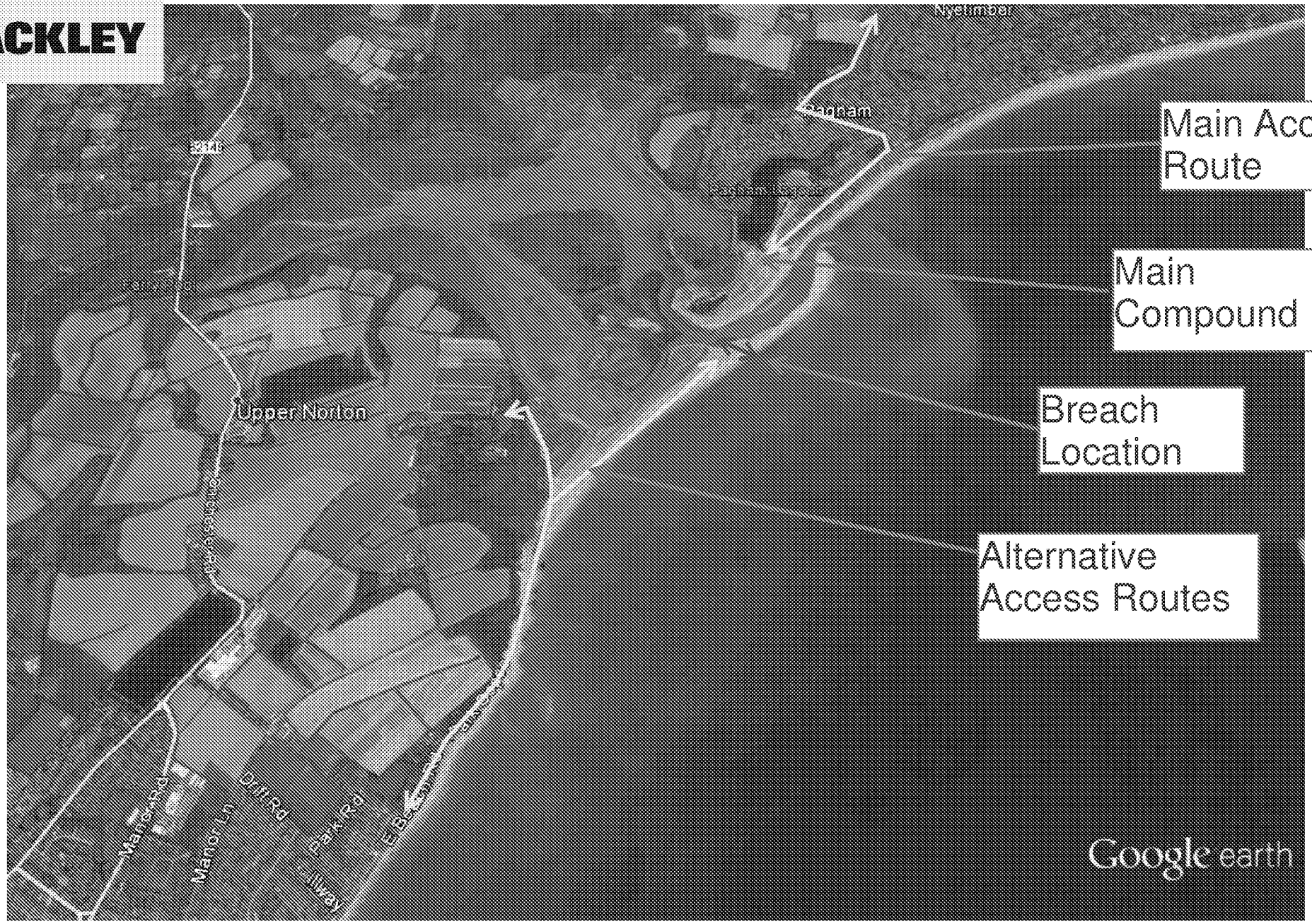
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- Sketch 2 Pagham Spit Breach – Site Access Routes;
- Sketch 3 Pagham Spit Breach – Step 1 – Temporary Sheet Piles for Access;
- Sketch 4 Pagham Spit Breach – Step 2 – Landward Breach Excavation & Initial Fill;
- Sketch 5 Pagham Spit Breach – Step 3 – Seaward Breach Excavation, Stockpile & Fill;
- Sketch 6 Pagham Spit Breach – Step 4 – Central Breach Excavation, Stockpile & Dam Fill; and
- Sketch 7 Pagham Spit Breach – Step 5 – Completed Breach & Dam.

ARUN DISTRICT COUNCIL P/93/25/PL

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Pagham Spit Breach - Location Plan & Access Routes

MACKLEY



Google earth

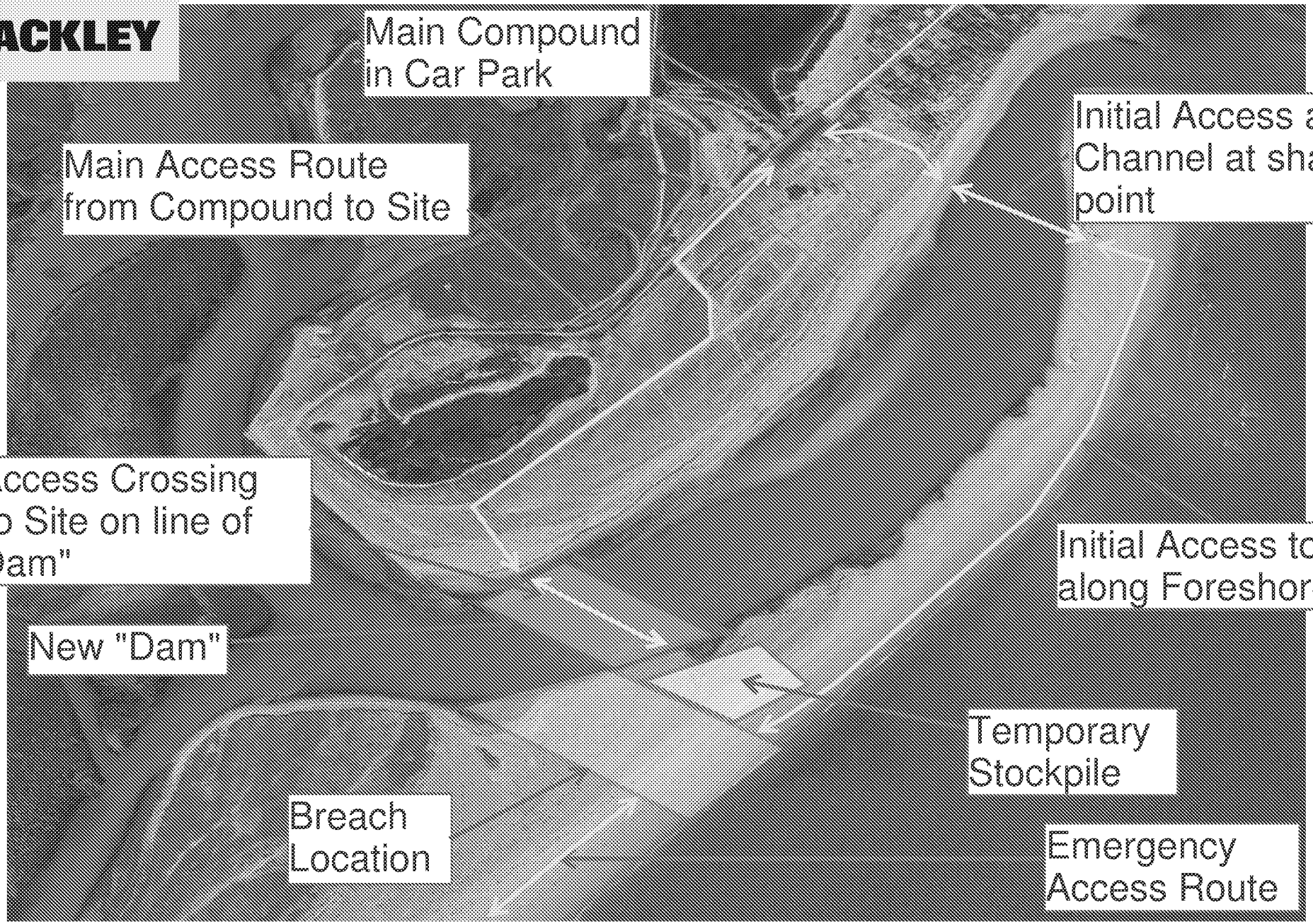
miles 2
km 3

ARUN DISTRICT COUNCIL P/93/21/PL

ARUN DISTRICT COUNCIL P/97/15/PL

Pagham Spit Breach - Site Access Routes

MACKLEY



Google earth

feet 1000
meters 600

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PL

Pagham Spit Breach - Step 1 - Temporary Sheet Piles for Access

MACKLEY



Google earth

feet 1000
meters 400

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Pagham Spit Breach - Step 2 - Landward Breach Excavation & Initial Fill

MACKLEY

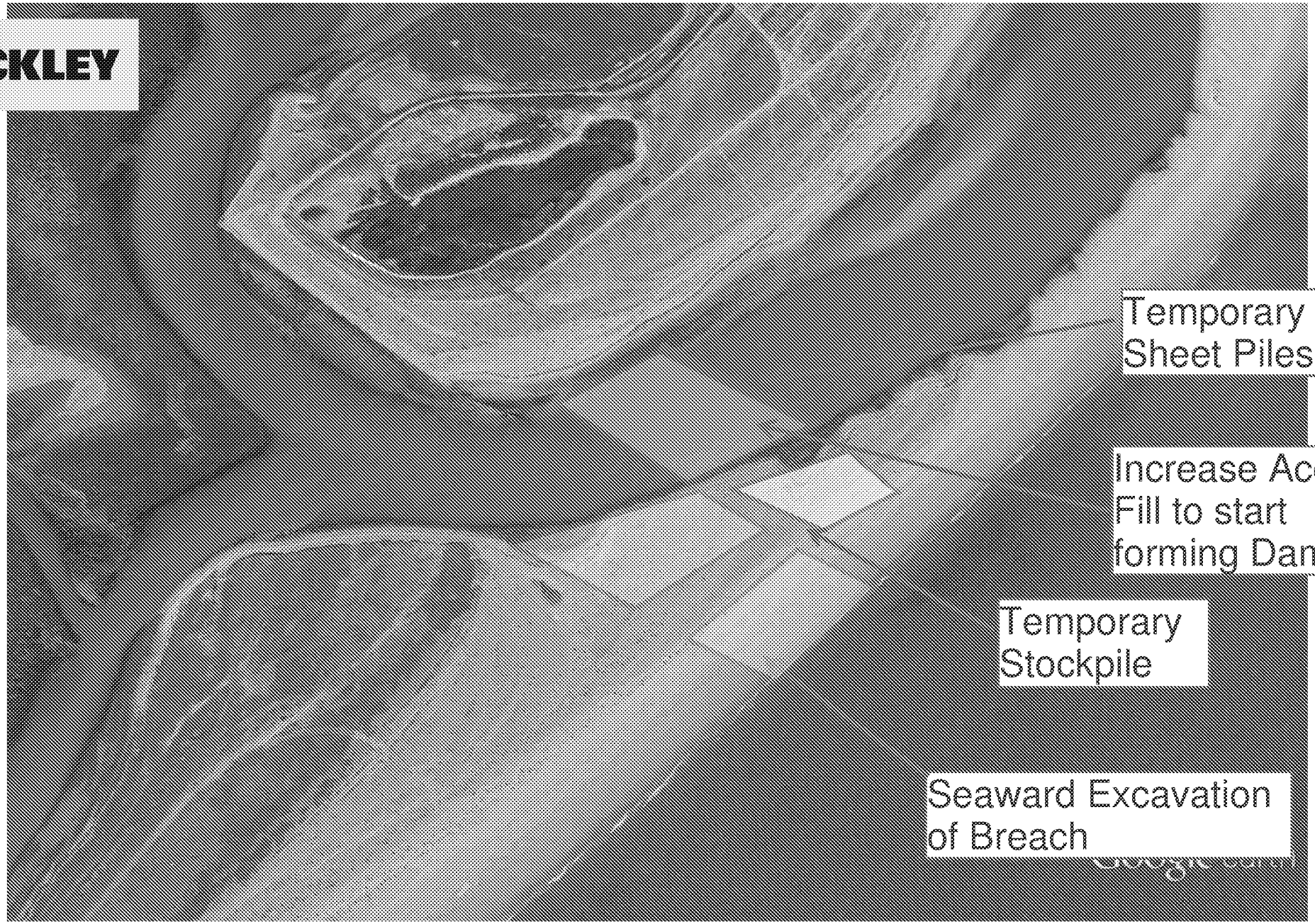


Google earth

feet 1000
meters 400

Pagham Spit Breach - Step 3 - Seaward Breach Excavation, Stockpile & Fill

MACKLEY



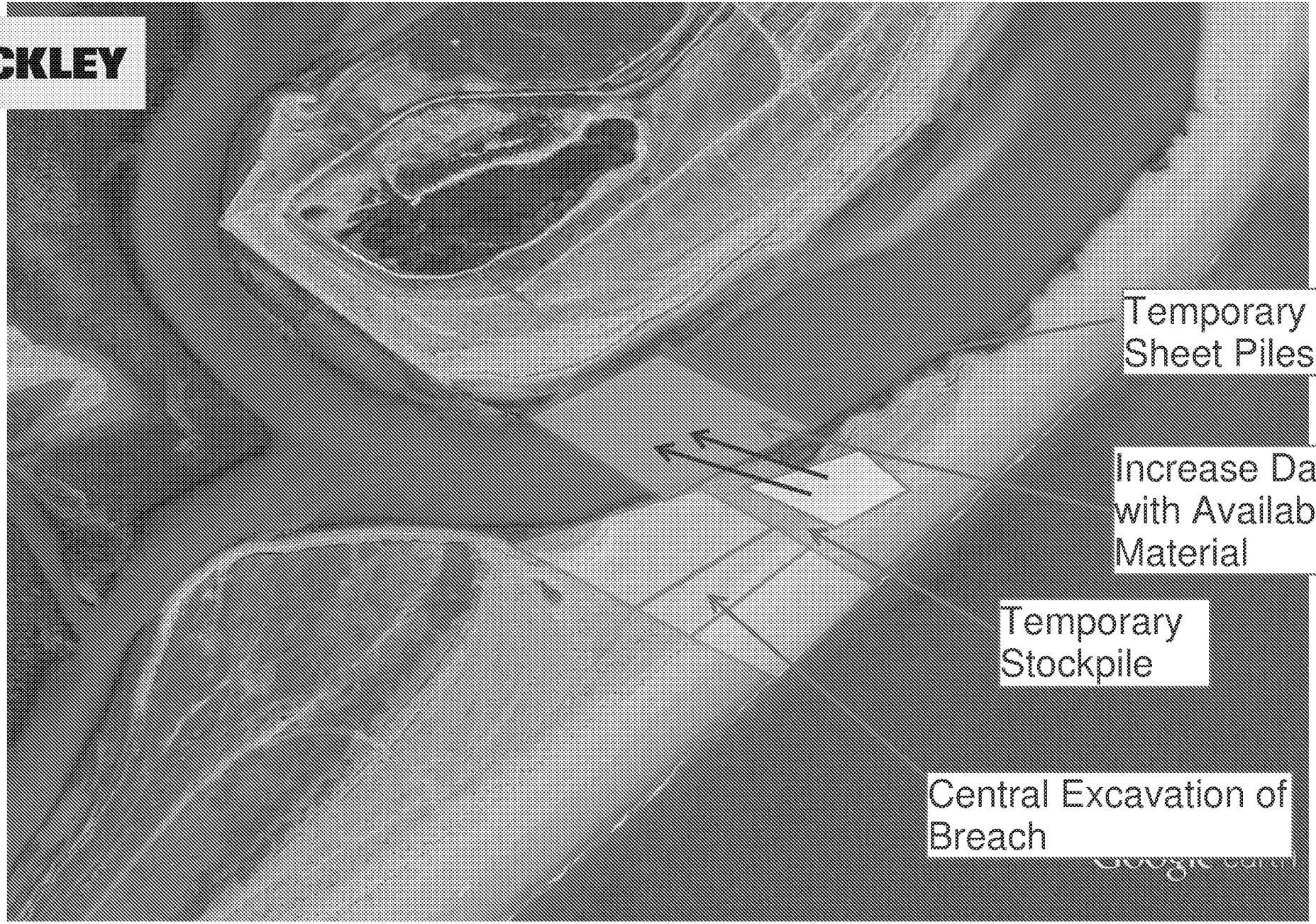
Google earth

feet 1000
meters 400

ARUN DISTRICT COUNCIL P/93/21/PL

Pagham Spit Breach - Step 4 - Central Breach Excavation, Stockpile & Dam Fill

MACKLEY



Google earth

feet 1000
meters 400

ARUN DISTRICT COUNCIL P/93/21/PL

ARUN DISTRICT COUNCIL P/97/15/PL

Pagham Spit Breach - Step 5 - Completed Breach & Dam

MACKLEY



Google earth

feet 1000
meters 400

ARUN DISTRICT COUNCIL P/93/21/PL

Appendix E

Legislation and Policy

Managed Breach of Shingle Spit at Pagham: Environmental Statement

Volume 2: Appendices

Contents

Page

E. Legislation and Policy 4
E.1 Internal Conventions 4
E.1.1 The Convention on the Conservation of European Wildlife and Natural Habitats 1979 (the Bern Convention) 4
E.1.2 The Convention on Biological Diversity 1992 (Biodiversity Convention or CBD) 4
E.1.3 The Convention on the Conservation of Migratory Species of Wild Animals 1979 (the Bonn Convention) 4
E.1.4 The Convention for the Protection of the Marine Environment of the North-East Atlantic 1992 (the OSPAR Convention) 5
E.1.5 The Convention on Wetlands of International Importance Especially as Waterfowl Habitat 1971 (the Ramsar Convention or Wetlands Convention) 5
E.2 European Directives 5
E.2.1 EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (EC Habitats Directive) 5
E.2.2 EC Directive on the Conservation of Wild Birds (2009/147/EC) (EC Birds Directive) 6
E.2.3 The Water Framework Directive (2000/60EC) 6
E.2.4 Priority Substances Directive (2008/105/EC) 7
E.2.5 Urban Waste Water Treatment Directive (91/271/EEC) 7
E.2.6 EC Bathing Waters Directive (2006/7/EC) 7
E.2.7 EU Marine Strategy Framework Directive (2008/56/EC) 8
E.3 National Legislation and Planning Policy 8
E.3.1 The Conservation of Habitats and Species Regulations 2010 (Habitats Regulations) 8
E.3.2 Marine and Coastal Access Act 2009 9
E.3.3 The Wildlife and Countryside Act 1981 (as amended) 10
E.3.4 Countryside and Rights of Way Act 2000 10
E.3.5 UK Marine Policy Statement 11
E.3.6 UK Biodiversity Action Plan 11
E.3.7 The Natural Environment and Rural Communities Act (NERC Act) 2006 11
E.3.8 The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 SI 3242 12
E.3.9 National Planning Policy Framework 12

ARUN DISTRICT COUNCIL P/93/25/PL

E.4 Local Planning Policy 13
E.4.1 Chichester District Local Plan 1999 Saved Policies 13
E.4.2 Chichester Local Plan: Key Policies 2014-2029 Proposed Modifications 13
E.4.3 Arun District Local Plan 2003 Saved Policies 15
E.4.4 Arun District Local Plan 2011-2029 15
E.4.5 Pagham to East Head Coastal Defence Strategy 16
E.4.6 Shoreline Management Plan 17
E.4.7 Pagham to East Head Coastal Defence Strategy 17
E.4.8 Other Plans 17
E.5 References 18

ARUN DISTRICT COUNCIL P/93/15/PL

E. Legislation and Policy

There is a wide range of environmental legislation with which the proposed project will need to comply. A summary of the principal legislation and national, regional and local planning context is provided in this appendix.

E.1 Internal Conventions

E.1.1 The Convention on the Conservation of European Wildlife and Natural Habitats 1979 (the Bern Convention)

The principle aims of the Bern Convention are the conservation and protection of the wild plant and animal species (and the natural habitats thereof) listed in Appendices I and II of the Convention. It also seeks to increase co-operation between governments and to regulate the exploitation of the species listed in Appendix III, which includes migratory fish species, cetaceans and grey seal.

The Bern Convention was implemented in Europe via two directives: Council Directive 79/409/EEC on the Conservation of Wild Birds (the EC Birds Directive) in 1979 and Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (the EC Habitats Directive) in 1992. The Convention is implemented in UK law by the Wildlife and Countryside Act (1981 and as amended). These are discussed further below.

E.1.2 The Convention on Biological Diversity 1992 (Biodiversity Convention or CBD)

The CBD was the first treaty to provide a legal framework for biodiversity conservation. It focuses on the conservation of all species and ecosystems and, therefore, provides protection to all biodiversity. The Convention requires that national strategies, plans or programmes are developed for the conservation and sustainable use of biodiversity.

In the UK, the CBD is implemented via the Post-2010 Biodiversity Framework, which in 2012 replaced the UK Biodiversity Action Plan (see below).

E.1.3 The Convention on the Conservation of Migratory Species of Wild Animals 1979 (the Bonn Convention)

The Convention aims to conserve migratory species and their habitats by providing strict protection for endangered migratory species that are listed in Appendix I of the Convention. It involves multilateral agreements for conserving and managing those migratory species that would benefit from international co-operation (listed in Appendix II of the Convention) and the undertaking of co-operative research.

ARUN DISTRICT COUNCIL P/93/25/PL

Within the UK, protection of Appendix I species is carried out through the Wildlife & Countryside Act (1981 as amended) (see below). The Countryside and Rights of Way Act 2000 (CRoW) was also enacted in England and Wales to offer further support by increasing penalties and enforcement powers. It also strengthened the protection of sites from damage caused by third parties.

E.1.4 The Convention for the Protection of the Marine Environment of the North-East Atlantic 1992 (the OSPAR Convention)

The OSPAR Convention provides a comprehensive approach to addressing sources of maritime pollution and other matters affecting the marine environment. Annex V of the Convention provides a framework for governments to develop their own conservation measures. Article 2 requires parties to 'take necessary measures to protect and conserve the ecosystems and the biological diversity of the maritime area, and to restore, where practicable, marine areas which have already been adversely affected'.

The Convention includes the establishment of a list of threatened and/or declining species and habitats. This list provides an overview of the biodiversity in need of protection in the North-East Atlantic and is being used by the OSPAR Commission to guide the setting of priorities for further work on the OSPAR Convention and protection of marine biodiversity OSPAR Convention protected habitats and species.

The most recent OSPAR List of Threatened and/or Declining Species and Habitats lists inter alia native oyster, allis shad, European eel, cod, sea lamprey, thornback ray, Atlantic salmon and harbour porpoise as being under threat and/or in decline in Region II (the Greater North Sea, which includes the English Channel).

E.1.5 The Convention on Wetlands of International Importance Especially as Waterfowl Habitat 1971 (the Ramsar Convention or Wetlands Convention)

The Ramsar Convention is an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their wetlands of international importance and to plan for the "wise use", or sustainable use, of all of the wetlands in their territories. Ramsar sites are wetlands of international importance designated under the Ramsar Convention.

Policy statements relating to the status of Ramsar sites have been issued by Government, to extend their level of protection to that of sites designated as part of the EU Natura 2000 network under the EC Birds and Habitats Directives (see below).

E.2 European Directives

E.2.1 EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (EC Habitats Directive)

The Habitats Directive was adopted in 1992 and is the means by which the EU meets its obligations under the Bern Convention. The Directive promotes the maintenance of biodiversity by requiring Member States to maintain or restore natural habitats and wild species that are listed on the Directive's

ARUN DISTRICT COUNCIL P/93/25/PL

annexes. Economic, social and cultural requirements must be considered, alongside regional and local characteristics.

To maintain or restore habitats listed in Annex I and species listed in Annex II of the Directive to 'Favourable Conservation Status', a network of Special Areas of Conservation (SACs) have been created. Annex II species include Atlantic salmon, harbour porpoise and grey and common seals.

Annex IV of the Habitats Directive lists European Protected Species which are species of plants and animals (other than birds) protected by law throughout the European Union. All species of cetacean are listed in Annex IV of the Habitats Directive.

In England, the Directive is implemented under the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended), which apply to land and territorial waters to the 12 nautical mile limit. The amendments are consolidated by the Conservation of Habitats and Species Regulations 2010 out to 12nm from the coast (see below) and by the Offshore Marine Conservation (Natural Habitats &c.) Regulations 2007 (as amended) between 12nm from the coast and 200nm or the limit of the UK Continental Designated Area.

E.2.2 EC Directive on the Conservation of Wild Birds (2009/147/EC) (EC Birds Directive)

The Birds Directive was adopted by the Members States in 1979 as a response to increasing concern about the declines in Europe's wild bird populations resulting from pollution and loss of habitats as well as unsustainable use. It was also in recognition that wild birds, many of which are migratory, are a shared heritage of the Member States and that their effective conservation required international co-operation.

The directive recognises that habitat loss and degradation are the most serious threats to the conservation of wild birds. It therefore places great emphasis on the protection of habitats for endangered as well as migratory species (listed in Annex I), especially through the establishment of a coherent network of Special Protection Areas (SPAs) comprising all the most suitable territories for these species. Since 1994 all SPAs form an integral part of the Natura 2000 ecological network.

In England the provisions of the Birds Directive are implemented through the Wildlife & Countryside Act 1981 (as amended), the Conservation of Habitats and Species Regulations 2010 and the Offshore Marine Conservation Regulations 2007.

E.2.3 The Water Framework Directive (2000/60EC)

The Water Framework Directive (WFD) establishes a framework for the management and protection of Europe's water resources. It is implemented in England and Wales through the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 (the Water Framework Regulations) (see below). The aim of the WFD is to achieve "good ecological and good chemical status" in all inland and coastal waters by 2015 unless alternative objectives are set or there are grounds for derogation. Ecological status is an expression of the quality of the structure and functioning of surface water ecosystems as indicated by the condition of a number of "quality

ARUN DISTRICT COUNCIL P/93/25/PL

elements". These include hydro-morphological, chemical and biological indicators (including benthic invertebrates, macroalgae, fish, phytoplankton and angiosperms).

The WFD Directive was transposed into UK law via the Water Environment (WFD) (England and Wales) Regulations 2003 SI 3242. The Regulations provide the mechanism to implement river basin districts within England and Wales in accordance with the Water Framework Directive. The proposed project is in the South East River Basin District. The WFD water bodies that occur within the study area and could potentially be affected by the proposed project are described in Section 7 and Appendix H of the ES.

E.2.4 Priority Substances Directive (2008/105/EC)

The Priority Substances Directive (PSD) establishes Environmental Quality Standards (EQS) for 33 priority substances and eight additional substances, of which 20 are categorised as 'priority hazardous substances', being those of particular concern. This list forms Annex I and X of the PSD relating to priority substances. Biota standards are given for three of these substances (hexachloro-benzene, hexachloro-butadiene, and mercury and its compounds).

The standards supersede previous standards applied under the Dangerous Substances Directive (76/474/EEC) and other specific ('daughter') Directives, and the WFD and PSD resulted in their repeal from 22 December 2012. However, a number of existing dangerous substances have not been included in the list of priority substances, and the existing standards for these substances will continue to be applied.

E.2.5 Urban Waste Water Treatment Directive (91/271/EEC)

The EC Urban Waste Water Treatment Directive seeks to protect the environment from the adverse effects of sewage discharges. It sets treatment levels on the basis of sizes of sewage discharges and the sensitivity of waters receiving the discharges. In general, the Directive requires that collected wastewater is treated to at least secondary treatment standards for significant discharges. Secondary treatment is a biological treatment process where bacteria are used to break down the biodegradable matter (already much reduced by primary treatment) in waste water. Under the Directive, the UK is required to review environmental waters at four-yearly intervals to determine whether they are sensitive to the effects of sewage discharges.

E.2.6 EC Bathing Waters Directive (2006/7/EC)

The Bathing Waters Directive sets out water quality standards to protect the environment at bathing waters throughout the bathing season. The mandatory standards used by the European Commission to determine compliance of bathing waters with the Directive are the microbiological parameters – total and faecal coliforms, and three physico-chemical parameters – surface-active substances, mineral oils and phenols. To comply with these standards, bathing waters must not exceed values of 10,000 total coliforms per 100ml and 2000 faecal coliforms per 100ml in 95% of samples. The Bathing Water Directive also sets more stringent guideline microbiological standards that Member States must endeavour to observe – no exceedance of 500 total coliforms per 100ml and 100 faecal coliforms per 100ml in 80% of water quality samples and 100 faecal streptococci per 100ml in 90% of samples taken.

ARUN DISTRICT COUNCIL P/93/25/PL

The revised Bathing Water Directive (2006/7/EC) entered into force in March 2006 and was incorporated into UK law in 2008. The overall objective of the revised Directive remains the protection of public health whilst bathing, but it also offers an opportunity to improve management practices at bathing waters and to standardise the information provided to bathers across Europe.

The revised Directive updated the way in which water quality is measured, focusing on fewer microbiological indicators, and setting different standards for inland and coastal bathing sites. The existing Directive will be repealed at the end of 2014 and revised in 2015, when the first set of classifications using new parameters will be published. Standard EU symbols for the classification of bathing waters will be implemented in 2016.

E.2.7 EU Marine Strategy Framework Directive (2008/56/EC)

The Marine Strategy Framework Directive (MSFD) provides a framework for managing human activities with an ecosystem-based approach to support the sustainable use of marine goods and services. The objective of the MSFD is for EU marine waters to achieve 'good environmental status' (GES) by 2020. GES involves protecting the marine environment, preventing its deterioration and restoring it where practical, while using marine resources sustainably. For the UK, the co-ordination of strategies for reaching GES is achieved through the OSPAR Convention.

The Directive sets out 11 high-level Descriptors of GES which cover all the key aspects of the marine ecosystem and all the main human pressures on them, including the consideration of hydrographical conditions. The European Commission has also produced a Decision document (Commission Decision 2010/477/EU) which provides more detailed criteria and indicators of GES which Member States must use when implementing the Directive. The Directive came into force on 15 July 2008, and was transposed into UK law via the Marine Strategy Regulations 2010.

E.3 National Legislation and Planning Policy

E.3.1 The Conservation of Habitats and Species Regulations 2010 (Habitats Regulations)

The Conservation of Habitats and Species Regulations 2010 (referred to as the Habitats Regulations) consolidate all the various amendments made to the 1994 Regulations in respect of England and Wales. The Regulations transpose the EC Habitats Directive into national law. The Habitats Regulations provide for the designation of Special Areas of Conservation (SACs). They also require the compilation of a register of European sites in a network called Natura 2000.

These European sites are defined in the Habitats Regulations as including the following:

- Special Areas of Conservation (SACs) designated under the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (the Habitats Directive) for their habitats and/or species of European importance;

ARUN DISTRICT COUNCIL P/93/15/PL

- Special Protection Areas (SPAs) classified under the EC Directive on the Conservation of Wild Birds (the Birds Directive) for rare, vulnerable and regularly occurring migratory bird species and internationally important wetlands;
- Sites of Community Importance (SCIs) that have been adopted by the European Commission but not yet formally designated by the government of each country; and
- Candidate SACs (cSACs) that have been submitted to the European Commission, but not yet formally adopted.

Furthermore, it is policy in England under paragraph 118 of the National Planning Policy Framework (NPFF, see Section E3.9) that the following wildlife sites should be given the same protection as European sites:

- Potential SPAs (pSPAs) and possible SACs (pSACs);
- Listed or proposed Ramsar sites under the 1971 Ramsar Convention on Wetlands of International Importance; and
- Sites identified, or required, as compensatory measures for adverse effects on European sites (e.g. Medmerry).

The European sites and features that overlap with the effects of the proposed project are described in Section 8 and Appendix F of the ES.

Natural England has statutory responsibility to advise relevant authorities as to the conservation objectives for European Marine Sites and operations which may cause deterioration or disturbance of natural habitats and species. This advice is provided under Regulation 35 of the Habitats Regulations. The role of the conservation objectives for a European Marine Site is to define the nature conservation aspirations for the features of interest, thereby representing the aims and requirements of the Habitats and Birds Directives in relation to the site.

The Habitats Regulations also protect animal species listed in Schedule 2 from deliberate capture, killing, disturbing or trading, and plant species in Schedule 4 from being picked, collected, cut, uprooted, destroyed or traded without a licence.

E.3.2 Marine and Coastal Access Act 2009

The Marine and Coastal Access Act 2009 aims to enable better protection of marine ecosystems and prevent a decline in marine biodiversity. The Act sets out provisions for more coherent planning in the marine environment in terms of issuing consents and permits for activities in the marine and coastal environment. The Marine and Coastal Access Act 2009, at section 58(1), makes clear that 'A public authority (which includes the MMO) must take any authorisation or enforcement decision in accordance with the appropriate marine policy documents, unless relevant considerations indicate otherwise'.

The Act also contains provisions to allow for the creation of a new type of Marine Protected Area (MPA), called a Marine Conservation Zone (MCZ). MCZs protect a range of nationally important marine wildlife, habitats, geology and geomorphology and can be designated anywhere in English inshore and UK offshore waters. Sites are selected to protect not just rare and threatened habitats and/or species, but the full range of marine wildlife (JNCC, 2012). Within the south east region, the

ARUN DISTRICT COUNCIL P/93/25/PL

development of recommendations for MCZ has been coordinated by the Balanced Seas Regional MCZ Project (Balanced Seas, 2011).

The UK Government consulted on the first tranche of recommended Marine Conservation Zones (rMCZs) in English Inshore and English and Welsh Offshore Waters between 13 December 2012 and 31 March 2013. On 21 November 2013, Defra announced the designation of 27 MCZs around England's coast. In January 2015, Defra opened the consultation on a second tranche of MCZs with the aim of designating sites in 2016 (Defra, 2015). For the second tranche, 23 sites from the Regional MCZ Project recommendations have been identified as suitable candidates for consideration (proposed MCZ (pMCZs)). The MCZ sites and features that occur within the study area and could potentially be affected by the proposed project are described in Section 8 and Appendix G of the ES.

E.3.3 The Wildlife and Countryside Act 1981 (as amended)

The Wildlife and Countryside Act (WCA) consolidates and amends existing legislation to implement the Bern Convention and the Birds Directive. The act contains four parts and 17 schedules, covering inter alia: protection of wildlife (birds and some animals and plants); the countryside; national parks; and the designation of protected areas.

The WCA 1981 provides for the designation and management of Sites of Special Scientific Interest (SSSI). These sites are designated to safeguard, for present and future generations, the diversity and geographic range of habitats, species, and geological and physiographical features, including the full range of natural and semi-natural ecosystems and of important geological and physiographical phenomena throughout England and Wales. The SSSI sites and features that occur within the study area and could potential be affected by the proposed project are described in Section 8 and Appendix F of the ES.

In addition, all cetaceans (whales and dolphins) are protected under Schedule 5 of the Wildlife and Countryside Act 1981 (and amendments), under which it is an offence to take, injure or kill these species. Disturbance in their place of rest, shelter or protection is also prohibited.

E.3.4 Countryside and Rights of Way Act 2000

The Countryside and Rights of Way Act (CRoW Act) 2000 applies to England and Wales only and contains five Parts and 16 Schedules. It complies with the provisions of the European Convention on Human Rights. Consultation is required where the rights of the individual may be affected.

The CRoW Act: provides for public access, on foot, to certain types of land; amends the law for public rights of way; increases protection for SSSIs and strengthens wildlife enforcement legislation; and provides for better management of Areas of Outstanding Natural Beauty (AONB). For example, the CROW Act (Section 28G of The Wildlife and Countryside Act (1981) (as amended)) imposes a duty on all government and public bodies, including Local Planning Authorities to conserve and enhance the special interest features of SSSIs.

ARUN DISTRICT COUNCIL P/93/15/PL

E.3.5 UK Marine Policy Statement

The UK Marine Policy Statement (MPS) is the framework for preparing Marine Plans and taking decisions affecting the marine environment. Adopted by the UK Government, the Scottish Government, the Welsh Government and the Northern Ireland Executive, the MPS is intended to help achieve the shared UK vision for clean, healthy, safe, productive and biologically diverse oceans and seas. The MPS aims to enable an appropriate and consistent approach to marine planning across UK waters, and to ensure the sustainable use of marine resources and strategic management of marine activities from renewable energy to nature conservation, fishing, recreation and tourism. The proposed project falls within the south marine plan areas which are the third and fourth areas in England to be selected for marine planning.

E.3.6 UK Biodiversity Action Plan

The UK Biodiversity Action Plan (UK BAP) was published in 1994, and was the UK Government's response to the Convention on Biological Diversity (CBD), which the UK signed up to in 1992 in Rio de Janeiro. Action plans for the most threatened species and habitats were set out to aid recovery, and national reports, produced every three- to five-years, showed how the UK BAP was contributing to the UK's progress towards the significant reduction of biodiversity loss called for by the CBD. The UK BAP priority list contains 1150 species and 65 habitats requiring special protection.

The 'UK Post-2010 Biodiversity Framework', published in July 2012, succeeds the UK BAP, and is the result of a change in strategic thinking following the publication of the CBD's 'Strategic Plan for Biodiversity 2011–2020' and its 20 'Aichi Biodiversity Targets', at Nagoya, Japan in October 2010, and the launch of the new EU Biodiversity Strategy in May 2011. The Framework demonstrates how the work of the UK contributes to achieving the Aichi Biodiversity Targets, and identifies the activities required to complement the country biodiversity strategies in achieving the targets. Many of the tools developed under UK BAP remain of use. Government Circular 06/2005 states that BAP species and habitats, "are capable of being a material consideration….in the making of planning decision". The lists of priority species and habitats agreed under UK BAP therefore still form the basis of much biodiversity work in each of the devolved administrations (see below).

E.3.7 The Natural Environment and Rural Communities Act (NERC Act) 2006

The NERC Act makes provision about bodies concerned with natural environment and rural communities, and it regulates inter alia nature conservation in the UK, wildlife and SSSIs. The UK BAP list has been used as a reference to draw up the species and habitats of principal importance in England under S41 of the NERC Act 2006 (NERC 2006). The S41 list contains 943 species and 56 habitats of principal importance which occur in England. These are the species and habitats which were identified as requiring action under the UK BAP and which continue to be regarded as conservation priorities under the UK Post-2010 Biodiversity Framework.

ARUN DISTRICT COUNCIL P/93/25/PL

E.3.8 The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 SI 3242

The Regulations provide the mechanism to implement river basin districts within England and Wales in accordance with the Water Framework Directive. The regulations require a new strategic planning process to be established for the purpose of managing, protecting and improving the quality of water resources. The proposed development is in the South East River Basin District.

E.3.9 National Planning Policy Framework

The National Planning Policy Framework (NPPF) which was published on 27 March 2012 sets out the Government's planning policies for England and how these are expected to be applied. The NPPF replaces previous national planning policy guidance which was primarily contained within a series of Planning Policy Guidance notes (PPGs) and Planning Policy Statements (PPSs). The framework is a key part of Government reforms to make the planning system less complex and more accessible, to protect the environment and to promote sustainable growth.

The NPPF acts as guidance for local planning authorities and decision-takers, both in drawing up plans and making decisions about planning applications. The framework incorporates polices relating to coastal change and biodiversity that are of direct relevance to the proposed project.

The aim of the policy on coastal change, as set out in paragraphs 105-108 of the NPPF, is to reduce risk from coastal change by avoiding inappropriate development in vulnerable areas or adding to the impacts of physical changes to the coast. The general approach can be summarised as follows:

- Local planning authorities apply Integrated Coastal Zone Management to integrate terrestrial and marine planning regimes;
- Local planning authorities identify Coastal Change Management Areas[1] likely to be affected by physical changes to the coast;
- Local planning authorities are expected to be clear what development will be appropriate in Coastal Change Management Areas[2] and make provision for development and infrastructure that needs to be relocated away from Coastal Change Management Areas.

Is set out in paragraph 168 of the NPPF, Shoreline Management Plans (SMPs) should inform the evidence base for planning in coastal areas. The prediction of future impacts should include the longer term nature and inherent uncertainty of coastal processes (including coastal landslip), and take account of climate change.

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[1] This is an area identified in Local Plans as likely to be affected by coastal change (physical change to the shoreline through erosion, coastal landslip, permanent inundation or coastal accretion).

[2] Essential infrastructure may be permitted in a coastal change management area, provided there are clear plans to manage the impacts of coastal change on it, and it will not have an adverse impact on rates of coastal change elsewhere.

ARUN DISTRICT COUNCIL P/93/25/PL

E.4 Local Planning Policy

E.4.1 Chichester District Local Plan 1999 Saved Policies

The Local Plan for Chichester District consists of the Saved Policies in the Chichester District Local Plan (adopted April 1999). These policies guide development in this district and are used to make decisions on planning applications. Until the new Local Plan 2014-2029 has been adopted (see Section E4.2), the following policies, which have been identified as being particularly relevant to the proposed project, remain current:

Policy C3: Managed Realignment states that "Proposals for the managed realignment of sea defences or coast protection structures which provide nature conservation and/or landscape benefits will be permitted providing there is no loss of the best and most versatile agricultural land or danger to buildings and provision is made for diversion of the coastal path or other affected public rights of way".

Policy C9: Sea Defence and Coast Protection Works states that "proposal for the construction of new or replacement sea defence and coast protection works… will be permitted provided that: the District Planning Authority can be satisfied that the technical requirements of the coast protection authority have been met; in the rural area they are not visually obtrusive or damaging to the open appearance or character of the shoreline…; they would not be damaging to features of ecological or archaeological significance to the locality; they do not involve the visible use of waste material; they are of a design… which, where technically feasible, will attract accretion of silt and plants to reduce the visual impact of works;… they maintain access for commercial and leisure fishing activities".

E.4.2 Chichester Local Plan: Key Policies 2014-2029 Proposed Modifications

On 30 May 2014, the Chichester Local Plan: Key Policies 2014-2029 and supporting documents were submitted for independent examination to the Secretary of State for Communities and Local Government via the Planning Inspectorate. The Secretary of State has appointed an independent Inspector to conduct the Examination.

The Local Plan provides the broad policy framework and a long-term strategy to manage development, protect the environment, deliver infrastructure and promote sustainable communities within Chichester District (excluding the area within the South Downs National Park) to 2029. Once adopted, all planning applications will be assessed against the policies in the Local Plan.

The final scheduled session on the examination of the Chichester Local Plan: Key Policies Pre-submission 2014-2029 was held on 3 December 2014 and the Council has consulted on the Proposed Modifications it considered were required to make the Plan sound. Any minor changes required on the basis of accuracy, clarity or for updating purposes will be included in the adopted version of the Chichester Local Plan.

The Proposed Modifications consultation ran for six weeks from 8 January 2015 to 19 February 2015. The Inspector has carefully considered all the representations submitted in response to the Council's proposed modifications and will take account of these in writing the report which was unavailable at the time of writing.

ARUN DISTRICT COUNCIL P/93/15/PL

Particularly pertinent policies in the pre-submission document (CDC, 2014) are now listed.

The proposed Policy 22 on 'Integrated Coastal Zone Management for the Manhood Peninsula' could be viewed as pertinent, as the Church Norton Spit is essentially part of the Peninsula, even though the affected community at Pagham is not on the Peninsula, nor is it within the boundaries of CDC. For the Manhood Peninsula, CDC pledges to "prepare plans, strategies, projects and other measures, in partnership with other organisations and local communities, to ensure that the Manhood Peninsula is planned for in a coordinated and integrated manner, whilst recognising the individual needs of the communities within the area'. 'Proposals and initiatives will be supported that promote the following general objectives:

1. Facilitate the economic, environmental and social well-being of the area;
2. Address proposals for the coastline and coastal communities set out in Coastal Defence Strategies and Shoreline Management Plans;
3. Contribute to greater safeguarding of property from flooding or erosion and/or enable the area and pattern of development to adapt to change, including the relocation of current settlement areas, and vulnerable facilities and infrastructure that might be directly affected by the consequences of climate change;
4. Provide resources to improve the process of harbour and coastal management, incorporating and integrating social, recreational, economic, physical and environmental issues and actions;
5. Improve infrastructure to support sustainable modes of transport, especially cycle ways, bridleways and footpaths, including the National Coastal Footpath; and
6. Provide the means of supporting regeneration on the Manhood Peninsula."

Proposed Policy 44, Development around the Coast, states that "planning permission will be granted for development in the coastal area, outside of Settlement Boundaries, where it can be demonstrated that all the following criteria have been considered:

1. There are no harmful effects on or net loss of nature conservation or areas of geological importance within the Chichester and Pagham Harbours and Medmerry Realignment;
2. The development provides recreational opportunities that do not adversely affect the character, environment and appearance of the coast and Chichester Harbour Area of Outstanding Natural Beauty;
3. Regard has been shown to the high quality and inclusive design of new buildings in coastal locations in accordance with other relevant design and historic environment policies;
4. There are measures for mitigation of any detrimental effects including where appropriate the improvement of existing landscapes relating to the proposal;
5. Where appropriate, opportunities have been taken to upgrade existing footpaths and cyclepaths, enhance and protect the National Coastal Footpath and ensure that public access is retained and provided to connect existing paths along the waterfront;
6. The development would result in improvements to or redistribution of moorings, marine berths or launch on demand facilities (dry berths) in the harbours; and
7. The development would not be detrimental to infrastructure for, and quality of, water-based recreation, or be detrimental to the safety of navigation."

ARUN DISTRICT COUNCIL P/93/15/PL

Proposed Policy 48 Natural Environment states that "planning permission will be granted where it can be demonstrated that all the following criteria have been met:

1. There is no adverse impact on:
   - The openness of the views in and around the coast, designated environmental areas and the setting of the South Downs National Park;
   - The tranquil and rural character of the area; and
   - Development recognises distinctive local landscape character and sensitively contributes to its setting and quality;
2. Proposals respect and enhance the landscape character of the surrounding area and site, public amenity and detailed design;
3. Development of poorer quality agricultural land has been fully considered in preference to best and most versatile land; and
4. The individual identity of settlements, actual or perceived, is maintained and the integrity of predominantly open and undeveloped land between settlements is not diminished."

E.4.3 Arun District Local Plan 2003 Saved Policies

The current Local Plan for Arun District was created in 2003 and the Council is currently in the process of producing a new one (Section E4.4). The following policies are of particular relevance to the proposed project:

Policy GEN10: Tidal Flooding and Coastal Defence states that "The risk to development in areas subject to flooding and coastal erosion is set out in the Coastal Defence Strategy. The Coastal Defence Strategy identifies standards of defence and future management".

Policy GEN19: Coast Protection and Sea Defence Works states that "Proposals for coast protection and sea defence works or improvements to existing works will be considered in the light of the following: (i) the recommendations of the shoreline management plan and the coastal defence strategies in respect of the physical maintenance of the coastline and coastal defences; (ii) their impact on the visual character of the open, undeveloped coast and on the appearance and use of the coastline in the built-up areas; and (iii) that the proposed method of coastal defence is technically sound and appropriate to the task". The main aim of the policy is to maintain sea defences and protect the coast where necessary through the use of the best technically, economically and environmentally appropriate solutions.

E.4.4 Arun District Local Plan 2011-2029

The Arun District Local Plan 2011-2031 and supporting documents were submitted on 30 January 2015 for independent examination to the Secretary of State for Communities and Local Government via the Planning Inspectorate.

The Local Plan sets out a vision for the future of Arun up to 2031. It sets the planning framework for the district and will detail planning policy and identify the amount of development proposed and where it should be located. It will be used in the consideration of planning applications. The Plan covers the Arun Local Planning Authority Area (LPA). The LPA is Arun District Council (ADC) administrative area excluding land within the South Downs National Park Authority boundary.

ARUN DISTRICT COUNCIL P/93/15/PL

Particularly pertinent policies in the pre-submission document (ADC, 2014) are now listed.

Policy W DM4 Coastal protection states that "Proposals for coast protection and sea defence works will be permitted if they:

a. Have been considered in light of their impact on the visual character and value of the open, undeveloped coast, protection and enhancement of coastal habitats and the provision of opportunities to complete the coastal footpath and improve the appearance and use of the coastline in the built-up areas.
b. Use methods of coastal defence that are technically sound and appropriate to the task and do not have a detrimental effect on other parts of the coastline; and
c. Are in accordance with the Shoreline Management Plan or Strategy for the particular frontage.

Proposals for development in coastal locations, including for example, sea defence works, will be permitted providing they protect and enhance coastal habitats such as vegetated shingle. Where habitats are lost through the provision of sea defence works, replacement habitats must be provided in a suitable location. Any works under this policy should take account of any local and/or interest features. Developments shall also be consistent with all other Local Plan policies."

Policy TOU SP1 Sustainable tourism and the visitor economy states that "sustainable tourism growth for Arun requires the protection of features that make the District attractive to visitors. Proposals for visitor related development will be determined by Arun's capacity to absorb such growth; for Arun this means tourism growth which:

- Encourages long-term visitor interest / activity;
- Ensures a viable visitor economy;
- Provides benefit to local people;
- Extends the visitor season; and
- Protects and enhances the natural and built environment of Arun."

E.4.5 Pagham to East Head Coastal Defence Strategy

The Pagham to East Head coastal defence strategy looks at ways to manage the risk of flooding and erosion to 5,300 properties on the West Sussex coastline, between Pagham Beach and West Wittering, over the next 100 years. The strategy covers the main population centres around Pagham, Selsey and the Witterings. There are 20,000 permanent residents, and thousands of people visit the area each year, many staying in local caravan parks.

The Environment Agency, Chichester District Council and Arun District Council worked together to produce the strategy. All three organisations approved the final version in 2008 and 2009. The Environment Agency has now begun to implement the recommended options. The recommended management option for Pagham is Adaptive Management[3] and that Pagham Beach and the mouth of

[3] Defined as "Managing complex coastal areas by monitoring changes and acting on them in a planned but flexible way, increasing our understanding over time".

ARUN DISTRICT COUNCIL P/93/15/PL

Pagham Harbour should be viewed as one frontage (Environment Agency, 2009). Given the level of uncertainty in this rapidly changing system, a flexible response is needed that can manage flood and erosion risk, as well as the internationally designated nature conservation site. For this reason Adaptive Management has been recommended for this frontage.

E.4.6 Shoreline Management Plan

Pagham Harbour falls within the Shoreline Management Plan 2 (SMP2) policy unit 4d25. The SMP2 indicates a policy of Managed Realignment at this location given the very dynamic and heavily environmentally designated nature of the area. There is a policy to 'Hold the Line' for Pagham Beach. There has been a change in the policy options for this part of the coast as a result of newer and more detailed Pagham to East Head Coastal Defence Strategy which has adopted a policy of 'Adaptive Management' (see Section E4.7).

E.4.7 Pagham to East Head Coastal Defence Strategy

The Pagham to East Head Coastal Defence Strategy has been produced by the Environment Agency in partnership with Chichester and Arun District Councils. It looks at ways to manage the risk of flooding and erosion to 5,300 properties on the West Sussex coastline, between Pagham Beach and West Wittering, over the next 100 years.

The Strategy area covers the main population centres around Pagham, Selsey and the Witterings. There are 20,000 permanent residents, and thousands of people visit the area each year, many staying in local caravan parks. Land is generally low but many of the area's properties are on higher ground, resulting in the need to manage the risks from both flooding and erosion.

The Strategy area is split into six management frontages. Chichester District Council (CDC) manages four frontages. The Environment Agency manages the Medmerry frontage, with joint responsibility for the Pagham frontage shared with Arun District Council (ADC) and CDC.

The recommended option at Pagham is "Adaptive Management". Urgent work is required to manage erosion at Pagham Beach. An adaptive management plan is to be produced and a management group set up to implement the plan subject to funding availability.

E.4.8 Other Plans

Pagham Parish Council has produces a Neighbourhood Development Plan (Pagham Parish Council, 2014). Such plans set out specific policy proposals for a given parish and involve detailed consultation with statutory stakeholders and the local community. The Neighbourhood Plan is awaiting final approval from ADC, pending some further work on associated assessments. It relates mainly to housing allocation. It sets out a vision of Pagham Parish in 15 years, which is as follows:

"By 2029, the parish of Pagham will have retained its special character by enhancing and protecting its rural context, habitats and open spaces to the west and foreshore to the south for future generations, whilst ensuring its viability as a sustainable rural community.

ARUN DISTRICT COUNCIL P/93/15/PL

The Harbour and other important environmental features of the area will have been protected from development. The investment in creating a major public open space as part of the new housing schemes near the Pagham Road shops has also meant that the Harbour has not been impacted by new development. Importantly too, the design of the new homes has fitted the local character of Pagham.

The new homes have helped meet the need of local people for properties suited to their needs, especially older people wanting to downsize from homes that are too large for their needs. There are also now more homes designed for providing extra care for older people to enable them to continue to live independent lives in the village.

The new homes have helped keep the Pagham Road shops busy as it is easy for residents to walk to them. The shops have also been protected from changes to other uses. As well as busy shops, there are now more local jobs as new business premises have been built to suit local small enterprises.

Crucially, our plans and projects have enabled the village to be better protected from the threats of coastal erosion and flooding than in previous years. The works have helped protect many hundreds of homes and businesses."

With respect to policies and proposals contained within, the following are particularly pertinent:

Policy 8: Tourism Development states that "The Neighbourhood Plan will strongly support proposals to broaden the range of attractions for visitors and residents. Initiatives seeking to increase the number and range of holiday accommodations available across the parish will be encouraged."

Proposal 1: Coastal Protection states that "The Parish Council will support proposals for coast protection and sea defence works, in the area shown on the Proposals Map, to reduce flood risk and to protect against the loss of homes, businesses, tourism attractions and habitats in Pagham, in pursuit of the adopted Pagham to East Head Coastal Defence Strategy 2010, together with its associated DEFRA Strategy Approval Report 2009 and its Decision Framework for Adaptive Management at Pagham Harbour. The detailed design of the works will be to the satisfaction of the regulatory authorities and should ensure that any significant impact on the Designated Nature Sites within the vicinity of the works is avoided."

E.5 References

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ARUN DISTRICT COUNCIL P/93/15/PL

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ARUN DISTRICT COUNCIL P/93/15/PL

Appendix F

Review of Nature Conservation Designations

Managed Breach of Shingle Spit at Pagham Environmental Statement

Volume 2: Appendices

Contents

Page

F. Review of Nature Conservation Designations 3
F.1 Ramsar Sites 3
F.1.1 Pagham Harbour Ramsar Site 3
F.2 Special Protection Areas 3
F.2.1 Pagham Harbour SPA 4
F.3 Special Areas of Conservation 6
F.4 European Sites 6
F.5 European Marine Sites 6
F.6 Sites of Special Scientific Interest 7
F.7 Marine Conservation Zones 9
F.8 National and Local Nature Reserves 10
F.8.1 Pagham Harbour LNR 10
F.9 NERC Habitats and Species of Principle Importance 11
F.9.1 S41 Habitats 11
F.9.2 S41 Species 11
F.10 Regionally Important Geological and Geomorphological Site 11
F.11 Pagham Harbour RIGS 12
F.12 Bognor Foreshore RIGS 12
F.12.1 Selsey East Beach RIGS 13
F.12.2 Bracklesham Bay RIGS 13
F.13 References 14

Tables

F1. Summary of Site Improvement Actions for the Pagham Harbour SPA 5
F2. Summary of SSSIs in the study area 8
F3. Features and conservation objectives for the Pagham Harbour MCZ 10

ARUN DISTRICT COUNCIL P/93/25/PL

F. Review of Nature Conservation Designations

The following sections review the sites of international, national and local designated nature conservation interest within 5km of the proposed breach works. A review of the Natural Environment Research Council (NERC) 'Species and Habitats of Principal Importance' that are relevant to the assessment is also included.

F.1 Ramsar Sites

Under the 1972 Ramsar Convention on Wetlands of International Importance, it is a requirement of signatory states to protect wetland sites of international importance, including those that are important waterfowl habitats. The boundary of the Ramsar site in the study area is included in Figures 8.1 and 8.2 of the main Environmental Statement (ES) document; the proposed development lies within its boundaries.

F.1.1 Pagham Harbour Ramsar Site

The Pagham Harbour Ramsar Site, covering 637ha, was designated in March 1988. The site comprises an estuarine harbour with shingle beaches, intertidal mudflats and saltmarsh, giving way to brackish marsh supporting reedbeds and damp pasture. The site includes a nationally important vegetation community and small amounts of ancient woodland. Nationally and internationally important numbers of wintering or breeding waterbirds or waders use the site.

Pagham Harbour was designated a Ramsar site by meeting the following qualifying criterion:

- Criterion 6: It is used regularly by species/populations occurring at levels of international importance. Qualifying species/populations that have peak counts in winter are Dark-bellied Brent Goose, Branta bernicla bernicla (as identified at designation) and Black-tailed Godwit, Limosa limosa islandica (as identified subsequent to designation).

F.2 Special Protection Areas

The EC Birds Directive (79/409/EEC) requires all Member States to identify areas to be given special protection for the rare or vulnerable waterbird species listed in Annex 1 (Article 4.1) and for regularly occurring migratory species (Article 4.2) and for the protection of wetlands, especially wetlands of international importance. The boundary of the Special Protection Area (SPA) in the study area is included in Figures 8.1 and 8.2 of the main ES document; the proposed development lies within its boundaries.

ARUN DISTRICT COUNCIL P/93/25/PL

F.2.1 Pagham Harbour SPA

The Pagham Harbour SPA, covering 636.68ha, was designated in March 1988. The SPA comprises 39% tidal rivers, estuaries, mudflats, sandflats and lagoons (including saltwork basins), 30% improved grassland, 20% shingle, sea cliffs and islets, 5.2% saltmarshes, salt pastures and salt steppes, 3% bog, marsh, water fringed vegetation and fens, 1% inland water bodies (standing water, running water), 0.7% broad-leaved deciduous woodland, and 0.6% marine areas and sea inlets.

The Pagham Harbour SPA qualifies under the EC Birds Directive (79/409/EEC) given that it achieves the following:

- Article 4.1 – regularly supports an internationally-important population of breeding Annex I species, comprising, during the breeding season: Little Tern Sterna albifrons and Common Tern S. hirundo; and overwintering: Ruff Philomachus pugnax.
- Article 4.2 – supports an internationally-important population of the following migratory, overwintering species: Dark-bellied Brent Goose, Branta bernicla bernicla.

A Site Improvement Plan (SIP) has been published for the SPA (Natural England, 2014); this provides a high level overview of the issues (both current and predicted) affecting the condition of the SPA features on the site and outlines the priority measures required to improve the condition of the features. It does not cover issues where remedial actions are already in place or ongoing management activities which are required for maintenance.

The issues and actions outlined in the SIP are shown in Table F1 below. For all the issues, all the bird features of the SPA are understood to be (potentially) affected. The Church Norton Spit changes are listed as the highest priority issue, ahead of bird disturbance at the Spit.

ARUN DISTRICT COUNCIL P/93/15/PL

Table F1. Summary of Site Improvement Actions for the Pagham Harbour SPA

Priority & Issue	Explanation	Measure(for Natural England)	Action	Delivery bodies
1 Physical modification (pressure and threat)	Church Norton Spit is accreting from the west; it has been extending due to a pulse of sediment. This is also causing changes to the location and size of the harbour mouth and has led to risk of coastal erosion. Changes to the shingle spit may also lead to a natural closure of the channel, leading to changes in the wetland areas behind the spits. This could affect the breeding, roosting and feeding habitats of many of the bird species currently using the intertidal areas. It is not clear if, to what extent, or how quickly this would happen. The issue is the subject of ongoing discussion with the EA and others regarding flood risk and coastal erosion issues.	Continue advice under Habitats Regulations in association with ongoing monitoring.	Monitor topographical and sedimentary changes to inform shingle management for coastal protection (2014 onwards).	Arun District Council (lead), Environment Agency
2 Public Access/Disturbance (pressure and threat)	The site has open access over the shingle beach areas, which includes along with other species, Little tern nesting sites and Brent geese feeding and roosting areas. The public footpath and open access areas are regularly used by walkers, bird watchers, dog walkers, anglers and kite surfers. The tern nesting area is fenced off during breeding season but many birds are disturbed by dogs being walked off leads. At Sidlesham Quay people are able to launch into the harbour (…), often causing trampling of the saltmarsh and other habitats. The bylaws and best practice protocols are not always adhered to (…).	The RSPB are to continue to manage the area using Local Nature Reserve (LNR) bylaws	RSPB to manage visitor numbers and direct disturbance to birds and habitat (2014 onwards). Pagham has an EU Life+ funded seasonal 'People Engagement Officer – Breeding Seabirds' post until 2018. RSPB to post the boating code of conduct on the Quay.	RSPB
3 Water Pollution (threat)	The Pagham Lagoon and Harbour both receive freshwater from agricultural land drainage through rife systems. Pagham lagoon in particular is vulnerable to freshwater ingress as it has limited saline input and also receives surface water via road drains, and other drains and overflows (…). Given the potential closure of the harbour by the shingle spit (priority 1), water pollution could become an issue over the long term for the inner harbour.	The lagoon will undergo detailed surveys and ongoing monitoring.	Pagham lagoon to undergo ecological surveys and monitoring (2014 onwards). An infiltration study has been commissioned to understand the cause of sewer flooding and surface water and sewage system and will focus on how polluted water enters Pagham Lagoon. (…)	West Sussex County Council (lead), ADC, Environment Agency, RSPB, Southern Water, Landowner(s)
4 Fisheries: Commercial marine and estuarine (threat)	Commercial fishing activities categorised as 'amber or green' in EMSs require assessment and (where appropriate) management. This assessment will be undertaken by Sussex IFCA. Set netting, hand gathering of shellfish, and bait digging are the main activities occurring in the site.	Introduce appropriate management measures where required, and ensure compliance.	Where assessments indicate management is required, appropriate measures will be introduced by the Regulator by 2016 (…).	Sussex Inshore Fisheries Conservation Authority (IFCA) (lead), Natural England
5 Fisheries: Recreational marine and estuarine (threat)	Bait digging and angling occur within the harbour. They were previously managed through a West Sussex County Council permitting scheme, which limited how much the activity could occur within the site, but this is no longer the case. There is currently no mechanism to restrict this activity in a relatively 'pristine' site.			
6 Change in land management (threat)	Some areas of land under agricultural use within the wet grassland are currently outside the management control of the RSPB or an environmental scheme(i.e. they are not within Environmental Stewardship or other formal management). NE is looking to target landowners to get the land into appropriate management either through the RSPB scheme or separately.	Get land into appropriate management.	Start the process of getting private land into appropriate management through ongoing advice or management scheme (2015-2016).	Natural England (lead); landowners (where applicable)

ARUN DISTRICT COUNCIL P/93/15/PL

F.3 Special Areas of Conservation

The EC Habitats Directive (92/43/EEC) requires the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended).

There are no Special Areas of Conservation (SACs) within the study area.

F.4 European Sites

The requirements of the EC Habitats Directive (92/43/EEC) have been transposed into UK legislation for England and Wales through the Conservation of Habitats and Species Regulations 2010 (SI 2010/490), which consolidates all the various amendments made to the Conservation (Natural Habitats &c.) Regulations 1994. SACs and SPAs are defined as European sites in the Habitats Regulations. The only European site in the study area is Pagham Harbour SPA (see Section F.2).

In addition, Paragraph 118 of the National Planning Policy Framework requires that potential SPAs, possible SACs, listed or proposed Ramsar sites, and any site identified as being necessary to compensate for adverse impacts on classified, potential or possible SPAs, SACs and Ramsar sites be treated in the same way as classified sites. On this basis, the proposed project overlaps with Pagham Harbour Ramsar site (Section F.1) and is located approximately 4km from the Medmerry Managed Realignment compensatory site (see Figure 8.1 of the main Environmental Statement).

F.5 European Marine Sites

Where the European site lies below the highest astronomical tide, i.e. covered continuously or intermittently by tidal waters, or any part of the sea, in or adjacent to Great Britain, up to the seaward limit of territorial waters, it is described as a European Marine Site (EMS).

The Pagham Harbour SPA is the only EMS located in the study area; this site has been reviewed above, and its extent is shown in Figures 8.1 and 8.2 of the main ES document.

Natural England has statutory responsibility to advise relevant authorities as to the Conservation Objectives for EMS and operations, which may cause deterioration or disturbance of natural habitats and species. This advice is provided under Regulation 35 of the Conservation of Habitats and Species Regulations 2010 (referred to as the Habitats Regulations thereafter).

The conservation objectives of the SPA are to 'subject to natural change; ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring' (Natural England, 2014):

ARUN DISTRICT COUNCIL P/93/15/PL

- The extent and distribution of the habitats of the qualifying features,
- The structure and function of the habitats of the qualifying features,
- The supporting processes on which the habitats of the qualifying features rely,
- The population of each of the qualifying features, and,
- The distribution of the qualifying features within the site.

The objectives for the supporting habitats, as outlined in the Regulation 33 Advice (English Nature, 2001) (now Regulation 35), are to 'subject to natural change, maintain the following in favourable condition':

- Mudflat and sandflat communities;
- Shallow water over intertidal areas (with permanent water channels);
- Saltmarsh; and
- Shingle for roosting.

F.6 Sites of Special Scientific Interest

At a national level, Sites of Special Scientific Interest (SSSI) are notified by the nature conservation agencies, such as Natural England, under the Wildlife and Countryside Act 1981. Under the Act, the conservation agencies are required 'to notify land which in their opinion is of special interest for its plants, animals, geological or physiographical features'. The Countryside and Rights of Way Act 2000 has strengthened the protection of SSSIs.

The area of the proposed works lies within the boundaries of the Pagham Harbour SSSI; three further SSSIs are within the study area (i.e. the 5km buffer). These SSSIs are shown in Figures 8.1 and 8.2 of the main ES document and summarised in Table F2.

ARUN DISTRICT COUNCIL P/93/25/PL

Table F2. Summary of SSSIs in the study area

SSSI (and distance to proposed works)	Date Notified	Area (Ha)	Key Interests	Condition of Units
Pagham Harbour (0km)	1954 (Under 1949 Act) 1986 (Under 1981 Act)	616	This site comprises an extensive central area of salt-marsh and tidal mudflats with surrounding habitats including shingle, open water, reed swamp and wet permanent grassland. Pagham Harbour is of national importance for wintering wildfowl and waders and also for breeding birds both within the Harbour and the surrounding grazing pasture. Over 120 species of bird overwinter here. The numbers of wintering pintail, ringed and grey plover and black-tailed godwit regularly reach 1% of British populations and the site is of international importance for wintering ruff and Brent Geese. The mudflats also provide food for a diverse breeding community of birds including oystercatcher, shelduck and redshank. The site supports nationally important communities of plants and invertebrates. It is also a key site for coastal geomorphology - both as a classic shingle spit landform and for the links that have been demonstrated between the coastal near shore and offshore forms and sediments. The shingle spit system comprises a series of sub-parallel ridges and recurves, marking different phases of extension and frontal accretion. This site also includes, at the north-eastern end, part of a key site for plant fossils from the London Clay. It is the only locality in the Hampshire Basin to yield abundant London Clay plants and the only site known to have yielded plants from the B2 division of this formation. The site has yielded examples of some 130 species (representing seventy families). An outstanding palaeobotanical site of great importance to studies of Tertiary floras.	17 Favourable, 5 Unfavourable recovering, 1 Unfavourable no change.
Bognor Reef (1.4km (as crow flies))	1980 (Under 1949 Act) 1988 (Under 1981 Act)	64	This site comprises a long stretch of foreshore of great geological interest and an extensive area of vegetated shingle, a habitat type which is rare in Britain. At the western end is a small area of old sand dune with an interesting flora.	1 Favourable, 1 Unfavourable recovering, 1 Unfavourable declining.
Selsey East Beach (3.8km (as crow flies))	1988 (Under 1981 Act)	1.8	Together with the Bracklesham Bay SSSI, this site forms a key Quaternary site for a sequence of freshwater and estuarine deposits of the Ipswichian Interglacial age. Raised beach deposits overlying the estuarine sediments extend up to 7m OD.	1 Favourable.

ARUN DISTRICT COUNCIL P/93/25/PL

SSSI (and distance to proposed works)	Date Notified	Area (Ha)	Key Interests	Condition of Units
Bracklesham Bay (4.6km (as crow flies))	1980 (Under 1949 Act) 1986 (Under 1981 Act)	202	Original citation: This site consists of a long stretch of coast with some rough unimproved grazing pastures which are important for the bird populations they support. The coastal habitats include a small area of salt marsh, shingle bank, the rifes (wide flowing ditches) and associated reed beds, together with a long stretch of intertidal exposures of high geological interest. Please note that this SSSI is now fully incorporated into the Medmerry Managed realignment site, which was breached in 2013. Thus, all non-coastal habitats listed above are now coastal / intertidal.	1 Favourable, 3 Unfavourable recovering.

F.7 Marine Conservation Zones

The UK has signed up to international agreements that aim to establish an 'ecologically coherent network of Marine Protected Areas (MPAs)' by 2012. This network will be made up of current MPAs as well as a new type of MPA called a Marine Conservation Zone (MCZ). The development of MCZs within the study area was coordinated by the Balanced Seas Project (www.balancedseas.org/). Ecological Network Guidance (ENG) was used to identify potential MCZs and ensure that the network would be ecologically coherent (JNCC and Natural England, 2010). The ENG identifies broad-scale habitats and Features of Conservation Importance (FOCI) which need to be protected through the network.

In 2011, a number of recommended MCZs (rMCZs) and recommended Reference Areas (rRAs) were identified by the Balanced Seas project (Balanced Seas, 2011). The first tranche of MCZs were designated in 2013. One of these, 'Pagham Harbour', falls within the study area (see Figure 8.2 of the main ES); the proposed breach would be within this MCZ, and the infill area immediately adjacent. Another MCZ initially put forward by Balanced Seas, 'Selsey Bill and the Hounds', is located in the study area (though its boundary is at least 4.4km distant from the proposed works). However, this proposed MCZ is currently on hold as Defra has indicated that there is not enough evidence to support designation (Wildlife Trusts, 2015), and it has not been included in the list of MCZs recently put forward for the second tranche of MCZs (for which Defra opened the consultation in January 2015 (see Defra, 2015)). Therefore, this MCZ has been screened out of the assessment.

The 'Pagham Harbour' MCZ has been screened into the assessment and its interest features and conservation objectives are outlined below. Please note that formal conservation advice has yet to be published for this MCZ. Thus, the features and general management approach that were listed in the 2013 Defra factsheet (Defra, 2013) are shown in Table F3 below.

ARUN DISTRICT COUNCIL P/93/15/PL

Table F3. Features and conservation objectives for the Pagham Harbour MCZ

Feature Name	General management approach
Seagrass beds	Maintain in favourable condition
Defolin's lagoon snail (Caecum armoricum)	Maintain in favourable condition
Lagoon sand shrimp (Gammarus insensibilis)	Maintain in favourable condition

The Designation Order for the MCZ (Her Majesty's Stationery Office, 2013) notes that the conservation objective of the MCZ is

'that the protected features:

(a) so far as already in favourable condition, remain in such condition; and
(b) so far as not already in favourable condition, be brought into such condition, and remain in such condition.'

F.8 National and Local Nature Reserves

National Nature Reserves (NNRs) are declared by the statutory country conservation agencies under the National Parks and Access to the Countryside Act 1949 and the Wildlife and Countryside Act 1981. Local Nature Reserves (LNRs) may be declared by local authorities, under the National Parks and Access to the Countryside Act 1949, after consultation with the relevant statutory nature conservation agencies.

Local designations contain examples of some of the most important natural and semi-natural terrestrial and coastal ecosystems in Great Britain. Both NNRs and LNRs are managed for nature conservation, and to provide opportunities for scientific study and education.

There are no NNRs within the study area. The only LNR within the study area is the Pagham Harbour LNR, which the works would be located within. This is described below.

F.8.1 Pagham Harbour LNR

Pagham Harbour LNR mostly overlaps with the SSSI, though it is slightly smaller. It was declared an LNR in 1964. The main habitats include intertidal mudflats, saltmarsh, saline lagoons and vegetated shingle. Up to 10,000 waders and wildfowl winter in the harbour with Brent geese, pintail and black-tailed godwit present in national/international numbers. Spring and autumn bird migrations include osprey, marsh harrier, honey buzzard, hobby and Montagu's harrier. Passerines include redstart, wheatear, whinchat, ring ousel, pied flycatcher and occasional red backed shrike. Waders include curlew, sandpiper, little stint, wood sandpiper and little ringed plover with more unusual birds such as yellow browed warbler, Pallas's warbler and wryneck. Other wildlife includes purple hairstreak butterfly, Childling pink, water voles and numerous species of dragonflies (Natural England, 2015).

ARUN DISTRICT COUNCIL P/93/25/PL

F.9 NERC Habitats and Species of Principle Importance

The NERC Act makes provision about bodies concerned with natural environment and rural communities, and it regulates inter alia nature conservation in the UK, wildlife and SSSIs. Section 40 of the NERC Act 2006 places a general duty on all public authorities, including local planning authorities, to conserve and enhance biodiversity. A list of 'Species and Habitats of Principal Importance' in England has been published under S41 of the NERC Act. The S41 list contains 943 species and 56 habitats of principal importance which occur in England. These are the species and habitats which were identified as requiring action under the UK BAP and which continue to be regarded as conservation priorities under the UK Post-2010 Biodiversity Framework. These species and habitats do not receive statutory protection, but are protected by planning policy. S41 habitats and species that are known to occur in the study area and have the potential to be affected by the proposed project (i.e. have connectivity with the effects of the project) are included below.

F.9.1 S41 Habitats

- Coastal Vegetated Shingle;
- Coastal Saltmarsh;
- Intertidal Mudflats;
- Maritime cliffs and slopes;
- Saline Lagoons; and
- Seagrass beds.

F.9.2 S41 Species

- Dark-bellied Brent Goose,
- Black-tailed Godwit,
- Curlew; and
- Water vole.

F.10 Regionally Important Geological and Geomorphological Site

Regionally Important Geological and Geomorphological Sites (RIGS), designated by locally developed criteria, are a non-statutory designation, which is viewed as a way of recognising and thereby protecting important Earth science and landscape features for the future.

There are four RIGS sites in the study area: Pagham Harbour and Bognor Foreshore, Selsey East Beach and Bracklesham Bay. All of these are concurrent with SSSI units, and, to a large extent, essentially duplicate the geological and / or geomorphological designation features of these SSSIs. The designation criteria, and their overlap with SSSI units are detailed below.

ARUN DISTRICT COUNCIL P/93/25/PL

F.11 Pagham Harbour RIGS

The area covered by Pagham Harbour RIGS corresponds to the following SSSI units of 'Pagham Harbour' SSSI designation: Units 14, 15, 16 and 24 (shingle spits and beach).

The RIGS Designation Criteria for Pagham Harbour can be summarised as follows:

- Stratigraphy: the area is underlain by Tertiary deposits of London Clay but these deposits are obscured by the mud flats, shingle beds and other beach deposits.
- Sedimentology: the visible sediments in and around the Harbour consist of shingle beds and mud.
- Palaeontology: the London Clay beneath the beach at Pagham is part of an outstanding palaeobotanical site of great importance to studies of Tertiary floras.
- Geomorphology: Pagham Harbour is a key site for coastal geomorphology. It is significant as a classic shingle spit landform and for the links that have been demonstrated between the coastal nearshore and offshore forms and sediments.
- Historical: Support for the baymouth bar theory comes from the history of the spits. To counteract erosion a complete shingle ridge was built across the harbour entrance in 1876, but this was breached in a storm in 1910, reverting to its double spit state.
- Biological interest: Pagham Harbour is of national importance for wintering wildfowl and waders and also for breeding birds both within the harbour and the surrounding grazing pasture. The site also supports nationally important communities of plants and invertebrates.
- Educational value: This is an outstanding palaeobotanical site of great importance to studies of Tertiary floras. It is a key site for coastal geomorphology and significant for its classic shingle spit formation. It is also of great biological importance especially for birds.

F.12 Bognor Foreshore RIGS

The area for this RIGS corresponds to the following SSSI units of 'Bognor Reef' SSSI designation: Unit 2 (supralittoral sediment), and Unit 3 (rock exposures).

The RIGS Designation Criteria for Bognor Foreshore can be summarised as follows:

- Stratigraphy: potentially, the whole of the thickness of the London Clay Formation is available on the foreshore from the pier to Pagham, but this is subject to infrequent favourable tides.
- Sedimentology: most of the sediments are clays or sands, with two sequences of more resistant rock.
- Palaeontology: this site is extremely important for its Tertiary flora and fauna.
- Educational value: this site is of national and international importance for its insect, bird and plant fossils. It is one of the few areas where a good section of London Clay can be seen (subject to tides). The site is very good for collecting mollusc fossils.

ARUN DISTRICT COUNCIL P/93/25/PL

F.12.1 Selsey East Beach RIGS

The area covering Selsey East Beach RIGS corresponds to all of the Selsey East Beach SSSI units.

The RIGS Designation Criteria can be summarised as follows:

- Stratigraphy: the deposits on the beach at Selsey are of Quaternary age, consisting of freshwater and estuarine deposits of the Ipswichian Interglacial.
- Sedimentology: the deposits are mainly silty clays and muds, with some erratics.
- Sedimentary structures: this site includes a Pleistocene channel.
- Palaeontology: the channel fill has yielded pollen, molluscs (Corbicula fluminalis), plant macrofossils and vertebrates as well as flint artefacts.
- Educational value: this site is important for the sequence of freshwater and estuarine deposits of Ipswichian Interglacial age.

F.12.2 Bracklesham Bay RIGS

The area covered by Bracklesham Bay RIGS corresponds to the foreshore SSSI units of the Bracklesham Bay SSSI.

The RIGS Designation Criteria can be summarised as follows:

- Stratigraphy: the geological exposures on the beach between West Wittering and Selsey consist of a complex series of Eocene (Cenozoic) age beds with some overlying Pleistocene (Quaternary) deposits.
- Sedimentology: the Cenozoic beach sediments are predominantly silts and silty sands. At Earnley there is a Quaternary site with raised beach deposits offering a sequence of marine deposits of middle Pleistocene interglacial age providing a unique record of sea level changes. Selsey West Beach is a key Quaternary site for a sequence of freshwater and estuarine deposits of Ipswichian interglacial age.
- Palaeontology: The Cenozoic beds are highly fossiliferous and yield a high diversity marine fauna. Some beds contain a brackish-water fauna.
- Historical background: Bracklesham has been an historically important fossil site since about 1850.
- Educational value: The site is critically important for European Cenozoic palaeobotany and coastal palaeoecology. There is considerable future research potential as it is the only site where marginal sandy facies of the Eocene sea can be seen and is of great importance for its fish fossils and in stratigraphical studies. The Quaternary deposits provide a unique record of sea level changes and abundant data for palaeoclimatic studies.

ARUN DISTRICT COUNCIL P/93/25/PL

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ARUN DISTRICT COUNCIL P/93/15/PL

Appendix G

Marine Conservation Zone Assessment

ARUN DISTRICT COUNCIL P/94/21/PL

Managed Breach of Shingle Spit at Pagham Environmental Statement

Volume 2: Appendices

Contents

Page

G. Marine Conservation Zone Assessment 3
G.1 Introduction 3
G.2 MCZ Assessment Guidance 3
G.3 Proposed Project 5
G.4 Baseline 5
G.4.1 Data Sources 5
G.4.2 Interest Features and Conservation Objectives 6
G.4.3 Screening 6
G.4.4 Baseline Description 7
G.4.4.1 Seagrass Beds 7
G.4.4.2 DeFolin's Lagoon Snail 7
G.5 Stage 1 MCZ Assessment 7
G.5.1 Effects of the Loss of, and Change to, Habitat for DeFolin's Lagoon Snail Within the Development Footprint 8
G.5.2 Temporary Effects on Habitats within Pagham Harbour from Changes to the Tidal Environment during the Shingle Excavation and Translocation Work 8
G.5.2.1 Changes in Water Levels 9
G.5.2.2 Changes in Suspended Sediment Concentrations 9
G.5.3 Operational Effects on Habitats and Species within Pagham Harbour from Changes to the Tidal Environment 9
G.5.3.1 Changes in Water Levels 9
G.5.3.2 Changes in Flow Speeds and Sedimentation Regime 10
G.5.3.3 Creation of a Temporary Saline Lagoon Feature 11
G.6 Summary 11
G.7 References 11

Tables

G1. Pagham Harbour MCZ interest features and Conservation Objectives 6
G2. Pagham Harbour MCZ interest features and scoping view 6

Images

G1. MCZ assessment framework 4

ARUN DISTRICT COUNCIL P/93/25/PL

G. Marine Conservation Zone Assessment

G.1 Introduction

The UK has signed up to international agreements that aim to establish an 'ecologically coherent network of Marine Protected Areas (MPAs)' by the end of 2012. This network is made up of current MPAs as well as the new type of MPA called a Marine Conservation Zone (MCZ).

The proposed project falls within the south east region, where the development of recommendations for MCZ was coordinated by the Balanced Seas Project (Balanced Seas, 2011). Ecological Network Guidance (ENG) was used to identify potential MCZs and ensure that the network would be ecologically coherent (JNCC and Natural England, 2010). The ENG identifies broad-scale habitats and Features of Conservation Importance (FOCI) which need to be protected through the network.

In 2011, a number of recommended MCZs (rMCZs) and recommended Reference Areas (rRAs) were identified by the Balanced Seas project (Balanced Seas, 2011). The first tranche of 27 new MCZs were designated in 2013. One of these, Pagham Harbour MCZ, falls within the study area for the proposed project (see Figure 8.4 of the main Environmental Statement (ES)). This designated MCZ overlaps with the proposed breach and is located adjacent to the channel that is proposed to be infilled with excavated material from the breach (see Figure 2.2 of the main of the main ES).

In January 2015, Defra opened consultation on a second tranche of MCZs with the aim of designating sites in 2016 (Defra, 2015). For the second tranche, 23 sites from the Regional MCZ Project recommendations have been identified as suitable for consideration (proposed MCZs (pMCZs)), none of which occur within 5km of the study area.

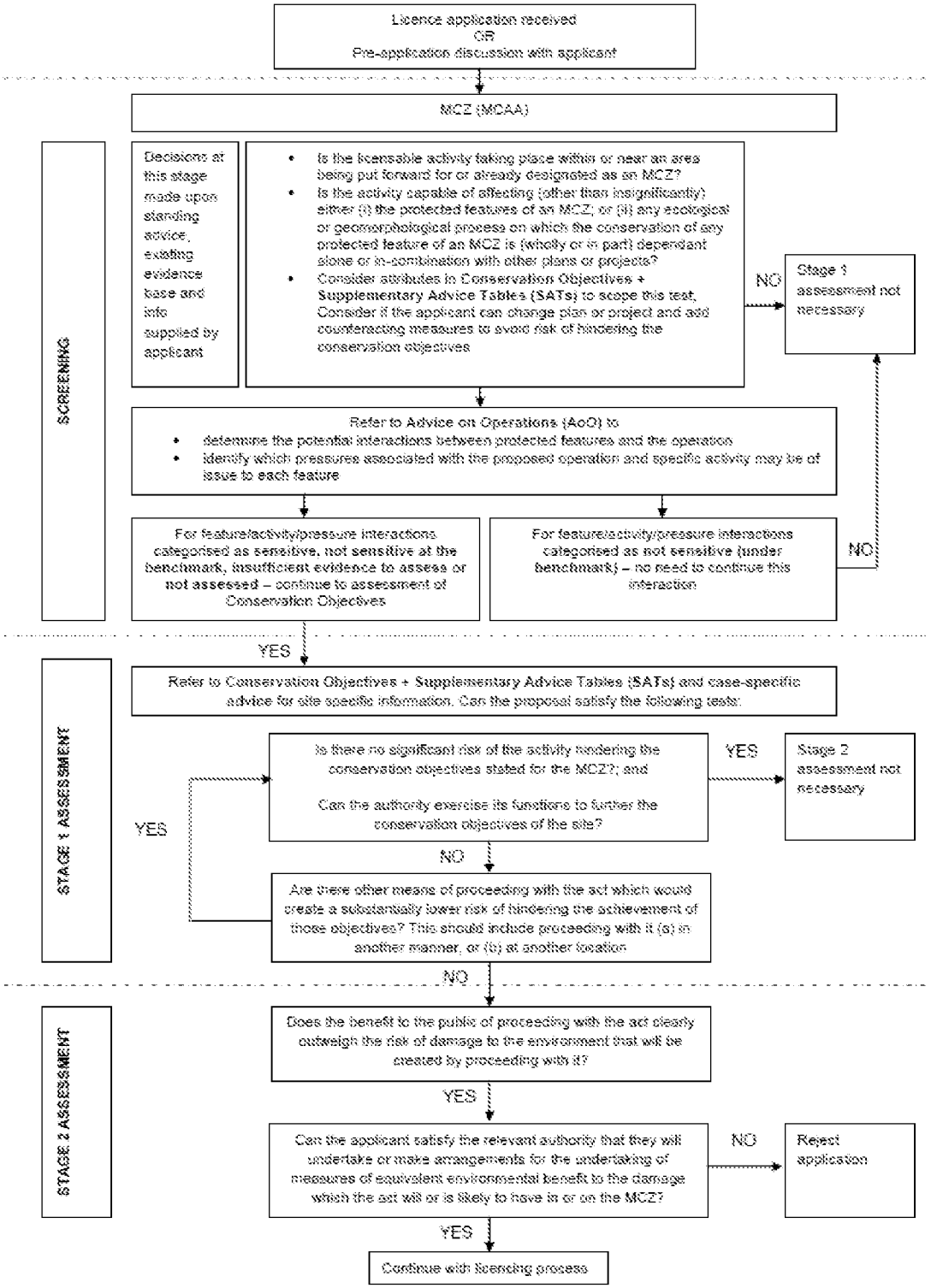
An rMCZ initially put forward by Balanced Seas, 'Selsey Bill and the Hounds', is located more than 4km from the proposed works. However, this rMCZ is currently on hold as Defra has indicated that there is not enough evidence to support designation (Wildlife Trusts, 2015). It has not been included in the list of pMCZs put forward for the second tranche of MCZs. Therefore, this rMCZ has been scoped out of the assessment.

As the proposed project is directly located within Pagham Harbour MCZ, there is potential for it to directly or indirectly affect MCZ interest features. Under Section 126 of the Marine and Coastal Act 2009 an assessment is required to determine the significance of impacts to the MCZ features and whether there is any significant risk of the proposed project hindering the Conservation Objectives of the MCZ. This appendix aims to provide such an assessment by summarising and cross referencing to the relevant sections of the main ES, and providing further supplementary data and interpretation as necessary.

G.2 MCZ Assessment Guidance

The Marine Management Organisation (MMO) and Natural England have produced general guidance for undertaking an MCZ assessment (MMO, 2013; Natural England, 2015). A framework illustrating the MCZ assessment process is shown in Image G1.

ARUN DISTRICT COUNCIL P/93/15/PL



(Natural England, 2015)

Image G1. MCZ assessment framework

ARUN DISTRICT COUNCIL P/93/25/PL

In the first instance, screening is undertaken to identify the potential for a licensable activity to have an effect (other than insignificantly) on MCZ interest features alone or in-combination with other plans and projects. A Stage 1 assessment is then undertaken to determine whether there is a significant risk that the activity will hinder the Conservation Objectives of the screened in MCZ interest features. If avoidance of this risk is not possible and there are no other means of continuing with the works which would cause less of an environmental impact, then a Stage 2 assessment is necessary. This appendix presents the results and conclusions of the screening (Section 4.3) and Stage 1 MCZ assessment (Section 5) for the proposed project.

Natural England is in the process of producing marine conservation advice packages[1] and supporting documents to help with individual site MCZ assessments and the impact of marine activity in sensitive areas. However, at the time of writing this MCZ Assessment, an individual conservation advice package for Pagham Harbour was not yet available.

G.3 Proposed Project

As described in detail in Sections 1 to 3 of the main ES, the proposed project is an 'adaptive management' measure with the intention of adjusting the morphology of the environment in as natural a manner as possible and then to allow the environment to naturally readjust.

The current morphology of the spit is resulting in immediate coastal erosion and flood risk to residential properties at Pagham Beach Estate. It is also posing a growing erosion threat to the remainder of the beach which is in a deteriorating condition and has reduced in amenity and recreational value. The proposed project will create a sustainable flood and coastal erosion risk management scheme for Pagham Beach and also improve its amenity and recreational value.

A review of the alternative options for the area concluded that the most appropriate long-term solution is to create a managed breach through the spit feature and infilling the adjacent channel. The breach is proposed to be located directly in front of Pagham Harbour where it was previously located throughout the latter half of the 20th Century (Figure 2.2 of the main ES). The current channel will be infilled and the new breach will allow for the water to flow in and out of the harbour. Natural processes will take over and no ongoing management of the site (e.g. maintaining the breach position) is proposed, apart from one breach intervention in the unlikely event that the breach should close.

G.4 Baseline

G.4.1 Data Sources

A range of data sources have been used to underpin the MCZ assessment and characterise the distribution and status of MCZ interest features, including the following:

[1] https://www.gov.uk/government/collections/conservation-advice-packages-for-marine-protected-areas

ARUN DISTRICT COUNCIL P/93/25/PL

- Natural England's advice to Defra (Natural England, 2013);
- Pagham Harbour MCZ factsheet (Defra, 2013);
- Environment Agency seagrass survey data, 2014;
- Seagrass survey data, 2005 (Balanced Seas, 2011); and
- Surveys for Caecum armoricum in Pagham Harbour, 2007 and 2013 (Pain et al., 2009; Wilkinson and Baldock, 2013).

G.4.2 Interest Features and Conservation Objectives

Formal conservation advice has yet to be published for this MCZ and therefore the interest features and conservation objectives proposed for this site have been taken from the 2013 Defra factsheet (Defra, 2013). These are included in Table G1. The existing records of interest features from Pagham Harbour MCZ are shown on Figure 8.4 of the main ES.

Table G1. Pagham Harbour MCZ interest features and Conservation Objectives

Interest Feature	Conservation Objectives
Seagrass beds	Maintain in Favourable Condition
DeFolin's lagoon snail (Caecum armoricum)	Maintain in Favourable Condition
Lagoon sand shrimp (Gammarus insensibilis)	Maintain in Favourable Condition

(Source: Defra, 2013)

The Designation Order for the MCZ (Her Majesty's Stationery Office, 2013) notes that the conservation objective of the MCZ is:

'that the protected features:

(a) so far as already in favourable condition, remain in such condition; and
(b) so far as not already in favourable condition, be brought into such condition, and remain in such condition.'

G.4.3 Screening

Table G2 presents the qualifying features of Pagham Harbour MCZ and provides a brief rationale for screening them in or out of the assessment.

Table G2. Pagham Harbour MCZ interest features and scoping view

Interest Features	Screening Opinion
Seagrass beds	Screened into the assessment on the basis that it is a marine feature that has hydrodynamic (indirect) connectivity with the proposed project.
DeFolin's lagoon snail (Caecum armoricum)	Screened into the assessment on the basis that it is a marine feature that potentially has physical (direct) and hydrodynamic (indirect) connectivity with the proposed project.
Lagoon sand shrimp (Gammarus insensibilis)	This species is only found in (Sidlesham) Ferry Pool lagoon which is a lagoon adjacent to the Pagham Harbour water body. Water levels in the lagoon are controlled by the RSPB via an inlet sluice from the harbour and a dropboard outlet sluice from the Pool (RSPB, 2013). This feature has therefore been screened out of the assessment on the basis that there is no hydrodynamic connectivity and will therefore not be affected by the proposed project.

ARUN DISTRICT COUNCIL P/93/15/PL

G.4.4 Baseline Description

G.4.4.1 Seagrass Beds

A detailed baseline description of seagrass beds in Pagham Harbour is provided in Section 8.1.3 of the main ES.

Based on 2014 spatial survey data obtained from the Environment Agency, there is currently one area of seagrass in Pagham Harbour which covers around 3.4ha (Figure 8.4 of the main ES). This seagrass bed occurs to the southwest of the harbour in the intertidal zone between 0.8 and 1.3mODN, which corresponds to mid to higher mudflat elevations. The two species of seagrass that have been recorded are Zostera Noltii and Z. angustifolia (Sussex Biodiversity Partnership, 2004).

G.4.4.2 DeFolin's Lagoon Snail

A detailed baseline description of DeFolin's lagoon snail in Pagham Harbour is provided in Section 8.1.4 of the main ES.

In 2007, both live and dead C. armoricum specimens were found during a survey undertaken on Church Norton Spit. The location of these specimens were on the landward side of the spit, just below the High Water Spring line, in habitat described as 'small pebbles with patches of organic detritus just below the surface layer'.

In March 2013, a dedicated DeFolin's lagoon snail survey was undertaken at Church Norton Spit and Little Lagoon on behalf of Natural England. Only four dead shells and several shell fragments were recorded from Church Norton Spit; including at the site where the 2007 finds took place. The presence of entire dead shells, as well as shell fragments, suggests that there is an extant population in close vicinity to the sampling sites. At Little Lagoon, 16 live DeFolin's lagoon snails were found at mid-shore level, with recently dead shells at other locations. The finds demonstrated that this species occupies a very restricted intertidal zone on the lagoon shore (Wilkinson and Baldock, 2013).

The locations of finds from samples taken on both the 2007 and 2013 surveys are shown on Figure 8.5 of the main ES.

G.5 Stage 1 MCZ Assessment

The proposed breach area lies within the boundary of the Pagham Harbour MCZ and the infill channel lies adjacent to it (Figures 2.2 and 8.4 of the main ES). Therefore impacts on interest features could be via both direct and indirect pathways, the latter as a consequence of the effect of the proposed works on the hydrodynamic and sedimentary regime.

As identified in Section 8.2 of the main ES, the key impact pathways in relation to MCZ features are as follows:

ARUN DISTRICT COUNCIL P/93/25/PL

- Effects of the Loss of, and Change to, Habitat for DeFolin's Lagoon Snail Within the Development Footprint (Section 5.1);
- Temporary Effects on Habitats and Species within Pagham Harbour from Changes to the Tidal Environment during the Shingle Excavation and Translocation Work (Section 5.2); and
- Operational Effects on Habitats and Species within Pagham Harbour from Changes to the Tidal Environment (Section 5.3).

The following sections provide a summary of the outcomes of the assessment of impacts on each of the above impact pathways. A more detailed assessment which includes the potential impacts on other designated habitats and protected species is provided in the main ES.

G.5.1 Effects of the Loss of, and Change to, Habitat for DeFolin's Lagoon Snail Within the Development Footprint

A detailed review of the DeFolin's lagoon snail ecology is provided in Appendix J and summarised in Section 8.2.3 of the main ES.

Surveys undertaken in 2007 and 2013 suggest that sheltered saline water bodies, for example lagoons such as the Fleet or the Little Lagoon on Pagham Spit provide optimal habitat. It is therefore thought that should live DeFolin's lagoon snails be present on the Spit, this would be towards the more sheltered landward sections of the Church Norton Spit, away from the proposed breach area. It is thought that because of this and the fact that the landward area of the shingle spit affected by these works is subject to high flow rates which are not favoured by the snail, that the breaching and infill works would not directly affect the DeFolin's lagoon snail habitat.

During construction, some daily pedestrian access may be required from Church Norton or via East Beach (see Section 3.2 of main ES). Alternative emergency access will also be from East Beach. However, no plant access is planned to take place from the western side of Pagham Harbour. Both the staff and emergency access routes will remain on top of and on the seaward side of the shingle ridge and therefore will not overlap with the DeFolin's lagoon snail habitat.

Given the above considerations, there is anticipated to be a small magnitude of change to the morphology of the shingle habitat and a low probability of an effect on DeFolin's lagoon snail (i.e. no significant overlap with the preferred DeFolin's habitat is anticipated). The exposure to change is therefore assessed as negligible. Despite the high sensitivity of this species to habitat loss and its high importance in terms of its rarity and nationally designated status, the overall impact on the DeFolin's lagoon snail from direct habitat loss and/or change is considered to be insignificant.

G.5.2 Temporary Effects on Habitats within Pagham Harbour from Changes to the Tidal Environment during the Shingle Excavation and Translocation Work

A review of the sensitivity of seagrass beds and DeFolin's lagoon snail to changes in emergence and suspended sediment levels is provided in Section 8.2.5 of the main ES.

ARUN DISTRICT COUNCIL P/93/25/PL

G.5.2.1 Changes in Water Levels

A temporary causeway will be constructed over a period of a week to a level of 0mAOD to provide low water access during construction (see Section 3.2 of the main ES). This causeway will remain in place for a period of up to 8 weeks, until the channel is fully infilled with excavated material from the breach location at the end of the campaign. The water level changes as a result of the temporary causeway and gradual infilling of the tidal inlet channel during construction will result in a small area of the existing low elevation intertidal mudflat habitat within the Pagham Harbour SPA and Ramsar site becoming subtidal over the construction period.

There will be no impact on seagrass beds as they occur in the mid to high mudflat elevations (above 0.8mODN) and will therefore not overlap with the changes in water levels that will occur within the harbour during the construction works. There will also be no impact on DeFolin's lagoon snails as they occur just below the Mean High Water Spring level and therefore outside the area of change.

G.5.2.2 Changes in Suspended Sediment Concentrations

There is the potential for sediment to be resuspended during the construction works as a result of excavating the breach and infilling the existing tidal channel. However, any resuspension of sediment caused by the works would be small in scale and highly localised. This is because the excavated sediment is predominantly coarse in nature with a mixture of sands, shingle and gravels and therefore any sediment deposited at the infill or breach location would quickly fall back out of suspension and thus rapidly return to the pre-work condition. Furthermore, the temporary access causeway that is proposed at the infill location during construction and the fact that coarser material will be placed on the southern side of the infill footprint will also reduce the potential for material to be transported by tidal action both into the harbour or out to sea (see Section 3.2 of the main ES). In any case, any changes in suspended sediment levels would be short term given the temporary and intermittent nature of the excavation and infilling works.

There will be no impact on seagrass beds or DeFolin's lagoon snails as they do not overlap with the potential changes in suspended sediments which are confined to the immediate spatial extent of the excavation and infill works.

G.5.3 Operational Effects on Habitats and Species within Pagham Harbour from Changes to the Tidal Environment

A review of the sensitivity of seagrass beds and DeFolin's lagoon snail to changes in emergence and suspended sediment levels is provided in Section 8.2.5 of the main ES.

G.5.3.1 Changes in Water Levels

Inside Pagham Harbour there are expected to be minor reductions in the water levels experienced at both high water and low water. These changes will occur because there will be a shorter inlet channel (compared to the present condition) that will provide more efficient drainage of the harbour. As a result of these factors there is anticipated to be a reduction in high water levels across the harbour on a

ARUN DISTRICT COUNCIL P/93/25/PL

spring tide for a brief period after the implementation of the project. There are also expected to be reductions in low water near to the tidal inlet on spring tides (and to a lesser degree on neaps) which are observed over a longer-term.

The changes will be in keeping with the range of conditions experienced previously (given the range of morphologies that previously existed at the site). In other words, future water levels will continue to be variable and an inherent function of the natural dynamic nature of the environment at this location.

In any case, changes are likely to be gradual and small, and unlikely to be measurable in the environment due to natural variations from meteorological effects, surface (wind driven) waves and even more long-term impacts, such as the lunar-nodal cycle and possibly even sea level rise.

The marginal reduction in high water levels within the harbour following the implementation of the proposed project will result in a temporary slight reduction in the area of upper saltmarsh habitat and a slight increase in transitional terrestrial habitat in the short term. These changes will not overlap with the seagrass beds and therefore there will be no impact to this MCZ interest feature.

The exposure of DeFolin's lagoon snail to the temporary changes in water levels is expected to be negligible (based on high probability of an occurrence but a negligible magnitude of change given the duration and extent of any change that could influence the relevant habitat). In the short term there will also be beneficial changes in the future from the formation of a temporary saline lagoon feature behind the separated Pagham Spit feature (see Section 5.3.3). The sensitivity of this species to the temporary changes following the breach is considered to be low given that these changes will be within the range of existing natural variability. This species is also mobile and will be able to tolerate and change its distribution in response to marginal changes in high water if necessary. Despite its high importance in terms of its rarity and nationally designated status, the overall impact on the DeFolin's lagoon snail is considered to be insignificant.

A small temporary reduction in high water levels has the potential to result in a marginal decrease in the time over which tidal water can percolate into saline lagoons which have a tidal connection to Pagham Harbour, including Little Lagoon where DeFolin's lagoon snail has been recorded. The overall exposure of this change is considered to be negligible given the high probability of a water level change by the negligible/de minimus magnitude of the change in the context of the existing restricted flushing regime of these lagoons. DeFolin's lagoon snail is considered to have a low sensitivity to these changes given that these changes will be gradual and within the range of existing natural variability. Overall, the impact of changes predicted in Little Lagoon during operation is considered to be insignificant.

G.5.3.2 Changes in Flow Speeds and Sedimentation Regime

As described in Section 6.3.4 of the main ES, the proposed project is not expected to alter the pattern of sedimentation within the harbour. Marginal changes to the hydrodynamic conditions and the alignment of the breach will not result in any measurable changes to the existing sediment regime (accretion/erosion patterns) within the harbour and the overall exposure to changes in sedimentation is considered to be negligible. Seagrass beds have a low sensitivity to changes in suspended sediment which will continue to occur as a gradual process on annual basis but not as a sudden pulse of imported sediment. The importance of intertidal habitats within the harbour is considered to be high

ARUN DISTRICT COUNCIL P/93/25/PL

given their internationally designated status. Therefore, the overall impact of changes in sediment regime on seagrass beds during operation is considered to be insignificant and not of a scale that would result in an indirect effect on DeFolin's lagoon snail.

G.5.3.3 Creation of a Temporary Saline Lagoon Feature

As described in Section 6.3.1 of the main ES, in the absence of the strong tidal flows along the closed existing inlet channel, the separated Pagham Spit feature that lies down-drift (north-east) of the breach will no longer be subject to migration constraints placed upon it by the channel. As such, under continued wave action and littoral drift processes, in the short term, the distal end of the spit is likely to reconnect with Pagham Beach forming a more enclosed saline lagoon behind the old spit. Over time, the material within the old spit is likely to be winnowed out through ongoing coastal processes, providing a large supply of material to the Pagham frontage and further down-drift. Depending on the drift rate, the old spit may take some 8 to 12 years to completely reintegrate back into the beach and/or into longshore processes. The lifetime of the newly created lagoon will therefore only be temporary.

A number of receptors could potentially benefit from the creation of this temporary saline lagoon habitat, including DeFolin's lagoon snail. The sensitivity of this interest feature to this change will depend on the potential value of this newly created lagoon and taking account of uncertainty is at most considered low. The overall impact of the creation of a temporary saline lagoon feature is therefore considered to be minor beneficial significant to DeFolin's lagoon snail.

G.6 Summary

The overall impacts of the proposed project on seagrass beds are considered to be insignificant. In terms of the DeFolin's lagoon snail, the majority of impacts are considered to be insignificant apart from the creation of a temporary lagoon behind the old spit which may provide additional supporting habitat to DeFolin's lagoon snail. Based on the outcomes of the Stage 1 MCZ assessment, there is no significant risk that the proposed project will hinder the Conservation Objectives for any of the interest features of the Pagham Harbour MCZ and therefore a Stage 2 MCZ assessment is not considered necessary.

G.7 References

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ARUN DISTRICT COUNCIL P/93/15/PL

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ARUN DISTRICT COUNCIL P/93/15/PL

Appendix H

Water Framework Directive
Compliance Assessment

ARUN DISTRICT COUNCIL P/94/21/PL

Managed Breach of Shingle Spit at Pagham Environmental Statement

Volume 2: Appendices

Contents

Page

H. Water Framework Directive Compliance Assessment 3
H.1 Introduction 3
H.2 Water Body Information 3
H.2.1 Overview 3
H.2.2 Potentially Affected Water Bodies 5
H.2.2.1 Sussex 5
H.2.2.2 Pagham Harbour 6
H.3 Water Quality and Protected Areas 7
H.3.1 Bathing Water Directive 7
H.3.2 Shellfish Waters Directive 8
H.3.3 Urban Waste Water Treatment Directive 8
H.3.4 Nitrates Directive 9
H.3.5 Protected Areas 9
H.4 Water Framework Directive Assessment 10
H.4.1 Assessment Methodology 10
H.4.2 Contributing to Improvements in WFD Status/Potential 17
H.5 Conclusion 18
H.6 References 18

Tables

H1. Water Framework Directive parameters for potentially affected water bodies based on 2009 RBMP classifications and 2013/2014 interim results 6
H2. Summary of proposed works 10
H3. WFD Compliance Assessment 12

ARUN DISTRICT COUNCIL P/93/25/PL

H. Water Framework Directive Compliance Assessment

H.1 Introduction

The Pagham Parish Council (PPC) and its working group, the Pagham Flood Defence Steering Group (PFDSG), are proposing to undertake a controlled breach of the shingle spit feature at the mouth of Pagham Harbour on behalf of the local community at Pagham, West Sussex. The primary aim of this proposed shoreline adjustment is to move the coastline towards a more sustainable morphology and address the severe coastal erosion problems that are being experienced on Pagham Beach.

The issues of erosion at Pagham Beach are largely being caused by the 'Church Norton Spit' in front of Pagham Harbour which has grown substantially over the last decade. In recent years, the northern end of this spit has migrated closer towards Pagham Beach and, in this position, it has caused a tidal channel to cut into the beach leading to rapid localised shoreline retreat. The formation of the spit and the tidal channel are also 'locking up' shingle and not allowing it to reach adjacent, and more slowly eroding, sections of the Pagham foreshore via the usual long-shore sediment transport pathways. The proposed controlled breach of the Church Norton Spit is designed to alleviate these erosion problems in a manner that works with natural coastal processes rather than alternatives which seek to 'battle' against such processes in a reactive manner.

On behalf of the PPC and PFDSG, ABP Marine Environmental Research Ltd (ABPmer) (with input from other relevant specialists as required) has undertaken a sequence of evidence-based studies to progressively verify, develop and inform this proposal. These studies have included reviewing the proposal against available alternatives, identifying a preferred approach and design for such a measure, confirming the construction methods and undertaking the required impact assessment work. An Environmental Statement (ES, see main report) has been prepared to review the environmental impacts of this proposal to inform the process of securing planning permission and other relevant consents.

In addition to the ES, there is a requirement to assess the effects of the proposed works under the requirements of the Water Framework Directive (WFD) (2000/60/EC). There is currently no specific guidance about the application of the WFD to marine/estuarine construction projects. Therefore, this WFD compliance assessment includes consideration of the guidance set-out in the existing Environment Agency (2012) 'Clearing the waters' user guide for marine dredging activities. Where appropriate, the assessment will provide reference to relevant sections of the ES.

H.2 Water Body Information

H.2.1 Overview

Under the WFD, coastal waters, estuaries, rivers, man-made docks and canals are divided up into a series of discrete water bodies. The WFD sets ecological as well as chemical targets (objectives) for each water body. However, as other factors can affect the ability of a water body to meet its ecological targets, objectives are also set under the WFD in respect of:

ARUN DISTRICT COUNCIL P/93/25/PL

- Changes in 'hydromorphological' parameters such as hydrology (tidal flows) and geomorphology (bed forms); and
- Changes in 'physico-chemical' parameters such as dissolved oxygen, salinity and nutrients.

Each water body has a hydromorphological designation that describes how modified a water body is from its natural state. Water bodies are either undesignated or designated as a heavily modified water body (HMWB) or artificial water body (AWB). HMWBs are defined as bodies of water which, as a result of physical alteration by human activities (such as flood protection, port/harbour use, commercial fin-fish and shellfisheries and resource extraction), are substantially changed in character and cannot therefore meet GES, whereas AWBs are artificially created. The default target for HMWBs and AWBs under the WFD is to achieve 'good ecological potential' (GEP), a status which recognises the importance of their human use whilst making sure ecology is protected as far as possible, and good surface water chemical status by 2015 or 2027. Ecological potential and status are measured on a scale of high, good, moderate, poor and bad, while chemical status is measured as either good or fail.

Compliance with chemical status objectives is assessed in relation to environmental quality standards (EQSs) for a specified list of 'priority' and 'priority hazardous' substances. These priority (hazardous) substances were first established by the Priority Substances Directive (2008/105/EC) which entered into force in early 2009. The Priority Substances Directive set objectives, amongst other things, for the reduction of these substances through the cessation of discharges or emissions. As required by the WFD and Priority Substances Directive, a proposal to revise the list of priority (hazardous) substances was submitted in 2012. Subsequently, an updated Priority Substances Directive (2013/39/EU) was published in 2013, identifying new priority substances, setting EQSs for those newly identified substances, revising the EQS for some existing substances in line with scientific progress and setting biota EQS for some existing and newly identified priority substances.

It is intended that the 'new' Priority Substances Directive will be transposed into UK legislation in September 2015, ahead of the publication of the second cycle RBMPs, along with revised directions for the Environment Agency. Therefore, at the time of writing, the original Priority Substances Directive (2008/105/EC) remains in force without the forthcoming amendments associated with the updated Priority Substances Directive (2013/39/EU); however, it is considered appropriate to report against revised EQS values where relevant data is available.

River Basin Management Plans (RBMPs) are a requirement of the WFD, setting out measures for each river basin district to improve water quality in rivers, lakes, estuaries, coasts and in groundwater. In 2009, the Environment Agency published the first cycle (2009 to 2015) of RBMPs for England and Wales, reporting the status and objectives of each individual water body. The managed breach at Pagham is located within the catchment of the South East RBMP (Environment Agency, 2009a).

The Environment Agency is currently updating RBMPs in preparation of the second cycle (2015 to 2021). Draft versions were made available for consultation in late 2014, including draft South East RBMP (Environment Agency, 2014). The draft RBMPs present interim results from 2013 and, therefore, provide an indication of water body status that will be reported in the updated RBMPs in 2015.

ARUN DISTRICT COUNCIL P/93/15/PL

In addition, interim results from 2014 are now available via the Environment Agency Catchment Data Explorer[1]. As the draft RBMPs have not been formally adopted and remain under consultation, it is considered prudent to continue to refer to the existing RBMPs in this assessment and exercise caution in the use of interim results.

H.2.2 Potentially Affected Water Bodies

Water bodies to be considered have been selected on the basis of the following criteria:

- All surface water bodies that could potentially be directly impacted by the proposal (i.e. those within the direct footprint of the proposed works); and
- Any surface water bodies that have direct connectivity and could potentially be indirectly affected by the proposed works.

The proposed works (breach and infill) are to be located wholly within the Sussex water body, although very close (<100 m) to the boundary of the adjacent Pagham Harbour water body (see Figure 7.1). Therefore, these two water bodies could be affected by the proposed works and are discussed in the following sections (Table H1 provides a summary, including water body status for each parameter assessed).

The Pagham Lagoon water body (ID: GB560704117300) is a small transitional AWB within 2 km of the proposed works (to the north-east), currently achieving an overall moderate potential (Environment Agency, 2009a). However, due to the discrete nature of the water body (i.e. separate from Pagham Harbour water body), Pagham Lagoon has therefore been scoped out of this assessment.

Three riverine water bodies are located upstream of the Pagham Harbour water body, namely Pagham Rife (ID: GB107041012880), Bremere Rife (ID: GB107041006610) and Broad Rife (ID: GB107041006580). These more distant surface water bodies are not considered to be affected by the proposed works at Pagham as the project will only alter the hydrodynamics of the environment in the locality of the works. There will be no physical or environmental effects to riverine environments beyond the Pagham Harbour water body, especially at a water body scale. Equally, these upstream water bodies will not be benefited by the project. However, sections of the Arun and Western Streams management catchment, within which the project site is located, could be altered (through erosion or accretion) in the event of an unmanaged breach at Pagham. It is this adverse effect that is aimed to be avoided by implementing the project. Therefore, these three upstream water bodies have been scoped out of the assessment.

H.2.2.1 Sussex

The Sussex water body (ID: GB640704540003) is a coastal water body, designated a HMWB for coastal protection and fin fisheries. The water body currently has an overall moderate potential, based on moderate ecological potential and good chemical status (Environment Agency, 2009a). Moderate ecological potential is due to the mitigation measures assessment identifying numerous measures

[1] Environment Agency Catchment Data Explorer (http://environment.data.gov.uk/catchment-planning/).

ARUN DISTRICT COUNCIL P/93/15/PL

which are 'not in place' (disproportionately expensive). The current classification is reflected in the latest interim results (2014) whereby the Sussex water body is considered to have overall moderate potential, with moderate ecological potential and good chemical status.

H.2.2.2 Pagham Harbour

The Pagham Harbour water body (ID: GB570704700000) was described as coastal in the first cycle South East RBMP (Environment Agency, 2009a); however, the second cycle South East draft RBMP (Environment Agency, 2014) and recent interim classifications have amended the designation to a transitional (i.e. estuarine) water body. Similarly, the water body was classified as an AWB in the 2009 classification, while the recent draft RBMP and interim results refer to the water body as a HMWB (reasons for designation unknown). For the purposes of this assessment, and to reflect the anticipated changes, the Pagham Harbour water body will be considered a transitional HMWB.

The overall status of the Pagham Harbour water body is currently moderate, based on moderate ecological potential and good chemical status ('does not require assessment'), and is therefore failing to meet its WFD objectives (Environment Agency, 2009a). Moderate ecological potential is due to the biological element macroalgae and supporting element dissolved inorganic nitrogen (DIN) both being assessed as moderate (uncertain). This is reflected in the latest interim results from 2014, whereby overall status is considered moderate. However, while these latest results also report ecological potential as moderate, chemical status is assessed as failing to achieve good. In terms of ecological potential, macroalgae is still assessed as moderate, while DIN has been upgraded to good (2013) and high (2014) status in the latest interim results. The biological element angiosperms is also assessed as moderate in the interim results (2014), while the priority substance fluoranthene is failing to achieve good with regards to chemical status.

Table H1. Water Framework Directive parameters for potentially affected water bodies based on 2009 RBMP classifications and 2013/2014 interim results

Parameter	Sussex		Pagham Harbour	
	2009	2013/2014	2009	2013/2014
Water Body ID	GB640704540003		GB570704700000	
Water Body Area	190.60 km²		2.57 km²	
Water Body Type	Coastal	Coastal	Coastal	Transitional
Hydromorphological Designation	HMWB	HMWB	AWB	HMWB
	Classification			
Overall Potential	Moderate	Moderate	Moderate	Moderate
Ecological Potential	Moderate	Moderate	Moderate	Moderate
Chemical Status	Good	Good	N/A	Fail
Invertebrates	Good	Good	Good	Good
Macroalgae	-	-	Moderate	Moderate
Phytoplankton	-	Good	High	High
Angiosperms	-	-	-	Moderate
Dissolved Inorganic Nitrogen	-	Good	Moderate	High
Dissolved Oxygen	-	High	High	High
Un-ionised Ammonia	-	-	High	High
Mitigation Measures Assessment	Moderate	Moderate	Good	-
Hydrological Regime	-	-	-	Good
1-1-1-trichloroethane	-	-	-	Good

ARUN DISTRICT COUNCIL P/93/15/PL

Parameter	Sussex		Pagham Harbour	
	2009	2013/2014	2009	2013/2014
Arsenic	High	High	-	High
Copper	High	High	-	High
Dimethoate	High	High	-	-
Iron	High	High	-	High
Zinc	High	High	-	High
1,2-Dichloroethane	High	Good	-	-
Cadmium and Its Compounds	High	Good	-	Good
Hexachlorobenzene	High	Good	-	-
Hexachlorobutadiene	High	Good	-	-
Hexachlorocyclohexane	High	Good	-	-
Nonylphenol	-	-	-	Good
Fluoranthene	-	-	-	Fail
Lead and Its Compounds	High	Good	-	Good
Mercury and Its Compounds	High	Good	-	-
Nickel and Its Compounds	High	Good	-	Good
Pentachlorophenol	High	Good	-	-
Trichlorobenzenes	High	Good	-	-
Trichloromethane	High	Good	-	Good
Aldrin, Dieldrin, Endrin and Isodrin	High	Good	-	-
Carbon Tetrachloride	High	Good	-	-
Para - para DDT	High	Good	-	-
Tetrachloroethylene	High	Good	-	-
Trichloroethylene	High	Good	-	-
Tributylin Compounds	-	Good	-	-

H.3 Water Quality and Protected Areas

This section outlines the relevant water quality information that is pertinent to other water quality directives and protected areas, specifically within 2 km of the proposed works. These areas are covered by the Bathing Water Directive, the Shellfish Waters Directive, the Urban Waste Water Treatment Directive (UWWTD), other water quality directives (e.g. Nitrates Directive) and international protected areas (e.g. Natura 2000 designations under the Birds and Habitats Directives).

H.3.1 Bathing Water Directive

The revised Bathing Water Directive (rBWD) (2006/7/EC) was adopted in 2006, updating the microbiological and physico-chemical standards set by the original Bathing Waters Directive (BWD) (76/160/EEC) and the process used to measure/monitor water quality at identified bathing waters. The rBWD focuses on fewer microbiological indicators, whilst setting higher standards, compared to those of the BWD. Bathing waters under the rBWD are classified as excellent, good, sufficient or poor according to the levels of certain types of bacteria (intestinal enterococci and Escherichia coli) in samples obtained during the bathing season (May to September).

The BWD was repealed at the end of 2014 and monitoring of bathing water quality will be reported against rBWD indicators from 2015. The new classification system considers all samples obtained during the previous four years and, therefore, data has been collected for rBWD indicators since 2012.

ARUN DISTRICT COUNCIL P/93/15/PL

However, this means rBWD classifications between 2012 and 2014 are 'projected' due to changes to the monitoring regime and the first official classification under this regime will be published towards the end of 2015, when there is a full four-year dataset. The UK Government's target under the rBWD is to achieve 'sufficient' for all bathing waters by 2015, as described under the Bathing Water Regulations 2013 which transposes the rBWD into UK law.

There is one bathing water (Pagham) situated within 2 km of the proposed works. Bathing water quality at Pagham, located approximately 1.5 km (sample point) to the east, has routinely been projected as excellent over the last three years (2012–2014) based on the rBWD.

H.3.2 Shellfish Waters Directive

The Shellfish Waters Directive was originally adopted on 30 October 1979 (79/923/EEC) and replaced on 12 December 2006 (2006/113/EC). It was developed in order to protect designated shellfish waters, thereby maintaining the high water quality necessary for producing edible shellfish (bivalve and gastropod molluscs, including oysters, mussels, cockles and clams). It set physical, chemical and microbiological water quality requirements that designated shellfish waters must either comply with ('mandatory' standards) or endeavour to meet ('guideline' standards), including:

- Dissolved oxygen – Measured as percentage saturation, should exceed 70% (as a mean), and individual measurements may not be less than 60% unless there are no harmful consequences on the development of shellfish colonies; and
- Suspended solids – A discharge affecting shellfish waters must not cause the suspended solid content of the water to exceed by more than 30% the content of waters not so affected.

The Shellfish Waters Directive was subsumed (repealed) by the WFD at the end of 2013, which must provide an equivalent level of protection for shellfish waters.

There are no shellfish waters situated within 2 km of the proposed works, with Chichester Harbour (Chichester Channel, Thornham Channel and Emsworth Channel) being the closest at a distance of >15 km to the west. Consequently, the footprint of effect from the proposed works will not overlap with any shellfish waters and this receptor is scoped out of further assessment.

H.3.3 Urban Waste Water Treatment Directive

The Urban Waste Water Treatment Directive (UWWTD) (91/271/EEC) aims to protect the environment from the adverse effects of the collection, treatment and discharge of urban waste water. It sets treatment levels on the basis of sizes of sewage discharges and the sensitivity of waters receiving the discharges. In general, the UWWTD requires that collected waste water is treated to at least secondary treatment standards for significant discharges. Secondary treatment is a biological treatment process where bacteria are used to break down the biodegradable matter (already much reduced by primary treatment) in waste water. Under the UWWTD, the UK is required to review environmental waters at four-yearly intervals to determine whether they are sensitive to the effects of sewage discharges.

ARUN DISTRICT COUNCIL P/93/15/PL

Sensitive areas under the UWWTD are water bodies affected by eutrophication due to elevated nitrate concentrations and act as an indication that action is required to prevent further pollution caused by nutrients. Nutrients are a particular problem for Pagham Harbour and it has been designated as a "Sensitive Area (Eutrophic)" under the UWWTD (Defra, 2012), located within 2 km of the proposed works.

H.3.4 Nitrates Directive

The Nitrates Directive (91/676/EEC) aims to reduce water pollution from agricultural sources and to prevent such pollution occurring in the future (nitrogen is one of the nutrients that can affect plant growth). Surface waters have to be identified if too much nitrogen has caused a change in plant growth which affects existing plants and animals and the use of the water body.

The Pagham Harbour and Sussex water bodies are both designated under the Nitrates Directive (Environment Agency, 2009a). In addition, areas to the south-west and north of Pagham Harbour and the entirety of Church Norton Spit are designated as Nitrate Vulnerable Zones (NVZs)[2].

H.3.5 Protected Areas

Article 3 of the Habitats Directive (92/43/EEC, as amended) requires the establishment of a European network of important high-quality conservation sites known as Special Areas of Conservation (SACs) that will contribute to conserving habitat and species identified in Annexes I and II of the Directive. The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds). In accordance with Article 4 of the EC Birds Directive (2009/147/EC), Special Protection Areas (SPAs) are strictly protected sites classified for rare and vulnerable birds (Annex I of the Directive), and for regularly occurring migratory species. Ramsar sites are wetlands of international importance designated under the Ramsar Convention (adopted in 1971 and came into force in 1975), providing a framework for the conservation and wise use of wetlands and their resources.

The following international nature conservation designations are located within 2 km of the proposed works:

- Pagham Harbour SPA; and
- Pagham Harbour Ramsar.

The proposed works at Pagham directly overlap with both the Pagham Harbour SPA and Pagham Harbour Ramsar site. Where a Natura 2000 protected area forms part of a water body or where a water body lies within a Natura 2000 protected area, the WFD status objectives apply in addition to the requirement to maintain favourable conservation status or restore it to that status under the Habitats Regulations. Both water bodies potentially affected by the works at Pagham (i.e. Sussex and Pagham Harbour) are designated as Natura 2000 protected areas.

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[2] Environment Agency What's In Your Backyard website (http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683&y=355134&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=nvz#x=488213&y=96944&lg=1,&scale=7).

ARUN DISTRICT COUNCIL P/93/15/PL

A European Marine Site (EMS) is the collective term used to refer to SACs and SPAs that are covered by tidal water and protect some of the most special marine and coastal habitats and species of European importance. They are defined by the Conservation of Habitats and Species Regulations 2010 (SI 2010/490), which transpose the EC Birds Directive (2009/147/EC) and EC Habitats Directive (92/43/EEC) into national law. The proposed works at Pagham directly overlaps with the Pagham Harbour EMS (English Nature, 2001), which comprises the Pagham Harbour SPA and refers to the Pagham Harbour Ramsar site.

H.4 Water Framework Directive Assessment

H.4.1 Assessment Methodology

Adjustment of the shoreline morphology within transitional (estuarine) and coastal (marine) environments has the potential to either cause deterioration in the ecological or chemical status/ potential of a water body, or to compromise improvements which might otherwise lead to a water body meeting its WFD objectives. Potential impacts associated with the proposed works at Pagham could, for example, include:

- Changes to morphology, water depth and bed substrate;
- Changes in current speeds and consequent changes to erosion or deposition patterns;
- Temporary increases in suspended sediment levels;
- Remobilisation of contaminated sediments from the seabed sediments; and
- Disturbance of fish and ecology.

Information relating to the scale of the proposed works is summarised in Table H2.

Table H2. Summary of proposed works

Parameter	Detail
Location of breach and existing channel to be infilled	See Figure 2.2 of main report. Proposed works to be located wholly within Sussex water body.
Area of spit to be breached (including side slopes)	19,580 m² (1.96 ha)
Area of existing channel to be infilled	7,125 m² (0.71 ha)
Volume of material to be excavated	An excavated volume of around 42,000 m³ (below 3.0 mODN) with an expected additional 10,500 m³ needing to be excavated above the +3.0 mODN elevation.
Breach methodology	Heavy plant machinery will be used to breach the spit and excavate material. See Section 3.2.2 of main report.
Infill methodology	Heavy plant machinery will be used to transport the excavated material from the breach to the infill site in the existing channel and/or to stockpile it adjacent to the infill channel until a final push of material is coordinated with the breach of the spit. See Section 3.2.3 of main report.
When the works are planned to be undertaken	Works planned for November/December 2015 for up to 11 weeks in total (weather depending).

ARUN DISTRICT COUNCIL P/93/15/PL

The WFD compliance assessment must determine whether the proposed works at Pagham could cause a change to the status of WFD water bodies or change the ability of a water body to meet its future objectives. The outcome of this assessment process is provided in Table H3 which includes consideration of the construction works (breach and infill) and the subsequent 'operational' phase (i.e. water body conditions post-construction). A temporary causeway will be created to provide low water access during the construction phase (Section 3.2.1). A vibratory hammer will be used to drive the sheet piles for this causeway to minimise noise disturbance to marine fauna. This temporary structure will be removed once construction work has been completed and any impacts, at water body level, will be similar to those associated with the infilling of the existing channel.

ARUN DISTRICT COUNCIL P/93/25/PL

Table H3. WFD Compliance Assessment

WFD Parameter	Water Body Assessment	
	Sussex	Pagham Harbour
Invertebrates	During construction, inter-tidal (and sub-tidal) habitat within the Sussex water body will be disturbed where Church Norton Spit is breached and the existing channel is infilled. Coarse sediment (shingle) shores tend to support very low macrofaunal abundance in their mobile and freely draining substratum. The few individuals that may be found are those washed into the habitat by the ebbing tide (e.g. from within Pagham Harbour), including the occasional amphipod or small polychaete. DeFolin's Lagoon Snail (Caecum armoricum), a nationally rare gastropod protected under Schedule 5 of the (1981) Wildlife and Countryside Act in 1992, has been occasionally found along Church Norton Spit. Sheltered saline water bodies are thought to provide the optimal habitat for this species, and to a lesser extent the landward edge of the spit (i.e. within Pagham Harbour as opposed to the exposed, seaward side). Overall, the direct loss of invertebrates and supporting habitat is considered insignificant. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as good in 2009 and 2014).	The mudflats of Pagham Harbour are rich in invertebrates, particularly polychaetes such as the lugworm Arenicola marina and the ragworm Nereis diversicolor. DeFolin's Lagoon Snail (Caecum armoricum), a nationally rare gastropod protected under Schedule 5 of the (1981) Wildlife and Countryside Act in 1992, has been occasionally found along Church Norton Spit. Sheltered saline water bodies are thought to provide the optimal habitat for this species, and to a lesser extent the landward edge of the spit (i.e. within Pagham Harbour water body). The proposed works (breach and infill) are not located within the Pagham Harbour water body and, therefore, there will be no direct loss/disturbance of habitat. Post-construction, Pagham Harbour is expected to fill and drain in much the same manner as present due to the carefully calculated breach dimensions. Therefore, as the scheme will only result in very small changes to water levels and tidal flows, minimal impact is anticipated for the benthic invertebrate community and supporting habitats. Sediment contamination levels are typically low in Pagham Harbour (see Section 7.1.4 of main report). Therefore, disturbance of coarse sediments within Church Norton Spit (downstream of Pagham Harbour) would be expected to result in minimal release of contaminants. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as good in 2009 and 2014).
Macroalgae	Not assessed.	Any macroalgae (seaweed) within the direct footprint of the scheme will be lost during the breach and infill activities. However, the proposed works are not located within the Pagham Harbour water body and, therefore, there will not be direct loss/disturbance of such habitat. Macroalgae within Pagham Harbour could be affected by changes in current velocities; however, Pagham Harbour is expected to fill and drain in much the same manner as present due to the carefully calculated breach dimensions.

ARUN DISTRICT COUNCIL P/93/15/PL

WFD Parameter	Water Body Assessment	
	Sussex	Pagham Harbour
		Pagham Harbour is designated a "Sensitive Area (Eutrophic)" under the UWWTD (Defra, 2012) and, therefore, the critical consideration relates to excessive nutrient availability and large scale macroalgae production. The proposed works are unlikely to significantly increase the nutrient concentration in the water column due to the low organic content anticipated in the sediment comprising Church Norton Spit. In other words, the proposed works will not introduce or result in the redistribution of nutrients in the marine environment and, therefore, would not be expected to result in excessive macroalgal growth. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as moderate in 2009 and 2014), nor prevent the potential achievement of good status/potential.
Phytoplankton	There is no obvious mechanism by which dredging (breach) and disposal (infill) activities could affect phytoplankton at water body level (Environment Agency, 2012). The dominant controls on phytoplankton are light availability, nutrients and salinity (Environment Agency, 2009b). Changes in salinity and light availability are not expected to have a material effect at a water body level compared to existing conditions, while excessive nutrient concentrations are not an issue for this large coastal water body. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as good in 2014).	There is no obvious mechanism by which dredging (breach) and disposal (infill) activities could affect phytoplankton at water body level (Environment Agency, 2012). The dominant controls on phytoplankton are light availability, nutrients and salinity (Environment Agency, 2009b). Changes in salinity and light availability are not expected to have a material effect at a water body level compared to existing conditions. Pagham Harbour is designated a "Sensitive Area (Eutrophic)" under the UWWTD (Defra, 2012) and, therefore, the critical consideration relates to excessive nutrient availability and potential eutrophication. The proposed works are unlikely to significantly increase the nutrient concentration in the water column due to the low organic content anticipated in the sediment comprising Church Norton Spit. In other words, the proposed works will not introduce or result in the redistribution of nutrients in the marine environment and, therefore, would not be expected to result in excessive phytoplankton growth. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as high in 2009 and 2014).
Angiosperms	Not assessed.	Angiosperm is a general term applied to flowering plants. For the purposes of this assessment, it is defined as a type of seagrass habitat (Zostera species). In

ARUN DISTRICT COUNCIL P/93/25/PL

WFD Parameter	Water Body Assessment	
	Sussex	Pagham Harbour
		2014, the extent of seagrass beds in Pagham Harbour measured approximately 3.4 ha (Environment Agency spatial data). There is no seagrass habitat located within the direct footprint of the scheme and therefore this habitat will not be lost during the breach and infill activities. Furthermore, the proposed works are not located within the Pagham Harbour water body and, therefore, there will be no direct loss/disturbance to such habitat. Despite their small extent, seagrass beds are important habitats in Pagham Harbour in ecological terms, providing supporting habitats for the bird interest features of the Pagham Harbour SPA, and are susceptible to the inundation of sediment. However, the proposed works are not anticipated to significantly increase sedimentation rates, and Pagham Harbour is expected to fill and drain in much the same manner as present due to the carefully calculated breach dimensions. In addition, the proposed works are designed to prevent a potentially unmanaged breach of the spit which could result in significant changes to sediment re-suspension and deposition rates in Pagham Harbour. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as moderate in 2014), nor prevent the potential achievement of good status/potential.
Dissolved Inorganic Nitrogen	Sussex water body is a large coastal water body, for which nutrient enrichment is not considered an issue (e.g. HMWB morphological designation is not related to the Nitrates Directive), and the proposed works will not introduce or result in the redistribution of nutrients in the marine environment. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as good in 2014).	Pagham Harbour is designated a "Sensitive Area (Eutrophic)" under the UWWTD (Defra, 2012) and, therefore, the critical consideration relates to excessive nutrient availability and potential eutrophication. The proposed works (breach and infill) are not located within the Pagham Harbour water body and will not introduce or result in the redistribution of nutrients in the marine environment. While the Pagham Harbour water body is designated a sensitive area, the sediment to be disturbed as part of the proposed works is coarser (e.g. shingle, sand and gravel) and likely to contain much lower nutrient loads. In addition, the proposed works are designed to prevent a potentially unmanaged breach of Church Norton Spit which could result in a large scale disturbance of nutrient-rich sediments due to significant changes in the hydrological regime/flushing rate of Pagham Harbour.

ARUN DISTRICT COUNCIL P/93/25/PL

WFD Parameter	Water Body Assessment	
	Sussex	Pagham Harbour
		The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as moderate in 2009 and high in 2014), nor prevent the potential achievement of good status/ potential.
Dissolved Oxygen	The potential increase in suspended sediment concentrations associated with the breach could theoretically lead to subtle changes in oxygen concentration (demand). No dissolved oxygen or oxygen saturation data is available for the Pagham Beach area (i.e. outside Pagham Harbour), but values would be anticipated to be relatively high due to the open nature of the coast and the lack of organic material and industrialisation (Royal Haskoning, 2013). The anticipated effects of the proposed works are short-term and small scale; thus, dissolved oxygen concentrations and saturation are unlikely to be an issue at the water body level. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as high in 2014).	The proposed works are not located within the Pagham Harbour water body; however, the potential increase in suspended sediment concentrations associated with the breach and channel infill could theoretically lead to subtle changes in oxygen concentration (demand) for this water body. Based on available information (Environment Agency monitoring data; see Section 7.1.3.2 of main report), both annual mean dissolved oxygen concentration (8.7 mg/L) and oxygen saturation (99.5%) within the Pagham Harbour water body are high. The anticipated effects of the proposed works are short-term and small scale; thus, dissolved oxygen concentrations and saturation are unlikely to be an issue at the water body level. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as high in 2009 and 2014).
Mitigation Measures Assessment	The South East RBMP (Environment Agency, 2009a) highlights a number of mitigations measures currently 'not in place'. The anticipated effects of the proposed works are largely within the scale of existing natural variability, and are not considered to contradict these mitigation measures should they be introduced. The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as moderate in 2009 and 2014), nor prevent the potential achievement of good status/potential.	Not assessed.
Hydrological Regime	Not assessed.	Changes in the locality of water flow will occur as a result of the proposed works (i.e. closure of existing channel and new flow through the breach); however, Pagham Harbour is expected to fill and drain in much the same manner as present due to the carefully calculated breach dimensions. In addition, the proposed works are designed to prevent a potentially unmanaged breach of Church Norton Spit which could result in significant alterations to the hydrological regime.

ARUN DISTRICT COUNCIL P/93/15/PL

WFD Parameter	Water Body Assessment	
	Sussex	Pagham Harbour
		The proposed works are not anticipated to cause deterioration in status for this parameter (assessed as good in 2014).
Specific Pollutants Priority Substances Priority Hazardous Substances Other Pollutants	Church Norton Spit is characterised by steep upper beaches and shallower mid-beaches mostly composed of a flint shingle, which grades to coarse sand and granules on the extensive low gradient foreshore. Due to the coarse nature of these sediments, the potential for contaminant accumulation is low. Therefore, based on the low contaminant concentrations within Pagham Harbour (higher silt fraction and thus likely higher contaminant concentrations; see Section 7.1.4 of the main report), sediment quality is considered to be good at the location of the breach. The proposed works are not anticipated to cause deterioration in status for these parameters.	Water quality is good within Pagham Harbour, with contaminant concentrations typically well below the annual average EQS (Environment Agency monitoring data; see Section 7.1.3.5 of main report). One sample for chromium and one sample for zinc exceeded the annual average EQS; however, the chromium concentration was less than the maximum allowable concentration EQS and, given the mean concentration for both metals was below the annual average EQS, these elevated values are not considered a major concern. Based on available information (Environment Agency sediment data; see Section 7.1.4 of main report), mean sediment contaminant concentrations were below Cefas Action Level 1 for the majority of samples obtained, with exceptions for arsenic, chromium and copper. There is a small potential for sediment-bound contaminants to be mobilised as the tide flows across after breaching. However, the proposed works are not located within the Pagham Harbour water body. Instead, Church Norton Spit is characterised by steep upper beaches and shallower mid-beaches mostly composed of a flint shingle. Due to the coarse nature of these sediments, the potential for contaminant accumulation is low. Therefore, it is unlikely that contaminants will be mobilised into Pagham Harbour as a result of the breach. The Pagham Harbour water body is assessed as failing to achieve good chemical status in the 2014 interim results due to fluoranthene. However, fluoranthene concentration in sediments collected from within Pagham Harbour is less than the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life threshold effect level (TEL) and the proposed works will not introduce or result in the redistribution of this chemical in the marine environment. The proposed works are not anticipated to cause deterioration in status for these parameters.

ARUN DISTRICT COUNCIL P/93/25/PL

The assessment terminology used in Table H3 refers to the objectives set under the WFD for all water bodies, whereby developments/schemes must:

- Not cause deterioration in status/potential;
- Not prevent the achievement of good status/potential;
- Not infringe or be in breach of other legislation; and
- Where possible, attempt to enhance the environment.

The proposed works are not considered to contradict other legislation and the potential environmental benefits of the project are discussed in Section 2 of the main ES report.

Based on the suite of WFD parameters reported for the Sussex and Pagham Harbour water bodies in Table H1, the following parameters (those currently failing to achieve good status/potential) are assessed against the first two objectives listed above:

- Sussex water body:
  - Mitigation Measures Assessment.
- Pagham Harbour water body:
  - Macroalgae;
  - Angiosperms;
  - Dissolved Inorganic Nitrogen (although classified as good in 2013 and high in 2014); and
  - Fluoranthene.

The remaining parameters are assessed against the objective of not causing deterioration in status/potential from their current classification of good or high. In some instances, WFD parameters were not assessed as part of the ES (see main report) and, therefore, the potential impact(s) of the project have been considered separately.

H.4.2 Contributing to Improvements in WFD Status/Potential

The proposed works are primarily driven by the need to move the coastline towards a more sustainable morphology and to address the coastal erosion problems being experienced on Pagham Beach. It is overly optimistic to conclude that the proposed works will lead to a direct improvement in status/potential of one or more WFD parameters. However, the works are expected to marginally improve the tidal flushing of Pagham Harbour, thus potentially improving water quality by reducing the risk of excessive nutrient build-up which can lead to eutrophic events. Furthermore, compared to the existing condition or a future unmanaged breach of Church Norton Spit, the proposed works provide greater certainty of benefit and enhanced stability and marginally lower likelihood of inlet closure. Therefore, it is concluded that the proposed project will support the status and future objectives of nearby water bodies.

A potential unmanaged breach of Church Norton Spit is likely to be highly mobile and unstable, for which the exact form, location and timing are highly uncertain. Increased suspended sediment concentrations may arise, impacting WFD parameters such as invertebrates, phytoplankton, angiosperms, macroalgae and dissolved oxygen. In addition, the ecological potential for dissolved

ARUN DISTRICT COUNCIL P/93/25/PL

inorganic nitrogen could deteriorate (assessed as high in 2014) due to changes in the hydrological regime/flushing rate of Pagham Harbour; a particular concern given that Pagham Harbour is designated a "Sensitive Area (Eutrophic)" under the UWWTD (Defra, 2012).

H.5 Conclusion

This WFD compliance assessment considers the anticipated effects of the proposed works on the Sussex and Pagham Harbour water bodies, determining whether they will be significantly affected in terms of specific quality elements and their overall objectives. While the project is expected to lead to some small adverse impacts on the marine environment during the construction phase (breach and infill), these are short-term, small scale and localised. In addition, the project could arguably provide a relative improvement in WFD status/potential compared to an unmanaged breach of Church Norton Spit. Therefore, it is concluded that the proposed works at Pagham will support nearby water body status and their future objectives.

H.6 References

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ARUN DISTRICT COUNCIL P/93/15/PL

Appendix I

Transport Statement

Managed Breach of Shingle Spit at Pagham Environmental Statement

Volume 2: Appendices

Contents

Page

I. Transport Statement 4
I.1 Introduction 4
I.2 Policy Context 4
I.2.1 National Planning Policy Framework 5
I.2.2 National Networks National Policy Statement 6
I.2.3 Chichester District Local Plan 6
I.2.3.1 1999 Saved Policies 6
I.2.3.2 Key Policies 2014-2029 Proposed Modifications 7
I.2.4 Arun District Local Plan 8
I.2.4.1 2003 Saved Policies 8
I.2.4.2 2011-2029 9
I.2.5 West Sussex Local Transport Plan 2011-2026 10
I.2.6 Conclusions 10
I.3 Baseline Transport and Traffic Conditions 10
I.3.1 Site Location and Land Use 10
I.3.2 Highway Network 12
I.3.3 Sustainable Travel 12
I.3.4 Traffic Flows 13
I.3.5 Existing Capacities 14
I.4 Proposed Project 14
I.4.1 Project Description 14
I.4.2 Access Arrangements 15
I.4.3 Programme 16
I.4.4 Team and Equipment 16
I.5 Impact on the Highway Network 17
I.6 Summary and Conclusions 18
I.7 References 18

ARUN DISTRICT COUNCIL P/93/15/PL

Tables

I1. Estimated construction programme 16
I2. Approximate numbers of staff and plant weeks 16

Images

I1. Plan of key local features at Pagham Harbour 11
I2. Coastal and marine recreation features at Pagham 12
I3. Average traffic counts at the B2145 Sidlesham ATC site during 2014 13
I4. Proposed project showing preferred breach design and location of infill 14
I5. Proposed main and alternative access routes 15
I6. Proposed location of New Tern Island 18

ARUN DISTRICT COUNCIL P/93/25/PL

I. Transport Statement

I.1 Introduction

This Transport Statement has been prepared to support the planning application for the managed breach of the shingle spit feature at the mouth of Pagham Harbour (the 'proposed project' hereafter). The current morphology of the spit is resulting in immediate coastal erosion and flood risk to residential properties at Pagham Beach. It is also posing a growing erosion threat to the remainder of the beach which is in a deteriorating condition and has reduced in amenity and recreational value. The proposed project will create a sustainable flood and coastal erosion risk management scheme for Pagham Beach and also improve its amenity and recreational value.

The footprint of the proposed project overlaps with the boundaries of both Chichester District Council's (CDC) and Arun District Council's (ADC) area. Planning permission will therefore be required from both councils under the Town and Country Planning Regulations 2011. West Sussex County Council, as the Local Highways Authority (LHA) has requested that a Transport Statement be submitted as part of the application setting out the anticipated vehicular movements and means of vehicular access.

This Transport Statement has been prepared in accordance with the Department for Transport's (DfT) "Guidance on Transport Assessment" published in March 2007. The guidance states that Transport Statements are appropriate in situations where the proposed development will have relatively small transport implications. Information regarding content and the need for assessment is also provided within the West Sussex County Council's "Transport Assessment Methodology".

This Transport Assessment is structured as follows:

Section I.2 Policy Context – presents the national, regional and local policy pertaining to the application site;

Section I.3 Baseline Transport and Traffic Conditions – provides an outline review of the existing highway network and the existing traffic conditions;

Section I.4 Proposed Project – describes the proposed project and details the access arrangements and trip generation expected during construction;

Section I.5 Impact and Mitigation – presents measures to reduce or minimise the impacts of the construction traffic; and

Section I.6 Summary and Conclusions – details the main conclusion from the Transport Statement.

I.2 Policy Context

It is important to set the proposed project in the context of national, regional and local policy. A review of the following documents has been undertaken:

ARUN DISTRICT COUNCIL P/93/25/PL

- National Planning Policy Framework;
- National Networks National Policy Statement;
- Chichester District Local Plan;
- Arun District Local Plan; and
- West Sussex Local Transport Plan

I.2.1 National Planning Policy Framework

The National Planning Policy Framework (NPPF) which was published on 27 March 2012 sets out the Government's planning policies for England and how these are expected to be applied. The NPPF replaces previous national planning policy guidance which was primarily contained within a series of Planning Policy Guidance notes (PPGs) and Planning Policy Statements (PPSs). The framework is a key part of Government reforms to make the planning system less complex and more accessible, to protect the environment and to promote sustainable growth.

The NPPF acts as guidance for local planning authorities and decision-takers, both in drawing up plans and making decisions about planning applications. The framework incorporates polices relating to coastal change and biodiversity that are of direct relevance to the proposed project.

The aim of the policy on coastal change, as set out in paragraphs 105-108 of the NPPF, is to reduce risk from coastal change by avoiding inappropriate development in vulnerable areas or adding to the impacts of physical changes to the coast. The general approach can be summarised as follows:

- Local planning authorities apply Integrated Coastal Zone Management to integrate terrestrial and marine planning regimes;
- Local planning authorities identify Coastal Change Management Areas[1] likely to be affected by physical changes to the coast;
- Local planning authorities are expected to be clear what development will be appropriate in Coastal Change Management Areas[2] and make provision for development and infrastructure that needs to be relocated away from Coastal Change Management Areas.

As set out in paragraph 168 of the NPPF, Shoreline Management Plans (SMPs) should inform the evidence base for planning in coastal areas. The prediction of future impacts should include the longer term nature and inherent uncertainty of coastal processes (including coastal landslip), and take account of climate change.

Within the Transport Chapter of the NPPF all developments that generate significant amounts of movement, as determined by local criteria, should be supported by a Transport Statement or Transport Assessment. Planning policies and decisions should consider whether:

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[1] This is an area identified in Local Plans as likely to be affected by coastal change (physical change to the shoreline through erosion, coastal landslip, permanent inundation or coastal accretion).

[2] Essential infrastructure may be permitted in a coastal change management area, provided there are clear plans to manage the impacts of coastal change on it, and it will not have an adverse impact on rates of coastal change elsewhere.

ARUN DISTRICT COUNCIL P/93/15/PL

- The opportunities for sustainable transport modes have been taken up depending on the nature and location of the site, to reduce the need for major transport infrastructure;
- Safe and suitable access to the site can be achieved for all people; and
- Improvements can be undertaken within the transport network that cost effectively limit the significant impacts of the development.

Subject to those considerations, development should not be prevented or refused on transport grounds unless the residual impacts of development are severe, and the need to encourage increased delivery of homes and sustainable economic development should be taken into account.'

I.2.2 National Networks National Policy Statement

The National Networks National Policy Statement for the national road and rail networks was published under the 2010 to 2015 Conservative and Liberal Democrat coalition government in December 2014. The coalition government recognised the need for development of the road and rail networks to relieve congestion on roads and overcrowding on rail. In doing so, this would support local and national economic growth, increase resilience, improve integration between transport modes and improve the environment, safety and accessibility. The Statement provides guidance on how decisions will be made relating to development consent orders for nationally significant infrastructure projects.

I.2.3 Chichester District Local Plan

I.2.3.1 1999 Saved Policies

The Local Plan for Chichester District consists of the Saved Policies in the Chichester District Local Plan (adopted April 1999). These policies guide development in this district and are used to make decisions on planning applications. Until the new Local Plan 2014-2029 has been adopted (see Section I.2.3.2), the following policies, which have been identified as being particularly relevant to the proposed project, remain current:

Policy C3: Managed Realignment states that "Proposals for the managed realignment of sea defences or coast protection structures which provide nature conservation and/or landscape benefits will be permitted providing there is no loss of the best and most versatile agricultural land or danger to buildings and provision is made for diversion of the coastal path or other affected public rights of way".

Policy C9: Sea Defence and Coast Protection Works states that "proposal for the construction of new or replacement sea defence and coast protection works… will be permitted provided that: the District Planning Authority can be satisfied that the technical requirements of the coast protection authority have been met; in the rural area they are not visually obtrusive or damaging to the open appearance or character of the shoreline…; they would not be damaging to features of ecological or archaeological significance to the locality; they do not involve the visible use of waste material; they are of a design… which, where technically feasible, will attract accretion of silt and plants to reduce the visual impact of works;… they maintain access for commercial and leisure fishing activities".

ARUN DISTRICT COUNCIL P/93/25/PL

I.2.3.2 Key Policies 2014-2029 Proposed Modifications

On 30 May 2014, the Chichester Local Plan: Key Policies 2014-2029 and supporting documents were submitted for independent examination to the Secretary of State for Communities and Local Government via the Planning Inspectorate. The Secretary of State has appointed an independent Inspector to conduct the Examination.

The Local Plan provides the broad policy framework and a long-term strategy to manage development, protect the environment, deliver infrastructure and promote sustainable communities within Chichester District (excluding the area within the South Downs National Park) to 2029. Once adopted, all planning applications will be assessed against the policies in the Local Plan.

The final scheduled session on the examination of the Chichester Local Plan: Key Policies Pre-submission 2014-2029 was held on 3 December 2014 and the Council has consulted on the Proposed Modifications it considered were required to make the Plan sound. Any minor changes required on the basis of accuracy, clarity or for updating purposes will be included in the adopted version of the Chichester Local Plan.

The Proposed Modifications consultation ran for six weeks from 8 January 2015 to 19 February 2015. The Inspector has carefully considered all the representations submitted in response to the Council's proposed modifications and will take account of these in writing the report which was unavailable at the time of writing.

Particularly pertinent policies in the pre-submission document (CDC, 2014) are now listed.

The proposed Policy 22 on 'Integrated Coastal Zone Management for the Manhood Peninsula' could be viewed as pertinent, as the Church Norton Spit is essentially part of the Peninsula, even though the affected community at Pagham is not on the Peninsula, nor is it within the boundaries of CDC. For the Manhood Peninsula, CDC pledges to "prepare plans, strategies, projects and other measures, in partnership with other organisations and local communities, to ensure that the Manhood Peninsula is planned for in a coordinated and integrated manner, whilst recognising the individual needs of the communities within the area'. 'Proposals and initiatives will be supported that promote the following general objectives:

1. Facilitate the economic, environmental and social well-being of the area;
2. Address proposals for the coastline and coastal communities set out in Coastal Defence Strategies and Shoreline Management Plans;
3. Contribute to greater safeguarding of property from flooding or erosion and/or enable the area and pattern of development to adapt to change, including the relocation of current settlement areas, and vulnerable facilities and infrastructure that might be directly affected by the consequences of climate change;
4. Provide resources to improve the process of harbour and coastal management, incorporating and integrating social, recreational, economic, physical and environmental issues and actions;
5. Improve infrastructure to support sustainable modes of transport, especially cycle ways, bridleways and footpaths, including the National Coastal Footpath; and
6. Provide the means of supporting regeneration on the Manhood Peninsula."

ARUN DISTRICT COUNCIL P/93/15/PL

Proposed Policy 44, Development around the Coast, states that "planning permission will be granted for development in the coastal area, outside of Settlement Boundaries, where it can be demonstrated that all the following criteria have been considered:

1. There are no harmful effects on or net loss of nature conservation or areas of geological importance within the Chichester and Pagham Harbours and Medmerry Realignment;
2. The development provides recreational opportunities that do not adversely affect the character, environment and appearance of the coast and Chichester Harbour Area of Outstanding Natural Beauty;
3. Regard has been shown to the high quality and inclusive design of new buildings in coastal locations in accordance with other relevant design and historic environment policies;
4. There are measures for mitigation of any detrimental effects including where appropriate the improvement of existing landscapes relating to the proposal;
5. Where appropriate, opportunities have been taken to upgrade existing footpaths and cyclepaths, enhance and protect the National Coastal Footpath and ensure that public access is retained and provided to connect existing paths along the waterfront;
6. The development would result in improvements to or redistribution of moorings, marine berths or launch on demand facilities (dry berths) in the harbours; and
7. The development would not be detrimental to infrastructure for, and quality of, water-based recreation, or be detrimental to the safety of navigation."

Proposed Policy 48 Natural Environment states that "planning permission will be granted where it can be demonstrated that all the following criteria have been met:

1. There is no adverse impact on:
   - The openness of the views in and around the coast, designated environmental areas and the setting of the South Downs National Park;
   - The tranquil and rural character of the area; and
   - Development recognises distinctive local landscape character and sensitively contributes to its setting and quality;
2. Proposals respect and enhance the landscape character of the surrounding area and site, public amenity and detailed design;
3. Development of poorer quality agricultural land has been fully considered in preference to best and most versatile land; and
4. The individual identity of settlements, actual or perceived, is maintained and the integrity of predominantly open and undeveloped land between settlements is not diminished."

I.2.4 Arun District Local Plan

I.2.4.1 2003 Saved Policies

The current Local Plan for Arun District was created in 2003 and the Council is currently in the process of producing a new one (Section I.2.4.2). The following policies are of particular relevance to the proposed project:

ARUN DISTRICT COUNCIL P/93/25/PL

Policy GEN10: Tidal Flooding and Coastal Defence states that "The risk to development in areas subject to flooding and coastal erosion is set out in the Coastal Defence Strategy. The Coastal Defence Strategy identifies standards of defence and future management".

Policy GEN19: Coast Protection and Sea Defence Works states that "Proposals for coast protection and sea defence works or improvements to existing works will be considered in the light of the following: (i) the recommendations of the shoreline management plan and the coastal defence strategies in respect of the physical maintenance of the coastline and coastal defences; (ii) their impact on the visual character of the open, undeveloped coast and on the appearance and use of the coastline in the built-up areas; and (iii) that the proposed method of coastal defence is technically sound and appropriate to the task". The main aim of the policy is to maintain sea defences and protect the coast where necessary through the use of the best technically, economically and environmentally appropriate solutions.

I.2.4.2 2011-2029

The Arun District Local Plan 2011-2031 and supporting documents were submitted on 30 January 2015 for independent examination to the Secretary of State for Communities and Local Government via the Planning Inspectorate.

The Local Plan sets out a vision for the future of Arun up to 2031. It sets the planning framework for the district and will detail planning policy and identify the amount of development proposed and where it should be located. It will be used in the consideration of planning applications. The Plan covers the Arun Local Planning Authority Area (LPA). The LPA is Arun District Council (ADC) administrative area excluding land within the South Downs National Park Authority boundary.

Particularly pertinent policies in the pre-submission document (ADC, 2014) are now listed.

Policy W DM4 Coastal protection states that "Proposals for coast protection and sea defence works will be permitted if they:

a. Have been considered in light of their impact on the visual character and value of the open, undeveloped coast, protection and enhancement of coastal habitats and the provision of opportunities to complete the coastal footpath and improve the appearance and use of the coastline in the built-up areas.
b. Use methods of coastal defence that are technically sound and appropriate to the task and do not have a detrimental effect on other parts of the coastline; and
c. Are in accordance with the Shoreline Management Plan or Strategy for the particular frontage.

Proposals for development in coastal locations, including for example, sea defence works, will be permitted providing they protect and enhance coastal habitats such as vegetated shingle. Where habitats are lost through the provision of sea defence works, replacement habitats must be provided in a suitable location. Any works under this policy should take account of any local and/or interest features. Developments shall also be consistent with all other Local Plan policies."

ARUN DISTRICT COUNCIL P/93/15/PL

Policy TOU SP1 Sustainable tourism and the visitor economy states that "sustainable tourism growth for Arun requires the protection of features that make the District attractive to visitors. Proposals for visitor related development will be determined by Arun's capacity to absorb such growth; for Arun this means tourism growth which:

- Encourages long-term visitor interest / activity;
- Ensures a viable visitor economy;
- Provides benefit to local people;
- Extends the visitor season; and
- Protects and enhances the natural and built environment of Arun."

I.2.5 West Sussex Local Transport Plan 2011-2026

The West Sussex Transport Plan 2011-26 (LTP3) sets the strategy for guiding future investment in our highways and transport infrastructure. It also sets a framework for considering transport infrastructure requirements associated with future development across the county.

The plan includes four strategies that guide our approach to maintaining, managing and investing in transport, and meeting our main objective of improving quality of life for the people of West Sussex. These four strategies are promoting economic growth; tackling climate change; providing access to services, employment and housing; and improving safety, security and health.

The first part of the plan lays out our vision and long term strategy, while part two sets out our implementation plan with key issues and aims for improvements to the transport network across West Sussex.

I.2.6 Conclusions

Given the proposed project, there are few policies that relate directly to transport and coastal defence. However, the principles remain that traffic should be managed on the network and where possible sustainable modes should be considered. The proposed project is in line with a number of policies in both the Chichester District Local Plan and Arun District Local Plan and is necessary to provide coastal protection to residents at Pagham Beach and sustaining the amenity and recreational value of the area.

I.3 Baseline Transport and Traffic Conditions

I.3.1 Site Location and Land Use

The proposed project is located at Pagham Harbour (Image I1). The wider area including the harbour, Pagham Beach and Pagham Lagoon all have an amenity value and these, along with watersports, contribute to the value of the area for day and staying visitors.

ARUN DISTRICT COUNCIL P/93/25/PL

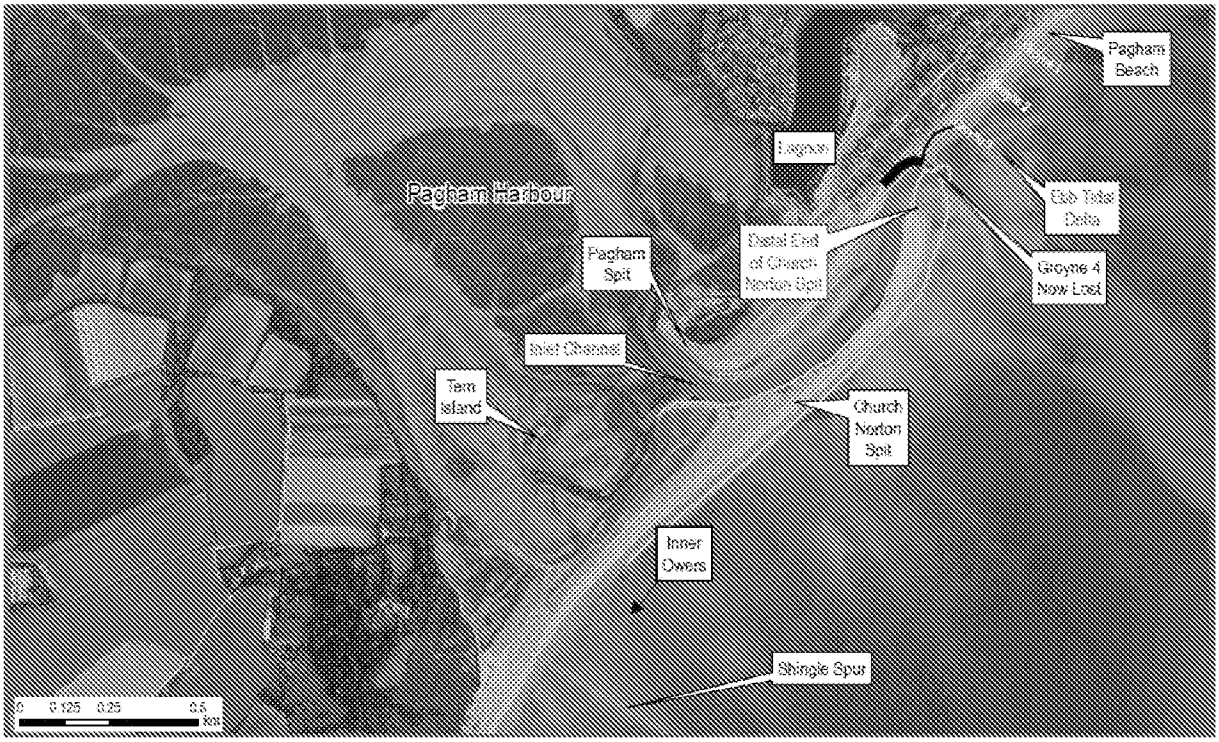


Image I1. Plan of key local features at Pagham Harbour

Pagham Harbour itself is a Royal Society for the Protection of Birds (RSPB) nature reserve, one of the few undeveloped stretches of the Sussex coast, and an internationally important wetland site for wildlife. There is a small Visitor Centre with car park and toilets, and long walks around the harbour edge to the sea. The Sidlesham Ferry and Church Norton car parks also provide access to the harbour for visitors.

Coastal tourism is of substantial importance to economy of the village of Pagham, which has just under 6,000 inhabitants (Pagham Parish Council, 2014). There are a range of facilities available for both day and staying visitors including cafés, take away shops and an amusement arcade. Some public parking is available within the village (Pagham Parish Council, 2013). Public parking was formerly also available just outside the village to the west, next to Pagham Harbour, on Pagham Spit. However, that parking area is now closed due to road and car park maintenance/upgrade issues (Pagham Parish Council, 2013). Prior to the closure of the latter car park, it would have taken an estimated 80,000 vehicle movements/year (Pagham Parish Council, 2012). Please refer to Image I2 for an illustration of the coastal and marine recreational features at Pagham.

With regard to accommodation, there is one caravan site in the village, behind Pagham Lagoon called 'Church Farm Holiday Village'. It contains 898 caravans and receives approximately 0.5 million visitors/year, over an eight month season (it is open from the beginning of March to the end of October). At least 15 private holiday lets are available in Pagham, many of which are located at the Holiday Village. Furthermore, there are a small number of hotel and bed and breakfasts offering accommodation (TripAdvisor website).

ARUN DISTRICT COUNCIL P/93/15/PL



Image I2. Coastal and marine recreation features at Pagham

I.3.2 Highway Network

The principal roads into Pagham Harbour are as follows:

- The B2145 which links Selsey with the A27 Chichester Bypass; and
- Pagham Road (B2166) which links the village of Pagham to the A27 Chichester Bypass (via the B2145).

Between these a network of minor roads and tracks provide access to the many farms in the area. Due to the location at the south coast there is no through traffic at the site.

I.3.3 Sustainable Travel

As the only traffic generated by the proposed project is during construction, there are limited opportunities to travel by more sustainable modes. There are several Public Rights of Way (PROW) in and around the locality of Pagham Harbour. The Bill Way cycle route (Sustrans Route 88), National Route 2 and Cycle Chichester Routes provide a link between Sidlesham Ferry/Pagham Harbour Nature Reserve and the Chichester Canal Basis combining both on and off-road sections.

ARUN DISTRICT COUNCIL P/93/15/PL

There are no railway stations in the vicinity of the site, with the closest located at Chichester (approximately 7 miles from Pagham), Fishbourne (8 miles) and Bognor Regis (4 miles). All three stations lie on the West Coastway Line which runs between Brighton and Southampton and is served by trains operated by Southern. In addition, Chichester station is located on the Worcester to Brighton line operated by First Great Western. From Chichester, services calling at London Victoria, London Bridge, Gatwick Airport, Brighton, Portsmouth, Southampton and Littlehampton can be caught as well as long distance services to Wales and the West Country.

The main bus service in the area is Stagecoach 51 which provides a link from Selsey to Chichester departing every 30 minutes at peak frequency. This service stops outside the RSPB Visitor Centre.

I.3.4 Traffic Flows

Traffic data from the permanent Automatic Traffic Counter (ATC) at B2145 Sidlesham indicates that the highest monthly flows occur during August and are as a result of the area being a popular holiday destination (Image I3). An assessment of the ATC data for the Monday to Friday peak hours found the morning (am) peak generally occurred between 11:00-12:00 and the evening (pm) peak between 17:00-18:00. In general, the northbound morning and evening peak flows occur earlier in the day than the southbound. This could be as a result of residents travelling north to work in areas such as Chichester. The southbound peak could be primarily visitors to the area, travelling to the coast or for recreational activities.

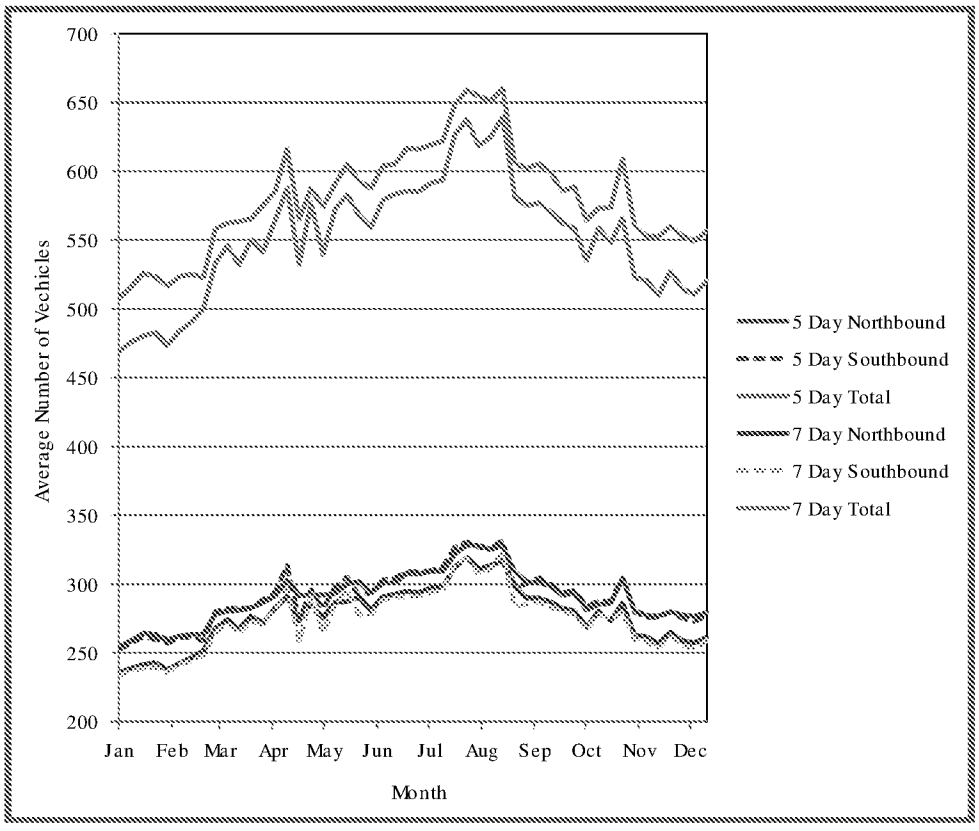


Image I3. Average traffic counts at the B2145 Sidlesham ATC site during 2014

ARUN DISTRICT COUNCIL P/93/15/PL

I.3.5 Existing Capacities

Hourly flow capacities for urban roads are included in the Design Manual for Roads and Bridges (Volume 5, Section 1, Part 3). This information has been used to assess the existing capacity of the B2145 in the vicinity of the traffic count site. In general, this route is considered to be of Urban All Purpose (UAP) 2 standard (good standards single/dual carriageway road and frontage access and more than two side roads per km). This has been decided due to the number of side roads, the access to residential properties and the location of bus stops at the kerbside. The maximum theoretical one way flow capacity of the B2145 is 764 vehicles per hour and assume HGV percentages to be less than or equal to 15%. Known HGV capacities at B2145 support this assumption. The theoretical capacity of the B2145 is less than that state in the DMRB and therefore suggest there to be no capacity issues.

I.4 Proposed Project

I.4.1 Project Description

The proposed project is to create a managed breach through Church Norton Spit. The location of the proposed breach is shown on Image I4. The position takes account of the topography within the harbour; proximity to the tidal channels; the position of the existing training wall; the shape of the spit; and the position of the harbour inlet historically (in 2003). The breach will follow a straight alignment to ensure that contractors can excavate it relatively easily and safely.

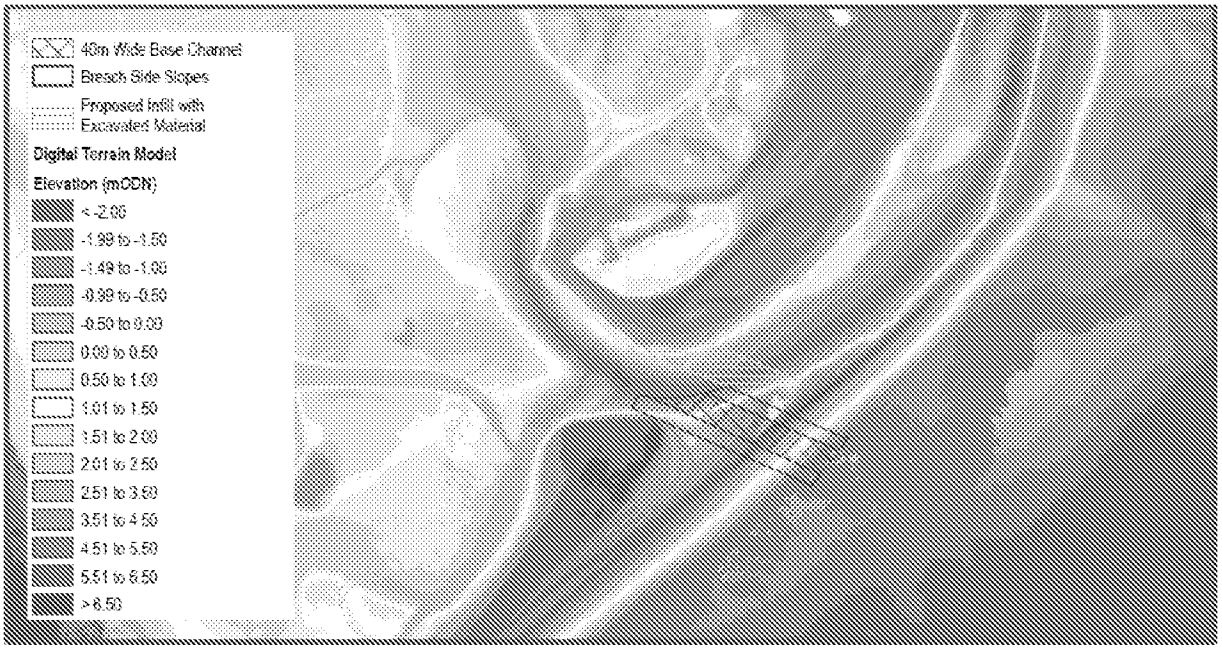


Image I4. Proposed project showing preferred breach design and location of infill

ARUN DISTRICT COUNCIL P/93/25/PL

The material excavated from this breach will be used to infill the existing channel to the north-east of the breach (Image I4). Once the existing channel is closed and the new breach is created, natural processes will take over and no ongoing management of the site (e.g. maintaining the breach position) is proposed. However, one subsequent breach intervention has been included as part of the proposal as a contingency in the unlikely event that the breach closes.

I.4.2 Access Arrangements

The main access route to the site will be from the east on the Pagham side of the harbour (see Image I5). Some daily pedestrian access may need to be via the west from Church Norton or via East Beach, Selsey. Alternative emergency access will be via East Beach, Selsey. A Heras fenced site compound will be created in the currently closed Pagham Car Park, which will also be used for turning lorries around. There will be minimal movement of plant in and out of the site as no materials will be imported for the proposed works.

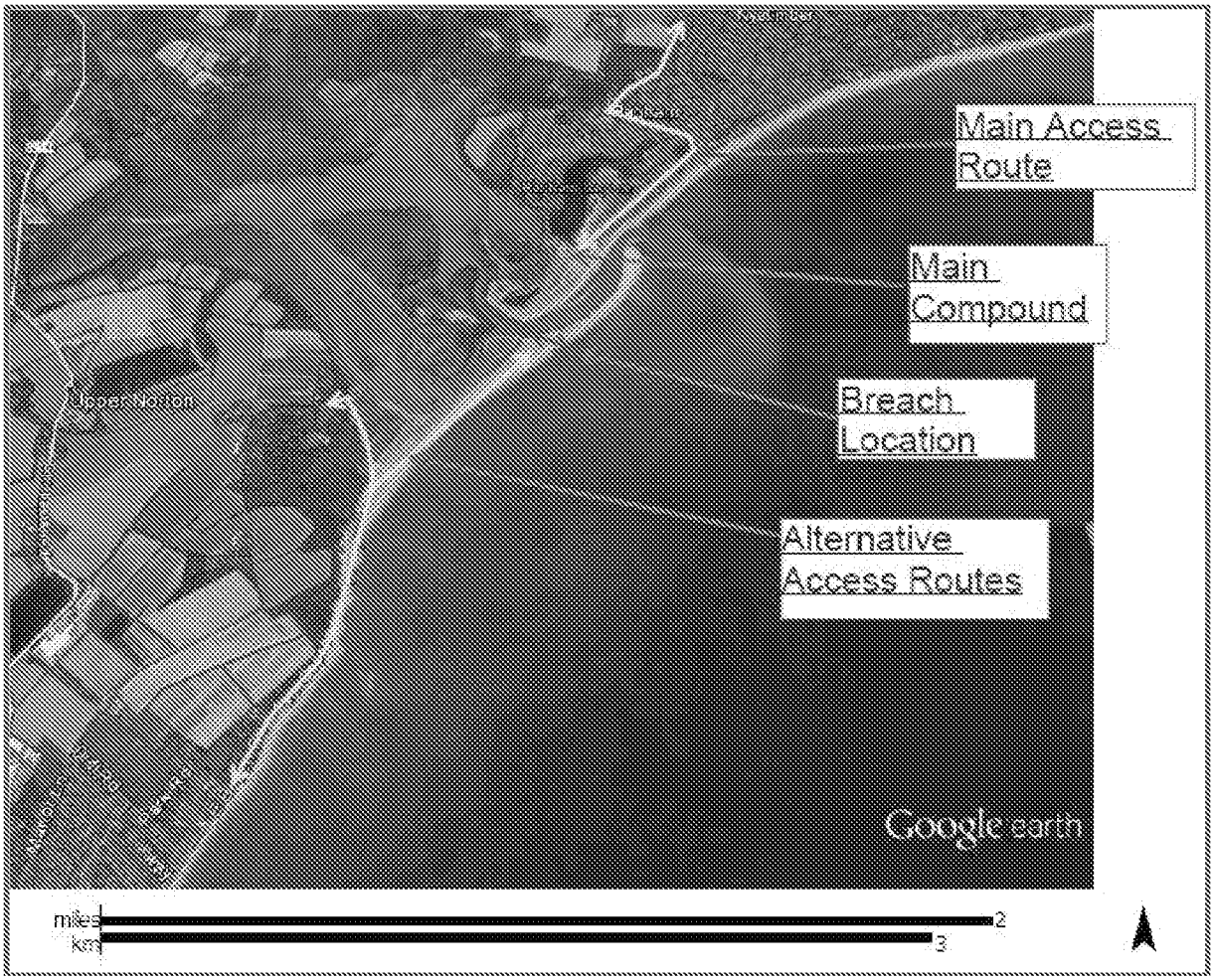


Image I5. Proposed main and alternative access routes

ARUN DISTRICT COUNCIL P/93/25/PL

I.4.3 Programme

The estimated construction programme is shown in Table I1. The actual programme will need to take into account when the operation is to take place (presently anticipated to be November to December 2015 or in 2016 outside Little Tern breeding period which is April to July) to allow for potential weather risk and downtime, as well as any logistical issues with accessing the spit initially.

Table I1. Estimated construction programme

Task	Duration (Weeks)
Mobilise	0.6
Install sheet piles to provide temporary access route	1
Excavation of breach	5-6
Channel infilling	1-2
Removal of sheet piles	0.6
Demobilisation	0.4
Total	9 to 11

I.4.4 Team and Equipment

It is anticipated that a single team will be used for week 1 and then a second team will be brought in for week 2. The two teams will take approximately 4 weeks excavating the new channel for the breach and infilling of the existing channel, with another week or so completing the infilling to finished level of the original channel. Each team would operate with 1 excavator, 1 dozer and 2 dump trucks. Support will be provided from a 4-wheel drive (or tracked) tractor & Op with a towable fuel bowser. The estimated overall numbers of staff and plan weeks involved in the works assuming an 11 week programme are shown in Table I2.

Table I2. Approximate numbers of staff and plant weeks

Week	Works	Team	Number of Staff	Number of Plant	Total Staff Weeks	Total Plant Weeks
Overall (based on 11 weeks)	Supervision	Site agent and engineer	2	0	22	0
Week 1	Site Set Up	Small team with excavator and dumper	3	2	6	4
Week 2	Temporary Sheet Piling	Small team with excavator and dumper Plant operator with Movac piling rig	4	3	4	3
Week 2	Access to spit and start excavation	One team excavating and filling	5	5	5	5
Week 3 - 10	Excavation and filling	Two teams excavating and filling	10	10	70	70
Week 11	Remove sheet piling and demobilise	Small team with excavator and dumper Plant operator with Movac piling rig	4	3	4	3
Total		111	85			

ARUN DISTRICT COUNCIL P/93/15/PL

I.5 Impact on the Highway Network

The proposed project will be constructed using material sourced on site and therefore there will be minimal vehicle movements during the construction period. These will be limited to vehicular movements generated through site set up and demobilisation and the movement of staff. The approximate number of plant that will be required during construction is small (Table I2) and once on site these plant will stay within the locality of the site and/or compound until no longer required.

The number of plant movements in and out of the site will therefore be very small (approximately 10 plant in and 10 plant out over the period of construction). Given the limited modes of sustainable transport to the site (see Section I.3.3), construction workers are likely to use individual cars as the most flexible mode of transport to and from the site each day. However, the number of staff involved in the construction of the project is relatively small, peaking to 10 individuals in weeks 3 to 10 of the programme (Table I2). Furthermore, the construction is anticipated to take place in the winter months and will avoid the nesting period for birds on site (April to July). The baseline traffic counts during the winter months are significantly lower than during the spring/summer months (Image I3). Taking all these considerations into account the impact on the local transport network during construction is considered to be insignificant.

Post construction, visitor numbers are anticipated to remain the same and within the range of existing and historic seasonal variability as no additional facilities (e.g. car park) will be developed that would attract further visitors from outside the area. The proposed project will reinstate the longshore supply of shingle to Pagham Beach (the beach has receded in recent years and is currently eroding). It will also reduce the high current flows of the existing inlet into Pagham Harbour that is currently located in front of Pagham Beach. The amenity and recreational value of Pagham Beach will therefore improve as a result of the proposed project in the short to medium term. However, this is not anticipated to significantly alter the overall number of visitors to the area compared to historic levels. Due to the location of a number of holiday homes in the area, it is expected that those already in the area may make use of the beach and therefore there will not be additional trips on the network. The overall impact on the local transport network to Pagham Beach post construction is therefore considered to be insignificant.

A new isolated bird island is proposed to be created within Pagham Harbour as compensation for the uncertainty associated with the potential impact on internationally designated birds (Image I6). This may provide an additional attraction feature at Pagham Harbour. However, it is assumed that there will be no additional trips on the network as a result of this island over and above those visitors that are already visiting the existing facilities at Pagham Harbour. The overall impact on the local transport network to Pagham Harbour post construction is therefore considered to be insignificant.

ARUN DISTRICT COUNCIL P/93/25/PL

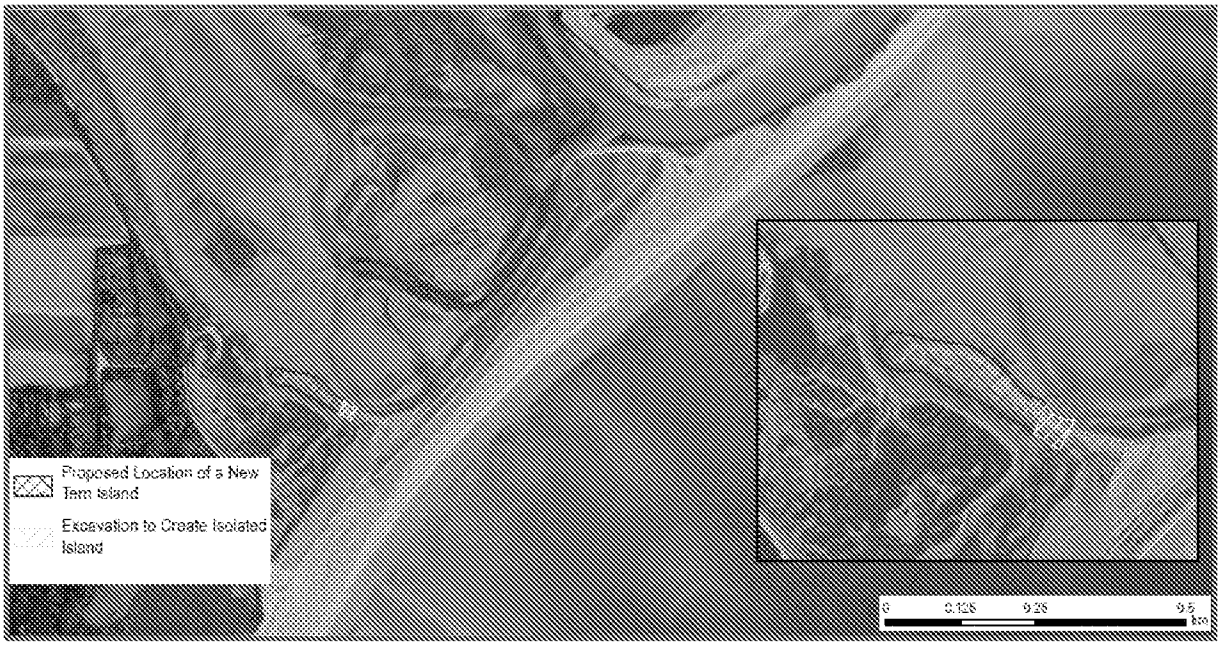


Image I6. Proposed location of New Tern Island

I.6 Summary and Conclusions

This Transport Statement considers the impact of the proposed project on the highway network. The proposed project will be constructed using material sourced on site and therefore there will be limited vehicle movements during the construction period associated with site set up and demobilisation and the movement of staff. The approximate number of plant and staff that will be required will be small and any increases in traffic will be temporary and minimal. There are unlikely to be any significant additional trips on the network post construction. The overall impact on the highway network is therefore considered to be negligible and the proposed project is considered acceptable in transport terms.

I.7 References

Arun District Council (ADC), 2014. Arun Local Plan 2011 – 2031 Publication Version October 2014. ADC, Littlehampton, 424p.

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ARUN DISTRICT COUNCIL P/93/15/PL

Appendix J

The Ecology of the DeFolin's Lagoon Snail

ARUN DISTRICT COUNCIL P/94/21/PL

Managed Breach of Shingle Spit at Pagham Environmental Statement

Volume 2: Appendices

Contents

Page

J. The Ecology of the DeFolin's Lagoon Snail 3
J.1 Records 3
J.2 Protection 3
J.3 Habitat and Feeding Ecology 4
J.4 References 6

Images

J1. DeFolin's lagoon snail 3
J2. Location of seep in mid-Fleet, just below the line of halophyte scrub (two sample locations shown (arrows added by ABPmer)) 5
J3. Close up of pebbles in a mid-Fleet seep area, showing open spaces between pebbles colonised by the bivalve Lasaea rubra 5

ARUN DISTRICT COUNCIL P/93/25/PL

J. The Ecology of the DeFolin's Lagoon Snail



(Source: Baldock and Bass, 2012)

Image J1. DeFolin's lagoon snail

J.1 Records

The DeFolin's lagoon snail (Caecum armoricum) is a very small gastropod, which measures only around 2mm long, and looks nothing like the more familiar sea snails with its curved test-tube like shell (see Image J1 above). The first UK specimen of this species was discovered on the Fleet in Dorset in 1987, on the landward side of Chesil Beach (Sussex Biodiversity Record Centre, 2009). It was long thought to only occur at the Fleet. It has since been discovered in at least three further locations, namely at Lydd Ranges (Dungeness), Church Norton Spit and Pagham Spit Lagoon Beach (Sussex Biodiversity Record Centre, 2009; Pain et al., 2009; Wilkinson and Baldock, 2013) (see baseline description in Section 8.1.4 of the ES for Pagham Harbour survey results).

It has been noted that these new records are unlikely to be a reflection of the species extending its range since its initial discovery in the Fleet; rather, it seems more likely that "the species is simply under-recorded in the UK and that more targeted searching of appropriate habitat is likely to reveal additional localities for the species" (Pain et al., 2009, p.780).

J.2 Protection

The DeFolin's lagoon snail was added to Schedule 5 of the (1981) Wildlife and Countryside Act in 1992, whereby it receives comprehensive protection under Sections 9.1, 9.2, 9.4 (a to c) and 9.5a. It is worth noting that, in 2013, the Conchological Society of Great Britain and Ireland (ConchSoc) suggested to downgrade the protection afforded to C. armoricum to Section 9(4) only, due to full protection hindering the recording and study of this species (sampling currently requires a licence from Natural England); as it is not considered at risk from collection. This does not mean, however, that ConchSoc considers that this species is not at risk of extinction through loss of its habitat (ConchSoc,

ARUN DISTRICT COUNCIL P/93/25/PL

2013). Protection would still be afforded in this respect by Section 9(4) of the Act ('places of shelter etc.').

The species is also considered to be nationally rare, and the habitat it is typically found in saline lagoon which is listed as a 'Habitat of Principal Importance' under S41 of the 2006 NERC Act.

J.3 Habitat and Feeding Ecology

Little is known of the ecology of this species. The snail resides in gaps between small pebbles (i.e. the 'interstitial') on the landward side of shingle ridges, in positions where seawater percolates into a lagoon. It is considered to be a sub-surface deposit feeder which likely consumes vegetable detritus as well as bacterial and diatom film (White, 2007).

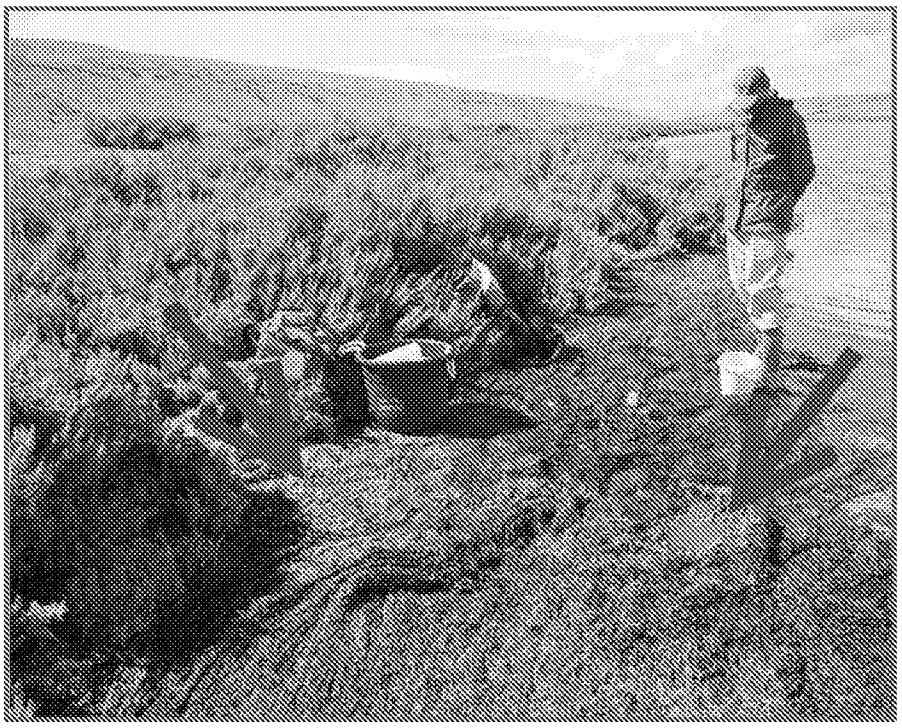
At the Fleet, a correlation has been found between slow flowing 'springs' or seeps through the shingle ridge and C. armoricum finds (Baldock and Bass, 2012). These seeps have been described as not being immediately obvious due to water not visibly flowing out. During a 2011 survey at the Fleet, they were also identified by the fact that they occurred in intertidal areas of the upper shore where the pebbles were not compacted by either fine or anaerobic sediment (at least not in the top 10cm). Pebbles at these seeps would shift easily underfoot, even though they would frequently be covered under a thick layer of dead Zostera leaves. Specimens would be located close to the halophyte shrub community[1], but not situated beneath the scrub itself (see Image J2). It was found that, at the Fleet, these seeps (n=2) supported vast numbers of the bivalve Lasaea rubra var pallida (100,000s m^{-2}) (see Image J3) and high densities of C. armoricum (up to 16,000m^{-2} (NB: extrapolated from cores)). The findings of the 2011 survey were considered to be consistent with research undertaken at Fleet in the late 1980s (Baldock and Bass, 2012).

Limited further insights into habitat preferences of the DeFolin's snail could be found. At Church Norton, samples taken during a 2007 survey were from habitat which consisted of small pebbles with patches of organic detritus just below the surface layer. This was located just below the High Water Springs line, although it was noted that 'a more detailed examination of the site would be needed in order to determine the vertical distribution of the species down the shore' (Pain et al., 2009; p.780). This seems to correlate with the findings at Fleet, where the species was observed at seeps below vegetation which typically establishes above the MHWS line. Thus, it is likely that the snail could be found below vegetated areas of the landward side of Church Norton Spit, and relatively high in the tidal frame (Figure 8.5 in the main Environmental Statement).

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[1] At Fleet, this was dominated by shrubby seablite (Suaeda vera) with an understorey of sea purslane (Atriplex portulacoides). In saltmarsh, these plants would typically be found in the upper and transitional zones, which are generally associated with the tide levels above the Mean High Water Springs (MHWS) and Highest Astronomical Tide (HAT) line respectively.

ARUN DISTRICT COUNCIL P/93/25/PL



(Source: Baldock and Bass, 2012)

Image J2. Location of seep in mid-Fleet, just below the line of halophyte scrub (two sample locations shown (arrows added by ABPmer))



(Source: Baldock and Bass, 2012)

Image J3. Close up of pebbles in a mid-Fleet seep area, showing open spaces between pebbles colonised by the bivalve Lasaea rubra

ARUN DISTRICT COUNCIL P/93/25/PL

The survey report for the 2013 survey at Pagham does not give any more insights into habitat preferences, merely stating that samples were taken from 'around high tide level', in locations where pebbles were loose and uncompacted, as well as relatively free of interstitial sand and fine sediment (Wilkinson and Baldock, 2013). As the 2007 survey had determined that DeFolin's snails occurred together with the gastropod mollusc Truncatella subcylindrica and the bivalve L. rubra, sample locations of the 2013 survey focused on areas of unconsolidated shingle where T. subcylindrica were found during a preliminary search. Interestingly, during the 2013 survey, the samples which contained live DeFolin's snails at Pagham Lagoon Spit, were found to also support high numbers of the bivalve L. adansoni (Wilkinson and Baldock, 2013), but not L. rubra, whereas at the Fleet, and during the 2007 survey at Pagham, a possible association was found with L. rubra (see above).

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ARUN DISTRICT COUNCIL P/93/15/PL

Appendix K

Review of Bird Disturbance

Managed Breach of Shingle Spit at Pagham Environmental Statement

Volume 2: Appendices

Contents

Page

K. Review of Bird Disturbance 3
K.1 Introduction 3
K.2 Bird Responses to Disturbance 3
K.2.1 Sub-dispersive responses 4
K.2.2 Dispersive and population impacts 5
K.2.3 Habituation and Other Compensatory Mechanisms 6
K.3 Disturbance Impacts due to Different Activities 7
K.3.1 Coastal Construction Work 8
K.3.2 Ports and Industry Operations 11
K.3.3 Recreation and other Human Activities 12
K.4 References 13

Tables

K1. Response level to activity 8
K2. Summary of Disturbance Studies 10

ARUN DISTRICT COUNCIL P/93/25/PL

K. Review of Bird Disturbance

K.1 Introduction

Human disturbance can be a major source of environmental pressure to migratory waterbirds in some temperate coastal regions (Lourenço et al., 2013).

There is a large amount of literature available on the subject and studies have demonstrated both behavioural and physiological effects of disturbance (Nisbet, 2000; Woodfield and Langston, 2004; Stillman et al., 2009). As a result disturbance impacts associated with human developments are now often considered in the planning process. Disturbance can be defined as any situation in which human activities cause a bird to behave differently from the behaviour it would exhibit without the presence of that activity (Oranjewoud, 1982).

Disturbance can cause birds to cease feeding which can decrease the total amount of time available for feeding as well as disrupting other behaviour such as breeding (Coleman et al., 2003; Martín et al., 2014). Where disturbance causes birds to take flight, it can increase energy demands and may increase food consumption by decreasing the available habitat area (Stillman et al., 2007).

Repetitive disturbance events can result in possible long-term effects such as loss of weight, condition and a reduction in reproductive success, leading to population impacts (Durell et al., 2005; Gill, 2007; Goss-Custard et al., 2006; Belanger and Bedard, 1990). Birds typically show a dispersive response to disturbance with prolonged disturbance causing displacement (Dwyer, 2010; Navedo and Herrera, 2012).

Disturbance often occurs through a combination of visual and noise stimuli simultaneously, although some occurrences may be through separate visual or noise stimuli (Wright et al., 2013). The effect of such disturbance is related to the frequency of the events and the status of the conditions that are prevalent (Liley and Fearnley, 2011; Coleman et al., 2003; Ruddock and Whitfield, 2007; Stillman et al., 2012).

This review initially discusses the responses waterbirds show to human disturbance and the potential short and long-term consequences of such disturbance (Section K.2). This is followed by a review of the disturbance response associated with a range of different activities (Section K.3).

K.2 Bird Responses to Disturbance

Foraging birds need to make a trade-off between energy intake and predator avoidance. This trade-off is particularly relevant to coastal waterbirds because their foraging time is often restricted by tides. Studies have shown that birds respond to a perceived threat from a predator and non-predatory human disturbance in a similar way (Frid and Dill, 2002; Femandez-Juricic, 2000).

ARUN DISTRICT COUNCIL P/93/25/PL

Foraging birds show a number of different responses to disturbance events. Birds initially show increased vigilance to threats perceived as low risk such as low level background noise. As perceived threat levels increase, birds begin to exhibit avoidance behaviour which can result in a flight response and dispersal from a site. Repeated disturbance may eventually lead to displacement from an area which may be permanent or temporary (Ferns et al., 2000; Stillman and Goss-Custard, 2002, Dwyer, 2010; Navedo and Herrera, 2012.).

The response to disturbance is dependent on a range of species and site specific factors. This includes the body weight and size of the birds, the size of the group in which they feed, distance to a roost of refuge, their previous experience of the disturbance (see Section K.2.3), their state at the time of the disturbance (e.g. hungry or satiated) and the quality of their alternative foraging sites (Gill et al., 2001a; Smit and Visser, 1993; Mullner et al., 2004; IECS, 2009a).

Birds will also vary their response to human activities depending on the type of the activity, the noise produced, the speed and randomness of approach, the distance to which the disturbance factor approaches and the frequency of disturbance (Burton et al., 2002., Rees et al., 2005).

It generally appears that birds are more easily disturbed by irregular human presence and predators such as dogs and raptors than the regular and defined presence of machinery, boats and other vehicles. The character of these activities is however also relevant. Smit and Visser (1993), for example, have indicated that regular and defined movements are less disturbing than erratic and random movements. Large groups of noisy people; the chaotic and high speed approach of dogs off of leads; aerial objects such as kites and small aircraft are all considered activities particularly likely to heighten the response of individuals (Smit and Visser, 1993; Beale and Monaghan, 2004a).

'Sub-dispersive' and 'dispersive' responses are discussed in greater detail in the sections below.

K.2.1 Sub-dispersive responses

Sub-dispersive behaviour is defined as the change in behaviour or increased vigilance which occurs prior to flight, when individuals are confronted with an approaching disturbance agent (Coleman et al., 2003). Studies have primarily focused on dispersive behaviour with relatively little research on 'sub-dispersive' effects of disturbance. Sub-dispersive responses to disturbance include heads up alert and avoidance running or swimming.

These responses can cause a reduction in time available for other important behaviours such as foraging, preening and resting (Burger and Gochfeld, 1998). Being vigilant at the cost of foraging can mean a decline in food intake and potentially health (Coleman et al., 2003). In addition, the increase in energy expenditure associated with increased stress and avoidance puts further pressure on individuals to meet their energy requirements (Ackerman et al., 2004). The temporal and energetic costs to individuals, associated with vigilance and avoidance behaviour, can be substantial if inhabiting a frequently disturbed area (Carless, 2005).

ARUN DISTRICT COUNCIL P/93/25/PL

K.2.2 Dispersive and population impacts

The perceived threat from some disturbance stimuli can cause a flight response in birds. For highly intermittent and low level disturbances, such dispersive reactions are only likely to evoke a short-term movement with birds typically rapidly resettling near the original location within a site. However, if the level of disturbance is such that the site becomes uninhabitable for individuals they may leave the site either temporarily or on a more permanent basis (Femandez-Juricic, 2000; Comelius et al., 2001; Navedo and Herrera, 2012.).

It has generally been assumed that birds which are displaced more frequently and which fly further and return to a site later, are most sensitive to human disturbance. However, it has also been suggested that birds which remain at the disturbance site or return quickly to it, may do so because of a lack of alternative sites, especially if they are territorial or experience high levels of interference competition (Gill et al., 2001a).

Theoretically, only if the costs of staying in a disturbed area (i.e. loss of feeding time and reduction in energy intake) outweigh the costs of relocating (i.e. energy expended when travelling, loss of feeding time, lower quality feeding area, increased competition), should individuals permanently or temporarily leave a site (Gill et al., 2001a).

As relocating to another area is potentially costly, researchers have frequently used dispersion response as an indicator of disturbance effects. Flight distance (the distance flown by birds when displaced from the site), the time taken after a disturbance event for the birds to return to the site and resume feeding and the flight initiation distance (FID, the distance at which a bird take flight in response to a perceived danger), have all been used to estimate the disruption of human activities to foraging birds (Smit and Visser, 1993; Stillman and Goss-Custard, 2002; Carless, 2005).

Generally birds aggregate in the better quality feeding areas. However, when such resources become unavailable, individuals may be displaced to lower quality sites, or to undisturbed feeding areas nearby (Gill et al., 1996; Gill and Sutherland, 2000). This can cause population impacts as increased competition can cause intake rates to decline as food is depleted, making individuals more vulnerable to starvation and predation (Yalden, 1992; Goss-Custard et al., 2001). Therefore, impact of disturbance needs to be measured in terms of its effect on population size, rather than simply in terms of behaviour (Stillman et al., 2007).

In migratory waterbirds, population size is a function of mortality rate and reproductive success in the breeding areas and mortality rate in non-breeding range (such as wintering grounds and migratory stop-over locations). The best measure of the impact of disturbance on population size is one which aims to determine these demographic rates (Stillman et al., 2008). For migratory shorebirds out of the breeding season, the population impact of disturbance is often measured using two key parameters; the storage of fat reserves needed to fuel migration in spring and to breed successfully after the birds have reached the breeding grounds, and the number of birds that die during the non-breeding season.

ARUN DISTRICT COUNCIL P/93/25/PL

Individual-based models based on fitness-maximizing individuals to predict storage and mortality rates have been used to link the behavioural responses to disturbance to population consequences. For example, Goss-Custard et al. (2006) used an individual-based behavioural model to establish critical thresholds for the frequency with which wading birds can be disturbed before they die of starvation.

The model was tested on oystercatchers in the baie de Somme, France where birds were put to flight by disturbance up to 1.73 times/daylight hour. The modelling results showed that the birds could be disturbed up to 1.0–1.5 times/h before their fitness was reduced in winters with good feeding conditions (abundant cockles and mild weather) but only up to 0.2–0.5 times/h when feeding conditions were poor (scarce cockles and severe winter weather).

Human disturbance can also impact on the breeding success of birds, which also has implications for populations (Leseberg et al., 2000). Flushing (i.e. taking flight) caused by disturbance, and the increased metabolic costs incurred as a result of stress can lead to a reduction in body condition. This can result in the desertion of nests, thus leaving eggs open to predation or cold temperatures; whilst a reduction in energy intake may prevent individuals from gaining sufficient energy to support both themselves and their young (Bolduc and Guillemette, 2003, Beale and Monaghan, 2004b; McClung et al., 2004).

K.2.3 Habituation and Other Compensatory Mechanisms

Waterbirds may have the ability to reduce the effects associated with human disturbance and associated reductions in energy intake. For example, individuals may extend their feeding period at the cost of other behaviours (Urfi et al., 1996) by feeding in supplementary feeding grounds (Velasquez and Hockey, 1992) or by feeding nocturnally (Goss-Custard and Verboven, 1993; Gill et al., 2001b; Lourenço et al., 2008). In addition individuals may change the timings of their feeding routine or increase their intake rate if not already feeding at their maximal rate (Carless, 2005). Waterbirds might also habituate (become accustomed) to repeated human activities regardless of an increase in their perceived predation risk.

For instance, a study on the Forth Estuary found that Redshank, Curlew, Oystercatcher and Shelduck in areas subject to higher levels of disturbance allowed a closer approach by humans than individuals of the same species in less disturbed areas, before becoming alert and moving away (Dwyer, 2010).

On the Exe Estuary and Exmouth Beach, Urfi et al. (1996) investigated disturbance to Oystercatcher from fishermen, raptors and experimental human disturbance. They found the distance at which birds took flight in response to activities (Flight Initiation Distances (FID)) to be significantly lower on a frequently disturbed site when compared to other, less disturbed, locations. The authors suggested that this was due to habituation to human presence within feeding grounds, and potentially a reason for a shorter reaction distance than Oystercatchers from the Delta and Wadden Sea Regions in the Netherlands (25.7m compared to 85m and 136m, respectively) (Smit and Visser, 1993).

Another study in the USA by Ikuta and Blumstein (2003) found similar results in a number of wetland bird species studied. Their results showed that between three locations subject to differing disturbance levels, FIDs were significantly shorter for all study species at the site which had the highest levels of

ARUN DISTRICT COUNCIL P/93/25/PL

human presence. Similar responses to regular disturbance have also been observed in other species (Burger and Gochfeld, 1983; Lord et al., 2001; Miller et al., 2001).

IECS (2009a) have suggested that birds will habituate to regular noise, typically below 70dB, but that they will be startled by sudden noises exceeding 50dB. Noise from construction (under 70dB(A)) and regular port vehicle or vessel movements are often tolerated more by birds than sporadic visits to a roost area (e.g. maintenance workers).

The demonstration that birds from disturbed sites show a higher tolerance to human presence and activities strongly suggests that birds are able to habituate to regular disturbance. However, it is recognised that proof of this habituation requires successive measurements of tolerance levels within the same group or individuals (Nisbet, 2000).

K.3 Disturbance Impacts due to Different Activities

A range of human activities take place in the coastal zone that may cause disturbance to coastal birds. Increasing urbanisation of coastal sites can result in increased disturbance, either due to construction or as a result of increased recreation and human presence (Burton et al., 2002).

In general, human presence on the foreshore (e.g. walking) is considered to cause greater disturbance than vehicles or watercraft (Glover et al., 2015; McLeod, et al., 2013; Guay et al., 2014; IECS, 2009a). For example, McLeod et al. (2013) conducted 730 experimental approaches to 39 species of waterbird, using five stimulus types (single walker, three walkers, bicycle, car and bus) selected to mimic different human management options available for a controlled access, Ramsar-listed wetland. Across species, where differences existed (56% of 25 cases), motor vehicles always evoked shorter FID than humans on foot. In a study investigating recreational canoeing related disturbance, canoes were found to evoke shorter FIDs compared with walkers (Glover et al., 2015).

Predictability and randomness is a factor of vessel traffic which may explain variation in waterbird response. Literature also suggests that vessels consistently using defined routes (such as ferries or cargo ships) elicit less of a disturbance response than recreational craft which are more unpredictable in terms of speed and course and thus their disturbance potential for birds may be enhanced (Rodgers and Schwikert, 2002; Burger, 1998; Schwemmer et al., 2011).

Overall, responses to construction noise and activity appear to initiate similar or less disturbance than that of human presence on the foreshore (e.g. recreation). For example, while some localised disturbance was caused as a result of piling activity as part of the construction work for ABB Power Generation Ltd (Pyewipe), this was not considered to have a major effect on surrounding bird populations and was found to be no greater than the effect arising from third party disturbance, including walkers and stopped cyclists, which were unrelated to the work carried out by ABB (ERM, 1996).

Lower levels of disturbance for construction activities compared with other nearby human activity was also observed during bird monitoring as part of the marine licensing consent for a quay wall construction development at the Port of Southampton. The study evaluated the disturbance effects of the extension work on waterbird species using the mudflat habitat on Bury Marsh opposite the Port of

ARUN DISTRICT COUNCIL P/93/25/PL

Southampton during the overwinter period.No bird disturbance behaviour (such as startling, rapid flight or abruptly stopping foraging) was observed during periods of percussive piling activity. However, disturbance to waterbirds was observed on several occasions due to vessels and kayaks within 50m of Bury Marsh (ABPmer, 2013).

The greater effect of human presence as opposed to general construction works and machinery is also supported by IECS (1997), in that a person approaching feeding birds on the mudflat caused birds to fly when the person was approximately 300m from the birds, whereas machinery could approach birds up to 50m before the birds moved away.

A number of studies have discussed and attempted to quantify the effects of such activities. In particular, comprehensive reviews of bird disturbance from a range of sources have been carried out by IECS (2009a) and as part of the Solent Disturbance and Mitigation Project (Stillman et al., 2009; Liley et al., 2010).

Response levels to different activities based on the review by IECS (2009a) are summarised in Table 1. The disturbance effects associated with different activities are discussed in more detail below. Section K.3.1 summaries information on coastal construction work, Section K.2.2 the operational phase of ports and other coastal developments and Section K.3.3 discusses disturbance associated with recreation.

Table K1. Response level to activity

Response Level	Activity
High	Jets (particularly low flying) Subsonic transport aircraft Free running dogs within 100m
High - Moderate	Irregular construction noises above 70dB (A)
Moderate	Shooting, (wildfowling and military) Recreational activity, (walking, running, dogs), within 100m Boat disturbance within 100m Regular construction noises 50-70dB (A)
Low	Recreational activity, (walking, running, dogs), outside 100m Noise below 50dB (A)

(Based on: IECS, 2009a)

K.3.1 Coastal Construction Work

Construction activity in the coastal zone may lead to disturbance which has the potential to cause a reduction in foraging activity as well as temporary displacement from a localised area around the works (Burton et al., 2002)

Studies into the distances from activities that evoke a disturbance response (or 'Flight-initiation Distance' (FID)) suggest that for most coastal construction, displacement behaviour is not typically observed when activities occur more than 200-250m away from a source (ABPmer, 2002; Ruddock and Whitfield, 2007; IECS, 2009a; Scott Wilson, 2009; IECS, 2009b; Dwyer, 2010). Despite variation in sensitivity between species and disturbance types, no activities elicited a flight response in birds

ARUN DISTRICT COUNCIL P/93/25/PL

present more than 250m from the source. As discussed previously in the above section, disturbance due to construction activities has been shown to cause similar or less disturbance than that of other nearby activities (such as human presence on the foreshore or water) (ERM, 1996; ABPmer, 2013; IECS, 1997).

Construction techniques which are known to cause loud source noise levels (such as piling) have been the subject of a number of disturbance monitoring studies which have investigated the relationship between activity source levels and the disturbance responses elicited by birds (IECS, 2009a; Xodus, 2012; Wright et al., 2013; ABPmer, 2002). Research suggests that irregular construction noise at levels typically above 70dB can cause behavioural responses in some waterbird species with flight responses generally occurring above 80dB (Table 2). However, responses of birds will be dependent on a range of site specific factors including ambient (background) noise levels, time of year, levels of existing activity and the species assemblage.

Birds generally appear to habituate to continual noises as long as there is no large amplitude 'startling' component (Hockin et al., 1992). With specific respect to piling, it has been concluded that although piling has the potential to create most noise during construction; it often consists of rhythmic "bangs", which birds are likely to become accustomed to after a short period (ABP Research, 2001). For example, observations as part of the construction work for ABB Power Generation Ltd (Pyewipe) suggested that it was the initial sudden bang during piling activities, which caused some localised disturbance, and that subsequent bangs typically resulted in reduced disturbance, demonstrating habituation (ERM, 1996). Habituation is discussed in greater detail in Section K.2.3.

ARUN DISTRICT COUNCIL P/93/25/PL

Table K2. Summary of Disturbance Studies

Study	Summary
IECS, 2009a; IECS, 2009b	A study of coastal construction noise effects on the Humber Estuary was undertaken based around the measurement of noise levels while simultaneously monitoring the behavioural response by birds during flood defence works at Saltend. The defence works involved the use of a double hydraulic pile on site. The study noted a moderate to high behavioural response to irregular piling noise above 70dB and a moderate response to regular piling noise below 70db. A flight response was noted to occur during works generating noise at between 80-85dB. Behavioural responses, notably the down-shore movements of wildfowl were noted above 70dB. Noise levels between 55dB and 84dB were generally accepted by birds. Other impacts associated with construction included a high response to personnel and plant equipment on the mudflat and a moderate to high response to personnel and plant equipment on the seaward toe and crest. Occasional movement of a crane jib and load resulted in a low to moderate response. Noises below 50dB, long-term plant activities only on the crest and activity behind the flood bank elicited a low response.
Xodus, 2012	Monitoring of birds as part of the Grimsby River Terminal Project found that noise from construction (including piling) caused only 1% of the disturbance events observed, with large disturbances mainly caused by the presence of raptors, aircraft and helicopters. The study concluded that percussive piling noise less than 66 dB $_{LAmax\,F}$ gave rise to no disturbance, whilst a mild behavioural response (such as heads up alert, short walk or swimming) was observed to occur in the range of 73-81 dB $_{LAmax\,F}$. Percussive piling noise over 83 dB $^{LAmax\,F}$ was considered likely to evoke a flight response.
Wright et al., (2013)	The experimental study intentionally disturbed birds at a high tide roost site, on the south bank of the Humber estuary using an impulsive sound similar to that associated with noise from port and power generation construction such as percussive piling and recorded the behavioural responses. Lapwing appeared to be the species most sensitive to intentional disturbance, while Curlew was the most tolerant. The study recommended that impulsive noise limits should be restricted to < 69.9dB at the site.
ABPmer, 2002	Disturbance monitoring of waterbirds in the vicinity of construction works (piling and dredging) at the ABP Teignmouth Quay Development concluded that sudden noise in the region of 80dB appears to elicit a flight response in waders up to 250m from the source, with levels of approximately 70dB causing flight or anxiety behaviour in some species.

ARUN DISTRICT COUNCIL P/93/25/PL

K.3.2 Ports and Industry Operations

The operational phase of ports and other coastal developments also provides a source of potential disturbance in the coastal environment. Waterbird monitoring work in the vicinity of port locations has generally recorded limited evidence of birds on nearby intertidal habitat being disturbed through regular land side port operations (such as the movement of cranes and cargo containers) (ABPmer; 2015a; ABPmer; 2015b; ABPmer, 2013; ABPmer, 2010).

Vessel movements and human presence around pontoons and jetties has the potential to cause a regular and often sustained source of visual and noise disturbance stimuli to birds on nearby foreshore habitat. However, empirical studies to try and quantify both short term disturbance and more permanent displacement effects due to vessel movements and human activity around port and other operational jetties and pontoons are generally limited due to a lack of long-term monitoring studies. As far as is known, only one such recent study has monitored waterbird disturbance at an operational port pontoon facility. This two year monitoring project was undertaken on the Dee Estuary from October 2013 to March 2014 and then from July 2014 to March 2015 (ABPmer, 2015b). This pontoon was put in place to support the development of offshore windfarms in Liverpool Bay. The adjacent foreshore (located within approximately 25-125m of the pontoon facility) provides feeding and roosting habitat for good numbers of Redshank and moderate numbers of Oystercatcher.

A large number of activities were observed on the pontoon during the monitoring period which had the potential to cause bird disturbance. Regular activities on the pontoon facility, such as vessel movements and equipment deliveries, were recorded in approximately half of the counts. Periods of highest vessel activity generally occurred outside of low water periods (when water levels become suitable to navigate through the Inner Channel). The number of vessels using the pontoon was typically one to three vessels with up to nine vessels during the busiest periods. Also activities unrelated to the pontoon facility were regularly recorded during the counts. These 'background noise sources' included those created by nearby construction, a helicopter overflight and dredging vessel movements.

Throughout the majority of counts, no or very little reaction from birds was observed even though there were activities on the pontoon and elsewhere during the majority (>90%) of the counts. Disturbance events in the area only occurred relatively infrequently. When disturbance was observed, events were generally low reaction with birds typically showing mild behavioural changes (such as increased vigilance, avoidance walking and short flights) before rapidly resettling and resuming feeding.

Large disturbance events which caused a stronger reaction in birds (i.e. flying out of the area) were only recorded occasionally, mainly due to noise elsewhere in the area or atypical movements or thruster noises when vessels were docked into the inner berths (closest to the mudflats).

There was also no consistent evidence of changes (reductions) in waterbird abundance which could be linked to the pontoon. In particular, no clear effect was observed during the passage period when it might be expected that transitory birds would be less likely to be habituated to pontoon activities (ABPmer, 2015b).

ARUN DISTRICT COUNCIL P/93/25/PL

K.3.3 Recreation and other Human Activities

Understanding the effects of human disturbance on wildlife has become increasingly important over recent years, as an increasing number of people participate, more frequently and for a greater proportion of the year, in outdoor recreational activities in coastal areas (Navedo and Herrera, 2012). Recreational activities which have the potential to cause disturbance to coastal birds include land based activity on the foreshore such as walking as well as water based activity such as powerboats, kayaks and jet skis.

Literature suggests that waterbirds generally show a flight response to walkers on the foreshore at approach distances of between 20m and 100m. However, distances over 200m have been recorded for some sensitive species (McLeod, et al., 2013; IECS, 2009a). Most disturbance events from recreational watercraft, vessels and ecotourism boats occurs within 50-100m of the foreshore with vessels approaching at faster speeds and out of defined channels eliciting higher disturbance (Chatwin et al., 2013; Rodgers and Schwikert, 2002; Bellefleur et al., 2013; Burger, 1998; Schwemmer et al., 2011).

The location and nature of recreational activities on the shoreline is a key factor in determining the disturbance responses of waterbirds. A detailed study of recreational disturbance was undertaken across the Solent involving a series of field surveys between December 2009 and February 2010 (Liley et al., 2010). In total, 420 hours of field work was undertaken at 20 locations in the Solent with 44 different bird species (including waders, ducks, geese, herons, cormorants, divers, grebes and rails) being recorded.

Of 5,405 observations of human activities, 50% were considered to cause no disturbance (where they were located more than 200m from birds) and of the remaining 2,507 'potential disturbance events' (within 200m of the birds) it was found that around one in five (495 events) resulted in an observable disturbance effect (i.e. a change in behaviour of birds within 200m) (Liley et al., 2010).

Disturbance reactions included birds simply becoming alert (4% of observations); walking or swimming away (3%); a short flight of less than 50m (2%) or a major flight (8%). Where these reactions were observed most (40%) were due to activities on the intertidal while 25% were water-based activities and 12% were shore-based movement. The vmajority of disturbances observed were due to dog walkers with at least one dog off the lead (involving over half of all intertidal and 27% of disturbance events involving major flight). The second most common source of disturbance was walkers (Liley et al., 2010).

Overall this study indicated that the majority of recorded human activities taking place on the coast (even where they encroached within 200m) did not result in a disturbance event and where effects were recorded they were mainly due to activities on the intertidal or the water.

ARUN DISTRICT COUNCIL P/93/25/PL

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ARUN DISTRICT COUNCIL P/93/25/PL

Appendix L

Little Tern Habitat Creation and Management Review

ARUN DISTRICT COUNCIL P/93/21/PL

Managed Breach of Shingle Spit at Pagham Environmental Statement

Volume 2: Appendices

Contents

Page

L. Little Tern Habitat Creation and Management Review 3
L.1 Introduction 3
L.2 Improving Established Nesting Areas 3
L.3 Habitat Creation and Restoration 5
L.4 References 9

Table

L1. Examples of recharge projects which have benefited Little Terns in the UK 8

Image

L1. Medmerry Realignment showing 4 shingle islands inside the site (7 July 2014) 6

ARUN DISTRICT COUNCIL P/93/25/PL

L. Little Tern Habitat Creation and Management Review

L.1 Introduction

In the UK, Little Terns nest in shallow scrapes on sandy or bare shingle beaches, spits or inshore islets. As these well-camouflaged nests are in a relatively open landscape, it helps maintain visual contact between chicks and returning adults, and provides the opportunity of plenty of forewarning of approaching predators or potential human disturbance events. Unfortunately, quality habitat of this type is threatened due to increased human disturbance, loss to coastal erosion or increased presence of predatory species (Allcorn, 2003; Ratcliffe et al., 2008).

The review of Little Tern has been undertaken to better understand what can be achieved with respect to the protection, management, restoration and creation of effective little tern breeding habitat. This information is needed to understand the levels of confidence that can be placed in any mitigation/compensation measures that are undertaken as part of the proposed community project at Pagham.

This Appendix has been split into two discrete sections.

- Section L.2 discusses techniques to improve the quality of established nesting areas and enhance the reproductive success of breeding Little Terns at these existing locations; and
- Section L.3 focuses on the techniques that exist to create and restore the habitat used by breeding Little Terns.

L.2 Improving Established Nesting Areas

The productivity of established nesting areas can be improved through a wide variety of different management techniques, including:

- Limiting Access to a Nesting Colony: The exclusion of disturbance sources and predation from a designated area is a commonly used technique to help protect nesting birds (Ikuta and Blumstein, 2003; Devney and Congdon, 2009). Exclusion areas at many Little Tern colonies have evolved from simple roped off areas to more sophisticated mesh electric fencing in pens in recent years. Individual nest cages have also proved useful at colonies where ground predation is high. For example, nests have been protected on Lindisfarne since 1993 where Oystercatchers were the primary predators and this site has maintained a 100% success rate since implementation (Denbighshire County Council Countryside Service, 2014; Allcorn, 2003).

- Surveillance: The use of wardening schemes and cameras to identify intruders (predators or human) entering zoned off areas. The presence of full-time and/or volunteer wardens to protect the area is considered essential for the protection of eggs at most UK colonies. Several sites such as North Denes (Norfolk) and Chesil Beach (Dorset) undertake surveillance around the clock both day and night. Other colonies such as the little Tern colony in Gronant Dunes

ARUN DISTRICT COUNCIL P/93/25/PL

(North Wales) use trail camera technology to monitor predators at night (RSPB, 2010; Denbighshire County Council Countryside Service, 2014).

- Predator and Competitor Control: The control of a predator or competitor from an area through various measures. This includes diversionary feeding of predators. This measure has been tested on kestrels to reduce predation at the North Denes colony (RSPB, 2010). Efforts in the United States have often focused on the systematic removal of gull nests. This is partly to reduce predation but also to limit the competition between terns and gulls for nest sites. Averse conditioning has also been successfully used to reduce raven predation on a Californian tern colony. The ravens were fed methiocarb-treated quail eggs that caused them to feel ill. The ravens, once aversively conditioned, defended their territories and prevented non-conditioned ravens from taking tern eggs (Allcorn, 2003).

- Flood protection: In order to help manage severe storm and flooding events the colony area can be 'banked' with sandbags to prevent the water reaching the nests. However, in larger colonies, this may not be practical to implement for the whole site. Small areas may be isolated from rising waters by either blocking or boxing individual nest scrapes or by raising the nest artificially (on a non-erodable structure) for the period of the inundation. Alternatively, the eggs may be removed from marked nest scrapes and returned when the tide has receded (Haddon and Knight 1983).

- Education and Local Community Engagement: The use of wardens, codes of conduct and signage to modify human behaviour is used around many UK tern nesting sites. This can be achieved through signs at the access points on to the beach or at the colony itself, or in media releases and local contact from paid staff and community volunteers. Research evaluating the influence of human disturbance on the nesting success of Little Tern found that individuals were 34 times more likely to succeed when warning signs and wardens were used (Medeiros et al., 2007).

- Vegetation Clearing: Spits and beaches are successional habitats, regularly scoured clear of encroaching vegetation and subject to the natural renourishment of the substratum. However, vegetation clearing by wardens may be required if changes in local hydrodynamics prevent natural clearing of vegetation or shingle islands are located in sheltered areas or at elevations which prevents natural clearing of vegetation.

- Chick Shelters: The provision of chick shelters has been documented as a potentially useful tool to increase the survivorship of young chicks. The introduction of cover into the colony creates a refuge from predators and shelter from inclement weather and sand storms. Various trials have been conducted at colonies around the UK with the use of a camouflaged plastic piping one of the most effective methods trialled. This type of shelter for example is used throughout most of the colonies in Norfolk (RSPB, 2010).

- Decoy Models: The use of decoy models of adult terns has been successfully shown to attract terns to degraded or new sites (Kotliar and Burger, 1984). For example, more than 100 models of Little Terns were made in 2015 through a community initiative with the aim of attracting little Terns to various sites in Langstone Harbour.

ARUN DISTRICT COUNCIL P/93/25/PL

Declines in Little Tern abundance were first recognised in the UK in the 1960s. In response, protective management techniques started to be developed and by 1967 it is estimated that 19% of UK colonies had part time wardens with low-intensity management efforts including some perimeter fencing, the erection of information signs and attempts to inform and educate the public. Since the 1970s the majority of British Little Tern colonies have received some form of active management with larger sites employing a range of high-intensity measures such as electrical mesh fencing, 24 hour wardening and education programmes. Many of these measures have been highly successful with productivity more than doubling at some sites (Pickerell, 1998). However, Little Tern numbers still continue to show a long term decline in the UK (JNCC website, accessed April 2015).

L.3 Habitat Creation and Restoration

The restoration of existing degraded habitat or creation of suitable new habitat through strengthening and stabilising of beaches or the creation of islets has been used widely for a range of tern species both in the UK and abroad. This includes:

- The use of rafts in sheltered harbours and estuaries covered in suitable substratum such as gravel, sand or shingle (Dunlop et al., 1991);
- The creation of a new island habitat feature for terns (Burgess and Hirons, 1992; Fasola and Canova, 1996);
- The addition of suitable nesting substratum to an existing beach, spit or island features not currently used as a nesting site by terns (Pakanen et al., 2014; Allcorn, 2003); and
- The addition of suitable nesting substratum to enhance existing colonies (Langstone Harbour Board, 2013; Langstone Harbour Board, 2014; Allcorn, 2003).

Newly formed islands and rafts have the potential to provide higher quality habitat than nearby natural habitat. This is because they are initially vegetation free, usually lack mammalian predators and their inaccessibility will often limit human disturbance. This could reduce the need for other measures such as fencing and wardening (Burgess and Hirons, 1992; Erwin et al., 2001; Dunlop et al., 1991).

Whilst construction of islands may be prohibitively expensive in some cases, it may be possible to successfully integrate it with coastal defence recharge (the introduction of additional sediment to the foreshore) and port dredging work (Ratcliffe et al., 2008). For example, Pakanen et al., (2014) compared Little Tern breeding success (nest and hatching success) between natural habitat (sandy beaches) and artificial port habitat at Bothnian Bay, Finland from 2006 to 2011. The port habitat consisted of dredged and translocated material (silt, sand and small stones) that was being used as part of a land reclaim project for future port developments. Nest success was found to be higher in the artificial habitat (82 %), than in the natural habitat (58 %). The study concluded that artificial habitats can be very productive breeding sites for habitat deprived tern populations, but management should focus on improving both natural and artificial habitats.

In the UK there is little evidence of islands having been created specifically for Little Terns although the use of recharge material added to existing beaches or spits has generally been successful in attracting breeding pairs. Some recharge projects have focused on reducing flood risk at existing colonies while other projects that have been implemented as part of more general flood defence schemes have

ARUN DISTRICT COUNCIL P/93/25/PL

attracted little Terns more opportunistically. Examples of recharge projects which have benefited Little Terns are provided in Table L1.

Islands created as part of the Medmerry Managed Realignment site in West Sussex were designed to provide breeding and roosting habitat for a range of waterbirds including Little Terns (Image L1). The agreed design allowed for a maximum of four islands, due to cost and construction difficulties and a concern that any additional area above HAT reduced the total area of intertidal habitat (183ha) that could be created as an objective for the scheme. However, during the construction works, a number of opportunities for additional islands were identified with a further eight islands built at three locations. The islands used shingle surfacing with a mixture of shingle, graded through 4 mm to 100 mm, but with a high proportion of finer materials to an average depth of 0.3m to specifically attract Little Terns to the islands.



Image L1. Medmerry Realignment showing 4 shingle islands inside the site (7 July 2014)

The following factors were highlighted in reviews by Allcorn (2003) and Fasola and Canova (1996) as desirable attributes of islands and other habitat creation schemes for Little Terns:

- Location: As a response to predation and disturbance, terns prefer isolated areas. Islands further away from the mainland promote the best opportunity as access by mammalian predators may be eliminated and even avian predation may be reduced if the colony is isolated sufficiently. Sheltered areas will reduce flooding and erosion risk. The positioning of colonies away from popular public access points will also help reduce disturbance from humans. It is also important that the site is within foraging range of suitable feeding areas otherwise terns may either fail to colonise the site or experience breeding failures (Holloway 1993, Perrow, 2003). Little Terns have very short foraging ranges compared to other seabirds, with most prey obtained from within 5 km of the colony and 1 km of the shore (Bertolero et al., 2005; Perrow et al., 2006).

ARUN DISTRICT COUNCIL P/93/15/PL

- Vegetation Cover: Reduced vegetation cover (less than 30 %) and sward heights less than 20 cm should be maintained (Fasola and Canova, 1996).

- Substratum: Sediment particle size is of primary importance for the success of a colony. Good coarse sand (construction grade) or beach quality sand, containing small pebbles and shells is preferable (Gochfeld 1983). A high proportion of silt, clay and fine sand may create areas of standing water after rain or high tides resulting in flooded nests, drowned or cold chicks (Gochfeld, 1983).

- Size and Profile: Fasola and Canova (1996) stated that small bare islets of 0.1-0.8 ha should be created, although larger islands may also be used, especially the spits at the ends of these islands. Topographically, an elevation of >3m is preferred, producing a profile with rounded peaks of deposited materials with gentle slopes running down to the water. The island must have enough space to provide breeding room above the anticipated high tide mark or for refuge from inundation. Terns also prefer not to roost or nest in areas in which their view is obscured.

- Shape: While shape is not considered to be as critical as location or substratum composition, evidence suggests that kidney-shaped islands, orientated towards the prevailing currents, may be less susceptible to erosion than more circular or elongated islands (Allcorn, 2003).

ARUN DISTRICT COUNCIL P/93/25/PL

Table L1. Examples of recharge projects which have benefited Little Terns in the UK

Site Name	Authority	Project Details	Lessons of the Project
Langstone Harbour (Bakers Island and Oysterbeds)	RSPB	In total, 378 tonnes of shingle was added to Bakers Island in 2014, including a fine sediment top layer which is attractive as nesting habitat for Little Terns in particular. This work resulted in the height of the shingle ridge on Bakers Island being increased by approximately 70cms. In addition to the work on Bakers Island, 100 tonnes of shingle was added to the bunds at the Oysterbeds.	A total of 31 pairs of Little Tern nested in the harbour in 2014, with all but four of these pairs choosing to nest upon the areas of recharged shingle. At least 28 young fledged (the 4th highest productivity in the harbour since 1979).
Langstone Harbour (South Binness Island)	RSPB	In March 2013, the western ridge of South Binness island was recharged with approximately 750 tonnes of sand and shingle in order to raise the nesting area and protect it from overtopping during large spring tides and storm surges.	At the South Binness site Little Terns had laid 26 eggs in 17 nests by 10th June but by 26th June 2013 the colony had been abandoned completely, probably as a result of avian predation. However, the recharged shingle ridge at South Binness remained a much safer height above the tide all year round and it is hoped the site will be used in future years.
Foreshore recharge and habitat creation in the Blackwater estuary.	Environment Agency.	Harbour dredge arising's from Harwich and Felixstowe were moved to the Blackwater Estuary between 1998 and 2002 as part of a coastal defence scheme. In total, 100,000m^3 of gravel recharge material was placed in the intertidal zone to provide short-term protection for the Old Hall Marshes nature reserve.	Blackwater Little Terns are quite nomadic and opportunistic. Little Terns were recorded using areas of recharge in numbers over 100 pairs.
Stone Point, Hamford Water	Unknown	Stone Point is a spit of land that runs from Walton On Naze to the entrance of Hamford Water. The purpose of the recharge was to slow down coastal erosion as the spit is seen as one of the defences for the saltmarsh within the National Nature Reserve. The recharge was in the region of 200,000 tonnes and was placed as a long strip from one end to the other about 2 metres high and 12 metres wide. The recharge took place between January and April 1999.	Before the recharge there were 8 to 10 pairs using the site. In 1999, this increased to 15 pairs and numbers then stayed approximately the same in subsequent years.
Foulton Hall Point, Hamford Water	Unknown	The recharge at Foulton Hall was put in place during September 1999. During the following winter, the recharge migrated both north and south and added to the beaches that terns favour.	In 2001, numbers went up to 30 pairs and to 34 pairs in 2002. Before the recharge took place, the colony was highly susceptible to flooding. Although a few nests continue to be still lost, since the recharge the extra sand has given the birds more room to use above the high tide mark.

ARUN DISTRICT COUNCIL P/93/25/PL

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ARUN DISTRICT COUNCIL P/93/15/PL

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