The Sizewell C Project

6.14 Coastal Processes Monitoring and Mitigation Plan

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Sizewell C Coastal Processes Monitoring and Mitigation Plan (DCO Requirement 7A and Marine Licence Condition 17)

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Version and Quality Control

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List of abbreviations and technical terms

Abbreviation	Explanation
ASV	Autonomous Survey Vessels
BEEMS	British Energy Estuarine & Marine Studies
BLF	Beach Landing Facility
CDO	Combined Drainage Outfall
DCO	Development Consent Order
DML	Deemed Marine Licence
DSM	Digital Surface Model
DWR	Directional Waverider
EA	Environment Agency
EDF	Électricité de France
EIA	Environmental Impact Assessment
ES	Environmental Statement
ESC	East Suffolk Council
EU	European Union
FRR	Fish Recovery and Return
HCDF	Hard Coastal Defence Feature
HPC	High-Performance Computer
JNCC	Joint Nature Conservation Committee
LiDAR	Light Detection and Ranging
MBIF	Marine Bulk Import Facility (*formerly Temporary BLF*)
MCA	Maritime and Coastguard Agency
MHWS	Mean High Water Springs
ML	Marine Licence
MMO	Marine Management Organisation
MTF	Marine Technical Forum
NE	Natural England
NVC	National Vegetation Classification
ODN	Ordnance Datum Newlyn
RGB	Red Green Blue
RLS	Radar Level Sensor
RPA	Remotely Piloted Aircraft
RTK-GPS	Real-Time Kinematic - Global Positioning System
SAC	Special Area of Conservation
SCDF	Soft Coastal Defence Feature
SMP	Shoreline Management Plan
SPA	Special Protected Area

SSSI	Site of Special Scientific Interest
SZB	Sizewell B
SZC	Sizewell C
SZCPR	Sizewell Coastal Processes Radar
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
VIWB	Virtual Inshore Wave Buoy
White ribbon	The gap around the low tide mark commonly observed between topographic and bathymetric surveys. On maps this appears as the uncoloured band between surveys, hence the name.

Executive summary

This report is Revision 2 of the draft Coastal Processes Monitoring and Mitigation Plan (CPMMP) for:

- detecting and reporting impacts of Sizewell C's marine components and activities on coastal geomorphology receptors, both inside and outside of designated conservation sites, and
- monitoring and, where necessary, implementing future mitigation to: (a) maintain the longshore shingle transport corridor, thereby minimising or avoiding impacts of an exposed hard coastal defence feature (HCDF), and (b) restore any persistent depressions from the Beach Landing Facility (BLF) grounding pocket (operation phase only) on the outer longshore bar if there are shoreline erosion concerns.

This second version of the CPMMP has been updated to account for design changes set out in the ES Addendum (NNB Generation Company (SZC) Limited, 2021a), three meetings[1] with the statutory members of the coastal geomorphology subgroup of the Sizewell Marine Technical Forum (MTF[2]) and written feedback from MTF members.

This draft CPMMP pertains to the monitoring and mitigation of any potential significant effects on coastal geomorphic features (receptors). However, monitoring is also proposed where it is standard procedure (i.e., scour), where there is uncertainty in predicted impacts, and/or where uncertainty in impact extent could overlap with a statutory designated site. The *annual vegetation of drift lines* habitat (Annex I, habitat type 1210 of the EU Habitats Directive (CD92/43/EEC)) would also be monitored under this plan because it is dependent on coastal geomorphology (i.e., supra-tidal shingle) and is easily monitored using similar measurement techniques.

The SZC components that are considered to require coastal geomorphology monitoring, along with the proposed method and rationale are summarised in Table i.

The suite of monitoring methods that would be used to track changes in coastal geomorphic receptors and annual vegetation, including impacts arising from SZC pressures and activities, is provided in Section 2. The methods combine the use of continuous remote sensing techniques for early warning of any impacts with targeted, high-accuracy, field surveys. Some new methods are under evaluation – if suitable they will be included in the CPMMP submitted to the MMO and ESC for approval prior to the commencement of construction of the HCDF/SCDF.

Sections 3 – 6 contain the rationale and monitoring frequency for the SZC components that would be built in the marine environment as part of SZC construction. Specifically, the offshore cooling water infrastructure, nearshore outfalls, and the beach landing facilities. An additional Section 6 has been introduced in this version to cover monitoring for the Temporary discharge outfall during the construction phase.

Section 7 pertains to monitoring and mitigation to maintain the shingle transport corridor along the SZC frontage. The monitoring plan in this section differs from the previous sections because it:

- employs *background monitoring* as a watching brief on the slow erosion of the SCDF;
- checks the beach volumes against a threshold trigger;
- initiates mitigation activity to maintain a continuous shingle beach along the SZC frontage, if triggered; and

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[1] September 2020, March 2021 and July 2021.
[2] The formal regulatory members of the MTF are the Marine Management Organisation (MMO), East Suffolk Council (ESC), Natural England (NE) and the Environment Agency (EA).

- undertakes performance assessment on all mitigation activities.

Section 7 has also been updated in this CPMMP version to reflect the findings of BEEMS Technical Report TR544, which sets out a vision for mitigation based on triggers (defined principally by beach volume, but with scope for refinement with additional factors such as crest level or shoreline orientation) that are determined by reference to storm erosion volumes. This version of the CPMMP updates the proposals for design and configuration of the SCDF and proposes a structured Adaptive Environmental Assessment and Management [AEAM] process i.e., using evidence from performance assessment to adjust triggers or mitigation actions over time to account for uncertainties. A document of this nature cannot anticipate with certainty all the consequences of ongoing R&D effort, or of future developments in environmental policy, in specifying present requirements for the conduct of surveys. The account therefore provides details on established approaches accompanied, where appropriate, by novel methodologies which will be employed. The CPMMP will also be updated at appropriate intervals to incorporate significant improvements to current practices arising from such developments as part of the AEAM process.

Section 7 sets out a Beach Management Framework including an initial determination of the mitigation trigger (Section 7.3). This also considers how the AEAM strategy will be based on regular revision and update of the performance assessment and trigger structure itself, in response to long-term environmental change. The need for recharge will be assessed by continuous monitoring throughout the operational and decommissioning period.

Section 8 is the monitoring plan for the annual vegetation of drift lines habitat (the formations of annuals or representatives of annuals and perennials, occupying accumulations of drift material and gravel rich in nitrogenous organic matter). This section is under development as the proposed monitoring methods are presently being assessed. It will be updated before the CPMMP is submitted for approval prior to the commencement of construction of the HCDF/SCDF.

Section 9 describes the schedule and content expected for monitoring and mitigation reporting. This section has been updated to set out a schedule of planned reports, including updated baseline reporting, a regular notification and review timetable, plus pre- and post-mitigation reporting for any interventions required.

Section 10 outlines the expectations of the reporting associated with cessation of the Project's monitoring and mitigation – namely the maintenance of the shingle transport corridor – which is scheduled to take place within the final ten years of decommissioning.

The decision as to whether or not to remove the HCDF will be confirmed as part of this mitigation cessation report, once the impacts have been assessed. The present assumption is that the HCDF would be removed after decommissioning but confirmation, or otherwise with justification, will be made as part of the cessation report. This is because the detail required to undertake that assessment will be better known closer to that time, when the nature of the HCDF exposure, the broad geomorphic setting and the locations of designated sites and features, and the impacts of works to remove the HCDF, are all known with confidence. Hence, the CPMMP cessation reporting is scheduled for approximately ten years prior to the end of the Sizewell C Project's decommissioning phase.

Table i: Summary of the features to be monitored, the rationale (why) and the proposed method.

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent	Reporting
3	Offshore cooling water infrastructure	Presence of the cooling water structures	Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation	100 x 100 metres (m)	Annual Report following installation
4	Nearshore outfalls	Presence of nearshore outfalls	Precautionary monitoring due to uncertainty around interaction with structures	Shoreline (beach topography)	Terrestrial remote sensing	Continuous sampling	1800 m	Baseline (shoreline and bars) Notification Reports (following quarterly or background monitoring surveys) Annual Report
					Topographic and bathymetric surveys	Quarterly until evidence of no significant effect. Then decreasing to *background monitoring*		
				Longshore bars	*Background monitoring*		1800 m alongshore; seaward to -7 m ODN (approximately 300 m)	
			Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation	50 x 50 m sub-area of bathymetry survey above	Notification Report Annual Report following installation
5	Beach Landing Facility (BLF) and Marine Bulk Import Facility (MBIF)	Navigational dredging (reprofiling), vessel traffic (propeller wash), and the presence of piles	Precautionary monitoring due to SPA / SAC proximity	Shoreline (beach topography)	Terrestrial remote sensing	Continuous sampling	1 km either side of the BLF / MBIF	Baseline (shoreline and bars) Notification Reports (following each navigational channel reprofiling) Annual Report
				Longshore bars	Topographic and bathymetric surveys	Pre and post reprofiling, with at least one survey per month initially during SZC construction (see Section 5.3.2)	1 km either side of the BLF / MBIF, and from the -8 m ODN contour (approximately 525 m) to the shore (observing vessel safety limitations)	
			Standard procedure: scour monitoring	Local seabed (including subaerial beach)	Topographic and bathymetric surveys	Pre and post installation	50 x 50 m per pile	Notification Report Annual Report following installation
6	Temporary discharge outfall	Heavy plant activities on the beach (installation and removal of discharge outfall)	Precautionary following compaction of surface sediments, and decompaction by backhoe or riddle on completion Standard procedure: scour monitoring	Beach topography	Beach survey	Pre and post installation. Within one month if used.	+/- 50m around the temporary discharge outfall	Annual Report following installation

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent	Reporting
7	SCDF and HCDF (beach management)	Erosion of the SCDF, beach management activities as determined from monitoring data	Maintain a continuous shingle beach to avoid or minimise the impacts of an exposed HCDF (blockage potential) to longshore shingle transport and downdrift erosion	Shoreline (beach topography)	*Background monitoring:* Terrestrial remote sensing Beach survey	 Continuous sampling Quarterly or bi-annually	 3000 m centred on Sizewell C Thorpe Ness headland to Minsmere Outfall	Annual Report Monthly Notification Report (trigger check) Event driven Trigger and Mitigation Reports
				Longshore bars and Sizewell – Dunwich Bank	*Background monitoring:* Terrestrial remote sensing Bathymetric survey	 Continuous sampling Once per five years	 3000 m centred on Sizewell C Thorpe Ness headland to Minsmere Outfall	

[1] Survey techniques are detailed in Section 2. Terrestrial remote sensing refers to area-based, continuously sampling, automated methods of detecting change in features of interest, such as detection of barlines from X-band radar – see Section 2.1 for method details. Topographic surveys provide beach elevation and visual data (substrate classification). See the relevant report section for details on what is being monitoring, the frequency and spatial extent. Background monitoring identified in subsequent sections consists of terrestrial remote sensing, two aerial topographic surveys per year, one bathymetric survey every five years.

1 Context

1.1 Introduction

This report is a draft version of the Coastal Processes Monitoring and Mitigation Plan (CPMMP) for:

- detecting and reporting impacts of Sizewell C's marine components and activities on coastal geomorphology receptors, both inside and outside of designated conservation sites, and
- monitoring and, where necessary, implementing future mitigation to (a) maintain the longshore shingle transport corridor, thereby minimising or avoiding impacts of an exposed hard coastal defence feature (HCDF), and (b) restore any persistent depressions from the Beach Landing Facility (BLF) grounding pocket (operation phase only) on the outer longshore bar if there are shoreline erosion concerns.

This version has been updated in response to feedback from the statutory members of the coastal geomorphology subgroup of the Sizewell Marine Technical Forum (MTF) on version 1.0 of the CPMMP and a follow up MTF meeting (in September 2020). As set out in the MTF feedback tracker tables, where appropriate, MTF feedback has been used to formulate version 2.0 of the CPMMP. If SZC Co. is granted a Development Consent Order (DCO) and a Deemed Marine Licence (DML) within the DCO approval, it is expected that most, or all, aspects of the monitoring plan would be via Requirement7A of the DCO and Condition 17 on the DML.

MTF consultation on this draft monitoring plan has, so far, been as follows:

- March 26 and 27, 2019: Presentation of the outline methods. The same outline methods were proposed in Chapter 20, Volume 2 of the Sizewell C Environmental Statement ([APP-311] and Appendix 20A [APP-312] of the DCO submission) (NNB Generation Company (SZC) Limited, 2020a and 2020b) - hereafter referred to as the "ES".
- April 2020: Version 1 of Coastal Processes Monitoring and Mitigation Plan (the preceding version of this report).
- September 23, 2020 Written feedback on Version 1 discussed at an MTF (via MS Teams) Where appropriate, MTF feedback will be used to formulate Version 2 of the monitoring plan.

  Note that Version 1.1 was a minor update to reflect the ES Addendum (Volume 1, Chapter 2 [AS-237]) only

1.1.1 Sizewell Marine Technical Forum

The purpose of the MTF is to facilitate open and transparent dialogue between SZC Co. and the statutory environmental bodies (and their advisors) relating to marine monitoring of the SZC Project. This dialogue will cover the design and delivery of SZC, DCO requirements and/ or DML Conditions and regulatory concerns, and environmental information or outputs such that:

- Operational and environmental monitoring by SZC Co. is informed by feedback from the MTF and can be shaped throughout the construction and operational phases of SZC, and monitoring plans can be modified in the light of knowledge gained or technical issues arising, through its Adaptive Environmental Assessment and Management Process (see Section 1.4); and
- Relevant information is shared between SZC Co., statutory environmental bodies and the wider community.

The MTF will help facilitate effective oversight of the Sizewell C Project by providing all parties with a high level of confidence that the environment is being properly protected in accordance with the DCO and DML. All monitoring plans, reports and proposed amendments to plans (due to monitoring results) will be available to the MTF for discussion and comment (see Section 0 for details). The discharging authorities for the final version of this plan, the related requirements under the DCO and conditions on the DML, and all reporting are expected to be the Marine Management Organisation (MMO) and East Suffolk Council (ESC). If the MTF is disbanded during the operational life of the station, subsequent reporting will be to the discharging authorities and their advisors.

1.1.2 Feedback

It is understood that this draft monitoring report may be shared more widely by some statutory regulators with non-statutory stakeholders and community groups. Their feedback, summarised and agreed by the relevant statutory regulator, is welcome and will be incorporated into the regulatory framework for impact monitoring where suitable and with a scientific rationale.

Where statutory regulators are incorporating feedback from other parties, they should either:

- Assimilate the feedback that they agree with into their own response, acknowledging the parties that have contributed (preferred).
- Vet the feedback and only supply content with which they agree.
- Supply all feedback but explicitly state if they agree or disagree with the comments.

The feedback supplied must be relevant to this plan and the coastal geomorphology receptors – any other comments that are not part of this work cannot be considered and should not be provided. Note that feedback on these initial proposals can only be accepted from the statutory regulators themselves. To ensure that all comments and responses are efficiently captured, it is requested that comments are only provided via the SZC Co. supplied Excel tracker form.

Throughout this draft monitoring report, unless otherwise stated, the terms baseline (pre-construction), construction, operation and decommissioning refer to the phases of the proposed development of the SZC Project. Where appropriate, a reference to the DCO also implies the DML.

1.2 Regulatory drivers

Although the MTF have received the ES (including Appendix 20A) and the ES Addendum (specifically Section 2.15), the final DCO monitoring and mitigation requirements will not be known until the DCO process has completed and (if consented) the DCO is made by BEIS. As a result, this updated version (2.0) of the CPMMP is based upon:

- Outline monitoring proposals presented and supplied (slides) to statutory regulators and the RSPB at the March 2019 meeting of MTF.
- The Coastal Geomorphology and Hydrodynamics chapter of the ES, which sets out SZC Co.'s assessment for monitoring and mitigation.
- Changes in designs presented in the ES Addendum and related monitoring and secondary mitigation.

The final version of the plan submitted for approval prior to the commencement of construction of the HCDF/SCDF will incorporate the actual requirements of the DCO, once granted.

The draft DCO Requirement (7a) states:

- 7A. Main development site: Coastal Processes Monitoring and Mitigation Plan

- (1) Construction of Work No. 1A(n) (soft coastal defence feature) and Work No. 1A(o) (hard coastal defence feature) must not commence until a coastal processes monitoring and mitigation plan has been submitted to and approved by East Suffolk Council, following consultation with the relevant Statutory Nature Conservation Body and the Environment Agency and the Marine Management Organisation. The plan shall include:
- (i) the area to be monitored;
- (ii) methods for monitoring;
- (iii) duration of monitoring;
- (iv) trigger points for mitigation; and
- (v) proposed mitigation.
- (2) The coastal processes monitoring and mitigation plan must be implemented as

approved.

The equivalent draft ML (17) condition states:

17. (1) *The undertaker must, after consultation with ESC and the EA, submit a Coastal Processes Monitoring and Mitigation Plan (CPMMP) to the MMO for approval. The plan must include:*

(a) area to be monitored;

(b) methods for monitoring;

(c) duration of monitoring;

(d) trigger points for mitigation;

(e) proposed mitigation; and

(f) an explanation of the undertakers confidence that the proposed mitigation will be effective;

(2) The coastal processes monitoring and mitigation plan shall be implemented as approved by the MMO.

(3) Unless a shorter period is agreed with the MMO in writing, the undertaker must use reasonable endeavours to submit the CPMMP to the MMO at least 6 months prior to the proposed commencement of any licensed activity.

(4) The determination date is 6 weeks from submission of the CPMMP to the MMO.

(5) On the date that requirement 7A of this Order is discharged, this condition 17 is deemed discharged.

The final version of the plan submitted for approval will align with the project's EIA.

The final version of the plan will align with the approved EIA output and ML.

The Sizewell C main development site is situated in an ecologically diverse area and, as a result, is subject to a range of nature conservation designations. Although no likely significant effects relevant to coastal geomorphology were predicted, precautionary monitoring is proposed due to the proximity of some activities (including mitigation) to the following statutory designated sites (see ES Figure 20.1):

- Minsmere to Walberswick Heaths and Marshes SAC,
- Minsmere to Walberswick SPA,
- Minsmere to Walberswick Heaths and Marshes SSSI, and
- Leiston to Aldeburgh SSSI.

As a geomorphic feature, supra-tidal shingle is important because it can support the *annual vegetation of drift lines* habitat (Habitats Directive 92/43/EEC Annex I, habitat type 1210; hereafter referred to as *annual vegetation*) and has potential for nesting little tern. The non-statutory Suffolk Shingle Beaches County Wildlife Site features a wide (relative to the surrounding coast) supra-tidal shingle adjacent to Sizewell B. Supra-tidal shingle was also previously recorded on the Minsmere to Walberswick Heaths and Marshes SAC frontage but was destroyed[3] a decade or so ago (between 2010 and 2011) by natural coastal erosion.

1.3 Sizewell C Project marine components

The Sizewell C Project's marine components that could affect coastal geomorphology are grouped into five sets, based on component type and location:

- Offshore cooling water infrastructure (Section 3) – four cooling water intake heads and two outfall heads;
- Nearshore Outfalls (Section 4) – Fish Recovery and Return (FRR) outfall heads (2no) and a Combined Drainage Outfall (CDO);
- Marine Import Facilities (Section 5)
  - A Beach Landing Facility (BLF), to be used during the construction, operation and (potentially) decommissioning phases of SZC;
  - A Marine Bulk Import Facility (MBIF), to be built, used and disassembled during the construction phase;
- A temporary, supra-tidal, storm water drain (present during the first two years of the construction phase; Section 6); and
- Soft and Hard Coastal Defence Features (SCDF, HCDF; Section 7.1.1).

The locations of the marine components are shown in Figure 1. Each of these components is associated with different activities and impacts during the building and usage phases[4], summarised in the relevant sections along with the rationale for the proposed monitoring specification (what, how and how often).

1.4 Principles

1.4.1 Precautionary principle

The precautionary principle is adopted to guide the definition of the monitoring and mitigation extents and methods, to ensure that all potential significant impacts are enveloped by routine procedures. Monitoring methods and frequency are set such that all anticipated impacts are within the scope of the plan – since monitoring the separate elements of the geomorphology receptor for impacts will capture both the potentially significant and the anticipated insignificant impacts. The receptor coverage is such that monitoring extents are always defined to be substantially larger than the predicted effect e.g., scour monitoring extents around structures are set at 7-11 times the scale of the predicted scour footprint. In this way the monitoring will be sufficiently extensive to determine whether any unanticipated impacts are occurring, or if conditions that could lead to unanticipated impacts are developing, within and in the vicinity of the Sizewell C development. A second aspect of the precautionary principle is the adoption of an adaptive management plan, such that the CPMMP remains an evolving document over all phases of the project and provisions for monitoring can be altered in response to specific environmental, technological, or societal/policy change, or to specific effect observations within the monitoring data. The extents of monitoring will be reactive and would be extended if the extents of effects are seen to grow beyond the monitoring footprint over time – likewise, the adaptive CPMMP includes provision to reduce monitoring extents if it is established that effect extents are well-known and sufficient coverage can be achieved with reduced effort. Specific monitoring of some activities would also be expected to cease once that activity is no longer occurring, provided that no ongoing or unanticipated

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[3] As recorded by Natural England condition surveys.
[4] The terms build and use are used to identify activities during the build and use phase of individual components. These terms are used to avoid confusion with the terms construction and operation, which refer to the construction and operation phases of the power station.

effects are observed in the monitoring data. In contrast, monitoring (and mitigation) can be expected to increase adaptively as observed risk changes. For example, an increase in frequency or spatial distribution of triggers for mitigation may require a reformulation of the relevant specifications of the CPMMP to ensure any impacts continue to be mitigated. As such allowance is made in the CPMMP for the possibility of modifications to sampling design or survey frequency in response to unanticipated manmade or natural influences.

1.4.2 Adaptive Environmental Assessment and Management Process

Adaptive environmental assessment and management is a structured, iterative process of robust decision making in the face of uncertainty. The aim of this process is to reduce uncertainty over time through comprehensive monitoring (Figure 2). For example, prediction of the long-term impacts of SZC on the coastal environment will depend on model evolution, precision in data collection and changing climate scenarios. It is thus appropriate to have an adaptive environmental assessment and management plan in place. This will allow for timely changes to the monitoring plan and improve the prediction modelling. Analysis and interpretation of results will then inform an updated sampling strategy, hence creating a robust environmental assessment and management based on latest technology and updated information. The process is broadly summarised in Figure 2.

To ensure transparency of the adaptive management plan and adequate opportunity for oversight by regulatory stakeholders, a comprehensive reporting schedule is included. The proposed detailed document framework comprises baseline reports and annexes (to be prepared for the onset of construction). This is supplemented with a framework for notification and reporting requirements throughout the construction, operations and decommissioning phases and is presented in Figure 3 (further details on the proposed reports is given in Section 9). The annexes to the baseline reports will hold details of the CPMMP with potential to change adaptively (with environmental, technological and potentially regulatory change) through the operation and decommissioning phases of the station. This will ensure sufficient updates of the core CPMMP at appropriate intervals throughout the project. Notification reports (which are generated when triggers for mitigation are reached) will also identify (and define) required changes to the future monitoring plans and modelling scenarios under the adaptive environmental assessment and management process.

Substantive reviews (initially 10-yearly, but also adaptable) will provide regular opportunity for ESC and the MMO to review the CPMMP (informed by the MTF), including the reporting schedule itself, which may equally be subject to change as part of the adaptive management process.

1.5 Report Outline

This report pertains to the monitoring and mitigation of any associated significant effects on coastal geomorphic features (receptors) from the Sizewell C Project. However, monitoring is also proposed where it is standard procedure (i.e., scour assessment), where there is uncertainty in predicted (particularly in-combination) impacts, and/or where uncertainty in impact extent could overlap with a statutory designated site. The *annual vegetation* of drift lines habitat would also be monitored under this plan because it is dependent on coastal geomorphology (specifically supra-tidal shingle) and is easily monitored using similar measurement techniques (see Section 2.2.3). Due to the scope of the techniques, the proposed monitoring encompasses the full scope of coastal process impacts assessed in the ES i.e., including where effects were assessed as not significant.

The Sizewell C Project components that are considered to require coastal geomorphology monitoring, along with the proposed method and rationale are summarised in Table 1, and detailed in the following sections.

The suite of methods used to track changes in coastal geomorphic receptors, including impacts arising from Sizewell C activities and pressures, is provided in Section 2. The methods included combine continuous remote sensing techniques for early warning of any impacts with targeted, high-accuracy, field surveys.

Sections 3 – 6 contain the rationale and monitoring frequency for the Sizewell C Project components that would be built in the marine environment as part of the Sizewell C Project's construction. Specifically, the offshore cooling water infrastructure, nearshore outfalls, the BLF and MBIF, and the temporary storm water drain.

Section 7 pertains to monitoring and mitigation to maintain the shingle transport corridor along the Sizewell C Project frontage. The monitoring plan in this section differs from the previous sections because it:

- employs *background monitoring* as a watching brief on the slow erosion of the SCDF;
- checks the beach volumes against a threshold trigger;
- initiates mitigation activity to maintain a continuous shingle beach along the Sizewell C power station frontage if triggered; and
- undertakes performance assessment on all mitigation activities.

Section 8 is the monitoring plan for *annual vegetation* – the formations of annuals, or representatives of annuals and perennials, which occupy accumulations of drift material and gravel rich in nitrogenous organic matter. This section remains subject to future development as the proposed methods are presently being assessed.

Section 9 describes the initial schedule and content proposals for reporting of monitoring and mitigation activity.

Section 10 outlines the expectations of the reporting associated with 'end of project' cessation of mitigation for maintenance of the shingle transport corridor.

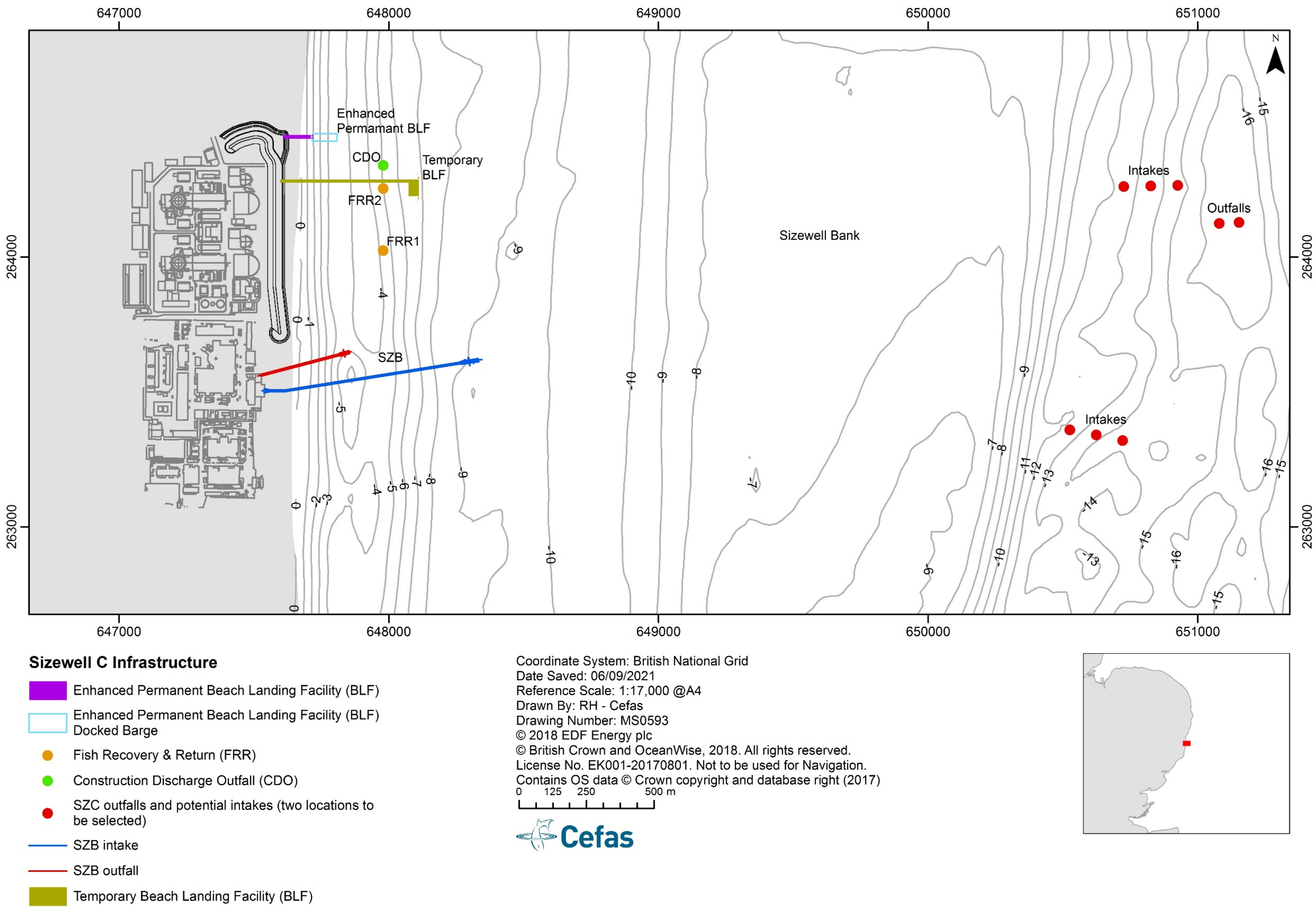

Figure 1: Marine components of SZC and the intake and outfall locations for Sizewell B. The dark black lines east and north of Sizewell C mark the HCDF.[Note: 1 that recent design changes bring the abutment at the BLF landwards to align with the main HCDF, and the HCDF seaward toe further landward than shown, to approximately 647620E, however engineering drawings were not available when this report was produced. This figure will be updated in the next version of this report. Note 2:Permanent BLF = BLF and Temporary BLF = MBIF]]

Figure 2: Adaptive environmental assessment and management process framework

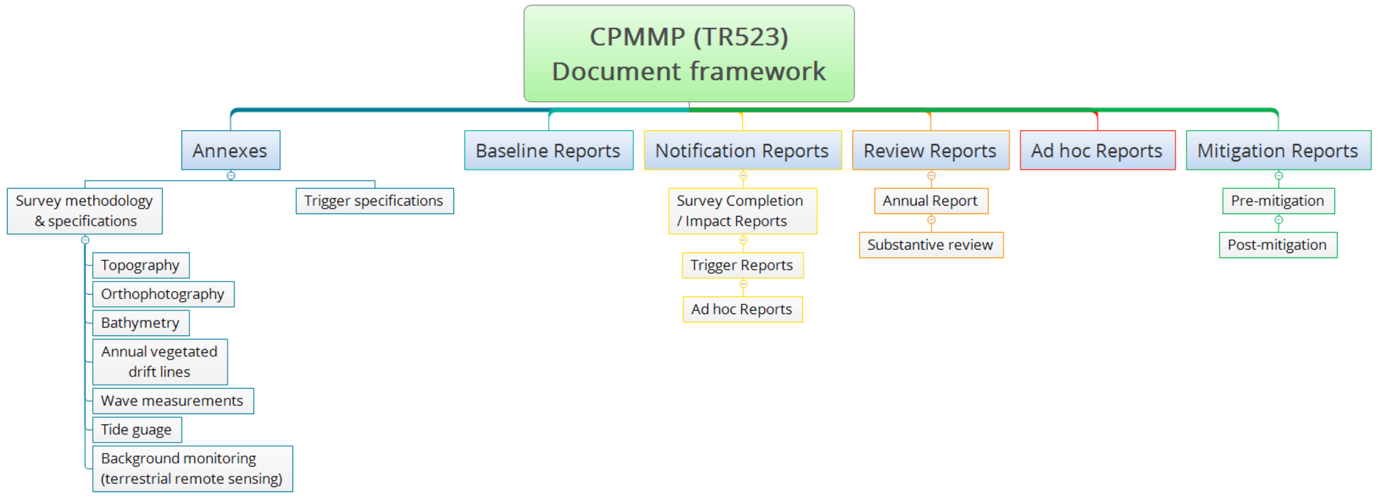

Figure 3: Framework for reporting under the CPMMP. Annexes will hold details of the CPMMP that are likely to change under an adaptive management approach through Sizewell C's operation and decommissioning phases.

Table 1: Summary of the proposed methods and rationale for monitoring associated with Sizewell C Project components.

Report section	Component set	Activities / pressures	Rationale	Feature	Method(s) [1]	Frequency	Monitoring extent	Reporting
3	Offshore cooling water infrastructure	Presence of the cooling water structures	Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation	100 x 100 m	Annual Report following installation
4	Nearshore outfalls	Presence of nearshore outfalls	Precautionary monitoring due to uncertainty around interaction with structures	Shoreline (beach topography)	Terrestrial remote sensing Topographic and bathymetric surveys	Continuous sampling Quarterly until evidence of no significant effect. Then decreasing to *background monitoring*	1800 m	Baseline (shoreline and bars) Notification Reports (following quarterly or background monitoring surveys) Annual Report
				Longshore bars	*Background monitoring*	See title	Bathymetry: 1800 m alongshore; seaward to -7 m ODN (approximately 300 m)	
			Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation	50 x 50 m sub-area of bathymetry survey above	Notification Report Annual Report following installation
5	Beach Landing Facility (BLF)	Navigational dredging (reprofiling), vessel traffic (propeller wash), and the presence of piles	Precautionary monitoring due to SPA / SAC proximity	Shoreline (beach topography)	Terrestrial remote sensing	Continuous sampling	1 km either side of the BLF	Baseline (shoreline and bars) Notification Reports (following each navigational channel reprofiling) Annual Report
				Longshore bars	Topographic and bathymetric surveys	Pre and post reprofiling, with at least one survey per month initially during SZC construction (see Section 5.3.2)	1 km either side of the BLF, and from the -8 m ODN contour (approximately 525 m) to the shore (observing vessel safety limitations)	

Report section	Component set	Activities / pressures	Rationale	Feature	Method(s) [1]	Frequency	Monitoring extent	Reporting
			Standard procedure: scour monitoring	Local seabed (including subaerial beach)	Topographic and bathymetric surveys	Pre and post installation	50 x 50 m per pile	Notification Report Annual Report following installation
5	Marine Bulk Import Facility (MBIF)	Navigational dredging (reprofiling), vessel traffic (propeller wash), and the presence of piles	Precautionary monitoring due to SPA / SAC proximity	Shoreline (beach topography)	Terrestrial remote sensing	Continuous sampling	1 km either side of the MBIF	Baseline (shoreline and bars) Notification Reports (following each navigational channel reprofiling) Annual Report
				Longshore bars	Topographic and bathymetric surveys	Pre and post reprofiling, with at least one survey per month initially during SZC construction (see Section 5.3.2)	1 km either side of the MBIF, and from the -8 m ODN contour (approximately 525 m) to the shore (observing vessel safety limitations)	
			Standard procedure: scour monitoring	Local seabed (including subaerial beach)	Topographic and bathymetric surveys	Pre and post installation	50 x 50 m per pile	Notification Report Annual Report following installation
6	Temporary discharge outfall	Heavy plant activities on the beach	Compaction of surface sediments during installation and removal of discharge outfall) Standard procedure: scour monitoring	Shoreline (beach topography)	Beach survey	Pre and post installation	+/- 50m around the temporary discharge outfall	Annual Report following installation
7	SCDF and HCDF (beach management)	Erosion of the SCDF, beach management activities as determined from monitoring data	Maintain a continuous shingle beach to avoid or minimise the impacts of an exposed HCDF (blockage potential) to longshore shingle transport and downdrift erosion	Shoreline (beach topography)	*Background monitoring:* Terrestrial remote sensing Beach survey	Continuous sampling Quarterly or bi-annually	3000 m centred on Sizewell C Thorpeness to Minsmere Outfall	Annual Report Monthly Notification Report (trigger check) Event driven Trigger and Mitigation Reports
				Longshore bars	*Background monitoring:* Terrestrial remote sensing Bathymetric survey	Continuous sampling Subject to SCDF risk index (Quarterly, bi-annual or annual)	3000 m centred on Sizewell C Thorpeness to Minsmere Outfall	
				Sizewell – Dunwich Bank	Bathymetric survey	Once per five years		

Title: [1] Survey techniques are detailed in Section 2. Terrestrial remote sensing refers to area-based, continuously sampling, automated methods of detecting change in features of interest, such as detection of barlines from X-band radar – see Section 2.1 for method details. Topographic surveys provide beach elevation and visual data (substrate classification). See the relevant report section for details on what is being monitoring, the frequency and spatial extent. Background monitoring identified in subsequent sections consists of terrestrial remote sensing, two aerial topographic surveys per year, one bathymetric survey every five years.

2 Monitoring techniques and baseline

This section details the intended monitoring techniques and the specific parameters or features to be monitored under this monitoring plan. The CPMMP will be submitted to ESC and the MMO for approval (in consultation with relevant bodies represented at the MTF) to discharge the related DCO requirement and DML condition, respectively, which will define which techniques and parameters are formally accepted and approved as elements of the final plan. The details of techniques have been separated from the proposed monitoring plans for each SZC marine component set out in Sections 3 – 6 to avoid repetition as the techniques proposed could be used to detect impacts from multiple components and activities.

The following monitoring techniques have been selected for their ability to detect and quantify natural change and impacts to geomorphic receptors. In many cases, continuous monitoring systems that facilitate early detection are combined with regular-interval or triggered surveys that provide higher resolution that are needed for impact confirmation.

Techniques are targeted to the elements of the coastal geomorphology receptor:

- Beach and shoreline position,
- Longshore bars,
- Sizewell-Dunwich Bank,

as well as wide areas of supra-tidal shingle supporting the *annual vegetation of drift lines* habitat (Annex 1, habitat 1210).

As shown in the Figure 20.1 of the ES (**Volume 2, Chapter 20**) [APP-313], there is no pathway to impact on the Coralline Crag outcrops that anchor Thorpeness and Sizewell Bank from any of the Sizewell C activities, and therefore Crag monitoring is not a requirement. However, because of its important roles in defining the edge of the coastal sediment cell and bank stability SZC Co. proposes to extend the proposed five-yearly b*ackground environmental monitoring* of Sizewell – Dunwich Bank (see Section 2.3) to include the Thorpeness Coralline Crag outcrops and ensure that any unexpected natural changes which may affect impact detection are identified. A separate *Sabellaria* Monitoring Plan which will be subject to a separate licence condition will include the geographically separate small section of the outcropping Crag seaward of Sizewell Bank at the southern intakes under the Marine Ecology theme.

The description of each technique that follows is also summarised in Table 2 and Figure 8 (at the end of this section) in terms of the features, survey frequency and Sizewell C marine components. The *Background monitoring* identified in subsequent sections consists of terrestrial remote sensing, two aerial topographic surveys per year, and one bathymetric survey every five years (described respectively in Section 2.1, 2.2 and 2.3). The five-yearly bathymetric survey is included as changes in the Bank over the decades of Sizewell C operation and decommissioning may result in subtle natural changes to nearshore conditions (the ES identified no significant effects on the bank from the Sizewell C development). The five-yearly interval is considered sufficient because the Bank volume and form changes very slowly.

2.1 Terrestrial remote sensing

Terrestrial remote sensing uses imaging techniques, such as X-band radar (Figure 4), to map coastal areas. These techniques have five important advantages as a method for coastal monitoring:

- **Area**. Moderately large areas (several hundred metres or more) can be consistently monitored.
- **Speed**. The monitored area is rapidly scanned, providing a snapshot of the whole area that cannot be achieved with field survey methods.

- **Frequency**. Raw data can be gathered frequently (e.g., hourly), providing an early warning for potential impacts compared to, for example, monthly or quarterly surveys.
- **Duration**. Background monitoring can be conducted for years to decades relatively easily, thereby facilitating a *watching brief* for future events of interest, such as natural cycles of erosion and recovery (relevant to mitigation proposed in Section 7) and impacts that may arise between scheduled surveys.
- **Cost**. Automated monitoring allows data to be collected between field surveys without the costly deployment of personnel and equipment, allowing greater confidence in planning field surveys and in reducing survey frequency once the specific activity or pressure ceases (or is sufficiently quantified).

As a result, it is proposed to carry out terrestrial remote sensing as part of a *background monitoring* approach to coastal monitoring throughout the Sizewell C Project's construction, operation and decommissioning phases, alongside scheduled topographic and bathymetric surveys (Sections 2.2 and 2.3). The temporally continuous nature of the remote sensing also makes it suitable as an early warning system (as described in Section 7) for early detection of conditions that could require mitigation.

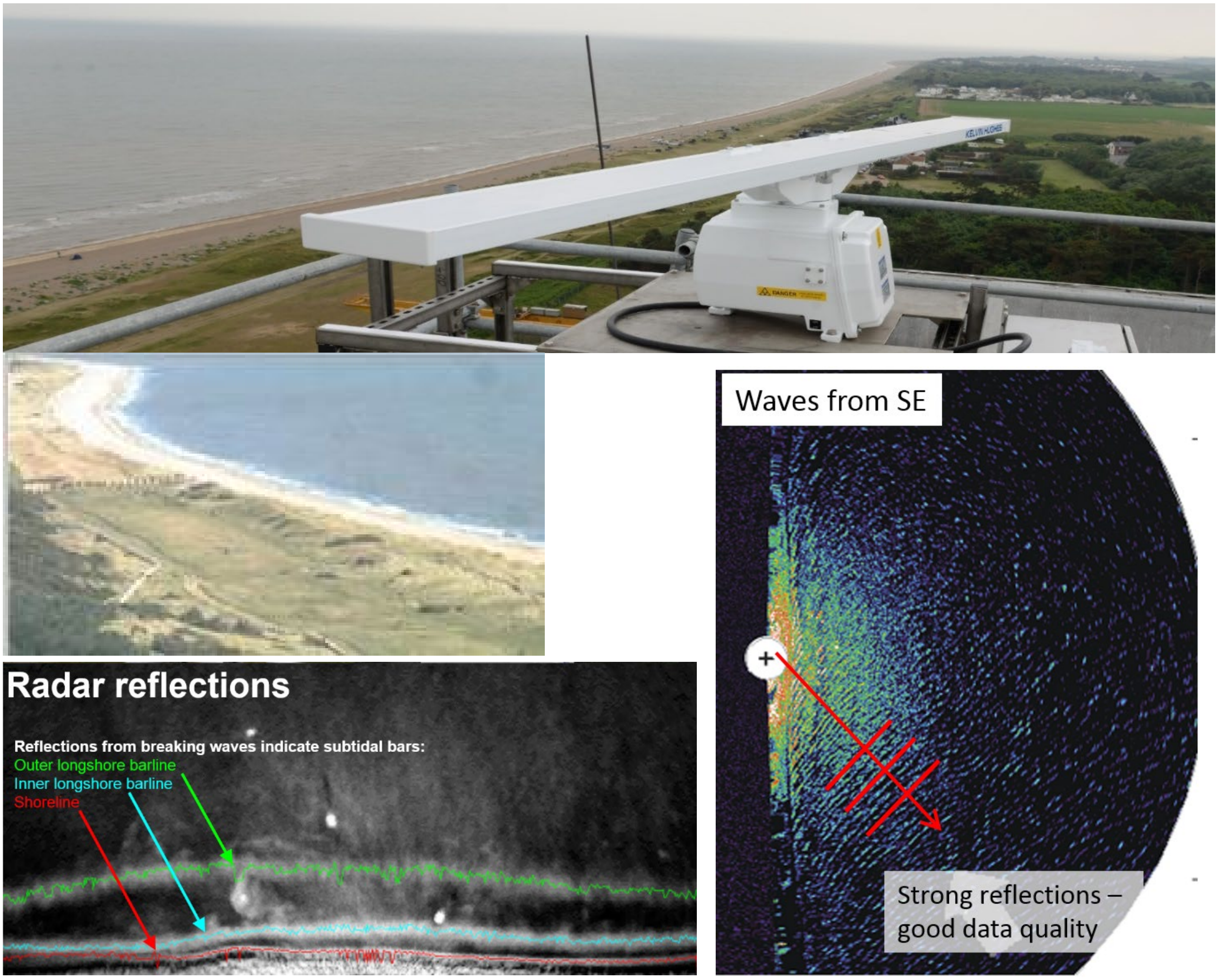

Figure 4: The Sizewell Coastal Processes Radar (SZCPR) and cameras are two methods of automated terrestrial remote sensing. Images (anti-clockwise from top) show: the SZCPR (looking south toward Thorpeness from Sizewell A); a video image of the Sizewell C to Minsmere frontage; and radar images showing (i) how wave breaking patterns highlight the shoreline, inner bar and outer bar and (ii) a SE wave field.

Terrestrial remote sensing methods have been used at Sizewell to monitor the position of the shoreline, inner and outer longshore bars (barlines), Coralline Crag and sub-tidal sandwaves. Shorelines and barlines are the primary parameters that would be measured with methods such as X-band radar, still and/or video cameras. The advantages of each of these methods and recommendations for their applications under the CPMMP remain under review, but will be finalised for approval prior to the commencement of construction of the HCDF/SCDF by ESC and the MMO following consultation with the MTF. For example, the X-band radar has the operational advantage of being able to detect shorelines and barlines 24 hours a day whereas, although cameras are restricted to daylight detection, they have the additional potential advantage of allowing the detection of changes in substrate and vegetation.

Baseline data using radar has been captured since 2013. Shorter video trials have also been conducted (see Table 2). These methods are being examined by SZC Co. with final recommendations due by the end of 2021.

2.2 Aerial remote sensing for topography and vegetation

2.2.1 Introduction

Small Remote Piloted Aircraft (RPA; see Figure 5), or drones, are now commonly used for monitoring coastal environments (e.g., Turner et al., 2016). They have been in use for the DCO/Marine Licence monitoring of rock platform erosion, gravel beach volumes and coastal ecology at Hinkley Point since 2013, and for baseline coastal geomorphology monitoring (topography and substrate) at Sizewell since 2015. Recent advances in miniaturisation of RTK-GPS for rotary RPA (such as the model used at Sizewell since July 2019), allows regular, survey-grade, measurements on the lower intertidal that is rarely achieved by traditional ground survey (which typically only includes the upper intertidal), making RTK-GPS enabled RPAs the preferred survey platform. Furthermore, RPA flights can survey hundreds of metres of foreshore in minutes and ground surveys (e.g., beach profiles) are comparatively time and labour intensive and offer very sparse data that can be difficult to interpret compared to the spatially continuous RPA data that enable earlier and more confident identification of impacts.

RPA is preferred ahead of aerial LiDAR (Light Detection and Ranging) primarily because of responsiveness and cost. LiDAR flown from manned aircraft is very expensive, difficult to schedule and reschedule, and cannot easily be used in a responsive mode. It has been shown in the literature (e.g., Brunier et al., 2016; Long et al., 2016; Medijkane et al., 2018 and Seymour et al., 2018) and at Sizewell (forthcoming BEEMS Technical Report TR546) that RPA provide high-quality data that compare favourably to LiDAR and ground surveys in accuracy, and at a substantially higher resolution.

Using high-quality RGB and multi-spectral cameras, image data from RPAs can be used to produce orthophotos and topographic elevation models that were previously only possible from manned aircraft. The RPA also has several advantages over manned aerial survey for individual study sites:

- **Resolution**. Typical ground resolutions from RPA flown by Cefas are 1 mm, 15 mm and 30 mm, compared to 250 – 500 mm commonly available from manned aircraft.
- **Responsiveness**. Using dedicated RPA and mobilising from a base close to Sizewell means that event triggered surveys can be readily conducted to capture conditions before and after storms.
- **Cloud cover**. RPA fly at or below 400 ft, compared to typical manned flights of 3000 ft. As a result, clouds are less likely to obscure the land surface.
- **Cost**. The costs of manned overflights are prohibitively high, due to the capital value and running costs. For large regional surveys, manned aircraft are cost-effective, but for individual sites they are too expensive.

Figure 5: Fixed-wing and rotary RPA surveys at Sizewell (top) and Hinkley Point (bottom).

2.2.2 Beach elevation and volumes

The RPA method is optical: hundreds of overlapping photos are merged into a single orthophoto (a photo map), and a digital topographic surface created, using the Structure from Motion technique.

Structure from Motion is an analytical method whereby the automatic identification of thousands of matching features in multiple overlapping images is used to estimate the relative position of all cameras and points photographed, before iteratively refining those positions. The refined positions are later aligned to a geographic coordinate system using known ground control points. With careful data processing, the result is an accurate, high-resolution digital surface model (DSM).

The spatially continuous, high-resolution digital surface allows analysis and interpretation of beach volumes, elevation changes and volumetric changes using standard GIS techniques.

2.2.3 Beach surface substrate and annual vegetation

Alongside the topography, RPA orthophotos allow a deeper, more informed interpretation of the DSM results, and greater confidence in the causes of change. For example, associations can be made between elevation changes and substrate (vegetation or sediment type). Substrate maps have already been produced distinguishing dry and wet sand, shingle, mixed sand and shingle, water and vegetation, from standard RPA imagery. This is likely to be augmented by low-altitude multi-spectral surveys in order to map the *annual vegetation* species growing on supra-tidal shingle, and to distinguish these from dune grasses and other species (see Section 8).

Due to the seasonally-varying height of the plant cover, the RPA technique (Section 2.2.2) is unsuitable for deriving a DSM of densely vegetated beach areas – these areas must be surveyed using ground-based methods. An Annex and associated technical reporting will be provided in the next version of this plan that will include a description of the survey methods including combining the topographic surfaces of the vegetated and unvegetated beach into a single DSM.

Fixed video methods (Section 2.1) will also be explored for their potential to track substrate and vegetation.

2.3 Bathymetry for bed elevation changes and scour

The primary method for building digital models of the sub-tidal seabed is echo-sounding. In most cases, a swathe (multi-beam) echo sounder would be used to provide accurate sea floor elevation maps at a spatial resolution sufficient to identify small scale scour marks (< 10 m) expected to form around marine structures.

Bathymetric surveys are typically conducted from manned vessels whose draft (especially for multi-beam sounders) makes surveying in shallow water (less than a few metres deep) challenging, especially when waves are present. The common result is a data gap, called the *white ribbon*, found in the shallow sub-tidal zone which manned bathymetric surveys struggle to reach. Data gaps are most likely where terrestrial surveys do not enter the water (for safety reasons or where optical or laser-based methods cannot penetrate through water), the sub-tidal nearshore has a shallow slope and/or where the tidal range is low, which makes it difficult for topographic and bathymetric surveys to overlap. All these factors are considerations at Sizewell.

Shallow draft vessels – jet skis and small boats with single-beam sounders – have been used to minimise or eliminate the white ribbon, but there are safety concerns in the southern North Sea due to exposure and water temperature. A recent proven alternative is small, survey-grade, Autonomous Survey Vessels (ASVs), which can survey in water less than on metre deep. ASVs may also facilitate more frequent or rapid response surveys (due to reduction in mobilisation activity), which may prove valuable in the SCDF mitigation pre- and post-application (performance assessment) monitoring. An ASV with a multi-beam sounder produces results directly comparable to that from manned vessels, they are accepted by the UKHO for the Civil Hydrography Programme and, as a platform, can meet IHO Order 1a.

The bathymetric survey techniques to be used will be finalised before construction begins, but are proposed to meet the following standards:

- General mapping of sediment boundaries and bedform structures; IHO Order 1a shall be implemented. This will give an overall vertical uncertainty of +/- 0.50 m, and allow a bathymetric surface to be produced with 1.00 m resolution.
- Data products which will be regarded as navigation critical shall be acquired to IHO Special Order. This will give an overall vertical uncertainty of 0.25 m, and allow a bathymetric surface to be produced with 0.50 m resolution.

- All acquired datasets will utilise horizontal control and vertical reduction techniques as outlined in each respective order.

Utilisation of multi-beam echosounders is the preferred data collection methodology, but shallow water conditions may warrant the use of a single beam sounder. These specifications will be applied to all bathymetric surveys unless there is a specific reason why this cannot be achieved, in which case permission will be sought from the MMO, including visibility and discussion with the MTF beforehand.

Bathymetric surveys would be conducted according to the schedule for each activity, as set out in Sections 3 – 6. Nearshore bathymetry surveys of the longshore bars may also be conducted during the operation and decommissioning phases (most likely using ASV). A full sandbank and nearshore bathymetry survey would be conducted once every five years as part of the background monitoring.

Remote sensing also has some potential for coarse shallow water bathymetric monitoring. The video wave inversion method tracks the position and speed of wave crests across the video field of view to estimate bathymetry based on the well-known dependence of wave speed (celerity) on depth (e.g., Holman et al., 2013); however, the method is relatively new and is not consistently or sufficiently accurate in shallow water to meet the required monitoring standards. Nevertheless, it is mentioned here as a means to potentially obtain useful bathymetric information between surveys (at higher frequency but lower quality compared to echo-sounders). Work continues on the development of new or novel methods for application in the field including the above technique. Significant developments from ongoing areas of research will be incorporated into future editions of this CPMMP as they become established for routine application.

2.4 Waves and water levels

Waves and water levels are the primary drivers of change for the coastal geomorphology at Sizewell. As such, it is essential to monitor these in order to gather sufficient evidence to explain observations of receptor change and distinguish natural changes from impacts related to the Sizewell C Project.

Waves approaching the Greater Sizewell Bay have been recorded half-hourly since February 2008 (12+ years) by a Datawell Directional Waverider (DWR) Mk III buoy just offshore of Sizewell – Dunwich Bank (52°12.62’N 001°41.12’E WGS84; Figure 6). Inshore wave conditions closer to the coast have been recorded by nine aperiodic inshore benthic lander deployments. These data were used to validate numerical hydrodynamic (waves and tides) models and to develop a virtual inshore wavebuoy (VIWB). The VIWB extracts wave data from the X-band radar (BEEMS Technical Report TR514) and inshore waves have now been back-calculated to 2013, when the radar was installed, giving a 7+ year record.

Water levels are being recorded using an OTT Hydrometry Radar Level Sensor (RLS) tide gauge on the Sizewell B cooling water intake structure (648298E, 263643N; Figure 7). The sensor records the tidal elevation at 5 min intervals, calculated as the average of 40 measurements obtained over a 20 s period.

2.5 Baseline monitoring

EDF’s BEEMS programme has been monitoring coastal processes along the Sizewell frontage in various forms since 2008 (see **Volume 2, Chapter 20** of the **ES** [APP-311] and **Appendix 20A** [APP-312]). Data were collected for engineering design, nuclear safety and environmental impact assessment. The date fields in Table 2 indicate the data collection periods each technique and measurement parameter. These records extend the following third-party datasets that are also used in the baseline:

- Sizewell Shoreline Management Group (EDF Energy and Magnox) beach surveys (1985 – present[5]).

[5] BEEMS, SSMSG and EA datasets will be updated and included as appendices to this plan (in an update of BEEMS Technical Report TR223) to complete the pre-construction baseline.

- Environment Agency beach profiles, aerial photography and lidar (1991 – present).
- Marine Coastguard Agency bathymetric survey (2017).
- Hindcast wave modelling (1980 – 2017)

Figure 6: A Datawell Directional Wave Rider buoy.

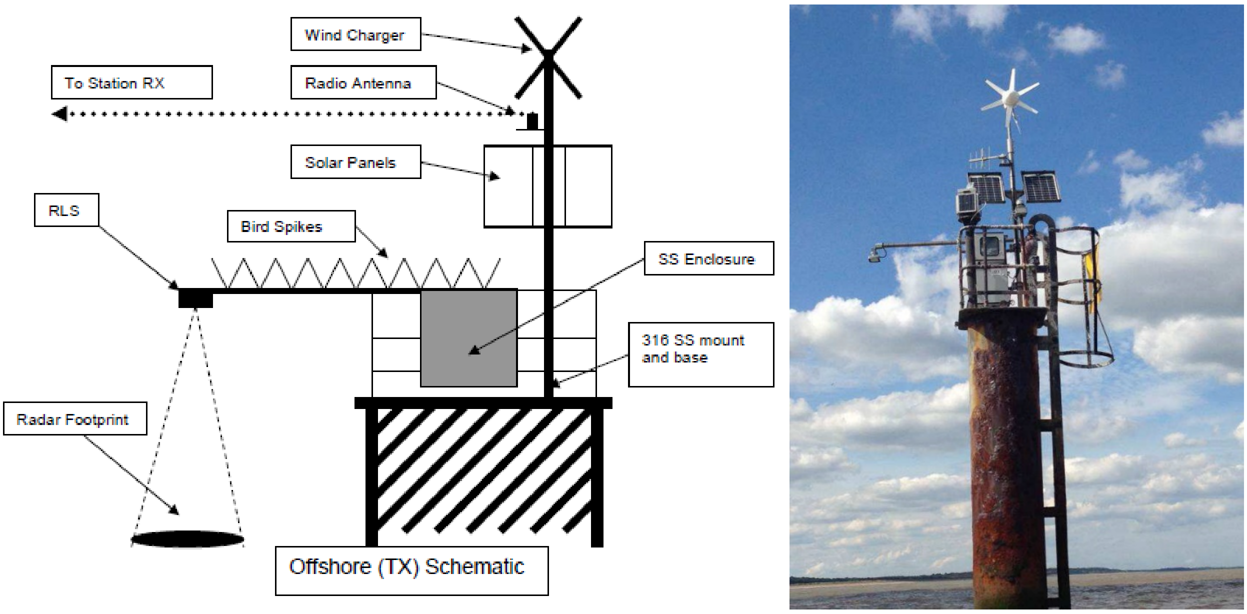

Figure 7: Schematic design and photograph tide gauge mounting and measurement system (OTT, 2016).

Table 2: Summary of method capabilities (baseline records in parentheses). Question marks represent measurement parameters that are possible in principle but have not been tested.

Method	Position		Topography			Bathymetry		Hydrodynamics	
	Shoreline	Barline	Elevation	Sediment	Vegetation	Elevation	Scour	Water levels	Waves
X-band radar (October 2013 – present)	✓	✓							✓
Video (April – August 2015; December 2015 – September 2017)	✓	✓		?	?				
RPA (drone) (September 2015 – present)	✓	✓	✓	✓	✓	?	?		
Bathymetric survey[6] (6 BEEMS & MCA surveys 2008 – 2017)						✓	✓		
Tide gauge (July 2016 – present)								✓	
Wavebuoy (February 2008 – present)									✓

[6] Eight historical surveys (1868 – 2007) are also considered in BEEMS Technical Reports TR058 and TR500. Bathymetric surveys may be conducted from manned or autonomous survey vessels.

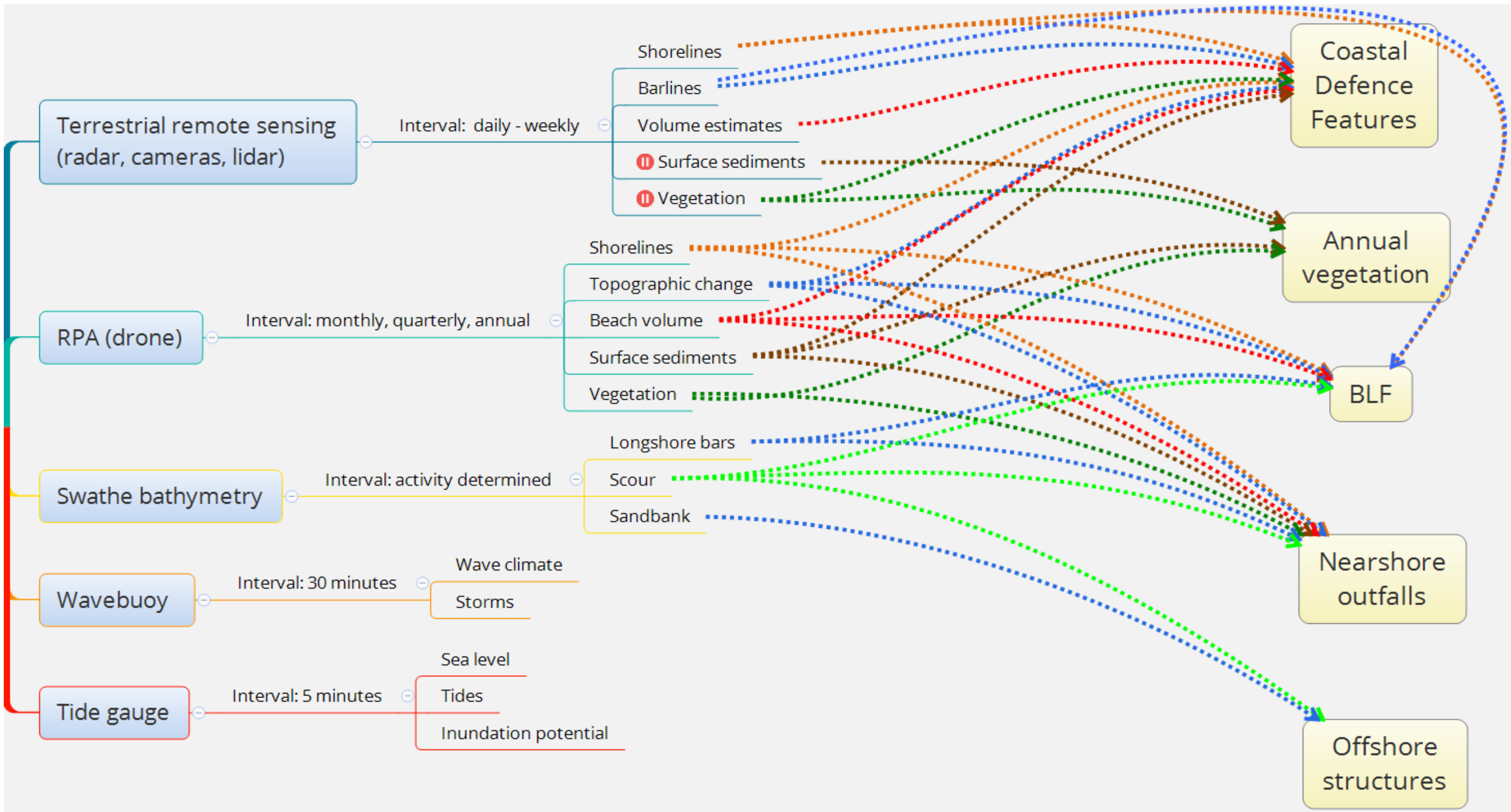

Figure 8: Organogram illustrating the monitoring methods, likely frequency, the parameters or indicators they can track, and the components that could impacts to these parameters. 'Annual vegetation' is also included to illustrate the parameters that would be tracked and how is relates to the monitoring plan.

3 Monitoring: Offshore cooling water infrastructure

3.1 Component description and activities

Two subterranean cooling water intake tunnels and one outfall tunnel, each approximately 3.5 km long, would be excavated by Tunnel Boring Machines from land. Tunnel construction has no impact on the marine environment or coastal geomorphology because it is subterranean, and its excavated arisings will be transported landward on a conveyor to a muck bay.

Offshore of the Sizewell – Dunwich Bank, two vertical connecting shafts will be driven down to meet each of the three tunnels, giving a total of six shafts that would connect to four intake heads and two outfall heads. The intakes would be up to 32.5 x 10 m (length, width) whilst the outfalls would have a 16 m x 16 m x 4.9 m (length, width, height) foundation chamber and a 3.2-m-high head. Head structures are expected to protrude 4 m above the bed. It is understood that the outfalls would discharge cooling water at a rate of 66 m^3/s each.

The activities/pressures associated with the offshore structures include preparatory dredging, dredge spoil disposal, drilling, head installation, the use of construction platforms (jack up barges) and the presence of the structures once installed. The Environmental Impact Assessment from the Coastal Geomorphology and Hydrodynamics chapter of the **ES** (see **Volume 2 Chapter 20** [APP-311] of the **ES** and **Appendix 20A** [APP-312]) showed *no significant effects* to coastal geomorphology receptors from the offshore structures (see Appendix A).

3.2 Rationale for monitoring

The building and usage of cooling water intakes and outfalls would not cause any significant effects on coastal geomorphology receptors – the effect level was *negligible, not significant*, for all activities/pressures [APP-311].

Therefore, the only monitoring proposed for the cooling water intakes and outfalls is for scour, as monitoring around structures to quantify the equilibrium scour is standard procedure in the Southern North Sea. Scour monitoring would also be used to quantify any secondary scour from scour protection (if used), depressions from jack-up barge legs and locally deposited drill arisings.

Elliptical scour pits up to 17 m long are expected to form up and down stream of the structures (lateral scour would be less than 10 m). Although their size may vary slightly as tidal currents strengthen and weaken over spring-neap cycles, their orientation is expected to remain relatively constant.

3.3 Geographical extent and schedule

High-resolution swath bathymetric survey would be used to survey an area centred on each structure and extending 100 m from infrastructure and jack-up spud marks. The area proposed is substantially larger than the predicted scour to ensure the full scour extents are captured. Revision of the survey area, as well as the survey intervals, will be considered if scour protection is used. For example, if scour protection were to be applied several months or years after the installation, additional monitoring using the same intervals (relative to installation; see below) would be required.

A pre-construction survey conducted not more than three months prior to the commencement of the relevant works would be followed by post-construction surveys three and six months after works completion. The timing of these surveys would allow scour to develop to an equilibrium state (three months), and confirmation with the follow-up check (six months).

4 Monitoring: Nearshore outfalls

4.1 Component description and activities

Three low-discharge outfalls would be located opposite the Sizewell C power station on the seaward flank of the outer longshore bar. The outfalls would be approximately 3 m x 3 m x 4.5 m (length, width, height) and have a mean discharge of 0.3 m^3/s during commissioning and operation for the FRRs and approximately 0.12 m^3/s for the CDO (during the Sizewell C construction phase). The northing of the two FRRs aligns with the forebays of each reactor, thus minimising the required tunnel length and hence the time taken for fish to be returned to the marine environment. The optimal easterly position of the seaward flank of the outer longshore bar was determined by several antagonistic factors relevant to fish ecology and minimising impacts to the longshore bars (see **Volume 2 Chapter 20 of the ES: Appendix 20A** [APP-312]).

The tunnels for the nearshore outfalls would be subterranean and have no impact on coastal geomorphology.

The activities/pressures associated with the nearshore outfalls include preparatory dredging, dredge material disposal, drilling, the use of construction platforms (jack up barges) and the presence of the structures once installed. The Environmental Impact Assessment from the Coastal Geomorphology and Hydrodynamics chapter of the **ES** (**Volume 2, Chapter 20**) [APP-311] concluded *no significant effects* to coastal geomorphology receptors from the nearshore outfalls.

4.2 Rationale

The nearshore outfalls would be placed toward the seaward margin of the nearshore sand transport corridor (i.e., the seaward flank of the outer longshore bar), which is defined by the longshore bars. Although scour marks under tidal flows are expected, they would be intermittent because of infilling during wave events. As the scour pits would be small (extending 7.2 m each side of each outfall along the tidal axis (N-S) and to 4.1 m each side (E-W)) and intermittent, they would not alter outer bar form or block the sand transport corridor. Scour depth was predicted to be 2.07 m at each structure using the worst-case scenario. Scour monitoring around structures would be conducted to quantify the equilibrium scour, as is standard procedure in the Southern North Sea associated with such marine infrastructure developments.

Despite the EIA effect level of *negligible, not significant* for all activities/pressures [APP-311], precautionary monitoring is proposed for the nearshore outfalls (with respect to bar and shoreline changes) in addition to scour monitoring around structures (outfalls), which is standard procedure in the Southern North Sea.

The precautionary monitoring is proposed because of analogous changes in the shoreline (accretion) and outer longshore bar (deflection) considered to be caused by the nearby Sizewell B (SZB) outfall. That is, SZB's high outfall discharge (51.5 m^3/s) would inhibit sediment deposition and, therefore, may have caused the landward migrating outer longshore bar to defect and change shape as it encountered the turbulent waters near the outfall. Subsequent shoreline accretion inshore of the outfall could be due to changes in wave refraction around the altered bar. Although this evidence is inferred, a similar feature was observed opposite the SZA outfall (during operation only). Unlike like the Sizewell C nearshore outfalls, which would be seaward of the outer longshore bar, the SZA and SZB outfalls are close to shore and landward of the outer longshore bar.

The proposed monitoring, stimulated by observations at SZB, is highly precautionary because the SZC nearshore outfalls are small, have a substantially lower discharge than those at SZB (over 100 times less, at 0.3 m^3/s), and they would be located seaward of the outer longshore bar crest[7]. These factors mean that the

[7] Meaning that the bar cannot subsequently migrate into these structures as it did at Sizewell B.

nearshore outfalls are unlikely to cause bar deflection and adjacent beach accretion, as appears to be the case at SZB. Monitoring of the nearshore outfalls would be discontinued if the anticipated *no significant impact* is confirmed.

4.3 Geographical extent and schedule

It is expected that the CDO would be installed early in the construction phase, followed by a 3 – 4 year gap before installation of FRR1 and a further 1 – 4 years before FRR2 is installed. All three outfalls would be present for several years before the Sizewell C Project moves into its operational phase. The scheduling below reflects the different timing for these outfalls, but would be adapted to accommodate changes in the Sizewell C Project's construction schedule.

The extent of changes to the outer longshore bar and shoreline near the SZB outfall are used as a conservative indicator of the extent to be monitored. The outer bar becomes deflected 500 m north and 1000 m south of the SZB outfall, whilst approximately 200 m of shoreline opposite the outfall accreted between 2005 and 2011, forming a salient (and creating a relatively wide area of supra-tidal shingle).

Based on these SZB observations, the proposed monitoring extent for the Sizewell C Project is 500 m north of the CDO and 1 km south of FRR1 (approximately 1800 m; see Figure 1); it would also include 50 x 50 m squares within the survey area examined for scour marks around the outfalls.

Terrestrial remote sensing data will be used to track the shoreline and barline response before, during and after outfall construction. Pre-construction surveys (for each outfall), conducted up to three months prior to commencement of the first nearshore outfall, would include:

- a subtidal swathe bathymetry survey of the outer bar[8] and
- an aerial topographic survey of the beach.

Weather permitting, these surveys should be conducted as close as possible to one another. It is likely that there will be a spatial gap – the white ribbon[9] – between the two datasets. Although this will not invalidate the results, the bathymetric survey should endeavour to scan as close to shore as possible at high water (including consideration of spring tides for this purpose) and likewise aerial surveys should be conducted as close as possible to low tide. This will minimise the white ribbon and aid interpretation of the results.

Post-installation surveys would then be conducted quarterly after completion of the first nearshore outfall, to detect scour (equilibrium expected in the first few months) and effects on the longshore bar and shoreline. As the outfalls would be built sequentially, monitoring would also capture any unexpected scour interactions[10].

Quarterly monitoring would continue for a few years. Evidence of the expected no significant effect would result in a subsequent decrease in the survey frequency, to a *background monitoring* schedule of two aerial topographic surveys per year, one bathymetric survey every five years[11] and the ongoing terrestrial remote sensing. Additional *ad hoc* surveys can be conducted as justified by monitoring evidence. The *background*

[8] The inner bar will also be surveyed if possible, however its very shallow depth is likely to limit the data that can be safely collected there. The -7 m ODN contour (approximately 300 m offshore) would be used as the seaward extent.
[9] A realistic target size for the *white ribbon* will be set once the survey method has been determined. This will be based on vessel type and draft, as well as safety considerations.
[10] Scour footprints are substantially smaller than the spacing between outfalls, so no significant cumulative effects are expected.
[11] One survey every five years is considered sufficient once equilibrium behaviour has been established. However, this area will be monitored more frequently as part of the SCDF monitoring (see Section 7).

monitoring of the beach and bars would also allow detection of any impacts lagging the installation (as was observed at SZB).

Changes in the schedule would be evidence based and require approval from ESC and the MMO.

5 Monitoring: Marine Import Facilities

5.1 Component description and activities

5.1.1 Beach Landing Facility (BLF)

The BLF consists of a 101 m long piled deck that abuts to the haul road on the 5.2 m ODN platform of the HCDF. The last 50 m of the BLF deck would be seaward of MHWS, and mooring dolphins would be positioned at approximately 81 m and 128 m from MHWS (Figure 9).

The BLF would consist of 28 permanent piles in total, comprising 26 piles (18 seaward of MHWS). The BLF piles would have an 9.2 m cross-shore spacing and 12 m between each pair. The jetty piles would be 1 m ∅ and the fender/dolphin piles 2.5 m ∅.

Construction of the BLF would commence from the beach and progress out to sea using plant typical of intertidal and shallow sub-tidal works. Dolphins would be installed from a standard or walking jack-up barge.

The BLF will be used to import AILs and marine freight during the Sizewell C Project's construction phase, and occasional AILs during the operational phase. During Sizewell C Project's operational life, AIL maintenance deliveries will be required for 3–4 weeks once every 5-10 years (approximately). During these maintenance phases, the BLF would be in use for less than four weeks (notwithstanding unexpected poor weather).

During the construction phase, a concrete mattress would be used as a grounding or berthing platform for barges – this removes the need for a grounding pocket and reduces maintenance dredging. It is intended that the mattress is installed at the beginning of each April – October campaign period and is likely to be removed after each campaign. Some light dredging may be occasionally required to remove sand accumulating on the concrete mattress.

During the operation phase, a grounding pocket would be used, as the duration of barge deliveries is short (3–4 weeks) and infrequent (approximately 5-10 years).

When the BLF is in use, a plough dredger would be used to dredge the outer longshore bar for navigational access and a grounding pocket for docked barges. Barges would transit over the nearshore bars to the end of the BLF pier at high tide and would become grounded as the tide falls; offloading is expected to be completed within one tidal cycle.

The activities/pressures associated with building the BLF include the use of jack-up barges, piling and navigational dredging. Activities/pressures associated with use of the BLF include the temporary presence of a grounded barge when the BLF is in use, vessel traffic and the presence of piles. The impacts of the concrete mattress are enveloped by the original assessment of the grillage (see Section 2.15 of **Volume 1**, **Chapter 2** of the **ES Addendum** [AS-181]) as the impacts are expected to be reduced, principally due to its removal over the winter season when the greater part of the annual longshore transport would occur. The ES concluded there would be *no significant effects* to coastal geomorphology receptors from any aspect of the BLF – most effects were *negligible* (though vessel traffic and navigational dredging were classified as *minor)*.

5.1.2 Marine Bulk Import Facility (MBIF) (formerly referred to as Temporary BLF)

To reduce the amount of construction material that would otherwise need to be delivered by land, a MBIF is proposed predominantly for the delivery of bulk construction materials, such as aggregate. Other types of material may also be imported through the MBIF, such as marine tunnel segments for marine works.

The MBIF would be in operation for approximately eight years and would be approximately 165 m south of the BLF. It would be approximately 505 m in length and 12 m in width for the main pier. An enlarged unloading area would form a jetty head with dimensions of up to approximately 62 m by 38 m. A single berth (for a single vessel) is assumed at its seaward end.

A conveyor would be installed along the length of the MBIF deck and would be the primary method of unloading material. The conveyor would be covered and follow the deck to the HCDF (once constructed) where it will continue into the secure construction area.

A self-propelled vessel typically delivering up to approximately 4,500 tonnes of cargo per delivery is assumed, making up to approximately 400 deliveries between April and October (inclusive) and up to approximately 200 additional deliveries for the remainder of the year, for each year of operation.

The MBIF would extend seaward of the outer longshore sand bar. As such, there would be no requirements for dredging and vessels could berth alongside with sufficient under-keel clearance. The length of the vessels may be up to approximately 120m.

Approximately 114 piles would be required to construct the MBIF, of which approximately 12 would be located above Mean High Water Springs. They would each be a maximum of approximately 1.2 m in diameter, except for two berthing dolphins and two mooring dolphins (each approximately 2.5 m in diameter). Six raking piles are assumed at the seaward end of the unloading platform. Cross braces would be required between some of the piles for stability.

Spacing between piles would be no less than 10 m on the MBIF pier and no less than 12 m on the unloading platform, with the exception of where the dolphins, raking piles and pier adjoin the unloading platform.

Except for the mooring dolphins, which would be installed using a jack-up barge, the MBIF would be constructed without placing construction vehicles into the sea. A crane, cantilever frame and piling equipment (including generators) would be located on the MBIF during its installation (Cantitravel). The MBIF would be constructed sequentially from the shore.

5.2 Rationale for monitoring

The BLF would be built during the construction phase, used during the construction and operation phases, and eventually removed during the decommissioning phase. The MBIF would be dismantled at the end of the construction phase. All BLF and MBIF effects were classified as *not significant*, although some were *minor* and some *negligible* [APP-311]. *Minor* effects were predicted to arise from the reprofiled navigation channel leading to the BLF jetty and propeller wash from tugboats on the longshore bars. Although the effect of the piles was classified as *negligible*, *not significant* [APP-311], monitoring around structures to quantify the equilibrium scour is standard procedure in the Southern North Sea and will therefore appropriate surveys will be conducted.

Seabed reprofiling (dredging) would be required to gain safe navigational access to the BLF jetty. A plough dredger would cast sediment to the sides of the access channel rather than being removed, thereby avoiding any interruption to sediment supply. However, the altered seabed elevation would cause changes in bed shear stress (compared to no reprofiling) extending as far north as 460 m of the Minsmere-Walberswick SPA and Minsmere to Walberswick Heaths and Marshes SAC frontage. The altered bed shear stress over this area would:

- only be apparent during storms,
- have a low probability of occurrence as storm frequency is lowest during the season when the BLF would be used (April – October inclusive), and
- shrink as storms progressed due to simultaneous (storm-induced) infilling of the reprofiled channel i.e., there would be no impacts during winter as the topography would recover during the first storms after reprofiling ceased for the year.

Hence the impact duration and probability would be low, with the extent shrinking rapidly following storms. Measurable changes in the beach profile are very unlikely, even where the impacts are largest, and increasingly unlikely on the SPA and SAC frontages to the north and south of the impact zones where the impacts reduce.

Propeller wash from tugboats would locally entrain bed sediments due to the shallow water and small draught between the propeller and the bed. Higher than natural quiescent levels of suspended sediment concentration would be expected for a small duration and extent. These would be directed to the south as barge manoeuvring activities would occur during southward flood tidal flows.

As the BLF is close to the Minsmere-Walberswick SPA and Minsmere to Walberswick Heaths and Marshes SAC, precautionary monitoring associated with BLF use is proposed in order to confirm the predicted *no significant effect* of bed reprofiling and tugboat propeller wash. This aspect of the beach and longshore bar monitoring would cease once it is determined that these activities do indeed have no significant effect on the designated sites, however during the construction phase the nearshore bathymetry will be monitored by up to four surveys per year (see Section 4.3) and *background monitoring* (two aerial topographic surveys per year, at least one bathymetric survey every five years and the ongoing terrestrial remote sensing) during operation. Therefore, any changes in bathymetry or other unanticipated impacts as a result of the BLF will be evident at an early change and will allow for the possibility of modifications to sampling design or survey frequency in response.

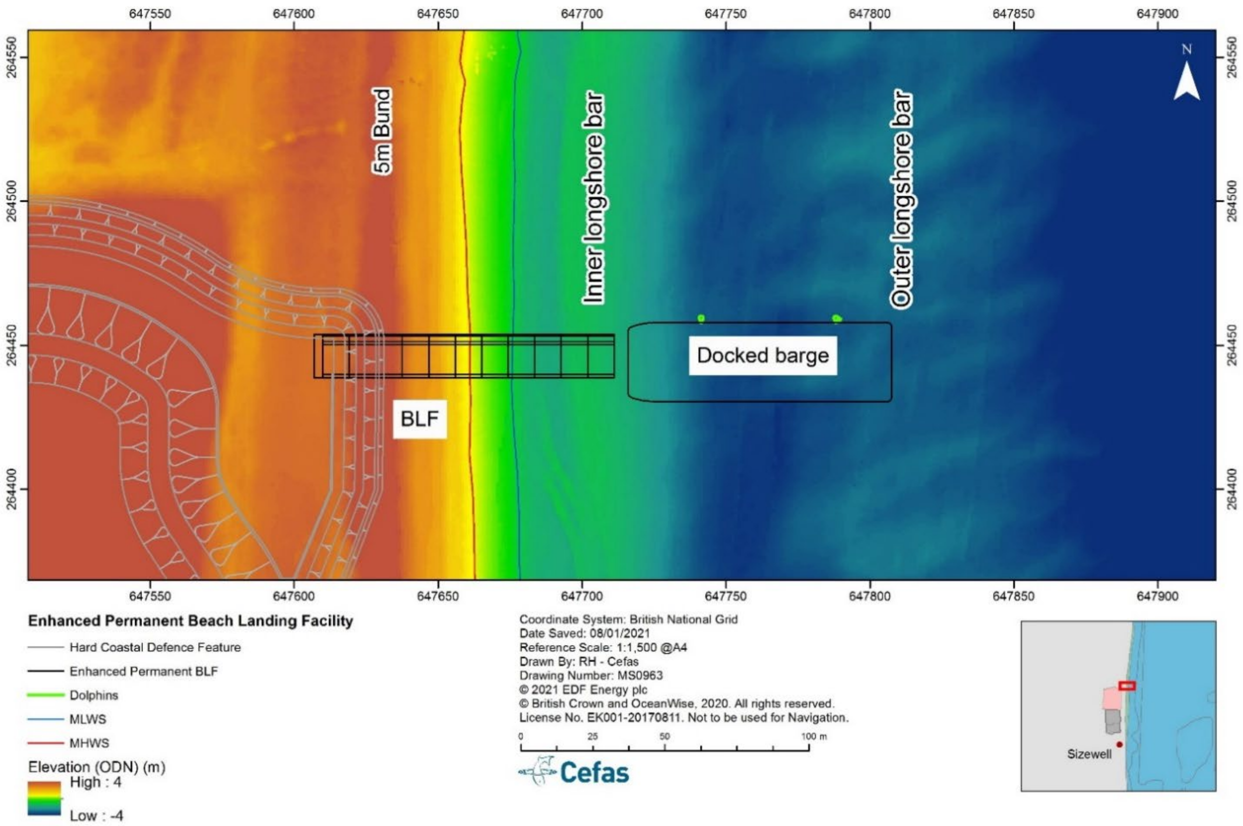

Figure 9: Beach Landing Facility (BLF) shown together with a docked barge. [Note 1: that recent design changes bring the abutment at the BLF landwards to align with the main HCDF, and the HCDF seaward toe further landward than shown, to approximately 647620E, however engineering drawings were not available when this report was produced. This figure will be updated in the next version of this report. Note 2: Permanent BLF = BLF]

The MBIF is further from the designated sites and is assessed as having impacts of *negligible* and *minor significance* [APP-311]. No dredging is required for the MBIF with the main impacts arising from pile scour and the presence of ships reducing inshore wave energy over a short distance.

5.3 Geographical extent and schedule

5.3.1 Scour around BLF and MBIF piles

As the piles of the BLF and MBIF are terrestrial and sub-tidal, RPA topography and swathe bathymetry surveys would be employed to document intertidal and sub-tidal scour. Pre-installation surveys in both settings would be scheduled not more than three months prior to the commencement of marine BLF and MBIF elements. Scour patterns would be documented using two surveys at three and six months after pile installation. Additional unscheduled surveys associated with dredging for the BLF navigation channel (Sections 5.3.2), may also be required to capture pile scour and will be used where appropriate in annual reporting.

The angle and size/depth of the BLF and MBIF scour marks is expected to vary according to the dominant antecedent hydrodynamic process – tidal currents or waves. In the transition from one dominant process to another, preceding scour marks will infill whilst new ones, on a different angle, will develop. Horizontal scour extents around jetty piles are predicted to be less than 7.1 m for subtidal piles and 4.4 m for terrestrial piles (see Table 5, Appendix 20A of the ES). A conservative monitoring extent of 50 m around the piles (i.e., 7 – 11 times larger than the largest subtidal and intertidal scour respectively) is proposed for scour quantification.

With sea level rise and shoreline retreat (landward translation of the beach profile), terrestrial piles could become exposed by the receding intertidal beach and become subtidal. The *background monitoring* of two aerial topographic surveys per year, and at least one bathymetric survey every five years, would be used to document any changes arising from beach profile translation.

5.3.2 BLF and MBIF in-use during construction phase

The geographical extent to be monitored is 2 km alongshore (1 km either side of the BLF and MBIF) and to the -8 m ODN contour (approximately 525 m offshore). The alongshore extent has been defined by the area corresponding to the change in bed shear stress for the BLF with a reprofiled bed, which spans 460 m of the Minsmere SPA/SAC frontage (see Figure 45, Appendix 20A of the ES). That is, the monitoring frontage is over twice that predicted.

These extents are conservative because:

- they are based on the magnitude of change which is larger than the +/-5% change in bed shear stress area,
- the largest area of change is only evident during storm conditions immediately after reprofiling (storms cause infilling, so the area would shrink during the storm), and
- the change in bed shear stress for short periods (and only during and slightly after each summer campaign) is not considered sufficient to cause a significant change to the bar or shoreline receptors.

The offshore survey extent would be defined by the -8 m ODN contour (hence the exact distance from shore would change), which is substantially seaward of the minor dredge clipping (a few tens of centimetres) of the outer bar for navigational clearance above the -3.5 m ODN contour. The -8 m ODN contour also fully captures the outer longshore bar feature as it is just beyond the end of the MBIF.

Bathymetric survey would be used for the subtidal area and RPA topography for the subaerial beach. As described in Section 4.3, these surveys will be timed to minimise the extent of the white ribbon. ASVs are presently being assessed for suitability and inclusion in the final monitoring plan as they may lessen or eliminate the white ribbon. Information from such further surveys may offer important insights, provide a cost-effective way to develop and improve future field survey and allow for improved survey frequency.

During the Sizewell C Project's construction phase, surveys would be conducted on a monthly basis during the first summer campaign to track changes including dispersal of any dredge plough mounds and recovery during any periods when the BLF is not in use and at the end of the summer campaign. As well as quantifying impacts and recovery, the data will be used to assess a reduction in survey frequency from the first campaign's intensive monthly schedule (surveys of this nature are typically quarterly) for subsequent campaigns. For example, if small sediment mounds from capital plough dredging disperse, the requirement to monitor for such features can be removed or significantly reduced. Where available, the data from any such surveys will be used to check clearance for safety and barge grounding and will be included in monitoring reporting. Following each subsequent campaign, the results will be reported and recommendations on the monitoring schedule will be made. The schedule will be progressively reduced based on any impacts detected and evidence for *no likely significant effect*.

Scour from terrestrial piles will be inspected after the first storm as a precautionary measure to address concerns raised by ESC regarding public access. Predicted scour depth of up to 0.7 m could occur at the most landward deck pile pair located in the intertidal zone. The predicted horizontal extent of scour around the piles was 1.1 m for the most landward deck piles. The scour predictions and evidence from other piers in the region do not suggest any reason for concern.

During the Sizewell C Project's operational phase, a pre-dredge survey (less than 3 months before dredging) would be followed by two surveys approximately three and six months after BLF use has ceased. Any additional unplanned dredging would also be accompanied by extra pre- and post-dredge surveys.

Any changes in the monitoring schedule included in the final monitoring plan would need to be evidence based and would require the prior approval of ESC and the MMO.

5.4 BLF mitigation – operation phase

During the operation phase, the seabed would need to be reprofiled (dredged) for access (if the outer bar is less than 3.5 m below mean sea level) and to create a grounding pocket for barge berthing. These changes in topography cause fluctuations in the inshore wave energy over a very small area but have a low probability as BLF use would only be used when predicted wave heights are less than Hs = 0.8 m for the 3–4 week period of use. Bed shear stress changes as a result of the reprofiled (dredged) seabed would extending onto the southern 230 m of the Minsmere SPA beach frontage. Monitoring would be used to assess the topographic changes in the outer longshore bar and the overall magnitude and spatial extent of change affecting this area of the receptor would be low and as a result, the impact magnitude is assessed as low.

BLF use during operation would take place during calm weather, but if the grounding pocket depression were very large (occupying most, or all, of the bar cross-section) and present during a significant storm, the leeward increase in wave energy could lead to localised shoreline erosion. As the erosion would be short-lived and small-scale (within the patterns that naturally occur on this beach), the effect was assessed as *minor*, *not significant* [AS-237]. However, as a precautionary measure, the assessment established that mitigation could be considered if the grounding pocket is not naturally infilling ahead of winter storms. The proposed mitigation is to move the accumulated dredged sediments back into the grounding pocket and reprofile the bar.

6 Temporary discharge outfall

6.1 Component description and activities

The temporary discharge outfall would only be required if a storm event with 1 in 30-year return interval were to occur prior to the construction of the CDO. Consequently, it may never be used during the 2-year period in which it is in place. Installation and removal of the outfall may require the overlying sediment to be excavated from the shingle ridge above MHWS. To balance the likelihood of its use and associated impacts against scour caused by the interaction of the outfall with wave run-up, it would be set back from MHWS at around 2 – 3 m above ODN. This design measure increases the likelihood that the unused temporary discharge outfall would have no impacts aside from those occurring due to its installation and removal. The presence of the temporary discharge outfall will therefore have no pathway to impact the longshore bars [AS-237].

During the process of construction and operation of the temporary discharge outfall, a narrow trench would be cut, the pipe installed/removed and backfilled. The excavation and removal would not affect the longshore continuity of the beach system. The resistance of the beach to compaction would be high, as mixed beaches are generally already compact. No hydrodynamic change due to the excavation and removal is expected as this work will occur above MHWS and will be temporary.

The presence of the outfall pipe could result in a minor obstruction to flow and sediment movement in the upper supra-tidal beach (during large storms only). A scour pit may form, but the duration of the event and the likely high wave activity would limit the scale of the immature pit, which would not reach an equilibrium.

6.2 Rationale

In the event of a 1-in-30-year storm, the discharge (up to 200 l/s and 1.02 m/s at the outlet) would generate a jet scour pit. The most conservative estimate of scour yields a 0.66 m deep and 2.2 m wide pit beneath the outfall, with a gully extending 5 m or more down the beach and across the intertidal. This would have a minimal impact on longshore transport, and the gully would rapidly infill. However, the scour in the supra-tidal could be considered long-term as the hydrodynamic processes needed to repair the scour pit and outflow channel are infrequent.

The outfall would be removed following use during construction, causing no effects during the operational phase. The EIA effect level for the excavation and removal of the temporary discharge outfall has been assessed as negligible/not significant.

6.3 Geographical extent and schedule

Scheduled RPA topographic monitoring will be used to identify any impacts arising from use of the temporary discharge outfall. If it were used, the area affected would have a very low spatial extent (+/- 50m around the temporary discharge outfall), which is fully encompassed by the RPA surveys for the BLF and MBIF.

7 Monitoring and future mitigation to maintain the shingle transport corridor

7.1 Rationale and context

BEEMS Technical Report TR403 and the ES (**Volume 2 Chapter 20** [APP-311] of the **ES** and **Appendix 20A**; NNB Generation Company (SZC) Limited, 2020a and b) justify the need for mitigation to avoid disruptions to longshore shingle transport. The proposed mitigation is a SCDF (primary mitigation) and SCDF / beach maintenance (secondary mitigation) to increase beach volume and reduce the risk of longshore transport disruption from an exposed HCDF. The mitigation is warranted because, if no intervention is undertaken, shoreline recession is likely to expose the HCDF within the timeframe of 2053 – 2087 (i.e., within the Sizewell C operational phase). Avoiding an exposed HCDF prevents dividing the otherwise continuous shingle beach in two and partially or fully blocking the longshore shingle transport corridor. Were such a condition to persist, shingle starvation and erosion on either side of the exposed HCDF would be expected. The impacts would be similar to those experienced at Minsmere Sluice outfall.

Therefore, the rationale for maintaining a continuous shingle beach, is to avoid or minimise the impacts of an exposed HCDF (blockage potential) to longshore shingle transport and adjacent beach erosion, which is achieved by the SCDF described in Section 7.1.1.2.

The following sections set out:

- 7.1.1: The design and purpose of the SCDF and HCDF.
- 7.2: The beach management framework.
- 7.3: The methods used to determine threshold beach conditions to trigger intervention (mitigation).
- 7.4: The methods used to monitor the beach, including key beach state indicators.
- 7.5: Mitigation options and the broad conditions for their selection.
- 7.6: Mitigation performance assessment.

7.1.1 Component description and activities – SCDF and HCDF

Sizewell C will have a hybrid coastal defence solution that combines hard and soft features. Hybrid systems fulfil the requirements of high levels of protection, adaptability to future challenges related to climate change, sustainability and pleasing natural aesthetics (Almarshed *et al*., 2019). This intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits is also known as ‘Engineering with Nature’. As well as maintaining local aesthetic values, the soft feature is dynamic, can evolve or be replenished and provides an additional source of sediment to the coast.

At Sizewell C, the HCDF and SCDF would serve two complementary functions. The HCDF is designed to protect the power station boundary from erosion and the site itself from marine inundation during extreme (high) water levels.

In comparison, the SCDF is a maintained sedimentary feature designed to prevent HCDF exposure to wave action and avoid the disruption to longshore shingle transport that would otherwise occur. Its functions are to maintain:

- the continuous sedimentary beach frontage at Sizewell C;
- the longshore shingle transport corridor across the Sizewell C frontage; and
- supply SCDF eroded sediments to the neighbouring frontages.

7.1.1.1 Hard coastal defence feature (HCDF)

The permanent HCDF would be built toward the end of the Sizewell C Project's construction phase. It features a 5.2 m ODN platform and haul road that would connect to the BLF (Figure 9). It is intended that the materials and rock armour to build the permanent HCDF would be delivered via the BLF. The HCDF would be built and maintained at or landward of the current 5 m ODN barrier/dune, and therefore not in the marine environment as it presently stands.

During construction, coffer dams may be required to place the initial toe of the HCDF, but they would be set further back and are unlikely to be exposed to the sea during construction, so long as the present beach width and elevation are maintained. The SCDF would then be constructed seaward of the HCDF, burying the HCDF toe of the structure under several metres of sediment.

7.1.1.2 Soft coastal defence feature (SCDF)

The SCDF design is described in BEEMS Technical Report TR544 and NNB Generation Company (SZC) Limited, 2021b [REP3-032 and REP2-116] and is summarised here. It is a maintained and volumetrically enlarged shingle beach (primarily pebble-sized[12]), seaward of the HCDF but distinct from the sandy subtidal beach. The SCDF uses a "working with nature" approach, whereby the release of sediment into the coastal system, and its re-distribution, are determined by natural coastal processes (erosion by waves) and thus avoiding or minimising disruption to longshore shingle transport, and the potential downdrift beach erosion, which could otherwise follow exposure of the HCDF.

The key SCDF design features to prevent HCDF exposure are:

- a large shingle reservoir (c. 210,000 m^3) sufficient to withstand severe storms,
- a high SCDF crest that accounts for future sea level rise (6.4 m (ODN) high and 1 – 2.4 m higher than the present beach ridge),
- maintenance of the SCDF (primarily by way of beach recharge), and
- coarse pebble-sized sediments within the size native range (very coarse pebbles; see Appendix C); to aid longevity and minimise this disturbance associated with secondary mitigation (beach maintenance). The use of sediments coarser than the native grain sizes (or even coarsening within the native size range) on the active beach is well-established practice – Rogers et al. (2010) and Pye and Blott (2018) provide multiple examples from around the UK. However, the SCDF's sediments would still be within the native size range.

Monitoring data on the SCDF would also be used for the civil design and maintenance aspects of defences.

The SCDF's reservoir of beach sediment is conceptually divided into two main components (notionally illustrated in Figure 10):

- a landward safety *buffer* volume, V_{buffer}, which is not intended to be depleted or frequently exposed but is sufficiently large in itself to avoid HCDF exposure under severe storms and
- a seaward *sacrificial* volume, V_{sac}, which would be allowed to erode (when elevated water levels were high enough to reach it, and wave run-up fast enough to entrain and drawdown its sediments) until V_{buffer} is reached, and would then be recharged (i.e., restoring the initial V_{sac}[13]).

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[12] See Appendix F for the Udden-Wentworth particle size classification.
[13] Subject to the nature of foreshore erosion, restoring V_{sac} may require recharge across the shallow subtidal beach that was formerly intertidal beach. The CPMMP will assess the recharge requirements in 50-m-wide alongshore cells across the 750-m-long SZC frontage.

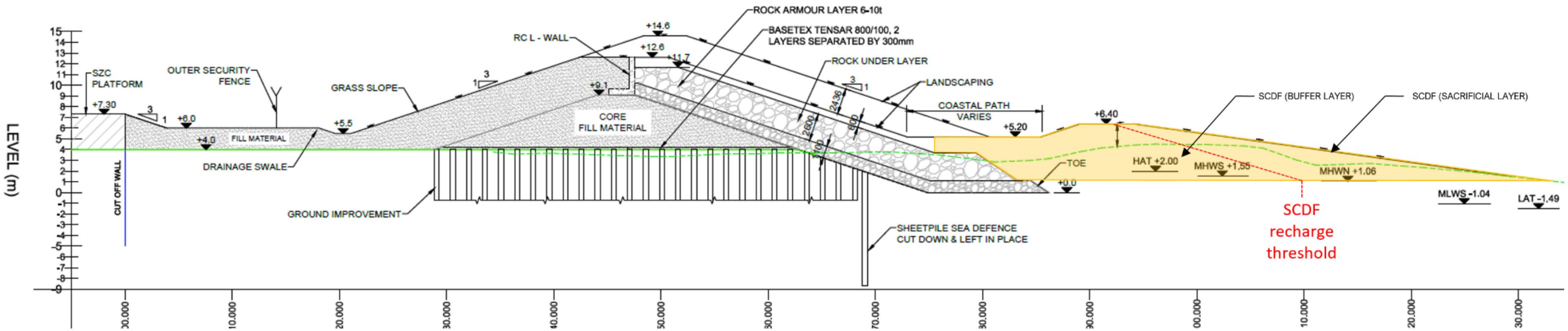

Figure 10: Schematic cross-section of the hard and soft coastal defence feature (HCDF and SCDF). The SCDF (yellow) is conceptually divided into two volumes, separated by the dividing SCDF recharge threshold (as the threshold is volumetric, the line is shown for illustrative purposes only, i.e., many different beach profile shapes can produce the threshold volume). The SCDF buffer layer (whose volume is V_{buffer}) sits to landward and is not intended to be exposed, whilst the SCDF sediment to seaward is sacrificial (V_{sac}) and would be replenished once the recharge threshold has been reached. The dashed green line running through the yellow SCDF is the present-day topographic cross-section.

Finalisation of V_{buffer}, V_{sac} and the SCDF particle size will be provided as an Annex to the next version of this plan (see also Section 7.3). BEEMS Technical Report TR544 [REP3-032] also proposed an option to include a layer of fine cobbles (c. 80 mm diameter, which is slightly larger than the native particles) within the buffer layer to increase resilience and further reduce the risk of HCDF exposure. The literature (e.g., Lorang, 1991; Komar and Allan, 2010; and Weiner et al., 2019) and numerical modelling for Sizewell (BEEMS Technical Report TR545 [REP3-048]) show fine cobbles would significantly reduce the risk of HCDF exposure. The intention is that the fine cobbles would not be exposed (owing to the large volume of pebbles fronting it), but if it were, it would minimise disruption to longshore transport (compared to an exposed HCDF) during the intervening period prior to SCDF reinstatement.

The preferred source of SCDF material would be suitable sediment won from earth works on the main development site (e.g., the HCDF footings excavation[14]), which would qualify as a form of beneficial re-use. All remaining material requirements would be met from a licensed aggregate extraction site.

Mitigation against the potential effects of exposing the HCDF – in the form of maintenance to retain a continuous shingle beach frontage – would be applied in accordance with the final form of this plan (Sections 7.2 – 7.5).

7.2 Beach management framework

The framework for beach management is shown in Figure 11 as a decision tree illustrating the monitoring steps and decisions leading to any implementation of secondary mitigation (beach maintenance). The framework is informed by the evidence gathered from the *background monitoring* that is: ongoing terrestrial remote sensing, topographic beach surveys (2-4 times per year) and bathymetric survey at least once every five years.

The stages leading to mitigation will be marked using an SCDF *buffer* exposure risk index, informed by an early-warning system (EWS; see Section 7.3). The *buffer* exposure risk index represents the stages of alert toward the mitigation trigger ($V_{recharge}$, which is when the SCDF buffer volume is reached) and use a Red, Amber, Green (RAG) colour scheme to identify areas of potential concern every 50 m along the SCDF frontage[15], which will facilitate advanced planning for potential recharge events. The *buffer* exposure risk index will be developed and finalised alongside mitigation trigger thresholds in the subsequent development of this plan in consultation with ESC/MMO and the wider MTF.

The broad steps of the beach management framework (see matching numbers in Figure 11) are:

1. Monthly checks of the triggers and alert levels for mitigation derived using remote sensing and / or field survey datasets (see Section 7.4). Beach and barrier volumes will be assessed in 50-m long cells along the coast. Once developed the SCDF *buffer* exposure risk index will be included in step 1 of Figure 11.

2. If an alert arises from the terrestrial remote sensing data (Section 7.4), a topographic field survey would be required to confirm the trigger. This will provide a more accurate assessment of the beach

[14] Initial investigations suggest the shingle won from the HCDF footings excavation are of suitable size and quality to provide some, or all, of the source material for construction of the SCDF. This is subject to a further suitability assessment once excavations begin.

[15] The monitoring will divide the Sizewell C frontage 50-m-wide sections in order to capture spatial variation in sediment loss, which is a typical feature of the Minsmere and Sizewell frontages. In particular, numerical modelling has shown that higher rates of erosion can be expected at the northern and southern SCDF extents if the adjacent shorelines receded significantly. Therefore, more frequent localised recharge may be needed in these areas as part of the structured Adaptive Environmental Assessment and Management process.

condition needed to inform mitigation specifications i.e., the location, volumes needed and mitigation method (see Section 7.5). The default method of mitigation is assumed to be beach recharge. A Trigger Notification Report would be issued to the MMO and ESC, and copied to MTF members, if the trigger was confirmed. In most or all cases the MTF will already be aware of the increasing likelihood of mitigation, as a result of previous updates to the buffer exposure risk index via the EWS.

3. To minimise the time-lag between the Trigger Notification Report and mitigation application, pre-approval of mitigation methods (as presented in Section 7.5) would be sought, in collaboration with the MTF. Pre-approval could be based on modelled specific examples, enveloping a range of proven mitigation methods (see Section 7.5), extents and sediment volumes.

4. If the mitigation proposed is consistent with the methods which have been pre-approved, it would then be conducted and its performance monitored. Performance monitoring is needed to assess whether certain aspects of the monitoring set out in the final monitoring plan could be improved. As noted in Section 1.4.2, the performance of the SCDF may lead to changes in mitigation over time, informed by monitoring data and potentially additional modelling as part of an Adaptive Environmental and Management Strategy.

5. If the mitigation is successful, *background monitoring* would be resumed and a Post-mitigation Assessment Note documenting the activity and results produced. If the mitigation is unsuccessful, the trigger alert would still be active. In this case, the evidence would again be reviewed, alongside understanding why the mitigation was not successful and recommendations on its resolution.

All reports would be submitted to ESC and the MMO and copied to the MTF.

7.3 Mitigation triggers

Mitigation triggers will be set (and updated if necessary) in a separate Annex. The basis of that annex will be the work presented in BEEMS Technical Reports TR544 and TR545 [REP3-032 and REP3-048]. It will also include an early warning system that tracks the stages leading to mitigation (SCDF *buffer* exposure risk index) and the associated HCDF exposure risk level.

7.3.1 Volumetric mitigation trigger

As stated in Section 7.1.1.2 and illustrated on Figure 10, gradual entrainment of sediment from the sacrificial volume (V_{sac}) of the SCDF will reduce its volume toward a stated minimum permissible buffer volume (V_{buffer}), which is defined on the basis of measured and modelled storm-driven volume changes. As defined, V_{buffer} represents the ultimate trigger for recharge.

As set out in BEEMS Technical Report TR544 [REP3-032], it is expected that V_{buffer} will be defined on the volume lost from a specific number of suitable ‘design storm events’. Definition of the suitable ‘design storm’ and volume multiplier (the number of storms), to account for the possibility that several such storms may occur in the interval between the trigger volume being reached and the recharge being possible, will be agreed with the ESC and the MMO (following consultation with the MTF) and reported in an Annex to this CPMMP.

On the basis of preliminary storm erosion modelling presented in BEEMS Technical Report TR544, an initial working value of 3 times the volume eroded in the 1:12 year return period ‘Beast from the East’ storm sequence was proposed (see BEEMS Technical Report TR544 [REP3-032]). The resulting V_{buffer} = 120 m^3/m is thought to be highly conservative as: (i) the modelled 40 m^3/m storm erosion volume is derived for a sand beach rather than a shingle SCDF, and (ii) the likelihood of three 1:12 year storm events occurring before the SCDF can be recharged is very low. Further numerical modelling is in progress that will lead to re-assessment of the V_{buffer} = 120 m^3/m initial working value. Improvements in model calibration and gravel models indicate that V_{buffer} is likely to be reduced.

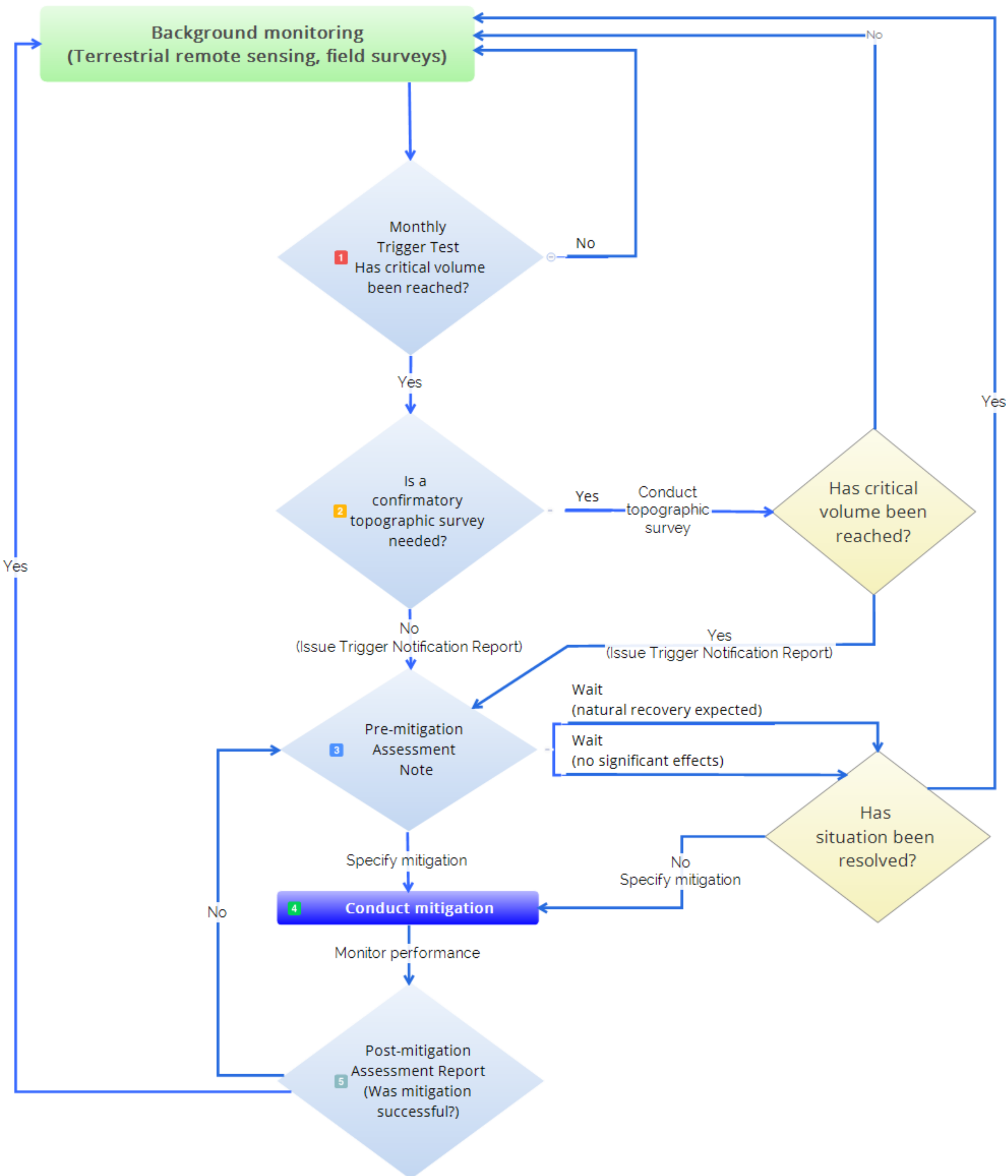

Figure 11: Decision tree broadly illustrating the conceptual monitoring and mitigation steps (for example, the integration with the reporting schedule and the definition of risk traffic lights prefiguring the mitigation trigger is not shown, for clarity). For details of the mitigation proposed, refer to the accompanying text.

As stated in BEEMS Technical Report TR544 [REP3-032], storm erosion of the SCDF is likely to increase over time with sea level rise and recession of adjacent shorelines. Thus, the required V_{buffer} is likely to be recalculated over the lifetime of this plan. A version of Table 3 will be incorporated into the CPMMP trigger Annex and subject to regular reassessment and agreement to update likely future demand for recharge and to revise plans and expectations accordingly.

7.3.1.1 Finalisation of the volumetric mitigation trigger

The trigger must strike a balance between setting a large V_{buffer} (low risk) and a large V_{sac} (low disruption from beach maintenance). Setting the risk level will be required before finalising the trigger; for example, if a 1% risk of exposure is acceptable then the buffer volume should be able to withstand a 1:100 year event.

There is also a balance to be struck between the volume eroded in regular (likely) storms and larger and (potentially) more erosive but less frequent events – which is likely to be strongly linked to cumulative wave power. This is being assessed by characterising Sizewell storms by their cumulative wave power or work (which is the hydrodynamic driver of coastal change). Note that it is the return interval of the 'storm energy'[16] that is of interest here, which is distinct from the exceedance intervals of individual wave heights often computed for flood risk and overtopping purposes. Put more simply, it is the energy imparted by the whole storm that drives beach change, not the peak wave height that occurred at one moment during the storm. The method used for determining the storm power return interval is included as Appendix B.

The trigger will also need to be adaptable to future scenarios, specifically sea level rise and the natural recession of adjacent shorelines, potentially leading to a Sizewell C foreland, which showed increased erosion rates when modelled (BEEMS Technical Report TR545 [REP3-048]). That is, the balance between V_{buffer} and V_{sac} may need to change. Equally, the particle size properties of recharge material could also be evolved to increase or decrease the rate of release of SCDF sediments into longshore shingle transport system.

Table 3: Representative recharge intervals (RIs) calculated from storm erosion modelling (BEEMS Technical Report TR544 [REP3-032]) and interpolated every 10 years. A version of this table is expected to form part of the adaptive management process for SCDF mitigation.

	Predicted RI's (years)		
Year	**Mean**	**Mean + 1STD**	**Maximum**
2020	*106 (17 m^3/m)*	*77 (23.5 m^3/m)*	*64 (28.2 m^3/m)*
2030	100	72	60
2040	94	67	57
2050	88	63	53
2060	82	59	50
2069	*78 (23 m^3/m)*	*55 (32.6 m^3/m)*	*47 (38.0 m^3/m)*
2080	73	52	45
2090	68	49	42
2099	*64 (28 m^3/m)*	*46 (39.0 m^3/m)*	*40 (45.2 m^3/m)*
2110	60	43	37

[16] More precisely, the work done by the storm.

To keep an accurate track on gradual climate change, Substantive Review Reports every ten years (see Section 9) will compare the actual progression of climate change (e.g., sea level rise, offshore and inshore wave climate[17] against predictions and re-assess the likely future beach recharge demands. It will also make evidence-based recommendations as to whether the volumetric trigger requires revision.

7.3.2 Potential additional risk criteria or mitigation triggers

Beach volume responses to storm events are to some extent affected by other parameters that could be reported as further risk criteria, or even mitigation triggers. For example, beach slope, width and crest height are known to affect beach storm responses (e.g., Davidson et al, 2013; Beuzen et al 2018). Likewise, under different environmental conditions to the present day, the existing inter-relationship between these additional parameters and the beach volume may change, such that separate risk criteria may need to be defined.

7.3.2.1 Crest integrity trigger

Under some conditions, storm events may erode the SCDF by cliffing, and potentially leading to slumping, lowering and reprofiling the overall crest level (while not lowering V_{sac} far enough to reach the V_{buffer} mitigation trigger). Change in the SCDF crest (level, alignment, vegetation) and drawdown of sediment will be detectable in orthophotos collected under this plan.

7.3.2.2 Shoreline alignment trigger

A relative shoreline alignment trigger to quantify the changing alignment or easterly position of the Sizewell C and adjacent frontages could be a useful indicator of potential changes to longshore shingle transport rates across. Numerical modelling suggests SCDF erosion will rise as adjacent shorelines recede, potentially compensating (and indeed contributing to) trapping. The proposed monitoring is suitable for establishing a basic sediment budget in which volumes of trapped natural sediments can be compared to the SCDF in order to determine whether the maintained frontage is depriving the downdrift coast of sediment.

7.4 Monitoring methods

Triggered beach maintenance activity is not expected for years or decades to come, as erosion rates on the Sizewell C frontage are low. The first trigger is likely to occur once the construction phase monitoring described in Sections 3 – 6 has ceased and *background monitoring* has begun[18].

7.4.1 Early warning – terrestrial remote sensing

The terrestrial remote sensing methods currently being used are X-band radar and video, although the method could change with technological advances. The regular automated data collection from these methods is capable of tracking shoreline change and quantifying beach state indicators; specifically beach width and beach volume (beach volumes at Sizewell are proportional to beach width; BEEMS Technical Report TR544, Section 3.1.1.2 [REP3-032]).

Indirect estimates of volume provide an early warning of the *buffer* exposure risk index and mitigation trigger, without the need to conduct frequent field work. The indirectly estimated volumes will be checked and reported each month.

The proposed SCDF crest integrity trigger would be assessed using camera data. Visual assessment of changes in surface sediments and loss of vegetation would be used to assess erosion on the seaward face and crest of the SCDF. Wave run-up stacks (video data on east-west transects that trace wave runup) would

[17] As registered in the water level (tide gauge) and wave monitoring.
[18] Terrestrial remote sensing (monthly, 1 km either side of SZC), beach surveys and five-yearly bathymetric survey (Minsmere Outfall to Thorpeness).

be used to ascertain if wave action has occurred close to, on or over the SCDF crest. Collectively these data would be used to as part of the early warning system and may trigger further *ad hoc* topographic surveys.

7.4.2 Mitigation (beach maintenance) triggers

As the terrestrial remote sensing methods currently cannot directly measure beach volume or SCDF topography, the definitive *buffer* exposure risk index and mitigation trigger must be assessed via topographic survey. If a monthly volumetric trigger alert is raised using terrestrial remote sensing survey, this would require an RPA flight to take place (subject to weather conditions), for confirmation (step 2 in Figure 11). Likewise, if the vegetated crest of the SCDF shows signs of erosion, a combined RPA – ground survey would be required.

The method for topographic data collection needs to be accurate and spatially continuous, to identify whether any sections of the beach have fallen below the mitigation threshold volume, and to inform recommendations for the type of mitigation to be undertaken, the volumes of material involved and precisely where the mitigation activity should take place. The intended method for these field surveys is photogrammetry from RPA, plus occasional ground survey in areas of continuous vegetation such as the SCDF crest, as it creates high resolution spatially continuous results. The RPA technique has been successfully used at Hinkley Point for impact detection (e.g., BEEMS Monitoring Report MHP5512, which is an annual report on localised gravel transport blockages and down-drift starvation) and at Sizewell to establish a baseline. The survey methods will be detailed by technical reporting (BEEMS Technical Report TR546, due in 2021) and an Annex to this report.

7.5 Mitigation options

The aim of the proposed mitigation is to maintain the longshore shingle transport corridor.

Mitigation (or the process of designing and agreeing mitigation) will begin when the volumetric (or other) triggers are met. Numerical modelling in BEEMS Technical Report TR545 [REP3-048] suggests that the volumetric trigger is very likely to be met first (before a crest level or shoreline alignment trigger) because overtopping and severe adjacent coastal recession is not predicted for several decades[19]. As the precise conditions requiring mitigation cannot be known *a priori*, neither can an individual mitigation activity be specified years or more in advance. This is, of course, the same problem faced by coastal managers when managing their frontages. Evidence based judgements must be made closer to the time when a beach or defence feature approaches a threshold condition and, according to the evidence, the specific mitigation activity devised. For beach volumes, the SCDF *buffer* exposure risk index should therefore provide forewarning of likely forthcoming mitigation, at least in terms of the location and extent.

It is important to note that changes to the broad coastal regime and coastal processes may occur within the operation and decommissioning phases, some of which may reduce or obviate the need for mitigation. In particular, decay and/or removal of the Minsmere Sluice and erosion of the Dunwich – Minsmere Cliffs are likely to increase shingle supply and alter the shoreline shape. A rising natural sediment supply may lead to reductions in the mitigation frequency and/or magnitude. Such changes would be detected by the *background monitoring*.

Although the precise beach conditions and matching mitigation actions cannot be known at this stage, there are a limited number of beach conditions that could threaten HCDF exposure. These have been used in the ES and are used here to illustrate the likely mitigation responses and will be subject to agreement at the appropriate time under this plan

The method, location and volumes for each mitigation action would depend on the circumstances at the time – the future monitoring evidence base (specifically the SCDF *buffer* exposure risk index) would be used to

[19] Overtopping requires high sea levels (e.g., 2099 RCP4.5 95th percentile predictions) and storms surge.

identify areas of potential exposure prior to the mitigation trigger. Areas experiencing a higher rate of erosion are likely to require more mitigation to restore V_{sac}. For example, an area around the BLF has higher erosion rates than the central or southern SCDF (BEEMS Technical Report TR544 [REP3-032]).

The mitigation methods would involve either moving existing beach sediment (bypassing or recycling) or introducing new material (recharge), working with natural processes to ensure a sustainable solution is provided (Rogers et al., 2010). BEEMS Technical Report TR544 [REP3-032] demonstrates that these mitigation methods are viable at Sizewell, initially at least, because:

- the shoreline retreat rates are not particularly high (peak rates of 2.2 m/year are localised and short lived);
- retreating areas typically have relatively small spatial extents (i.e., spatially localised erosion/accretion patterns following individual events is a strong characteristic of this coast), meaning that mitigation volumes would not be large – a conservative worst-case requirement of 270,550 m^3 of recharge material to 2099 is well within the scope of beach recharge schemes currently in operation;
- shingle has a high entrainment threshold (i.e., low mobility) so maintenance activities would have a moderately high resilience; and
- longshore shingle transport rates are low, meaning that deposited sediments would be moved away slowly.

Hence the environment around Sizewell is considered suitable for the mitigation methods proposed. Note that beach recycling is a practice that has been employed in the UK at sites with both Hold the Line (e.g., South Beach, Lowestoft) and Managed Realignment (e.g., Slapton Sands) Shoreline Management Plans.

The broad conditions for method selection are outlined below.

7.5.1 Longshore beach sediment recycling

Longshore beach sediment recycling (beach recycling for short) usually involves the mechanical movement of sediment from the downdrift end of a beach, back to the updrift end, but can be in the opposite direction, which has relevance for beaches like Sizewell where the gross transport directions often reverse. Beach recycling involves no additional sediments but redistributes native beach material from an accreting borrow area (orange in Figure 12) to an eroding area (green). It can be carried out at relatively short notice. Should this situation arise (i.e., accumulation and depletion) beach recycling would be applied. Through this approach, a degree of continuity of beach material supply and transport can be achieved along the beach frontage. The effect on the shorelines would be accretion or a reduction in erosion rates local to those deposition sites, and the sediment would slowly disperse with time.

Recycling is well-suited for Sizewell because of its low to moderate rates of longshore drift, meaning that volumes required, and dispersion rates, would be relatively small. Rogers et al. (2010) suggest that beaches with longshore drift rates less than 80,000 m^3/yr are suitable for recycling – the rates at Sizewell are around 10,000 m^3/yr and so fall well within this specification. Beach recycling has also been used on nearby South Beach (Lowestoft) by Suffolk County Council and at the UK's largest coastal shingle landform at Dungeness by EDF Energy and the Environment Agency. Dungeness, like the Sizewell – Minsmere area, has several statutory conservation designations.

At Sizewell, monitoring data would be used to take account of natural shoreline variation and identify potential borrow areas in the event of a trigger requiring mitigation. The intention is not to extract sediment from the designated Minsmere sites, however if a case for this did arise it would be subject to any necessary assessments and legislative approvals relevant at that time; as the future environment naturally changes, some designated habitats/features (as described by Natural England's condition assessment reports and DCO/DML monitoring reports from this monitoring plan) may also naturally change in quality or disappear, potentially allowing such an activity.

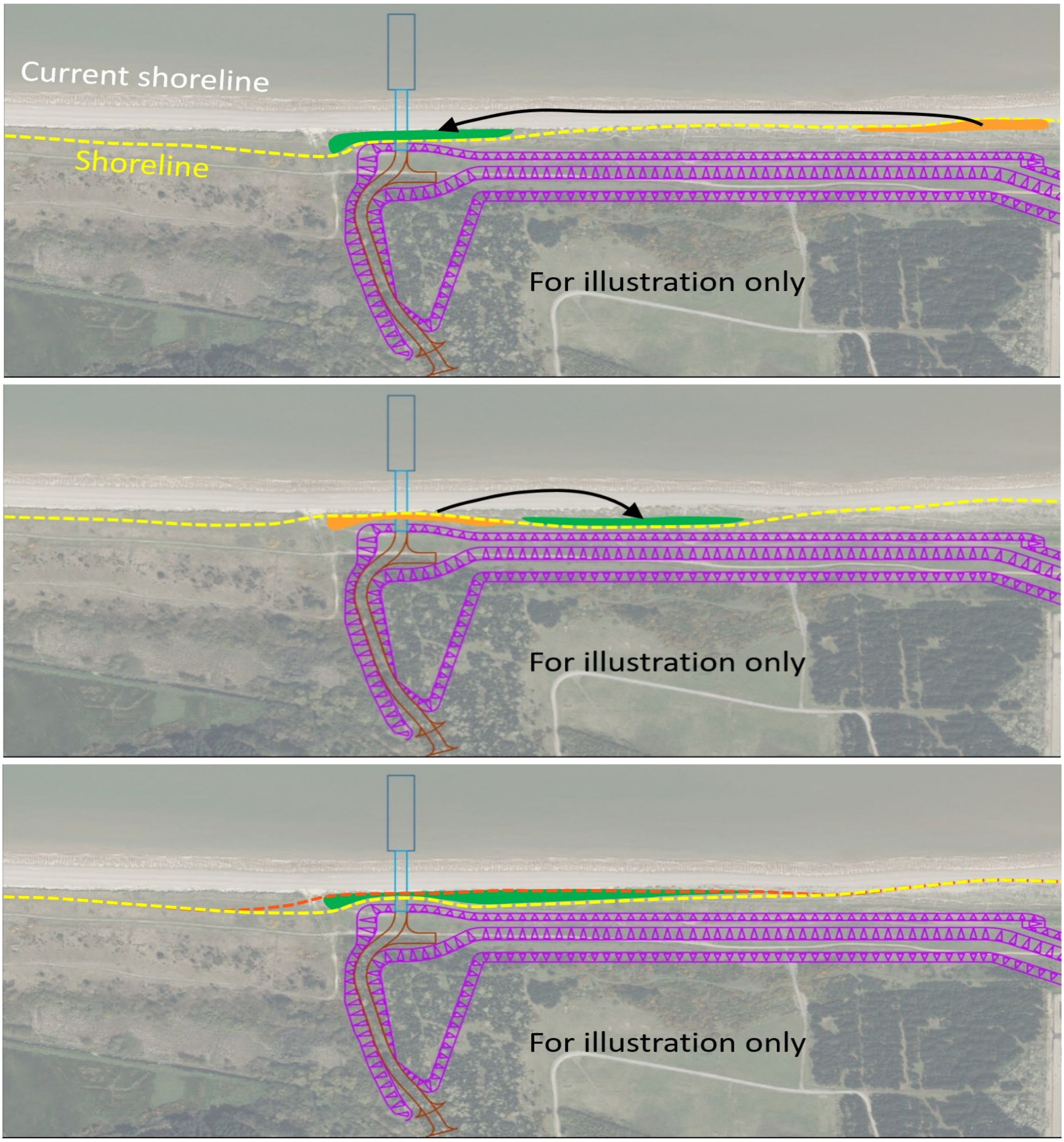

Figure 12: Schematics showing examples of depleted beach sections and the likely mitigation method: beach recycling (top), sediment bypassing (middle) and beach recharge (bottom). The examples assume a net southerly (left to right) longshore drift, but the same principles can be applied in the unlikely event of any period of persistent reversal in the net transport direction. Orange indicates the borrow area and green the deposition area. [Note that recent design changes bring the abutment at the BLF landwards to align with the main HCDF, and the HCDF seaward toe further landward than shown, to approximately 647620E, however engineering drawings were not available when this report was produced. This figure will be updated in the next version of this report.]

7.5.2 Sediment bypassing

Sediment bypassing involves moving beach material from areas of accumulation to areas of erosion: similar to beach recycling, but for the case where erosion has resulted from the interception or disturbance of natural longshore transport processes. The effect of bypassing is to manually restore longshore sediment supply past an area where it has been interrupted, altering the shoreline position local to the extraction and deposition sites. For example, shingle that was temporarily blocked (for several months) by sea wall construction material at HPC was detected (using RPA topographic surveys) and successfully bypassed to avoid any impacts to downdrift beaches. Bypassing is most relevant to a disruption to net southerly longshore transport at Sizewell, though it could be applied to persistent phases (years) of transport reversal.

As discussed in Section 7.7, mechanical sediment bypassing is most likely to be used if the HCDF were exposed (temporarily or permanently) and causing persistent updrift sediment accretion – the excess sediment accreting updrift would then manually bypass the HCDF to restore downdrift supply (Figure 12, middle panel). The potential accumulation sites for bypassing are north of the HCDF (under the prevailing southerly transport), or, under phases of northerly transport, immediately south of the BLF and south of the HCDF adjacent to the SZB defences. Given the natural bi-directionality in longshore transport, consideration would be given to the persistence of erosion/accretion patterns so as to avoid unnecessary disturbance and mitigation activity. As with beach recycling, the intention is not to extract sediment from the designated Minsmere sites, however if a case for this did arise, it would be subject to any assessments and legislative approvals relevant at that time.

7.5.3 Beach sediment recharge

Beach sediment recharge is the process of actively increasing beach volume using imported material. Unless there are obvious borrow areas, trigger alerts are most likely to be addressed using recharge mitigation (Figure 12, bottom panel). The effect of introducing extra sediment would be to initially decrease, halt or reverse the erosion rate, to maintain continuity in the beach and longshore transport system. Over time, the introduced material would slowly disperse. Over the decades of station operation and decommissioning, sediments lost from the SCDF are expected to accumulate on adjacent beaches to the immediate north and south. These shorelines are likely to benefit from this greater than normal deposition of additional sediment, which would act counter to sea level rise, reducing erosion rates. As the SCDF is primarily made of pebble-sized sediments, any expansion of supra-tidal zones could lead to colonisation by annual drift line vegetation, which to the north of Sizewell C was lost over a decade ago due to natural coastal erosion.

Whilst the target particle size for the SCDF and beach recharge has not been finalised at the time of writing, the ES and BEEMS Technical Report TR544 [REP3-032] recommend pebbles at, or preferably coarser than, the modal size c. 10 mm), initially up to the native distribution limit of approximately 40 mm. The physical characteristics of the material used in any beach recharge (e.g., size and angularity) are critical to the performance of recharge and coarsening is commonly used in the UK to improve beach recharge longevity (Rogers et al., 2010): for example, the Environment Agency's Lincshore Scheme in Lincolnshire (Environment Agency, 2017) and the Bacton to Walcott Sandscaping Scheme in North Norfolk (North Norfolk County Council, 2019).

Accordingly, primarily pebble-sized material would likely be used for any Sizewell beach recharge to increase longevity. Subject to performance assessment from any previous beach recharge, the intention would be for the particle size to fall within the range of the natural size distribution. Sand is unlikely to be deliberately used because it can be rapidly lost from the subaerial beach through cross-shore sediment exchange during storms[20], it can reduce recharge longevity and at high volumes it can increase cliffing and

[20] Cross-shore sediment exchange is dominated by sand; in comparison, shingle is retained almost exclusively above low tide.

can cause mixed sand-shingle beaches to exhibit more dynamic sand-beach behaviour[21], which could lead to rapid erosion and poor mitigation performance.

As it is not possible to predict depleted areas in advance, it is also not possible to predict the required volumes of sediment to be supplied, as this would depend on the beach condition (volume, extent) warranting intervention. However, worst case assessments provided in BEEMS Technical Report TR544 [REP3-032] (based on sand erosion rates and simultaneous depletion of the whole length of the SCDF) indicate that recharge volumes required to maintain the SCDF into the decommissioning phase (post 2099) would be less than 270,500 m^3, well within the scope of present-day recharge schemes operating on far shorter timescales. The monitoring results would provide the evidence needed to design the beach recharge, including the location, thickness and volumes.

7.5.4 Example cases requiring SCDF mitigation

A separate Annex to this report will be provided detailing three 'sample' cases illustrating the proposed application of SCDF mitigation measures. The examples are not intended to represent the limits of specific applications, simply to provide enumerated examples of their potential, based on storm erosion modelling data and future shoreline change scenarios.

7.5.5 What are the potential impacts of beach maintenance practices on designated sites?

The beach maintenance / sediment management approaches described in Sections 7.5.1 to 7.5.3 are not predicted to have an adverse effect on designated supra-tidal shingle habitats (annual vegetated drift lines and potential little tern nesting sites) as:

- they would not cause erosion;
- they would cause some localised short-term beach accretion, limited in extent by the relatively small volumes being moved or introduced (which may enhance habitat over time e.g., the southern extent of the Minsmere frontage, subject to the volumes of sediment naturally eroded and transported from the SCDF);
- in the cases of bypassing or beach recycling, sediment would not be extracted from statutory designated sites (unless sediments accumulating on these frontages were a direct effect of the Sizewell C Project i.e., mitigation or presence of the HCDF, and approval was given following demonstration that designated features would not be affected);
- sediment would not be deposited on the supra-tidal beach within statutory designated sites, unless approval was given following demonstration that designated features would not be adversely affected; and
- the Leiston – Aldeburgh SSSI is too distant to be affected by beach management activity at Sizewell C, as shown by modelled longshore transport and measured shingle movement (BEEMS Technical Reports TR329 and TR420).

Deposited material would move under natural coastal processes within the active beach, behaving in the same fashion as the rest of the beach material. These sediments are no different from the material already present. Sediment deposited as mitigation would be placed appropriately to avoid unnatural mounds or shapes, thereby allowing the beach to function naturally. Any beach maintenance activity directly on the designated frontage would require assessment and approvals from Natural England. Notwithstanding approvals, sediment extraction from the active beach face (not the supra-tidal zone) could still be undertaken in areas experiencing long-term deposition of SCDF sediments.

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21 Mason (1997) suggested that once the sand ratio in a beach was 40% or higher, it would behave more like a pure-sand beach.

7.6 Performance assessment

All mitigation interventions will be monitored to assess their performance and improve the selection and specification of any future mitigation required. The performance assessment would involve a pre-mitigation survey to be conducted less than one month before the mitigation action, preferably (weather permitting) less than a week. In some cases, a pre-mitigation survey may not be possible; for example, if a very long duration storm, or storm sequence, would otherwise unacceptably delay mitigation. Unless warranted, the survey would extend 1 km alongshore north and south from a beach recharge or 1 km north and south of the northern and southern borrow and deposition areas, respectively.

A second survey would be conducted as soon as possible after mitigation, to document the beach state and spatial changes in volumes as a result of mitigation. Three subsequent monthly surveys would be used in a Post-mitigation Assessment Report, to be delivered 3 – 4 months after the mitigation action. As well as assessing performance, this report would indicate whether further surveys were needed (e.g., temporarily increasing survey frequency) or whether the *background monitoring* (ongoing terrestrial remote sensing, beach surveys and bathymetric survey once every five years) was adequate.

7.7 SCDF viability and mitigation in the event of HCDF exposure

Storm erosion volumes and the observed beach volume changes over time have been used to illustrate the viability of the SCDF over the operations and into the decommissioning phase in BEEMS Technical Report TR544 [REP3-032]. However, even allowing for a conservative SCDF buffer volume, a finite risk will remain that the HCDF could be temporarily exposed (in the case that an extreme storm or storm sequence occurs in the interval between the trigger being activated and conduction of mitigation being possible). In this (highly unlikely[22]) event, the SCDF would be rebuilt as soon as practicable. Monitoring will also enable determination of the degree to which the exposure interval had impacted on longshore transport and beach volumes on the up- and down-drift sides of the HCDF. These assessments would determine if, and where, bypassing or recharge should be applied (in addition to fully recharging the SCDF).

These proposed measures would be sufficient to manage the impacts of a short-term exposure during the operations phase – the data presented in BEEMS Technical Report TR544 [REP3-032] make clear that storm-driven volume changes on the beach in conditions up to projected 2099 sea level conditions can be managed or compensated for via the SCDF primary and secondary mitigation measures. Prolonged exposure of the HCDF for a significant period would require the same approach to quantify the updrift accumulation and downdrift starvation volumes which would require restoration (by secondary mitigation measures), to minimise the alongshore extent of consequential impacts on adjacent frontages.

Further modelling is ongoing to assess SCDF viability to the end of decommissioning. Modelling will be used to determine the general principles of beach volume change under a range of plausible future shoreline morphodynamic settings.

[22] The buffer volume should be defined to correspond to an agreed risk of HCDF exposure i.e., a buffer volume equal to a 1:100 year event erosion volume would represent a 1% risk of HCDF exposure.

8 Annual vegetation of drift lines

A high-quality annual vegetation of drift lines habitat is considered to be located within the non-statutory Suffolk County Wildlife Site just south of the Sizewell C frontage. Establishing a baseline and distinguishing natural variability in the spatially sparse vegetation, including its natural seasonal growth and die-back, is likely to require methods more sophisticated than traditional ground survey / quadrat approaches. The JNCC recommends the National Vegetation Classification (NVC)[23] to help develop a conceptual basis for understanding the purpose and practice of, and furnish protocols for, monitoring. The proposed method will, therefore, use the NVC as an initial reference.

The proposal for monitoring annual vegetation is to use very high resolution (< 3 cm) multi-spectral (visible and near infra-red) data gathered from an RPA platform to provide a spatially continuous substrate/vegetation map over the annual vegetation habitats. This approach would be used to detect and characterise the annual vegetation to a spatial degree not possible with traditional sub-sampling quadrat approaches, and would aim to distinguish annual vegetation[24] from shingle and other vegetation / habitats (e.g., dunes and dune grasses). Cefas has conducted similar work at Hinkley Point on rock platform algae for EDF Energy and at Two Tree Island (Essex) and Budle Bay (Northumberland) on sea grasses in partnership with the Environment Agency.

The method is under development with final reporting due in 2021. Early results show that the RPA accurately monitors habitat extents and can characterise zonation (e.g., between types of grasslands and pioneer communities); it shows promise with respect to species-level composition in that it can detect two of the key shingle beach species (*Crambe maritima* (sea kale) and *Ammophila arenaria* (marram grass)). Additional multi-spectral channels (ten rather than five) are being used to improve detailed zonation and some of the other CSMP[25] attributes. A separate Annex to the CPMMP will be provided following issue of a Technical Report detailing the method, when a subsequent version of this monitoring plan is issued.

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[23] JNCC: https://jncc.gov.uk/our-work/nvc/
[24] formations of annuals or representatives of annuals and perennials, occupying accumulations of drift material and gravel rich in nitrogenous organic matter.
[25] UK Common Standards Monitoring Programme

9 Monitoring reports

The scope of the proposed monitoring is illustrated in Figure 8 and often uses the same monitoring methods and parameters for several different components. To streamline the reporting, and avoid repetition of the same data for different impacts, eight types of report are proposed (as outlined in Section 1.5 and Figure 2):

- **Baseline Reports (pre-construction):** the final pre-construction reports, updating the baselines with monitoring data for the period between DCO reporting and the start of marine construction. Baseline reports pertaining to geomorphic receptors and hydrodynamics relevant to the station's marine activities and structure would be submitted to the MTF, allowing sufficient time for regulatory feedback before construction (of each component) commences.
- **Notification Reports (SZC construction, operation and decommissioning):** short reports to advise the MTF that scheduled monitoring has taken place, that the data collected are fit for purpose[26], and whether any apparent impacts are within the predicted range. These reports would be delivered within eight weeks[27] of data collection. If unexpected impacts arise that have the potential to cause a likely significant effect, the Notification Report will recommend an Ad Hoc Report to follow up within one month.
  - **Trigger Notification Reports**: short notification reports to be used only in conjunction with the monitoring and mitigation, for example, to maintain the shingle beach along the SZC frontage. For the SCDF, they would be based on beach surveys needed to indicate the trigger ($V < V_{recharge}$) location and the potential need to apply mitigation. They would only be produced if beach volume falls below the agreed threshold. An early warning RAG[28] scheme to indicate the stages leading up to recharge (under development) would also utilise trigger notification reports.
  - **Ad Hoc Reports (SZC construction, operation and decommissioning):** for unexpected circumstances or magnitudes of impact that have the potential to cause a significant effect. These reports would be used where mitigation might be required immediately or before the Annual Report. No Ad Hoc Reports are expected, but they are included to make the monitoring plan robust.
- **Annual and Substantive Review Reports (SZC construction, operation and decommissioning):** detailed examination of the monitoring data for all activities, with a particular focus on impact detection, mitigation and mitigation performance. Annual reports would be issued by the end of September each year and include data up until the end of May (spring). They would also include evidence-based recommendations regarding:
  - any proposed changes to the monitoring schedule, such as frequency increases or decreases, or cessation of individual monitoring components (e.g., some monitoring is specific to construction activities and would not be required *ad infinitum*),
  - proposed additional surveys where unexpected issues may have occurred,
  - proposed changes to the *background monitoring*,
  - method changes due to, for example, changes in measurement technology, and

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[26] We expect that our experimental design will deliver fit for purpose data, and we will operate rigorous QA procedures to ensure that this is so. However, external factors such as weather could mean that on occasions the data are not fit for purpose. In such circumstances, the notification report will alert the MTF and the survey will be re-scheduled for the soonest possible date.
[27] The delivery period will be assessed for each survey type. Due to the nature of the data collected and data processing requirements, some surveys may require a different post-survey period.
[28] Red Amber Green

- changes in reporting schedules.

Substantive reviews (initially proposed on a ten-yearly cycle) would provide an overview of these same elements, identifying whether:

- trends or patterns suggest that projected changes should be updated (e.g., likely frequency of beach recharge),
- technological advances suggest changes to monitoring methods should be applied,
- predictive modelling improvements would provide an improved future assessment of SCDF erosivity, and
- to provide updated projections of the recharge volumes and anticipated recharge interval of the SCDF, including the RAG scheme being developed (following BEEMS Technical Report TR544 [REP3-032]) to track any change in risk due to SCDF and adjacent shoreline evolution.

The substantive reviews would also update the environmental baselines (tracking sea level rise against initial projections, for example, and reviewing wave conditions), trigger levels and, if required, propose updating of the modelling underpinning the appropriate mitigation triggers. Toward the end of the operation phase, the substantive reviews should also consider the potential impacts of HCDF retention or removal, so as to inform the Cessation (of Sizewell C Co.'s monitoring and mitigation) Report (see Section 10).

- **Mitigation Reports (Sizewell C operation and decommissioning)**: mitigation for coastal geomorphology is only proposed with respect to two potential interruptions to continuous longshore transport – (i) for maintaining a continuous shingle beach seaward of the HCDF and, (ii) sediment transfer at the BLF grounding pocket during the operations phase (if needed). Mitigation reports would be triggered (and therefore do not have a reporting schedule). There are two types:
  - **pre-mitigation assessment note:** to provide the analysis of the monitoring data to confirm the mitigation trigger[29]. If mitigation is needed, they would determine which method of mitigation is most appropriate (e.g., to maintain the shingle beach) which would be submitted for approval; and
  - **post-mitigation assessment report**: assessing the effectiveness of the mitigation applied - for example, by examining the volumetric changes in the area of concern (including the borrow areas for beach recycling and bypassing) and the effects on neighbouring features. Specifically, these reports would document the changes arising as a result of mitigation and would recommend whether additional monitoring is needed (further to recommendations in prior Annual Reports) and any changes to be considered in subsequent mitigation.

The reporting associated with each activity is shown in Table 1 and Figure 2.

Note that, with the exception of Mitigation and Ad Hoc Reports, the reporting described is analogous to that being successfully used at Hinkley Point C. All reports will be submitted to the regulatory MTF stakeholders and, following receipt of their comments, an annual MTF meeting will be offered.

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[29] For example, that beach volumes have fallen below the trigger threshold.

10 Monitoring and mitigation cessation report

Toward the end of the Sizewell C Project's decommissioning phase, an assessment on the cessation of the Project's monitoring and mitigation will be made, as stated in the ES. It noted that "*Prior to cessation of beach monitoring and mitigation, any remaining residual significant effects would need to be identified, assessed and, if required, compensated. However, the detail required to undertake that assessment cannot be known until much closer to that time, when the nature of the HCDF exposure, the broad geomorphic setting and the locations of designated sites and features are all known with confidence*".

SZC Co. has since agreed that the default position will be removal of the HCDF. The impacts of retention or removal – whichever is finally confirmed later in the development – will need to be assessed. Although the detail required to undertake such assessments cannot be known, the ES did set out some plausible geomorphic settings and the associated potential impacts for context, whilst further noting that they are not suitable for impact assessment and compensation evaluation, due to the very high uncertainty in both the geomorphic setting and designated features. Instead, those plausible geomorphic configurations and potential residual effects, which are not reiterated here, would be established with many decades of monitoring evidence until, closer to the time, they are fit for purpose to assess the significance of any impacts arising.

Within ten years prior to the end of decommissioning, a Sizewell C Co. monitoring and mitigation cessation report will be submitted to the MMO and ESC (or the equivalent future authorities) for their approval. This report is necessary as Sizewell C Co. will cease to exist at the end of decommissioning, as will this monitoring and mitigation plan, but it does not necessarily equate to the end of monitoring and mitigation. The cessation report would be expected to include:

- The condition of Greater Sizewell Bay, its geomorphic elements, coastal processes and sediment transport rates and pathways.
- The status of statutory designated sites and features relevant to potential SZC impacts at that time, and their condition.
- The likely impacts resulting from exposure of the HCDF following cessation of mitigation, including an assessment of any likely significant effects on statutory designated sites.
- Assessment of the impacts from removal of HCDF at end of decommissioning.
- Recommendations on any alternative mitigation options.

The cessation report would be the evidence basis to underpin any subsequent actions. The cessation action(s) and potential final measures would reflect policy, the shoreline management plan and statutory designations at that time, in the context of decommissioning, and cannot be fully evaluated at present. The monitoring and mitigation described in this plan, and any future approved versions, will continue until superseded by the approved Monitoring and Mitigation Cessation Report.

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Annex List

This section will be updated with a list of Annexes to the CPMMP as they become available. Annexes will be updated as part of the adaptive management methods throughout the period of application of this CPMMP. Presently envisaged Annexes would include:

- Beach survey methodology
- Beach mitigation triggers and the SCDF *buffer* exposure risk index
- Digital beach mitigation examples to illustrate how mitigation would be triggered for different patterns of erosion and accretion, how the method would be selected, and a method statement regarding design specifications and how they meet guidance in the beach manual etc). The examples would be the digital (surface) equivalents of the schematics shown in Figure 12.

Appendix A Residual effects on coastal geomorphology

The following tables, Table 4 and Table 5, present a summary of the coastal geomorphology and hydrodynamics assessment, as presented in the ES (Tables 20.8 and 20.9 of Chapter 20, Volume 2. They present the receptor likely to be impacted, the level of effect and, where the effect is deemed to be significant due to impact magnitude, receptor value, or uncertainty in the assessment, the tables include the mitigation proposed and the resulting residual effect. The monitoring for scour around structures is standard practice and is included here despite there being no significant effect on coastal geomorphology receptors.

Table 4: Summary of effects for the construction phase. Source: SZC Co. ES (Table 20.8, Chapter 20, Volume 2) (NNB Generation Company (SZC) Limited, 2020a).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Shoreline / beach.	Sediment compaction by heavy plant building the SCDF.	None.	Minor adverse.	None required.	None proposed.	Minor adverse (**not significant**).
Shoreline / beach.	Increased beach sediment due to SCDF erosion. Reduction in erosion rate on Sizewell C and Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA frontage. Increased longevity of a natural beach fronting the HCDF and the annual vegetation of drift lines habitat.	None.	Minor beneficial.	Required.	None proposed.	Minor beneficial (**not significant**).
Shoreline / beach.	Sediment compaction by heavy plant building the BLF.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Inner bar and beach.	Physical loss of substrate during BLF and MBIF piling.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Inner bar and beach.	Altered hydrodynamics and sedimentation due to presence of BLF and MBIF piles.	Low number of slender piles – transmissive to water and sediment. Short BLF deck length.	Negligible.	None required.	None proposed.	Negligible (**not significant**).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Longshore bars and beach.	Altered hydrodynamics and sedimentation due to dredging and reprofiled bed for BLF access and docking.	Use of shallow draft vessels and plough dredger to minimise dredging and retain sediment in the system.	Minor adverse.	Required.	None proposed.	Minor adverse. (**not significant**)
Longshore bars and beach.	Altered hydrodynamics and sedimentation due to grounded barge docked at BLF deck.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Longshore bars.	Altered hydrodynamics and sedimentation due to propeller wash from tugboats during BLF use.	BLF / docking not used year round.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).
Longshore bars and beach.	Dredging and bed lowering for installation of nearshore outfall heads.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Longshore bars and beach.	Dredge spoil disposal on outer bar 500m from nearshore outfalls.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Outer longshore bar.	Drilling connection shafts from subterranean nearshore outfall tunnels would locally disturb bed sediment and slightly increase SSC.	None.	Negligible.	Not required but the affected area of the bar will be monitored for scour'.	None proposed.	Negligible (**not significant**).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Outer longshore bar.	Sediment disturbance by jack-up barges for installing nearshore outfalls.	None.	Negligible.	Not required but the affected area of the bar will be monitored for scour'.	None proposed.	Negligible (**not significant**).
Longshore bars and beach.	Scour around nearshore outfalls and the potential to alter the shape of the outer. bar and the beach, following the Sizewell B analogy.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank.	Dredging for the cooling water heads installation.	Located away from the bank. No intersection with scour.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank.	Dredge spoil disposal for cooling water head installation within 500m of the heads.	Disposal at least 500m away from bank.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank and Coralline Crag.	Sediment disturbance during cooling water head installation.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank and Coralline Crag.	Sediment disturbance during cooling water head installation, including piling for seismic qualification.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Sizewell – Dunwich Bank and Coralline Crag.	Sediment disturbance by jack-up barges due to cooling water head installation.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank and Coralline Crag.	Loss of seabed substrate under cooling water heads (sand, Red Crag). Long-term obstruction to flow forming scour pits where the bed is sandy.	None.	Negligible.	None Required	None proposed.	Negligible (**not significant**).

Table 5: Summary of effects for the operational phase. Source: SZC Co. ES (Table 20.8, Chapter 20, Volume 2) (NNB Generation Company (SZC) Limited, 2020a)

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Shoreline / beach.	Sediment compaction by heavy plant maintaining the SCDF (if required).	None.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).
Shoreline / beach.	Increased beach sediment due to SCDF erosion. Reduction in erosion rate on Sizewell C and Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA frontage. Increased longevity of a natural beach fronting the	None.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
	HCDF and the annual vegetation of drift lines habitat.					
Inner bar and beach.	Altered hydrodynamics and sedimentation due to presence of BLF piles.	Low number of slender piles – transmissive to water and sediment. Short BLF deck length.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).
Longshore bars and beach.	Altered hydrodynamics and sedimentation due to dredging and reprofiled bed for BLF access and docking.	Use of shallow draft vessels and plough dredger to minimise dredging and retain sediment in the system. Only required once every 5-10 years.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Longshore bars.	Altered hydrodynamics and sedimentation due to propeller wash from tugboats during BLF use.	Only required once as docking will be every 5-10 years.	Minor adverse.	None.	None proposed.	Minor adverse (**not significant**).
Longshore bars and beach.	Scour around nearshore outfalls and the potential to alter the shape of the outer bar and the beach, following the Sizewell B analogy.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank.	Loss of seabed substrate (sand, red crag) under cooling water heads. Long-term obstruction to flow forming scour pits.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).

Appendix B Calculating Return Intervals of Storm Cumulative Power

Note: this text has been previously included in BEEMS Technical Report TR531, Appendix B.

B.1 Methodology

Return periods can be calculated for storm cumulative wave power (P_{cuml}), or Work, by fitting a Weibull distribution, assuming that measurements of P_{cuml} are independent and identically distributed[30]. This assumption is true if there is no autocorrelation between P_{cuml} for successive storms, if the timing of the storms themselves is independent, and if the natural processes that generate the storms lead to values of P_{cuml} being drawn from the same distribution.

To calculate return periods for P_{cuml} at Sizewell, storms were extracted from the Sizewell Waverider telemetry dataset by searching for periods of significant wave height over 1 m for at least six hours. In the Waverider record from 02/2008 – 11/2020 this represented 18.6% of all data. Although there was a seasonal pattern in storms frequency, the frequency and magnitude of storms was reasonably stationary. P_{cuml} was calculated as the sum of wave powers for all significant wave height readings during a storm.

The Weibull empirical cumulative distribution function can be linearised to allow shape and scale parameters for the distribution to be calculated.

$$F(x) = 1 - e^{-(x/\lambda)^k}$$

$$-\ln(1 - F(x)) = (x/\lambda)^k$$

$$\underbrace{\ln(-\ln(1 - F(x)))}_{\text{'y'}} = \underbrace{k \ln x}_{\text{'mx'}} - \underbrace{k \ln \lambda}_{\text{'c'}}$$

Figure 13: Derivation of the linear form of the Weibull empirical cumulative distribution function, F(x).

To calculate F(P_{cuml}) 100 evenly spaced thresholds were set between the minimum and maximum values of P_{cuml} in the dataset. Cumulative counts of storms below each threshold were then calculated and divided by the total number of storms to give F(P_{cuml}) at each threshold value. This was regressed against ln(P_{cuml}) for each threshold. The slope of the regression (k in Figure 13) is the shape parameter of the fitted Weibull distribution and the intercept can be used to calculate the scale parameter (λ in Figure 13).

Once the shape and scale parameters were derived, the probabilities of 1:n year events were used to calculate return periods. The probability of a 1:n year storm is 1/(n × N(storms/yr)), where N(storms/yr) is the number of storms in the Waverider dataset divided by its length in years, accounting for missing data. The equivalent quantile (1 – P(1:n storm)) and the quantile function of the Weibull distribution with shape and scale parameters equal to those calculated from the regression were then used to calculate the cumulative power of a 1:n storm.

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[30] Dhoop, T.; Mason, T., Spatial Characteristics and Duration of Extreme Waves, 2018.

B.2 Results

Based on the 12-years of observations from the Sizewell Waverider, Figure 14 shows a plot of the cumulative wave power vs the return interval. Table 6 summarizes the cumulative power for various return intervals.

Following the calculation of the cumulative power return intervals, the BfE sequence has been analyzed to assess the return interval of cumulative power of the entire sequence and its subsequent components (E1 + E2 + E3). This is summarized in Table 7.

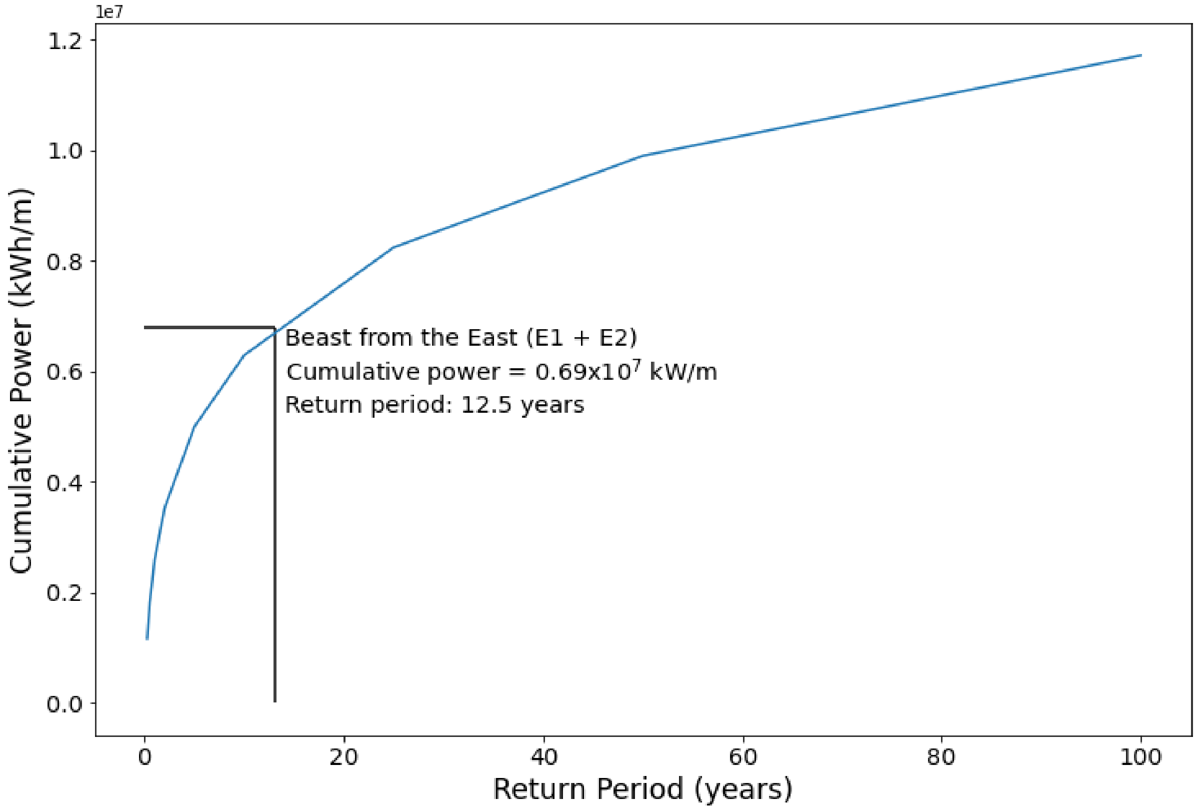

Figure 14: Cumulative power return periods, calculated from Sizewell Waverider Data 02/2008 - 11/2020.

Table 6: Cumulative power return periods, calculated from Sizewell Waverider Data 02/2008 - 11/2020.

Return Period (Years)	Cumulative Power (kW/m)
0.25	1.16E+06
0.5	1.80E+06
1	2.59E+06
2	3.53E+06
5	5.00E+06
10	6.30E+06
25	8.24E+06
50	9.90E+06
100	1.17E+07
200	1.37E+07

Table 7: Summary of the cumulative power of the components of the BfE storm sequence, Storm Ciara and the May 2020 storm and their respective return interval. The BfE E1 + E2 storms were modelled in this report.

Event	Cumulative Power (kW/m)	Return Period (years)
E1	5.42E+05	0.1
E2	6.37E+06	9.7
E3	5.68E+06	6.9
E1 + E2	6.91E+06	12.5
E2 + E3	1.21E+07	89.5
E1 + E2 + E3	1.26E+07	107
Storm Ciara	2.01E+06	0.64
May 2020 Storm	1.82E+06	0.54

Appendix C Modified Udden-Wentworth classification

PARTICLE LENGTH (dɪ) km	m	mm	ϕ	GRADE	CLASS	FRACTION Unlithified	FRACTION Lithified
1075			-30	very coarse	Megalith	Megagravel	Mega-conglomerate
538			-29	coarse			
269			-28	medium			
134			-27	fine			
67.2			-26	very fine			
33.6			-25	very coarse	Monolith		
16.8			-24	coarse			
8.4			-23	medium			
4.2			-22	fine			
2.1			-21	very fine			
1.0	1048.6		-20	very coarse	Slab		
0.5	524.3		-19	coarse			
0.26	262.1		-18	medium			
	131.1		-17	fine			
	65.5		-16	very coarse	Block		
	32.8		-15	coarse			
	16.4		-14	medium			
	8.2		-13	fine			
	4.1	4096	-12	very coarse	Boulder	Gravel	Conglomerate
	2.0	2048	-11	coarse			
	1.0	1024	-10	medium			
	0.5	512	-9	fine			
	0.25	256	-8	coarse	Cobble		
		128	-7	fine			
		64	-6	very coarse	Pebble		
		32	-5	coarse			
		16	-4	medium			
		8	-3	fine			
		4	-2		Granule		
		2	-1	very coarse	Sand	Sand	Sandstone
		1	0	coarse			
		0.50	1	medium			
		0.25	2	fine			
		0.125	3	very fine			
		0.063	4	coarse	Silt	Mud	Mudstone or Shale
		0.031	5	medium			
		0.015	6	fine			
		0.008	7	very fine			
		0.004	8		Clay ↓ ?		
		0.002	9				
		0.001	10				
		0.0005	11				
		0.0002	12				
		0.0001	13				

Source: Blair and McPherson (1999).