The Sizewell C Project

6.3 Volume 2 Main Development Site

Chapter 21 Marine Water Quality and Sediments

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21 Marine Water Quality and Sediment

21.1 Introduction

21.1.1 This chapter of **Volume 2** of the **Environmental Statement** (**ES)** (Doc Ref. 6.3) presents an assessment of the marine water quality and sediment effects arising from the construction, commissioning and operation of the Sizewell C nuclear power station at the main development site (referred to throughout this volume as 'the proposed development'). This includes an assessment of potential effects and their significance and the requirements for mitigation and the residual effects.

21.1.2 Detailed descriptions of the site, the proposed development and the different phases of development are provided in **Chapters 1** to **4** of this volume of the **ES**. A description of the anticipated activities for the decommissioning of the Sizewell C power station, including a summary of the types of environmental effects likely to occur is provided in **Chapter 5** of this volume. A glossary of terms and list of abbreviations used in this chapter is provided in **Volume 1, Appendix 1A** of the **ES** (Doc Ref. 6.2).

21.1.3 This assessment has been informed by data from other assessments as following:

- Coastal geomorphology and hydrodynamics in **Chapter 20** of this volume.
- Marine ecology and fisheries in **Chapter 22** of this volume.
- Operational liquid discharges are set out in **Appendix 4B** of this volume.

21.1.4 Marine water and sediment quality assessment is undertaken in the context of baseline conditions for the main development site and the wider southern North Sea area. These characterisation reports are presented in the following technical appendices:

- **Appendix 21A** of this volume: Sizewell Water Quality Literature Report Edition 2. 2016. BEEMS Technical Report TR131 Ed.2.
- **Appendix 21B** of this volume: Sizewell Marine Water Quality Monitoring Final Summary Report. 2019. BEEMS Technical Report TR189.
- **Appendix 21C** of this volume: Sizewell supplementary water quality monitoring data 2014/2015. 2019. BEEMS Technical Report TR314.

- **Appendix 21D** of this volume: Sizewell Marine Sediment Quality. 2019. BEEMS Technical Report TR305.

21.1.5 Impacts of the proposed development based on indicative scenarios have been identified and assessed in detail in a series of specific technical reports that form appendices to the **ES**. Impact assessments are considered in relation to the baseline environmental conditions to determine the potential for effects from the proposed development and to ascertain if effects are significant. The primary technical reports that inform **ES** assessments include:

- **Appendix 21E** of this volume: Sizewell C- Marine Water and Sediment Quality Synthesis (MSR2/4). 2019. BEEMS Technical Report TR306 Edition 5.
- **Appendix 21F** of this volume: Sizewell C H1 Assessment Edition 2 – Supporting Data Report. 2019. BEEMS Technical Report TR193 Edition 5.
- **Appendix 20A** of this volume: Sizewell Coastal Geomorphology and Hydrodynamics: Synthesis for Environmental Impact Assessment (MSR1/4). 2019. BEEMS Technical Report TR311 Ed.3.
- **Appendix 22A** of this volume: Phytoplankton characterisation. Technical Report TR346 Edition 2. Cefas, Lowestoft.
- **Appendix 22H** of this volume: Modelling the effect of Sizewell C entrainment on the phytoplankton of Sizewell Bay. 2019. BEEMS Technical Report TR385.
- **Appendix 22I** of this volume**:** Impingement predictions. 2019. BEEMS Technical Report TR406.
- **Appendix 22J** of this volume: Modelling of sediment dispersion of dredge material from Sizewell C construction and operation. 2019. BEEMS Technical Report TR480.
- **Appendix 22M** of this volume: Marine Ecology and Fisheries Final Scoping Report. 2019. BEEMS Technical Report TR490 Ed.2

21.1.6 The Marine Water Quality and Sediment **ES** chapter follows the structure of technical chapters maintained throughout the **ES**, as explained in **Volume 1, Chapter 6**. Assessment methodologies conform to those detailed in the updated 2019 SZC Co. Environment Impact Assessment (EIA) Scoping Report included within **Volume 1, Appendix 6A** of the **ES**.

21.1.7 A dedicated cumulative effects assessment has been completed in **Volume 10, Chapter 4** of the **ES** (Doc Ref. 6.11). Assessments are based on the components of the proposed development and consider construction including commissioning and operational impacts of each component. The development components considered in the Marine Water Quality and Sediments assessments presented within this chapter during construction and operation of the proposed development comprise of:

- the coastal defence feature;
- the Beach Landing Facility (BLF);
- the combined drainage outfall (CDO);
- the cooling water infrastructure (intakes and outfalls);
- the fish return and recovery (FRR) system.

21.1.8 Activities associated with each development component have been identified and the relevant pressures with the potential to affect water quality are assessed. The intention of this structure is to allow rapid identification of the potential for effects for any given development component. A description of the anticipated activities for the decommissioning of the Sizewell C power station, including a summary of the types of environmental effects likely to occur is provided in **Volume 2, Chapter 5** of the **ES**.

21.1.9 It is noted that works above the mean high water spring (MHWS) mark are not considered to result in direct effects on marine water quality and sediments and are, therefore, not directly referred to in this chapter. These include (but are not limited to) works associated with the Sizewell B relocated facilities proposals and the off-site developments considered in this volume of the **ES**.

21.2 Legislation, policy and guidance

21.2.1 **Volume 1, Chapter 3** of the **ES** identifies and describes legislation, policy and guidance of relevance to the assessment of the potential water and sediment quality impacts associated with the Sizewell C Project. This section lists the specific legislation, policy and guidance of relevance to the marine water quality and sediment assessment with further details provided in **Volume 1, Appendix 6Q** of the **ES** and catchment data assessments (Ref. 21.1).

a) International legislation

21.2.2 Sites designated under the following international legislation have been considered within the marine water quality and sediment assessment presented in this chapter:

- Directive 92/43/ECC on the conservation of natural habitats and of wild fauna and flora (‘Habitats Directive’) (Ref. 21.2); Directive 2009/147/EC, on the conservation of wild birds (‘Birds Directive’) (Ref. 21.3).
- Ramsar Convention (Ref. 21.4).
- Oslo and Paris Convention for the protection of the marine environment of the north-east Atlantic (Ref. 21.5).
- The Water Framework Directive (WFD) (Ref. 21.6).
- Bathing Waters Directive (Ref. 21.7).
- Shellfish Waters Directive (Ref. 21.8).
- Marine Strategy Framework Directive (Ref. 21.9).

b) National legislation

21.2.3 The following national legislation are relevant to the marine water quality and sediment assessment, as described in **Volume 1 Appendix 6Q** of the **ES**.

- Water Environment (WFD) (England and Wales) Regulations 2003 and 2016 amendment for inclusion of shellfish waters (Ref. 21.10).
- Bathing Waters Regulations 2013 (Ref. 21.11).
- Countryside and Rights of Way Act 2000 (Ref. 21.12).
- Marine and Coastal Access Act 2009 (Ref. 21.13).
- The Orford Inshore Marine Conservation Zone[1].
- Conservation of Habitats and Species Regulations 2017 (Ref. 21.14).

[1] The proposed development is not considered to have any effect on the management objectives of the protected features at the site as it is situated beyond the ZoI for development impacts. Offshore, approximately 16km south-east of the MDS and 14km from the Alde Ore estuary

- Salmon and Freshwater Fisheries Act 1975 (Ref. 21.15).

c) National policy

21.2.4 As stated in **Volume 1, Chapter 3** of the **ES**, the Overarching National Policy Statement (NPS) for Energy (NPS EN-1) (Ref. 21.16) when combined with the NPS for Nuclear Power Generation (NPS EN-6) (Ref. 21.17) provides the primary basis for decisions on applications for nuclear power generation developments. In addition, whilst the development consent for the proposed development would be determined in accordance with NPS EN-1 and EN-6, the application must also have regard to the United Kingdom (UK) Marine Policy Statement 2011 (Ref. 21.18). The requirements of NPS EN-1, EN-6 and the Marine Policy Statement relevant to the marine water quality and sediment assessment, and where these have been addressed within this **ES** are set out in **Volume 1, Appendix 6Q**.

21.2.5 The Marine Policy Statement supports maintaining the 11 descriptors of good ecological status (GES) detailed in the Marine Strategy Framework Directive.

21.2.6 The descriptors for achieving GES under the Marine Strategy Framework Directive include ensuring that contaminants are at a level not giving rise to pollution effects. Proposals should take account of any potential impacts on ecological and chemical quality.

d) Regional policy

21.2.7 East Inshore Marine Plan (Ref. 21.19) which sets out policy requirements for the management of the East Inshore area, including its resources, activities and development which take place within this area.

21.2.8 Eel management plans are a requirement of each Member State. The Anglian River Basin District Eel Management Plan (Ref. 21.20) identifies the potential for mortalities of adult yellow eels and migrating silver eels resulting from various factors including development activities with the potential to act as a barrier (either physical, thermal or chemical) to eel or other migratory fish species.

e) Local policy

21.2.9 Suffolk Coastal District Local Plan July 2013 – policy SP13 (Ref. 21.21) lists the assessment of ecological impacts on nearby designated sites as a local issue to be considered by the Council in the Local Impact Report if an application for the Sizewell C power station is submitted.

f) Guidance

21.2.10 Marine water quality and sediments methods apply an assessment based approach to assess the potential effects of the proposed development based on the principles used for marine ecology receptors following the Chartered Institute of Ecology and Environmental Management (CIEEM) good practice guidelines (CIEEM, 2018) (Ref. 21.22).

21.2.11 The potential effects of the proposed development were identified by applying an activities-pressures matrix following the approach outlined in the Healthy and Biologically Diverse Seas Evidence Group (JNCC, 2013) (Ref. 21.23)

21.2.12 The marine water quality and sediment assessments draw on several guidance documents for chemical standards and approaches to effects assessment and these are discussed and referenced in relevant sections and technical appendices.

21.3 Methodology

21.3.1 The generic EIA methodology is detailed in **Volume 1**, **Chapter 6** of the **ES**.

21.3.2 Topic specific methodology details are provided in **Volume 1, Appendix 6Q** of the **ES**.

21.3.3 Potential development activities and associated pressures were considered and assessed to identify those likely to influence marine water quality and sediment.

a) Scope of the assessment

21.3.4 The assessment considers the impacts of the activities taking place during the construction, commissioning and operation of the proposed development.

21.3.5 A separate EIA for decommissioning will be made based on the available technology, methods of decommissioning, and baseline environmental conditions at the time following a process of consultation. A high-level description of the anticipated activities for the decommissioning of the Sizewell C power station, including a summary of the types of environmental effects likely to occur is provided in **Chapter 5** of this volume.

21.3.6 The relevant pressure themes for water quality and sediment are hydrological changes, specifically local temperature change and ‘Pollution and Other Chemical Changes from Sediment Resuspension or Discharges’

(Ref. 21.24). Activities have been linked to pressures (an approach also taken in **Chapter 22** (marine ecology) of this volume) and the following pressures have been identified as of relevance to this assessment:

- hydrological changes (primarily temperature but includes salinity);
- synthetic compound contamination;
- introduction of other substances (solid, liquid or gas);
- nutrient enrichment;
- organic enrichment from sediment resuspension or discharge; and
- deoxygenation.

21.3.7 Potential development activities and associated pressures were considered and assessed to identify those likely to influence marine water and sediment quality and specifically those with potential to cause significant effects which require further assessment in this chapter or **Chapter 22** of this volume- Marine Ecology.

b) Consultation

21.3.8 The scope of the assessment has also been informed by ongoing consultation and engagement with statutory consultees throughout the design and assessment process. To facilitate engagement with statutory stakeholders on the marine assessments, the Sizewell C Marine Technical Forum was established on 26 March 2014.

21.3.9 The Marine Technical Forum has an independent chair, supported by a technical secretariat supplied by SZC Co. together with nominated technical representatives from relevant statutory stakeholders: Natural England, the Environment Agency, East Suffolk Council and the Marine Management Organisation (MMO), together with consultants working on their behalf. Additional participation by non-statutory stakeholders (for example, Royal Society for the Protection of Birds and the Eastern Inshore Fisheries Conservation Authority) is encouraged with the agreement of Marine Technical Forum members when specific issues are being discussed.

21.3.10 The key aim of the Marine Technical Forum is to provide a means whereby the nature of the marine monitoring at Sizewell and the results and their outcomes can be readily discussed. Agreement or consensus between SZC Co. and the statutory environmental bodies, and clarity on any points of difference, is sought. The Marine Technical Forum aims to seek a common view whilst respecting the independence of the statutory environmental bodies so that relevant advice to SZC Co. may be distilled, and that statutory environmental bodies' consultations and decision making may be best informed.

21.3.11 In advance of the Development Consent Order (DCO), the Sizewell C Marine Technical Forum has sought to develop a shared understanding of the status and sufficiency of the marine studies advanced by SZC Co., the assessments of project impact based upon these studies and the proposed means of mitigation, in order both to facilitate advice given by its members to the Planning Inspectorate and inform their own procedures.

21.3.12 Since October 2018, the Marine Technical Forum has convened on two occasions for marine water quality and sediment discussions alone. The meetings have focused on the following areas:

- 31st October 2018: Evidence in support of the Stage 3 Preliminary Environmental Information.
- 26th March 2019: Presentation and discussion of approach to water quality and sediment impact assessments of all construction, commissioning and operational activities planned for the Sizewell C development.

c) Study area

21.3.13 The Greater Sizewell Bay (GSB) is anchored in the north by the Blyth river jetties and in the south by the Thorpeness Headland and underlying erosion-resistant Coralline Crag, which outcrops sub-tidally. The seaward boundary extends to the eastern flank of the Sizewell-Dunwich Bank, to include the spatial extent of the proposed cooling water infrastructure. The landward limit is delineated by the mean high-water springs (MHWS) tidal mark.

21.3.14 As the GSB is an open coastal system, water exchanges between the bay and the rest of the southern North Sea (see **Figure 20.1 of Chapter 20** of this volume). The spatial extent of potential impacts from the proposed development are therefore dependent on the tidal regime and the transmission and persistence of the pressure. Zones of Influence (ZoI) for marine water quality and sediment assessment has been informed by a comprehensive programme of engagement with regulators / statutory consultees and is based on the largest-scale potential impacts associated with the proposed development. These include:

- results from suspended sediment plume modelling associated with dredging and drilling activities;

- thermal plume modelling of the in-combination impacts of Sizewell B and Sizewell C cooling water discharges (applying the 2ºC mean excess temperature contour at the seabed).

d) Designated sites within the study area

21.3.15 Several statutory and non-statutory designated sites are located within the ZoI of the proposed development.

21.3.16 The proposed development has the potential to affect water quality and sediment for sites designated as being of European or international importance for nature conservation. Consequently, **a Shadow Habitats Regulations Assessment** (**HRA**) (Doc ref. 5.10) has been prepared to detail the likely significant effects (with this process continuing through appropriate assessment) on the designated features within the ZoI of the proposed development.

21.3.17 In conjunction with the **Shadow HRA**, this chapter considers the influence of marine water quality which is of relevance to specific marine components (below MHWS) of designated European sites. Water quality impacts are assessed for areas associated with coastal designated habitats and sites and these include:

- Alde-Ore Estuary Special Protection Area (SPA).
- Minsmere to Walberswick SPA and Ramsar site.
- Minsmere to Walberswick Heaths and Marshes Site of Special Scientific Interest (SSSI).
- Outer Thames SPA.
- Southern North Sea Special Area of Conservation (SAC).

21.3.18 The potential for water quality issues associated with the proposed development to affect the Minsmere to Walberswick SPA, Ramsar site, Minsmere to Walberswick Heaths and Marshes SSSI, and the associated Royal Society for the Protection of Birds (RSPB) Minsmere reserve has been identified. This due to potential effects from direct entry into the Minsmere reserve through the Leiston drain when the Minsmere sluice is open. Alternatively, contaminants may percolate through the dune system or overtop during storm events or as a result of future baselines.

21.3.19 Modelling assessments consider the potential for construction, commissioning and operational discharges to influence Minsmere habitats.

e) Assessment scenarios

21.3.20 Marine water quality and sediment assessment scenarios consider the construction, commissioning and operational phases of the proposed development. Representative, conservative scenarios are evaluated in each case based on the best information available at the time of completion.

21.3.21 The construction period is expected to last between nine and twelve years. An indicative starting point for construction in Year 1 is taken to be 2022, refer to **Chapter 3** of this volume for further detail. Details of construction activities are described in **Chapter 3**; commissioning and operational activities are described in **Chapter 4** of this volume.

21.3.22 The marine components relevant to each phase are briefly summarised in this section. An understanding of the construction sequence is required in order to assess in-combination effects within the Sizewell C Project (inter-relationships).

21.3.23 During Phase 1 of construction, the work will commence with the construction of the BLF and the northern coastal defence that supports the BLF haul road. The CDO system would be constructed to allow construction discharges into the GSB, subject to the requirements of an environmental permit granted by the Environment Agency. Prior to establishment of the CDO, wastewater would be tankered off site for appropriate licensed disposal.

21.3.24 Phase 2 of construction would involve the primary earthworks including the excavation of the Made Ground at the main platform area, within the cut-off wall. During Phase 2, the majority of dewatering discharges from within the cut off wall are anticipated.

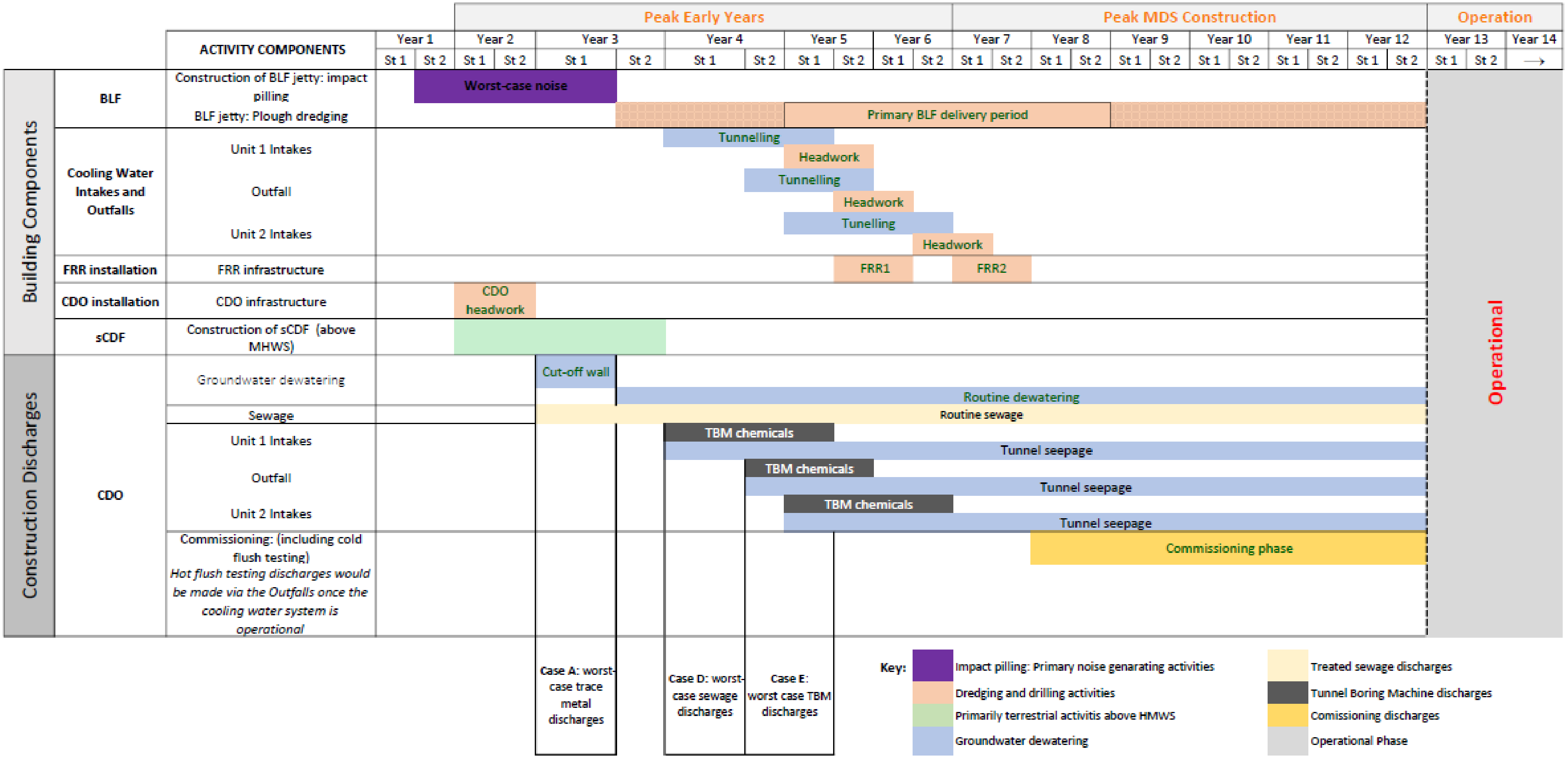
21.3.25 The construction of the power station and ancillary infrastructure would occur in Phase 3. The accommodation campus would be in full use, and the associated discharge of treated sewage is assessed. Permanent infrastructure relevant to the marine environment includes:

- construction of permanent coastal defence feature;
- construction of the cooling water intake and outfall tunnels;
- placement of the intake and outfall headworks and drilling of the vertical shafts;
- installation cooling water structures (intakes and outfall); and
- construction of the two FRR tunnels and associated outfalls.

21.3.26 In Phase 4, building works including the cooling water infrastructure and the two reactors are primarily completed and engineering of the main power station begins. Completion of reactor Unit 1 and Unit 2 is expected to be separated by 12 months. During commissioning, the power station will be tested including flushing of the fluid systems. Discharges would be made via the CDO during early (cold) commissioning or via the main cooling water infrastructure once completed.

21.3.27 An indicative timeline is presented in **Plate 21.1** and is applied as a starting point for assessment.

Plate 21.1: Indicative development timeline for assessment scenarios.



f) Impact assessment criteria: Marine water quality and sediment

21.3.28 As described in **Volume 1**, **Chapter 6** of the **ES**, the EIA methodology considers whether impacts of the proposed development would influence any resources or receptors.

21.3.29 The predicted amount of change for a given impact is assessed in relation to standardised pressure benchmarks applied in sensitivity assessments (Ref. 21.25).

21.3.30 Assessments broadly consider the magnitude of impacts relative to baseline conditions and sensitivity of resources/receptors that could be affected in order to classify significance of effects.

21.3.31 For marine water quality and sediment, the term receptor refers to the model domain for the relevant water quality parameter for which the total extent over which an individual water quality assessment value is exceeded is assessed. The outcome indicates where further detailed assessment of impacts on designated areas or species are indicated.

i. Receptor value

21.3.32 Water quality and sediment of the study area are identified as supporting features.Receptor value is dependent on the species and habitats that would be influenced by any changes to baseline conditions and may influence the judgement of the significance of effect.

21.3.33 Value of the receptor for water quality and sediment is uncoupled from assessment of sensitivity so that the latter can be undertaken for a given impact independently of value. The value of receptor (model domain) which encompasses designated areas would be medium or high dependent on overlap with specific sensitivities. However, the assessment is made on the basis of magnitude and sensitivity with further evaluation made in the Marine Ecology chapter for those results in particular that indicate more than minor effects for marine water quality.

ii. Impact magnitude

21.3.34 Impact magnitude primarily considers the spatial extent of the impact, the duration of the impact and the amount of change (positive or negative) relative to baseline conditions. Additional factors such as frequency, timing and reversibility will be taken into consideration and reported where appropriate as these factors can contribute towards the sensitivity to an impact of the features that are supported.

21.3.35 The predicted amount of change for a given impact is assessed in relation to standardised pressure benchmarks applied in sensitivity assessments (Ref. 21.25).

21.3.36 Benchmark thresholds, for example Environmental Quality Standards (EQS), are applied to trigger further ecological investigation and do not necessarily infer sensitivity of all receptor groups.

21.3.37 The duration of the impact is considered in relation to pressure benchmarks and constructions timelines. The construction phase is anticipated to last between 9 to 12 years, impacts during the construction phase are considered short to medium-term whilst impacts that occur (or persist) for longer durations are considered long-term. Pressure benchmarks often consider changes over the course of a year, therefore impacts under one year are considered low duration.

21.3.38 Impact magnitude is assessed on a four-point scale: very low, low, medium and high (**Table 21.1**).

iii. Sensitivity

21.3.39 Sensitivity assessments determine the resistance (or tolerance) of a receptor to a pressure and the ability to recover following the cessation of the pressure, termed resilience. Within the context of the **ES**, sensitivity assessments are completed relative to the site-specific magnitude of impacts predicted during construction and operational phases of the development.

21.3.40 Sensitivity is assessed on a four-point scale: very low, low, medium, and high. A general guide for sensitivity is provided in **Table 21.2.**

Table 21.1: Guidance for marine water quality and sediment impact magnitude.

Impact Magnitude	Generic description	Spatial Extent	Amount of Change	Duration
High	Large-scale measurable changes, which are typically permanent or long-duration over most of the study area and potentially beyond.	Changes occur across much of the area of interest and possibly beyond. (e.g. 1,000s of hectares (ha)).	Clear, measurable changes beyond natural variation and exceeds site-specific pressure benchmark.	Long-term or even permanent, more than 12 years.
Medium	Medium-scale measurable	Changes occur across a	Measurable changes beyond	Medium-term temporary impacts, 1 to 12 years (taking

Impact Magnitude	Generic description	Spatial Extent	Amount of Change	Duration
	changes over much of the study area. Impacts are not permanent.	significant proportion of the area of interest. (e.g. 100s of ha)	natural variation.	account of the potential maximum construction period).
Low	Noticeable but small-scale changes over a partial area. Impacts are typically short-term.	A partial spatial area is exposed to changes (e.g. 10s of ha).	Measurable changes within range of natural variation.	Short-term temporary, less than a year.
Very Low	Very small-scale or barely discernible changes, over a small area. Impacts are short-lived.	Very small extent is exposed to changes (e.g. 1ha).	Changes possible but cannot be discriminated from natural background.	Very short term, e.g. spring-neap tidal cycle or less.

Table 21.2: Guidance for marine water quality sensitivity criteria.

Sensitivity	General description for assigning sensitivity
High	Little or no capacity for resistance, limited or prolonged recovery.
Medium	Low capacity for resistance, low capacity for resilience (e.g. recovery after 10 years).
Low	Moderate resistance to the pressure, moderate capability for resilience (e.g. recovery after 5 years).
Very Low	High capacity for resistance, high capacity of resilience (e.g. recovery after 1 year).

21.3.41 Resistance and resilience descriptors follow the general approach described in **Volume 1, Chapter 6**.

21.3.42 The resistance of a marine water quality and sediment as a supporting receptor is assessed against the predicted impact magnitude. Resistance is evaluated in terms of the extent of water quality change e.g. the degree of exceedance of an EQS or equivalent value and likely extent of effects for associated habitats and species. Nominally the same scale as applied to ecology features is used for water quality but taking account of e.g. inherent chemical persistence:

- None: A severe decline in the extent, density or abundance of the habitat or species indicated by level of exceedance of EQS or equivalent effects thresholds.
- Low: A significant decline in the extent, density or abundance of the habitat or species indicated by level of exceedance of EQS or equivalent effects thresholds.
- Medium: A moderate decline in the extent, density or abundance of the habitat or species indicated by level of exceedance of EQS or equivalent effects thresholds.
- High: No or very minor changes in the extent, density or abundance of the habitat or species indicated by level of exceedance of EQS or equivalent effects thresholds.

21.3.43 The resilience of a receptor is assessed in terms of its ability to recover once the pressure is removed and the environment returns to pre-impact conditions. For marine water quality and sediment assessment of resilience primarily considers the chemical/physical changes to water quality and of the return to baseline/background conditions of quality e.g. based on duration of activity/input and local hydrodynamic regime, refreshment rate, tidal currents.

21.3.44 A final cross tabulation of the magnitude of impacts and sensitivity of the receptor provides a guideline for the classification of effects (**Table 21.3**).

Table 21.3: Classification of effects based on sensitivity of receptors and magnitude of impact.

Impact magnitude	Sensitivity of receptor			
	Very Low	Low	Medium	High
Very Low	Negligible	Negligible	Minor	Minor
Low	Negligible	Minor	Minor	Moderate
Medium	Minor	Minor	Moderate	Major
High	Minor	Moderate	Major	Major

21.3.45 The definitions of effect for marine water and sediment quality are shown in **Table 21.4**. The tabulation is treated as a guideline and expert judgement must be applied once all the factors of the assessment have been considered and reported.

Table 21.4: Description of Effects Classification.

Value	General description for assigning value
Major	Effects, both adverse and beneficial, that are likely to be important considerations at an international or national level because they contribute to achieving international/national objectives or are likely to result in exceedance of statutory objectives and/or breaches of legislation.
Moderate	Intermediate changes that are likely to be important and could cause subtle changes in other ecosystem features.
Minor	Small changes with limited discernible effects on other ecosystem features. These effects may be raised as local issues but are unlikely to be instrumental in the decision-making process.
Negligible	No discernible changes. An effect that is likely to have a negligible or neutral influence, irrespective of other effects.

21.3.46 Following the classification of an effect as presented in **Table 21.4**, a clear statement is made as to whether the effect is '**significant**' or **'not significant'**. In general, major and moderate effects are evaluated as **significant** and minor and negligible effects are evaluated as **not significant**. However, expert judgement is also applied where appropriate.

21.3.47 Receptor value may influence the judgement of the significance of effect. For example, a minor effect to water quality or a sediment receptor which contravenes conservation objectives may be considered significant.

g) Assessment methodology

i. Introduction

21.3.48 During construction, commissioning and operation of Sizewell C, various activities may influence the physical and chemical properties of the marine environment.

21.3.49 The amount of change resulting from development activities is determined by reference to the baseline condition of the marine environment and to standards that define acceptable boundaries within which site water quality parameters should lie to remain at or to achieve an acceptable status.

21.3.50 Baseline physical and chemical quality of seawater and sediment for the study area have been established in several surveys for seawater and sediment chemical quality and in long-term monitoring programmes for temperature and these are described in the section on 'Baseline conditions'.

21.3.51 As sediments act as a net sink for anthropogenic contaminants in marine ecosystems as described by Roberts 2012 (Ref. 21.26) the potential impact of sediment disturbance is an important consideration.

21.3.52 More detail is provided in **Volume 1 Appendix 6Q** of the **ES** but the following are considered in this assessment:

- Standards for chemical contamination of sediments and waterbody turbidity classified by suspended sediment levels in relation to dredging and other activity causing sediment disturbance (Ref. 21.27 and 21.28).
- Nutrient standards for the coastal waters of Sizewell Bay and potential influence of contributions from discharges from the proposed development.
- Dissolved oxygen standards in relation to influence of thermal plumes and potential deoxygenation caused by treated sewage and organic matter.
- Microbiological standards for bathing waters in relation to the treated sewage discharge (Ref. 21.11).
- Chemical standards in relation to screening and modelling of discharges during construction/commissioning and operation.

21.3.53 During construction and the cold commissioning phase, wastewater containing several chemicals would be discharged through the CDO.

21.3.54 During operation of the power station large volumes of cooling water, with an elevated temperature above background of approximately 11.6°C would be discharged through the main cooling water outfall.

21.3.55 Operational discharges would contain residual chemicals from various operations, and it would be chlorinated to prevent biofouling so would contain residual oxidants from chlorination (termed total residual oxidants, TRO) and chlorination by-products with the main one assessed being bromoform.

21.3.56 For construction/commissioning and operation discharges, the mixing zone within which there is exceedance of any given quality standard, or derived environmental assessment limit, must be sufficiently limited.

21.3.57 Environmental Quality Standards (EQSs are concentrations below which a substance is not believed to be detrimental to aquatic life. To provide a safety factor, the EQS is set substantially below the concentration observed to have a toxic effect on selected test organisms.

21.3.58 Some chemicals have EQS set at European or national level. For some substances, e.g. boron standards derived under earlier chemical regulation are adopted (Ref. 21.29).

21.3.59 In the absence of EQS values, predicted no effect concentration (PNEC) values are used. PNEC values have only been used where there is no existing EQS and where a relevant saltwater PNEC standard has been determined by independent authorities (as recommended in European Chemicals Bureau Technical Guidance, 2003 (Ref. 21.30) and CIS, 2011 (Ref. 21.31).

21.3.60 Under the WFD, chemical status is assessed by compliance with EQS.

21.3.61 For Sizewell C, the relevant priority substances are cadmium, lead, mercury and nickel and the relevant specific pollutants are un-ionised ammonia, arsenic, chromium (VI), chlorine, copper, iron, and zinc.

21.3.62 To cover both long- and short-term effects resulting from exposure, two water column EQSs are normally required:

- A long-term standard expressed as an annual average (AA) concentration and normally based on chronic toxicity data.
- A short-term standard, referred to as a maximum acceptable concentration (MAC) which is based on acute toxicity data.

21.3.63 If a substance degrades rapidly only a short-term standard may be derived. If a substance persists and may accumulate in the environment, a long-term standard would be appropriate. Both standards may be derived for substances for which short- and longer-term exposures are relevant.

ii. Approach to screening assessment construction discharges

21.3.64 As part of a surface water risk assessment (as referenced in 'Clearing the Waters for All', Environment Agency and Department for Environment Food and Rural Affairs Guidance, 2016) (Ref. 21.32) the concentration of substances present in the discharge must be assessed against a list of specific pollutants and their EQS or equivalent assessment value.

21.3.65 Initial screening tests (historically referred to as H1 tests) were conducted to determine if the concentrations of priority substances and specific pollutants in the discharge exceeded their respective EQS.

21.3.66 For any substances that breach the EQS in the initial screening tests (test 1), a further screening test is applied that takes account of initial dilution upon discharge (test 5) -see **Volume 1, Appendix 6Q** of the **ES** for more detail.

21.3.67 Test 5 screening applies to the discharge from the CDO because the discharge is to the subtidal environment and beyond 50m from mean low-water spring tidal level. Separate guidance is provided for assessment of large cooling water discharges that would occur during operation -see **Volume 1, Appendix 6Q** of the **ES** for more details of the approach.

21.3.68 During the construction period, the CDO will be the primary discharge point.

21.3.69 During different parts of the construction period discharges may include groundwater, treated sewage and tunnel boring wastewater that contribute sources of metals, nutrients, un-ionised ammonia and tunnelling chemicals.

21.3.70 A series of potential scenarios or cases is described for which each of these sources is at a maximum level and these are assessed using the screening methodology.

21.3.71 Chemical inputs exceeding relevant EQS values in screening tests 1 and 5 were further evaluated using more detailed modelling.

21.3.72 During construction and commissioning various discharges may occur individually and in-combination via the CDO. Maximum metals discharges for groundwater were assessed and arsenic, cadmium, copper, mercury, iron and lead met the screening criteria and passed the assessment; zinc and chromium were taken forward for modelling.

21.3.73 Construction inputs of cadmium and mercury were also assessed in terms of total annual load contributions and these met acceptable load criteria.

21.3.74 Ammonia, dissolved inorganic nitrogen (DIN) and phosphate are present in groundwater, treated sewage and commissioning discharges. Nitrogen and phosphorus can contribute to enhanced growth of marine phytoplankton and macroalgae, so further modelling is considered for these inputs. Ammonia from several potential sources can contribute to un-ionised ammonia with the amount dependent on local physicochemical conditions so the total ammonia input during construction was taken forward for further modelling.

21.3.75 Representative chemical additives for TBM operation did not pass screening so these were taken forward for modelling assessment. Predicted residual concentrations of bentonite if a slurry tunnelling method is employed were also modelled.

21.3.76 Microbiological inputs from treated sewage effluents during construction were also taken forward for modelling assessment to confirm compliance against bathing water standards.

iii. Approach to screening assessment commissioning discharges

21.3.77 No operational cooling system will be available for the dilution and disposal of commissioning phase effluents during the cold flush testing stage. Therefore, the only available discharge route for this wastewater stream will be through the CDO.

21.3.78 Chemical discharges during commissioning are evaluated using the screening methodology described for construction using test 1 and test 5.

21.3.79 The chemicals discharged during commissioning are un-ionised ammonia which is assessed in terms of toxicity and with respect to its nitrogen contribution, phosphorus also assessed for its influence on nutrient status and ethanolamine and hydrazine.

21.3.80 Predicted ethanolamine loadings during commissioning passed screening assessment (morpholine use is not planned during commissioning).

21.3.81 Nitrogen and phosphorus can contribute to enhanced growth of marine phytoplankton and macroalgae, so further modelling is considered for these inputs. Combined sources or ammonia can contribute to un-ionised ammonia with the amount dependent on local physicochemical conditions so the total ammonia input during commissioning was taken forward for further modelling with total loads from combined construction and commissioning inputs considered.

iv. Approach to screening assessment operational discharges

21.3.82 Potential discharges to the marine environment have been assessed for the operational phase of the planned Sizewell C project. For large cooling water discharges that are discharged to estuaries or coastal waters a specific screening assessment for chemical discharges recommended by the Department for Environment, Food and Rural Affairs and the Environment Agency, (Ref. 21.32) was applied - see **Volume 1, Appendix 6Q** of the **ES** for more details of the approach.

21.3.83 Various substances used or produced during operation and discharged via the cooling water system met the discharge screening assessment criteria. Predicted concentrations of TRO and bromoform produced from seawater chlorination, and discharges of hydrazine all failed the screening assessment and were taken forward for modelling.

21.3.84 Nitrogen and phosphorus discharges during operation can contribute to enhanced growth of marine phytoplankton and macroalgae, so further modelling is considered for these inputs.

21.3.85 Microbiological inputs from treated sewage effluents during operation were also taken forward for modelling assessment to confirm compliance against bathing water standards.

21.3.86 Thermal elevation of the cooling water discharge was taken forward for modelling assessment as it represents a major change to seawater physical quality and can also influence chemical behaviour.

21.3.87 During operation, a fish recovery and return (FRR) system will be in place to minimise impacts on impinged fish and other marine animals. Some species would not survive impingement, so some moribund or dead individuals will be returned to the marine environment. Therefore, the contribution to nutrients, un-ionised ammonia and deoxygenation that may be contributed by decaying fish biomass is also assessed.

v. Thermal and chemical modelling

21.3.88 For the development of new nuclear build power stations that use and discharge cooling water to the environment, it is necessary to establish hydrodynamic models to predict the impact of the discharged thermal and chemical plumes on a variety of sensitive ecological receptors.

21.3.89 More detail on model selection and setup and how these meet Environment Agency guidance are provided in **Volume 1, Appendix 6Q** of the **ES** .

21.3.90 Thermal discharges during operation were modelled using the validated Sizewell curvilinear General Estuarine Transport Model (GETM). The release and mixing of substances in the construction, commissioning and operational discharges was modelled using CORMIX US EPA supported mixing zone model (Ref. 21.33) and detail on both models is provided in **Appendix 21E and Appendix 21F** of this volume.

21.3.91 Near field discharge modelling was conducted using CORMIX but the General Estuarine Transport Model is a better model to use away from the near field (further than 10s of metres (m) from the outfall). Specifically, the General Estuarine Transport Model can replicate wind driven behaviour and has precise bathymetry so that interactions with the tidal flow (e.g. eddies) are well replicated.

vi. Assessment of thermal effects against standards

21.3.92 During the operational phase, the primary change to the characteristics of discharged cooling water will be an increase in temperature. The main concerns over the thermal plume generation are related specifically to impacts upon species in the water including those that are prey species. The potential effects of a thermal plume are predominantly:

- Acute effects – lethal effects where temperatures approach critical thresholds for survival of a species (most likely close to parts of the cooling water system where rapid temperature increase occurs).
- Chronic effects – long term effect on biological processes (e.g. growth, reproduction) where the concern is elevation of mean temperatures.

21.3.93 In addition, as fish can actively avoid areas of high temperatures, if they so choose, it is necessary to consider:

- Any potential thermal barriers to fish migration and the linked concern about the potential displacement of fish prey out of marine bird foraging ranges.

21.3.94 Various thermal standards are considered to assess areas of exceedance for thermal uplift and absolute standards and to consider any potential for thermal barriers. More detail on standard source, derivation, and application is provided in **Volume 1, Appendix 6Q** of the **ES**.

vii. Selection of modelling scenarios for discharge assessment against chemical standards

21.3.95 During the timetable for construction and cold commissioning different activities that could potentially contribute chemicals to discharges via the CDO may overlap, as seen in **section 21.5e** of this chapter.

21.3.96 The chemical concentrations used for modelling for construction and cold commissioning are conservative as they assume the maximum concentration that could occur where there is potential for overlap between different contributing activities.

21.3.97 Using outputs from CORMIX and the General Estuarine Transport Model the area over which a given chemical standard is exceeded is determined and provides the basis on which the potential influence on marine water quality and sediment is evaluated.

21.3.98 For the operational phase, the main chemical discharges occur via the cooling water infrastructure and are described in more detail in **section 21.5** of this chapter, with the following scenarios modelled:

- Chlorination of the power station cooling water system to avoid bio-fouling.
- Chlorination by-products. Chlorination of seawater results in a complex series of reactions with reaction products based on bromine chemistry. Bromoform was the only chlorination by-product detected in laboratory experiments on Sizewell seawater.

- Addition of hydrazine to control the oxygen concentration in the secondary circuit of Sizewell C. Hydrazine is an oxygen scavenger that would be used to prevent corrosion in the primary and secondary circuits of Sizewell C. Hydrazine is modelled by using an empirical decay formulation derived from laboratory experiments on Sizewell seawater and coupled into the Sizewell General Esturarine Transport Model.

- Reduction in dissolved oxygen (DO) in seawater due to the warming effect of the discharge plume. The WFD threshold is set as an annual 5th percentile, with high status being > 5.7 mg/l and good status being > 4 mg/l.

- Un-ionised ammonia where concentrations are defined in relation to the annual mean (the EQS is an annual mean of 21µg/l). The proportion of un-ionised ammonia is determined by temperature, pH and salinity the values for which were adjusted in the model to evaluate the most conservative assessment including the thermal influence of Sizewell C and Sizewell B cooling water discharges.

21.3.99 During operation of the FRR systems, fish that do not survive impingement would be discharged from the FRR and their decaying biomass would potentially contribute additional nutrients, un-ionised ammonia and may influence DO. An assessment of these potential contributions was therefore also made.

h) Assumptions and limitations

21.3.100 In several cases the principal limitation on the assessments is that the detailed design and method statements for marine construction and infrastructure are yet to be finalised, which limits the accuracy of predicted environmental impacts. Assumptions are therefore conservative and made to envelope the likely worst-case impacts to ensure the assessment is robust and not limited. Additional information is provided in **Volume 1, Appendix 6Q** of the **ES**.

21.3.101 The assessments are based on baseline information and engineering designs at the time of DCO submission. **Volume 2, Chapter 2** of the **ES** provides a description of the main development site. **Volume 2, Chapters 3** and **4** of the **ES** provide a description of the construction and commissioning, and operational phases of the development.

i. Beach Landing Facility

21.3.102 The BLF would facilitate occasional abnormal indivisible loads (AILs) deliveries during the operational life of the station, approximately every 5-10 years.

ii. Cooling water infrastructure

Construction

21.3.103 Offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by TBM from land. The TBM heads would be left at the end of each tunnel run, approximately 30m under the seabed.

Tunnelling spoil and chemical discharges

21.3.104 The specific TBM method to be used during construction of the cooling water tunnels is dependent on the underlying geology and is still to be confirmed.

21.3.105 Based on current understanding of the underlying geology a TBM slurry method is the most likely scenario for tunnelling.

21.3.106 Bentonite, a clay mineral regularly used in construction and offshore drilling operations, may be applied at the cutter face. Bentonite is considered to pose minor risks to the environment as it is included on the OSPAR list of PLONOR substances (pose little or no risk to the environment). However, the potential for discharges of bentonite from the CDO to affect suspended sediments concentrations (SSC) is considered.

21.3.107 Ground conditioning chemicals are used at the cutter head to optimise TBM efficiency and include anti-clogging agents, anti-wear components and soil conditioning compounds. The exact chemical constituents of the ground conditioning chemicals are dependent upon the ground conditions encountered on site and therefore cannot be precisely specified in advance of drilling trials by the tunnelling contractor. To enable the discharge to be assessed, wastewater discharge parameters and representative chemicals are taken from those applied for Hinkley Point C assessments to envelope potential drilling scenarios.

21.3.108 If surfactant compounds are required (as expected at Hinkley Point C), the assessments consider the anti- clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M as representative compounds. The active substances from these products with the lowest PPNEC were applied for assessment.

21.3.109 Plausible conservative estimates of volume and contaminant concentrations are considered for permitting and for assessment in the **ES** by consideration of several scenarios that assume overlap between different input sources (**Plate 21.1**):

- Case A is associated with the dewatering phase of the cut-off wall for the main development site. Initial dewatering is anticipated to remove 300,000m^3 of groundwater at rate of 124l/s. Initial dewatering drawdown is anticipated to last 28 days and represents the worst-case for metals contamination. For the remainder of the construction period groundwater dewatering is estimated to occur at a nominal rate of 15l/s to remove rainwater and seepage through the cut-off wall.

- Case D is based on the expected number of personnel on site during the construction phase and represents the typical high scenario for sewage discharges, nutrient inputs and un-ionised ammonia. Sewage discharge rates are anticipated to be 13.3l/s throughout much of the construction period.

- Case D1 represents an extreme case of sewage discharge, it is likely to be highly transitory with a maximum sewage discharge rate of 30l/s. Groundwater from main site with inputs from tunnelling are also included.

- Case E waste from the TBM soil conditioning chemicals, if present, is likely to make the largest contribution during Case E. This assumes consecutive TBM machines operating with the potential for two sources of ground conditioning chemicals (6l/s) to be discharged in a total estimated volume of 34.3l/s although recovery systems mean some chemical inputs are likely to be minimised.

Operation

21.3.110 The thermal uplift of the 11.8m^3/s that supplies the essential and auxiliary cooling water systems is 6.6°C. In the absence of full details on the design of the Sizewell C cooling water system, thermal modelling assumed 125m^3/s would be discharged at 11.6°C thermal uplift. This is within 1.4% of the predicted total heat flux in the cooling water discharge of 131.8m^3/s at a net thermal uplift of 11.15°C and the modelling reported in BEEMS Technical Report 302 (Ref. 21.34) and is, therefore, considered of sufficient accuracy for assessment.

21.3.111 During operation, the combined Sizewell C intakes would abstract seawater at a rate of ca., 131.8m^3/s (each UK European Pressurised Reactor (EPR^{TM})) abstracting 65.9m^3/s via its respective intake tunnel) during standard operating procedures. A maximum of 8.6% of the total cooling water flow would supply the essential and auxiliary cooling water systems and the remaining 91.4% (120m^3/s) would supply the main cooling water systems.

21.3.112 An additional worst-case scenario was assessed during normal operation of Sizewell B and maintenance of Sizewell C. In this (unlikely) scenario two of the four pumps are not operating and the two UK EPRs™ remain running at full power. Under such circumstances approximately half the cooling water would be abstracted with the same level of thermal energy applied. Therefore, excess temperatures could potentially rise from 11.6°C to 23.2°C (Ref. 21.34)

21.3.113 Modelling has shown that a warmer thermal plume loses heat faster to the atmosphere with less heat mixed into the water column with a resulting lower total area of exceedance, as such thermal assessments consider normal operating scenarios as most conservative - **Appendix 21E** of this volume.

21.3.114 Chlorination would be applied at a dose level to produce a TRO concentration of 0.2mg/l after the drum screens which remove fish and larger organisms to be returned by the FRR system.

21.3.115 The TRO discharge concentration from the Cooling Water systems at the outfall would be 0.15mg/l. A conservative scenario for water quality modelling considers the impacts of 0.15mg/l TRO released at the outfalls in $132m^3/s$.

21.3.116 The chlorination strategy for the proposed development involves seasonal chlorination, this is currently based on the period of the year when water temperatures exceed 10ºC. By 2030, predicted water temperatures at the Sizewell C intakes would exceed 10ºC from the beginning of May until the start of December - **Appendix 21E** of this volume.

21.3.117 The potential exists for future climate change to extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination. Whilst the duration of the growing season is likely to extend in the future, day length and solar elevation are likely to restrict the total growth period. In the coastal waters at Sizewell, high levels of turbidity in the winter and early spring limit biological production and increases in the duration of annual chlorination is likely to be in the order of weeks at most. The influence of climate change on the seasonal chlorination strategy is considered further within this chapter and as part of the Sizewell C project-wide in-combination climate impact assessment in **Chapter 26** of this volume.

21.3.118 The lowest volume of water abstracted under normal operating conditions would be $116m^3/s$. Water quality assessments for discharged contaminants are based on this discharge rate as it represents the worst-case dilution scenario for standard operation of the power station - **Appendix 21E** of this volume.

iii. Fish recovery and return system

Construction

21.3.119 Two FRR systems would be constructed, one for each reactor. The small diameter FRR tunnels (approximately 0.65m internal diameter) would be drilled beneath the seabed with arisings transported to landward for disposal.

21.3.120 Prior to installation of the FRR outfall headworks, overlying soft sediment in the shallow subtidal (<6m) would be removed by dredging using a cutter suction dredger with spoil disposed locally within a licensed disposal site. The FRR outfall headwork is assumed to comprise a concrete block approximately 3m long, 4.5m high, and 3m wide buried 2m into the sediment.

21.3.121 The proposed position for the FRR outfalls is ca. 475m from the forebays on the seaward flank of the outer longshore bar in water depths of 5.5-6m below ordnance datum (Newlyn) (ODN).

Operation

21.3.122 Abstracted water would be transported along the intake tunnels to the station forebays where rotating drum and band screens would impinge larger biota, including fish and crustaceans. Impinged biota would be washed off the drum and band screens and returned to the GSB via the FRR headworks.

iv. Combined drainage outfall

Construction and construction phase function of the combined drainage outfall

21.3.123 The CDO would be constructed early in the construction phase and act as the construction site discharge outfall. Prior to CDO completion, station effluents would be reused where possible or tankered offsite for managed disposal.

21.3.124 As required, the CDO would discharge tertiary treated sewage, dewatered groundwater, surface run-off, tunnelling wastewater, and commissioning discharges. A water discharge activity (WDA) environmental permit assessment will be required prior to any discharges.

21.3.125 The exact position of the CDO headwork will depend on constructability. For assessment purposes the CDO headwork is assumed to be located at 647980 E, 264340 N on the seaward flank of the outer longshore bar, approximately 400m from the hard coastal defence feature (HCDF), in water depths of ca. -6.2m ODN. The location limits the potential for discharges to interact with the coastline.

21.3.126 The CDO tunnel would be drilled beneath the seabed with arisings transported to landward for disposal, with no marine impact pathway. The tunnels would be connected to a concrete outfall structure anticipated to be of similar dimensions to the FRR headworks.

21.3.127 Prior to installation of the CDO outfall headwork, overlying soft sediment in the shallow subtidal (<6m) would be removed by dredging via a cutter suction dredger with spoil disposed locally within a licensed disposal site with local disposal.

Commissioning function of the combined drainage outfall

21.3.128 The CDO would act as a discharge point during part of the commissioning phase of the proposed development.

21.3.129 The commissioning process for each unit would last for about 24 months. A 12-month gap is anticipated between the completion of the two reactor units.

21.3.130 Commissioning of the reactors is proposed to take place in two stages;

- cold flush testing; and
- hot functional testing.

21.3.131 Cold flush testing mainly involves cleansing and flushing the various plant systems with demineralised water to remove surface deposits and residual debris from the installation.

21.3.132 Waste streams during cold flush testing of Unit 1 would be directed to a storage tank with controlled discharge via the CDO. The discharge routing for Unit 2 has yet to be confirmed. A Rochdale envelope approach was therefore applied to represent the most conservative scenario for commissioning discharges, whereby treatment tanks for both Units were assumed to discharge to the CDO. This represents a highly precautionary assessment. A second assessment assumes the case whereby cold flush testing discharges from Unit 2 are released via the CDO, whilst Unit 1 is operational. This represents a potential conservative scenario for fish and other biota discharged from the FRR associated with Unit 1, approximately 340m south of the CDO.

21.3.133 Cold flush testing discharges would be directed to storage tanks and controlled releases via the CDO may contain conditioning chemicals:

- hydrazine[2];
- ammonia;
- phosphate; and
- ethanolamine.

21.3.134 The commissioning discharge of hydrazine[3] is further evaluated in terms of derived acute and chronic toxicity PNECs.

21.3.135 Discharges of ammonia (in the un-ionised form) are also considered in relation to the potential exceedance of the EQS. Nutrient discharges, including DIN and phosphate are considered as part of the wider construction nutrient release scenarios.

21.3.136 The ethanolamine discharge passes the screening assessment and discharge modelling indicates that it does not exceed the applied PNEC(160µg/l) at the surface or seabed as a mean concentration or as a 95th percentile - **Appendix 21E** of this volume. Ethanolamine is therefore not further assessed.

21.3.137 Hot flush testing takes place before fuelling the reactor, once the cooling water infrastructure is operational. The effluent produced during hot functional testing would be diluted within the cooling water system before being discharged via the outfall tunnel. See **Chapter 4** of this volume for further details.

Operational function of the combined drainage outfall

21.3.138 There is no operational function anticipated for the CDO.

[2] Commissioning modelling for hydrazine discharges incorporates a hydrazine decay rate appropriate for the concentration of hydrazine in sea water. Prior to release, hydrazine in the storage tanks would be mixed in demineralised water. Hydrazine will decay at a slower rate in demineralised water. This behaviour has not been included in the model as freshwater will very rapidly mix with the sea water, meaning results will not be affected by the slower initial decay rate **Appendix 21E** of this volume**.**

[3] A seasonal survey acquired surface water samples at the Sizewell B cooling water outfall (Station 5) and a reference site (Station 11) at intervals of approximately two weeks from November 2010 to February 2011 using a gas chromatography mass spectrometry (GC-MS) technique to measure hydrazine concentrations. The sensitive GC-MS technique indicated that hydrazine concentrations were below the limit of detection (10 ng/l) **Appendix 21E**. As no hydrazine was detected at the Sizewell B outfall or at the reference location, the background concentration for hydrazine was set to zero.

v. Summary of dredging activities for assessment

21.3.139 In the UK dredging and disposal is a licensable activity managed by the Marine Management Organisation (MMO) under the Marine and Coastal Access Act (2009). Disposal activities are licenced under a Marine Licence which must reference a designated disposal site.

21.3.140 A summary of the dredge activities for each development component is provided in **Table 21.5**. Local disposal is the intended option for all dredging activities.

21.3.141 A disposal site designation report **Appendix 22K** of this volume is submitted as part of the DCO application process. The disposal site designation report details:

- the need for a new disposal site;
- the characteristics of the material to be disposed;
- the disposal site characteristics, and;
- the assessment of potential impacts.

21.3.142 A deemed Marine Licence condition for dredging and drilling activities includes the requirement to monitor sediment contamination levels to ensure dredge/drill material is deemed acceptable for the proposed disposal route. Samples must have been collected within three years of dredging/drilling activities and analysed in an MMO accredited laboratory. Assessments of impacts from sediment contaminants are based on vibrocores samples collected across the dredging and drilling areas. Further monitoring will be completed as required in accordance with licence conditions.

21.3.143 The impact of SSC plumes from dredging activities has been modelled in **Appendix 22J** of this volume. Indicative dredge areas applied for assessment purposes, and sediment plume characteristics as a result of dredging activities are provided in **Table 21.6** and **Table 21.7**.

21.3.144 Resuspension of pollutants and nutrients from contaminated sediments has the potential to influence ecological receptors. The sandy nature of the sediments within the GSB, low organic content and sediment contamination levels present a low risk of releases of sediment-bound contaminants or nutrients to the water column. No further assessments on contaminants or nutrient release from sediments are made. However, dredging activities would be subject to Marine Licence conditions for sediment quality, thus mitigating environmental impacts. Direct effects of increased SSC and sedimentation rates are considered in detail for marine water quality. In addition, the potential for indirect effects from elevated SSC is considered for designated species with marine prey and for marine food webs, in **Chapter 22** of this volume.

21.3.145 The CDO and FRR headworks are in the inshore environment. These small structures would be partially buried in the surfical sediment.

21.3.146 The cooling water infrastructure headworks would be located further offshore seaward of the Sizewell-Dunwich Bank.

21.3.147 The northern intakes (Unit 2) and the outfalls are located in soft sediment environments. To allow for precautionary assessments of dredge volumes for plume modelling assumed overlying sediments were approximately 6m deep. Geological interpretation of the overlying sediment indicates sediment thickness varies between tens of centimetres to more than two metres in these areas. As such, volume estimates applied in plume modelling are precautionary.

21.3.148 The southern intakes associated with Unit 1 would be positioned on exposed Coralline Crag deposits, with no or minimal overlying sediment. As such, dredge volume estimates applied in plume modelling are highly precautionary.

Table 21.5: Summary of dredging and drilling activities and disposal routes.

Development Component	Dredge/drill type and frequency	Anticipated dredge method	Disposal option
Navigational dredging for the BLF.	Capital dredge: The first instance of dredging for the BLF navigational channel would require dredging to a depth that had not occurred in the preceeding 10 years and would involve a small-scale capital dredge. Maintenance dredge: Maximum vessel activity at the BLF is anticipated during the 'campaign period' (31st March to 31st October), however deliveries may occur at any time. Infilling would necessitate the requirement for maintenance dredging to ensure the navigable channel. The volume and frequency of maintenance dredging would depend on ambient conditions determining infilling rates and the tolerance of the vessels. Assessments assume maintenance dredging of 10% the initial capital volume to occur at approximately monthly intervals during the campaign period. Preparatory dredging: Each season during the construction period (or following large infilling episodes following storm events), preparatory dredging of the initial capital dredge volume would be required.	Plough Dredger	Plough dredging pushes the sediment aside from the required area, which is then redistributed by subsequent tides. Spoil is not extracted and a Marine Licence for disposal is not required for this activity.
Installation of CDO and FRR headworks.	Capital dredge: To install the CDO headwork (and same for two FRRs) small scale capital dredging would be required to bury the headwork within the sediment. Dredging would be a single event.	Cutter suction dredger	Marine Licence required for local disposal.
Installation of cooling water intake and outfall headworks.	Capital dredge: To install the cooling water headworks capital dredging would be required to remove the surficial sediments enabling the cooling water headworks to be installed on the underlying bedrock. Dredging would occur once for each structure including two outfall headworks and four intake headworks.	Cutter suction dredger	Marine Licence required for local disposal.

Development Component	Dredge/drill type and frequency	Anticipated dredge method	Disposal option
Drilling for vertical shafts connecting cooling water tunnels with the headworks.	Drilling for vertical shafts connecting cooling water tunnels with the headworks.	Drilling for vertical shafts connecting cooling water tunnels with the headworks.	Marine Licence required for local disposal.

Table 21.6: Dredging and drilling activities associated with the proposed development. It should be noted that area and volume estimates are indicative and used for assessment to envelope anticipated activities.

Component	Dredge/drilling method and proposed disposal option*	Dredge volume and surface area**	Duration and frequency	Assessed further in the ES
BLF	Plough dredging, with sediment redistributed by subsequent tides.	4,600 m^3 9,068m^2	Initial maintenance dredge expected to take 2.1 days per year. Maintenance dredging (10% volume) expected monthly.	Yes
CDO	Cutter suction dredger with local disposal via a down tide pipe.	1,845m^3 1,320m^2	Single dredge event for the CDO head. Dredging expected to take 9.5 hours.	Yes
Cooling Water System (CWS) intakes.	Cutter suction dredger with local disposal via a down tide pipe.	69,600m^3 20,150m^2	Single dredge event anticipated for each of the four CWS intake heads. Dredging expected to take 34 hours in total (8.5 hours per head).	Yes
	Drilling with arisings released at drill site.	3,016m^3 201m^2	Continuous drilling lasting 120 hours (30 hours per head).	No. SSC plume would be indiscernable above background conditions. Spoil heap would form within the dredge footprint. Wider

Component	Dredge/drilling method and proposed disposal option*	Dredge volume and surface area**	Duration and frequency	Assessed further in the ES
				sedimentation would be minimal.
CWS outfalls.	Cutter suction dredger with local disposal via a down tide pipe.	23,500m^3 7,442m^2	Single dredge event anticipated for each of the two CWS outfall heads. Dredging expected to take 14 hours in total (7 hours per head).	Yes
	Drilling with arisings released at drill site.	1,908m^3 127m^2	Continuous drilling lasting 60 hours (30 hours per head).	No. Same reasons as for drilling for CWS intakes.
FRR outfalls	Cutter suction dredger with local disposal via a down tide pipe.	3,690m^3 2,640m^2	Single dredge event for each of the two FRR outfall heads. Dredging expected to take 19 hours in total (9.5 hours per head).	Yes

* The Marine Management Organisation consent dredging and disposal activities by means of a Marine Licence, which would be subject to licencing conditions.

** Based on recent geotechnical survey work, which shows surficial sediment depths are shallower than previously predicted, dredge volumes for the cooling water infrastructure are conservative estimates.

Table 21.7: Substrate removal, suspended sediment plumes associated with dredging activities for the proposed development. It should be noted that area and volume estimates are indicative and used in assessment to envelope anticipated activities.

Component	Removal of substratum			Changes in SSC (maximum instantaneous plume): spatial extent and amount of change		
	Spatial extent	Amount of change	Duration and frequency	Depth average	Surface water.	Persistence
BLF – capital dredging.	0.91ha	>0.5m	2.1 days x one event per year.	188ha (>50mg/l) 83ha (100mg/l) 6ha (1,000mg/l)	248ha (>50mg/l) 108ha (100mg/l) 7ha (1,000mg/l)	Return to background levels within several days.
BLF – maintenance dredging.	0.91ha	>0.5m	5 hours x monthly events per campaign.	62ha (>50mg/l) 28ha (100mg/l) 1ha (1,000mg/l)	59ha (>50mg/l) 17ha (100mg/l) 1ha (1,000mg/l)	Return to background levels within several days.
CDO	0.13ha	>0.5m	<24 hours x one event.	91ha (>50mg/l) 28ha (100mg/l) 1ha (1,000mg/l)	152ha (>50mg/l) 89ha (100mg/l) 1ha (1,000mg/l)	Return to background levels within several days.
CWS intakes	2.02ha total (four heads)	>0.5m	<24 hours x four events.	932ha (>50mg/l) 373ha (100mg/l) 14ha (1,000mg/l)	553ha (>50mg/l) 291ha (100mg/l) 34ha (1,000mg/l)	Return to background levels within several days.
CWS outfalls	0.74ha total (two heads)	>0.5m	<24 hours x two events.	(enveloped within intake assessment).	(enveloped within intake assessment).	(enveloped within intake assessment).
FRR outfalls	0.26ha total (two heads)	>0.5m	<24 hours x two events.	91ha (>50mg/l) 28ha (100mg/l) 1ha (1,000mg/l)	152ha (>50mg/l) 89ha (100mg/l) 1ha (1,000mg/l)	Return to background levels within several days.

21.4 Baseline environment

21.4.1 This section summarises the factors that influence water and sediment quality of the site and the actual measures of quality, including;

- physical environment;
- temperature;
- salinity;
- dissolved oxygen;
- SSC;
- nutrient status;
- un-ionised ammonia;
- sediment quality;
- trace metal concentrations in the water and sediment; and
- Polcyclic aromatic hydrocarbons (PAH) and contaminants.

a) Physical environment

i. Hydrodynamics

21.4.2 The tidal currents off the Sizewell coast are semi-diurnal and are highly rectilinear with a north–south orientation. Spring tide velocities are approximately 1.2m/s (peak). Tidal currents reduce close to shore to approximately 0.2m/s (peak) within 50m of the coast.

21.4.3 Water movement is dominated by tidal currents that flow south for most of the rising (flood) tide peaking at a velocity of 1.14m/s seaward of Sizewell Bank and flow north for most of the falling (ebb) tide (1.08m/s). The strong tides and generally shallow bathymetry combine so that the water column is well mixed throughout the year.

b) Water quality parameters

i. Temperature

21.4.4 Seawater temperature trends at Sizewell follow a seasonal cycle with winter minimum temperatures of approximately 4ºC occuring in February. Temperatures rise throughout the spring and peak in summer with temperatures in August reaching a maximum of 20°C in 2014 - **Appendix 22A** of this volume.

21.4.5 Long-term datasets from Lowestoft, Southwold and existing Sizewell power stations provide temperature records for over 50 years. Yearly average temperatures were derived from years (1963-2013) with complete sets of monthly values at locations in the Suffolk coastal waterbody. The 98th percentile temperature for the five year period from 2009-2013 is 19.4°C - refer to **Appendix 21A** of this volume (and Ref. 21.35).

ii. Salinity

21.4.6 Salinity at Sizewell follows an annual trend with lowest values observed in winter months. The mean annual salinity is 33.3 whilst the 5th percentile winter salinity is 31.7.

iii. Dissolved oxygen

21.4.7 DO concentrations are an important factor governing the functioning of ecological communities. DO can be influenced by the physical environment and biological processes. For example, increases in water temperature reduce the solubility of DO and therefore an important consideration for thermal discharges from power stations.

21.4.8 Monitoring of DO levels at Sizewell has shown levels range between 7 and 11mg/l. Minimum summer DO values were recorded in July 2015 (6.96–7.04mg/l) but remained well above the WFD threshold for 'high' (5.7mg/l) - refer to **Appendix 21A** of this volume.

iv. Suspended sediments concentration

21.4.9 Sediment suspended in sea water is the result of both natural processes and anthropogenic activities - refer to **Appendix 21D** of this volume. The SSC is depth dependent, highly seasonal, and varies throughout the tidal cycle due to processes of deposition and resuspension. The SSC environment is an important factor determining ecological processes.

21.4.10 SSC from seabed mounted instrumentation deployed 500m off the coast adjacent to the proposed Sizewell C station recorded the daily minimum, mean and maximum SSCs (**Table 21.8**). High SSCs are driven by both high wave energy events and peak spring tidal currents. Minimum observations are observed when neap tides coincide with low wave energy. The difference between daily maximum and minimum suspended load is approximately 300mg/l at 1m above the seabed and 500mg/l at 0.3m above the seabed.

Table 21.8: Seabed SSC 500m off the Sizewell coast.

SSC statistic.	SSC at 0.3m above the seabed (mg/l).	SSC at 1m above the seabed (mg/l).
Daily minimum	24–28	16–18
Daily mean	103–161	72–105
Daily maximum	357–609	266–459

21.4.11 Further sampling inside the Sizewell-Dunwich Bank established seasonal variation in SSC at 1m above the seabed, near the existing Sizewell B outfall (**Table 21.9**).

Table 21.9: Inshore SSC 1m above the seabed.

Temporal SSC statistic	SSC at 1m above the seabed (mg/l)
April to August (2010/11)	15–144
September to February (2010/11)	9–426
July 2016	8.7–68.4
August 2016	7.2–38.4
September 2016	5.2–17.0

21.4.12 Equivalent SSC data has been collected from the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite database. Satellite data for suspended particulate matter showed average mean SSC values at Sizewell during April to August of 31mg/l and average maximum values of 80mg/l. Between September to March mean SSC values of 73mg/l were recorded in the surface waters at Sizewell with average maximum values of 180mg/l.

21.4.13 Suspended matter is an important driver for ecological functioning of coastal systems. The WFD DIN standards for coastal waterbodies account for turbidity within the system as phytoplankton are less able to utilise nutrients in turbid systems. DIN standards are based on the annual mean concentration of SSC (Ref. 21.27). Based on satellite data, the surface waters at Sizewell are classed as 'intermediate turbidity' (10–100mg/l) - refer to **Appendix 21D** of this volume.

v. Nutrients

21.4.14 The availability of inorganic nutrients influences the growth of phytoplankton populations. Nitrate and phosphate are the primary limiting nutrient, silicate is also important for diatoms, which dominate the phytoplankton off Sizewell.

21.4.15 Inshore waters off Sizewell have higher nutrient concentrations than waters further offshore. The highest nitrate and silicate concentrations occur between January and March and at Sizewell nitrate concentrations of 30µmol/l (equivalent to 420µg/l NO_3-N) have been reported. In July and August, the concentrations of nitrates were the lowest (5µmol/l). All nutrients decrease in concentration in the summer and autumn months and show peak concentrations in the winter and spring months - **Appendix 22H** of this volume.

21.4.16 In the southern North Sea, during the winter months, light is limited and phytoplankton growth occurs in spring when nutrients are available, temperature increases, and light is no longer limiting.

21.4.17 At Sizewell, a combined Phytoplankton and Macroalgae model determined that light limitation is the primary factor limiting growth until mid-May, at which point nutrients start to become limiting. Initially phosphate is the primary limiting factor, however, this is very short-term, and the system enters a period of nitrate limitation until August when light limitation reoccurs as the primary limiting factor controlling phytoplankton growth as provided in **Appendix 22H** of this volume.

21.4.18 As excessive phytoplankton growth stimulated by excess nutrients from anthropogenic sources can reach nuisance levels and can cause oxygen depletion. The WFD sets DIN thresholds for the classification of WFD waterbodies.

21.4.19 The assessment of nutrient status considers waterbody turbidity with higher DIN thresholds applied to more turbid waters as photosynthesis is limited by light availability.

21.4.20 The WFD classifies waterbodies based on the 99th percentile winter DIN concentration in relation to the turbidity of the waterbody. The waters off Sizewell have been described as 'intermediate turbidity' based on satellite surface SSC data. DIN concentrations are within the 'good' classification for waterbodies of intermediate turbidity. However, it should be noted that the WFD Suffolk Coastal transitional and coastal waterbody is classified as 'moderate' potential for DIN during Cycle 2 (2013-2016) (Ref. 21.1)

vi. Un-ionised ammonia

21.4.21 Ammonia is a commonly occurring pollutant that enters waterbodies from diffuse and point sources from sewage effluents, industrial and agricultural activities and decomposition of organic matter. Ammonia exists in the toxic un-ionised phase (NH_3) and as ionised ammonium (NH_4^+). The relative proportion of each form depends on the temperature, salinity and pH of the water. With higher temperature and higher pH favouring un-ionised ammonia, and higher salinity favouring ammonium (Ref. 21.36)

21.4.22 The EQS for un-ionised ammonia is 21µg/l as an annual mean. The mean background concentration of un-ionised ammonia in Sizewell seawater is 0.2µg/l (calculated from average background salinity, temperature and pH and an NH_4-N concentration of 11.4µg/l, based on modelling approaches recommended in Clegg and Whitfield,1995) (Ref. 21.37) and is well below EQS concentrations. The 95th percentile NH_4-N concentration is 26.3µg/l (with a calculated un-ionised equivalent of 0.5µg/l NH_3-N) - refer to **Appendix 21F** of this volume.

vii. Priority and other substances

21.4.23 A marine water quality monitoring programme was established off the Suffolk Coast in Sizewell Bay to assess the concentrations of many elements and compounds and their variation over the area assessed with time. The initial programme ran from February 2010 to February 2011, and involved a spatial survey conducted at twelve sampling stations centred upon the existing cooling water outfall for Sizewell B (at station 5) as shown in **Figure 21.1**. The results are presented in **Appendix 21B** of this volume. Further monitoring surveys were conducted in 2014-2015 as shown in **Figure 21.2** - refer to **Appendix 21C** of this volume. This latter survey allowed more reliable data to be collected for nutrients and some metals (for which detection limits were not adequate for these parameters in earlier work).

21.4.24 In 2014-2015, additional water samples were collected monthly from up to four locations (representing Sizewell B outfall and intake, Sizewell C planned outfall location and a Centre for Environment, Fisheries and Aquaculture Science (Cefas) reference site ca. 2 kilometres (km) south of Dunwich and ~1.2km offshore).

21.4.25 However, the tidal cycle surveys in the earlier work in 2010 and 2011 provide a useful perspective of daily variation in physicochemical parameters in the marine environment off Sizewell. Sampling sites during both periods are shown in **Figures 21.1** and **21.2**.

21.4.26 **Table 21.10** and **21.11** summarise the data obtained in 2014/15, as data averages and ranges. This provides an indication of the background water quality and represents the current baseline situation with Sizewell B power station in operation.

21.4.27 Except for zinc, the mean measured concentrations of all the priority metals in the water samples were below their respective EQS.

Table 21.10: Survey mean of priority analytes at SZ3 reference site , Sizewell C intake/outfall and Sizewell B outfall (sampling points shown in Figure 21.2).

Substance	Annual average EQS (µg/l)	Annual average all sites (µg/l)
Arsenic, dissolved	25	1.07
Cadmium, dissolved	0.2	0.05
Copper, dissolved	3.76	2.15
Nickel, dissolved	8.6(34)[1]	0.79(1.16)[1]
Zinc, dissolved	6.8	15.12
Iron, dissolved	1000	<100
Mercury, dissolved	(0.07)[1]	0.02(0.02)[1]
Chromium VI, dissolved	0.6(32)[1]	0.57(2.18)[1]

[1] These values in brackets are maximum allowable concentrations set as a 95 percentile EQS, for mercury there is only a 95th percentile defined.

Table 21.11: Survey averages of nutrients for three sampling locations in the GSB (sampling points shown in Figure 21.2; EQS are not available).

Substance	Units	Annual average
Phosphate PO4 – P	µg/l	33.48
Phosphate	µmol	1.56
DIN (winter)	µg/l	306.80
DIN (winter)	µmol	21.90
DIN 99th percentile (winter)	µg/l	425.00
DIN 99th percentile (winter)	µmol	30.00
NH4-N	µg/l	11.38

viii. Sediment quality standards

21.4.28 There are no statutory thresholds to assess the quality of marine sediment in the UK. However, there are upper threshold limits of sediment contamination which are acceptable for disposal to sea.

21.4.29 The key findings from both surveys for the non-radiochemical water quality monitoring work are:

- In the 2010/11 survey concentrations of dissolved copper, arsenic, zinc, mercury and cadmium exceeded EQS levels on occasions. Some exceedance of the EQS concentrations for these metal/metalloid substances was detected at all stations except for stations 2 and 6.

- A small number of samples with concentrations in excess of their EQS were recorded for some PAHs, biphenyl and bis (2-ethylhexyl) phthalate though most analyses for these compounds were negative. Exceedances of EQS concentrations for these organic compounds were detected at stations 1, 5, 9 and 12. All exceedances of organic EQS were observed in samples acquired on three sampling dates: 7th and 8th April and the 19th May 2010.

- The survey conducted in 2014/15 repeated the metals analysis when improved detection limits were available for copper, zinc, mercury and cadmium and copper.

- Copper was detected above its EQS on 4/57 samples occasions across the four locations surveyed and zinc was above its EQS for 44/57 samples. In this more recent survey chromium was above detection in 10/57 samples with the remainder below detection (<0.5µg/l). Annual average values for chromium and copper were below their respective annual average EQS values.

- In 2010/11 TRO discharge concentration following seawater chlorination varied between 10–160µg/l. The EQS for TRO is 10µg/l. The mean of all TRO measurements (n=725) was 40µg/l. Slight localised elevation of TRO was observed near the cooling water outfall and was below the level of detection within 2.4 km to the north and 500 m to the south. Elevated TRO were observed at the southern extremity of the survey area (at stations 9 and 12) but there was no spatial pattern to indicate that this elevation was connected to the power station outfall.

- Bromoform was detected at station 5 (near the cooling water outfall of Sizewell B) at concentrations of 2–10µg/l.

- Of the 81 water samples acquired at Stations 1 to 12, 78 gave negative results for morpholine. The three positive results (all obtained from surface-water samples) were measured in two samples from station 5 (Sizewell B outfall) and one further offshore (station 11). Morpholine is not used by Sizewell B power station as a conditioning product and does not occur naturally. The reason for these analysis results is therefore uncertain.

- Another conditioning product ethanolamine was not detected in any of the samples acquired.

- Many of the chemical analyses gave negative results, indicating that the analytes were either absent or present at concentrations below the limits of detection.

- Few differences between results from inshore of Sizewell Bank and offshore were noted.

- In 2014/15, a small percentage of the samples acquired indicated that EQSs may occasionally be exceeded, but there was no spatial pattern to indicate a specific source.

c) Sediment quality parameters

i. Sediment quality

21.4.30 Sediment characteristics including particle size and contaminant loading are important criteria for the assessment of development activities with the potential to disturb or resuspend sediments. Such activities include dredging and drilling.

21.4.31 As part of the 2015 geotechnical survey, vibrocores were taken in the marine environment off Sizewell corresponding to areas where proposed marine infrastructure installations would occur as shown in **Appendix 21D** of this volume. An additional geotechnical Ground Investigation survey was completed in August 2019, sample results will be used in future licence applications but were not available for reference in this chapter. Samples from 2015 were analysed for chemical and heavy metal contaminants including:

- heavy metals and insecticides – arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, dichlorodiphenyltrichloroethane (DDT) and dieldrin;

- organotin and particle size – monobutyl-tin, dibutyl-tin, tributyl-tin and particle size analysis;

- organic and chlorinated compounds – PAHs, total hydrocarbon content and polychlorinated biphenyls (PCBs); and

- radionuclides (five core sample).

21.4.32 Radionuclide sampling show that concentrations in marine sediments at Sizewell are low (with many values below the limit of detection) and consistent with routine local radionuclide monitoring by the Environment Agency.

21.4.33 Disposal of drill arisings and dredge spoil is regulated in England by the MMO. There are no statutory thresholds to assess the quality of marine sediment in the UK. Cefas Action Levels are used as part of a 'weight of evidence' approach to assessing the contaminant loading in dredged material and its suitability for disposal to sea. The general guidance for Cefas Action Levels is as follows:

- Below Cefas Action Level 1: Contaminant levels in dredged material are generally considered of no environmental concern.
- Between Cefas Action Level 1 and Cefas Action Level 2: Contaminant levels in dredged material require further consideration before a licensing decision can be made.
- Above Cefas Action Level 2: Contaminant levels in dredged material is generally considered unsuitable for sea disposal.

21.4.34 In addition to Cefas Action Levels, evidence can be drawn from the Interim Canadian Sediment Quality Guidelines. Although not specific to the UK, the guidelines are commonly used to assess sediment quality. The guidelines provide threshold effect levels and probable effect levels. The guidance for ISQGs is as follows:

- Below threshold effect levels: minimal effect range within which adverse effects rarely occur.
- Between threshold effect levels and probable effect levels: possible effect range within which adverse effects occasionally occur.
- Above probable effect levels: probable effect range within which adverse effects frequently occur.

21.4.35 The sediment samples collected at Sizewell indicate that organotin and some heavy metals were below Cefas Action Level 1 and pose no environmental concern. Nickel and chromium exceeded Cefas Action Level 1 but the highest concentrations reported were less than 25% of Cefas Action Level 2 concentrations and below Interim Canadian Sediment Quality Guidelines and probable effect level concentrations.

21.4.36 Arsenic exceeded Cefas Action Level 1 concentrations in six of the samples at different locations and depth profiles. Two samples from the inshore areas (VC18 and VC30) at a sediment depth of 2–2.2m and 5–5.2m showed the highest levels of arsenic, close to, but not exceeding the Cefas Action Level 2 of 100 mg/kg (measurements of 84.7mg/kg and 91.5mg/kg).

21.4.37 High levels of arsenic have been reported in the region under similar studies (for example (Ref. 21.38)). The elevated levels of arsenic at location VC18 and VC30 are not associated with any other elevated contaminants of anthropogenic origin and are found only sub-surface, and as such are evaluated as representative of the natural geology and not anthropogenic contamination.

21.4.38 PCBs and organotin were below detection levels in most samples and where detected were considerably below the respective Action Level 1 levels.

21.4.39 PAHs and total hydrocarbon content exceeded Cefas Action Level 1 for some determinants (at present no Cefas Action Level 2 exists for hydrocarbons). Elevated levels above the probable effect level for dimethyl naphthalene's occurred in eleven samples. All other determinants were below probable effect level limits.

21.4.40 Hydrocarbons can be grouped into low molecular weight and high molecular weight compounds[4]. Low molecular weight hydrocarbons are typically from oil (termed 'petrogenic') sources, are highly volatile so evaporate quickly, have high solubility and are easily absorbed across cell membranes and are acutely toxic and carcinogenic. High molecular weight hydrocarbons are typically derived from 'pyrolytic' sources (e.g. burning of fossil fuels) they have low volatility, are often bound to particulates e.g. sediment and are more persistent in the environment. Two effects ranges are typically used for assessment, the effect range low and the effects range medium. Below effect range low effects are rarely observed however above the effects range medium effects are generally or always observed. The effects range low is 552ng/g and 1,700ng/g for low and high molecular weight PAHs respectively; whereas the effects range medium is 3,160ng/g and 9,600ng/g for low and high molecular weight PAHs, respectively (Ref. 21.39). All values for the sediment samples were below the relative effects range medium values and all except two samples were below the effects range low values.

21.4.41 Samples VC10 (surface) and VC24 (surface) marginally exceed the effects range low for low molecular weight PAHs (levels of 725ng/g and 793ng/g, respectively). However, these exceedances are marginal.

21.4.42 The analysis of contaminants from the core samples indicate that surface sediments are at, or close to, background levels (i.e. Cefas Action Level 1) or are shown to be considerably below the levels at which biological effects are expected.

[4] Low Molecular Weight (LMW: naphthalene, methyl naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene) and High Molecular Weight (HMW: fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[a]pyrene, dibenz[a,h]anthracene).

21.4.43 Elevated arsenic levels, although still below Cefas Action Level 2, are observed in sub-surface samples from >2m below the seabed. The only pathway for disturbance of these sub-surface sediments would be dredging or drilling.

21.4.44 The locations of elevated arsenic are >160m from the proposed dredging site (FRR2), dredging at this site is expected to cover a footprint of 9m by 23m, and therefore it is unlikely that these sediments would be disturbed by the proposed works. The acceptability of material for dredging and disposal will be reassessed if required at the time of dredging and will take account of the specific details of the dredging requirement and, if necessary, obtain and interpret new sediment sample data.

21.4.45 The sediments are therefore considered uncontaminated - refer to **Appendix 21E** of this volume, and the effects of resuspension of contaminants on marine water quality and sediment is not considered further.

21.4.46 Particle size analysis indicated that most of the samples consisted of sandy material with low organic carbon content (0.08–0.1 OC % inshore and 0.58–0.82 % further offshore), as provided in **Appendix 21D** of this volume.

d) Future baseline

21.4.47 For assessment, an indicative start date for constructing the proposed development in 2022 is assumed. The construction phase is anticipated to last for an indicative period of 9 to 12 years before the station becomes fully operational. The current baseline is therefore considered appropriate for the duration of the construction and commissioning phases.

21.4.48 The effects of operational impacts on water quality and sediment are considered against well-established current baselines. The operational life of the proposed development (60 years) means that some impacts must be considered in relation to potential shifts in future baselines due to climate change.

21.4.49 Thermal discharges and entrainment predictions are assessed against a baseline of elevated ambient temperature. The Sizewell B power station is expected to operate until 2035, with the potential for an extension of its lifetime for 20 years, to 2055. The thermal footprint within the GSB would be reduced once Sizewell B ceases to operate.

21.4.50 The water quality and sediment future baseline in this section is primarily taken from the Marine Climate Change Impacts Partnership the most comprehensive and up to date reviews of climate change impacts on the UK marine environment. The following summarises the Marine Climate

Change Impacts Partnership findings of relevance to water quality and sediment (Ref 21.40).

Sea temperature rises

21.4.51 The southern North Sea is shallower with a faster warming rate than other areas of the UK. Climate predictions assume a linear increase in temperature which will be subject to increased uncertainty further into the future.

Ocean acidification

21.4.52 Towards the end of the 21st century, ocean acidification may become an environmental concern around the UK for marine ecology. Decreasing pH will influence chemical speciation e.g. partitioning of ionised and un-ionised ammonia favouring the less toxic ionised form.

21.5 Environmental design and mitigation

21.5.1 Several primary and tertiary mitigation measures have been identified through the iterative EIA process and are incorporated into the design and construction planning of the proposed development.

21.5.2 As the primary and tertiary mitigation measures have been either embedded into the design, are legal requirements or are standard practices that will be implemented, the impact assessment in this chapter assumes that they are in place. They are identified in **Chapters 2, 3** and **4** of this volume and are summarised in this section so that it is clear where and why these measures have been included and the way in which they have contributed to the management and reduction of environmental effects.

21.5.3 For marine water quality and sediment, the following primary and tertiary mitigation measures have been embedded into the design and construction management of the proposed development.

21.5.4 Primary mitigation ('embedded mitigation') includes modifications to the location or design of the development made during the pre-application phase that are an inherent part of Sizewell C Project, become a fundamental part of the design for which consent is sought, and do not require additional action to be taken.

21.5.5 In some instances where it is possible to make an assessment with and without embedded mitigation assessments include both scenarios with intent to demonstrate the effectiveness of mitigation measures in reducing environmental effects. An example of this approach is the assessment of fish impingement with and without the FRR systems.

21.5.6 Tertiary mitigation measures are legislative requirements and/or standard sectoral practices and will be implemented irrespective of the EIA assessment.

21.5.7 The environmental design and primary and tertiary mitigation measures that have been embedded into the design and construction management of the proposed development are detailed in this section. Where necessary to provide context for assessments, the construction activities are briefly described. For the main development site, the impact of the following development components is assessed:

a) Coastal defence features

21.5.8 The SCDF would be made of landscaped beach grade sediments and constructed to 5m ODN elevation between the HCDF and the MHWS.

21.5.9 Design and maintenance of the SCDF is discussed in Appendix 20A. In summary, the SCDF would be maintained for as long as mitigation was active.

21.5.10 Maintenance of the SCDF would require vehicular access and works close to the shoreline. To avoid any impact on water quality various measures would be adopted.

21.5.11 Work undertaken in the marine environment or in close proximity should have regard to best practice for pollution prevention as identified in Guidance for Pollution Prevention, i.e. Guidance for Pollution Prevention 5 works and maintenance in or near water (Ref. 21.41 and 21.42), Guidance for Pollution Prevention P6 working at construction and demolition sites (Ref. 21.43 and Ref. 21.44) Guidance for Pollution Prevention P2 oil storage tanks and Guidance for Pollution Prevention 8 safe storage and disposal of used oils, (Ref. 21.45 and Ref. 21.46), Guidance for Pollution Prevention 22 dealing with spills (Ref. 21.47 and Ref. 21.48).

21.5.12 Other best management practice to be adopted as described in the **Code of Construction Practice** (**CoCP**) (Doc Ref. 8.11)

b) Beach Landing Facility

21.5.13 The BLF would be used to receive large deliveries (including AILs) into Sizewell C by barge.

21.5.14 All substances and objects deposited are inert (or appropriately coated or protected) and do not contain toxic elements.

21.5.15 As detailed in the **Code of Construction Practice** (**CoCP**) (Doc Ref. 8.11) any coatings or treatments applied to the BLF or other infrastructure must be suitable for use in the marine environment in accordance with best environmental practice (i.e. be on the list of substances approved for use by the offshore oil and gas industry or have undergone a similar level of risk assessment).

21.5.16 Work undertaken in the marine environment or in close proximity should have regard to best practice for pollution prevention as identified in Guidance for Pollution Prevention as discussed for the SCDF.

Dredging

21.5.17 Plough dredging would be used to create a planar surface for the barges to come aground at the BLF. Plough dredging pushes the sediment aside from the required area, which is then redistributed by subsequent tides. Sediment is not removed with the vast majority remaining within the same sediment cell. This approach minimises the resulting plumes of SSC and any resultant effects on water quality.

Vessel traffic and pollution

21.5.18 A number of measures would be implemented to mitigate potential effects of vessel traffic at the site. These measures are detailed in the **CoCP** (Doc Ref. 8.11) which proposes the implementation of a site **Vessel Management Plan.** In summary the mitigation includes;

- vessel waste management procedures outlined in the **Vessel Management Plan** and Site Waste Management Protocols would be in place to mitigate impacts of marine litter;
- the potential for chemical and oil spills whilst recognised would be mitigated by compliance with International Maritime Organisation regulations and the Marine Licence;
- transport of chemicals in line with the International Maritime Dangerous Goods Code (Ref. 21.49);
- storage of chemicals in line with the Control of Substances Hazardous to Health Regulations (COSHH) 2002 (Ref. 21.50); the REACH Enforcement Regulations 2008 (Ref. 21.51), the Classifying, labelling and packaging of substances (CLP) Regulation (European Regulation (EC) No 1272/2008) (Ref. 21.52); and Health and Safety Executive (HSE) guidance on offshore storage of chemicals (Offshore Chemicals Management guidance note 8) (Ref. 21.53); in addition to applicable manufacturer’s guidance on storage.

c) Cooling water infrastructure

i. Construction

Tunnels

21.5.19 Spoil from the cutting face of TBMs used in construction of the cooling water intakes and outfall tunnels would be removed, then transported landward. Groundwater would be generated from digging the galleries allowing access to the tunnels. During the transport of spoil material and during slurry recovery and treatment, groundwater and some residual TBM chemicals would be produced and these would be recovered for discharge via the CDO in accordance with the requirements of an environmental permit.

21.5.20 Discharges would be treated with a siltbuster or similar technology to minimise sediment inputs and oil separator. Groundwater discharges are not considered to represent an environmental risk during the tunnelling phase as other phases of construction that have higher groundwater loadings provide a conservative assessment as provided in **Appendix 21F** of this volume.

21.5.21 Chemicals used at the cutter face may persist in the leachate and are assessed further. This section considers assessments undertaken in relation to tunnelling chemicals, which are associated with three broad functions:

- fuelling and lubrication of the TBM;
- sealing the tunnel walls against water/soil ingress; and
- ground conditioning.

21.5.22 Fuel and lubricants would be managed to ensure compliance with relevant Environment Agency permit, and/or/ Marine Management Organisation licence, conditions. Oil/chemical spills would be contained and cleaned with appropriate treatment and disposal.

ii. Operation

Cooling water headworks

21.5.23 Embedded mitigation measures implemented into the design of the intake and outfall headworks are set out below with an explanation of the effects mitigated. It is noted that measures which reduce the impingement of fish and other organisms in turn also reduce the biomass that might contribute to the reduction of water quality upon discharge from the FRR.

- The outfalls of the cooling water infrastructure would be located east of the Sizewell-Dunwich Bank approximately 3km offshore, thereby allowing greater dilution of cooling water discharges and reducing potential intersections with the shore.

- The long axis of the intakes would be positioned parallel to the current in a north-south orientation. Intake slits would be positioned on the side of the headworks perpendicular to the tidal flow. This reduces both vertical currents, which fish are susceptible to, and reduces the probability of fish being forced into the intakes by tidal currents and, therefore, being discharged via the FRR and potentially affecting water quality.

- The outfall headworks are designed to funnel thermally buoyant discharges away from the seabed thereby minimising effects on the seabed.

- The selection of an offshore location reduces the area of thermal impact exceedance inshore of the Sizewell-Dunwich Bank.

21.5.24 Seasonal chlorination would be applied to achieve protection of critical plant (essential cooling water systems for the nuclear island and the turbine hall, and the condensers). However, spot-chlorination may be required to protect critical plant outside these periods. This approach minimises chlorination, and associated TRO discharges, in the winter.

21.5.25 Following passage through the condensers the cooling water would enter the discharge pit before passing through the cooling water tunnel to be discharged at the outfall. Additional inputs at the discharge pit include sanitary waste, groundwater and surface run-off, and daily hydrazine discharges. Discharges into the cooling water flow allow dilution prior to mixing in the receiving waters.

21.5.26 Hydrazine is used in power plants to inhibit corrosion in steam generation circuits. At intervals there may be a reactor shutdown to allow refuelling. During this period frequently there is a need to carry out additional chemical dosing of plant – termed ‘wet lay-up’. Therefore the worst-case daily hydrazine discharge would be after wet lay-up of steam generators. However, hydrazine discharges would be treated until the hydrazine concentration falls below a level that is acceptable for a batch discharge. Wet lay-up is not expected in a normal refuelling outage. In the case of Sizewell B, wet lay-up first occurred ~15 years after first operation.

21.5.27 Operational discharges to the marine environment would be controlled by the limits set by the Water Discharge Activity permit granted by the Environment Agency.

d) Fish recovery and return system

21.5.28 The FRR is a key element of embedded mitigation, allowing robust species of fish and invertebrates to be impinged prior to being returned to the receiving waters thereby reducing mortality and potential contribution of dead biomass to deterioration in water quality.

i. Construction

21.5.29 FRR systems would be constructed, one for each reactor. The FRR tunnels would be directional-drilled beneath the seabed with arisings transported to landward for disposal. Any liquid discharges associated with the directional drill would be treated as required prior to discharge via the CDO (and would be subject to an environmental permit granted by the Environment Agency).

ii. Operation

21.5.30 The FRR wash water would not be chlorinated. This allows better survival of impinged fish and removes the need to discharge chlorinated inputs to the GSB.

21.5.31 Operational discharges to the marine environment would be controlled by the limits set by the Water Discharge Activity permit granted by the Environment Agency.

e) Combined drainage outfall

i. Construction phase function of the combined drainage outfall

21.5.32 The CDO would be constructed early in the construction phase and act as the primary site discharge outfall. The CDO would be in a similar position on the seaward flank of the outer longshore bar as the FRR to allow mixing and avoid effluent contact with the shore.

21.5.33 The CDO tunnel would be drilled beneath the seabed with arisings transported to landward for disposal. The tunnels would be connected to a concrete outfall structure anticipated to be of similar dimensions to the FRR headworks.

21.5.34 The location of the CDO, approximately 400m offshore from the HCDF, limits the potential for discharges to interact with the coastline.

21.5.35 Prior to installation of the CDO outfall headwork, overlying soft sediment in the shallow subtidal (<6m) would be removed by dredging via a cutter suction dredger with spoil disposed locally within a licenced disposal site (**Tables 21.5 and 21.6**).

21.5.36 The CDO would discharge tertiary treated sewage, dewatered groundwater, surface run-off and tunnelling wastewater discharges.

21.5.37 In accordance with **CoCP,** (Doc Ref. 8.11) discharges would be treated with oil separators to minimise potential hydrocarbon contamination from mobile or fixed plant operations and a siltbuster or similar technology to reduce sediment loading. A WDA environmental permit would be required prior to any discharges to ensure compliance with EQS.

ii. Commissioning function of the combined drainage outfall

21.5.38 The CDO would act as a discharge point during part of the commissioning phase of the proposed development.

21.5.39 Hydrazine discharges produced during cold commissioning of the reactors would be directed to treatment tanks to reduce discharges to permitted levels prior to controlled release via the CDO. This embedded mitigation would allow the managed release of hydrazine to achieve environmentally acceptable standards.

21.5.40 These discharges would also need to be included in the WDA environmental permit to ensure compliance with EQS.

iii. Operational function of the combined drainage outfall

21.5.41 There is no anticipated operational function for the CDO.

21.6 Marine water quality and sediment assessment

a) Introduction

21.6.1 This section applies the methodology outlined in **section 21.3** of this chapter to determine the potential for significant effects arising from the construction, commissioning and operational phases of the proposed development on marine water quality and sediment.

21.6.2 In making this assessment various indicative scenarios are applied based on the best information available to provide representative most conservative determinations of potential impact.

21.6.3 The magnitude of the environmental impacts prior to any additional (secondary) mitigation is considered and assessed assuming the primary and tertiary measures detailed in **section 21.5** of this chapter are embedded. Where secondary mitigation or monitoring is deemed appropriate to minimise any adverse effects, assessments are considered further as a residual effect, provided in **section 21.8** of this chapter.

b) Construction

21.6.4 The construction phase including commissioning of the proposed development has the potential to affect water and sediment quality.

21.6.5 This section considers the development components and associated activities that were identified during scoping to result in pressures warranting further investigation.

i. Coastal defence feature

21.6.6 Maintenance of the SCDF would require vehicular access and works close to the shoreline. To avoid any impact on water quality various measures would be adopted as described under mitigation.

ii. Beach Landing Facility

21.6.7 The BLF would be built at the beginning of the construction phase to facilitate deliveries, including AILs, by barge. Once constructed, deliveries would occur throughout the construction phase. This section describes the impacts associated with the installation and operation of the BLF during the construction phase. Scoping identified that dredging activities represent the primary activity with the potential to affect water quality and marine ecology , as provided in **Appendix 22M** of this volume. By application of best practice negligible effects from chemicals leaching from structures would be predicted.

21.6.8 As sediment contamination levels are not deemed significant the main pressure with the potential to affect water quality is resuspension of sediment.

Changes in suspended sediment concentration: Beach Landing Facility

21.6.9 Sediments agitated and moved by plough dredging would be removed and reprofiled by tidal flows away from the dredge area. Following the initial capital dredging event, a plume with an instantaneous SSC of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. A small area of up to 7ha would experience an instantaneous SSC plume of >1,000 mg/l above background levels. Maintenance dredging, occurring at approximately monthly intervals, would result in up to 28ha of sea surface expected to experience >100mg/l, and 1ha expected to experience >1,000 mg/l above background SSC on each occasion (**Table 21.7**).

21.6.10 Ambient conditions at the site are highly variable, seen in **section 21.4** of this chapter, and the surface waters are considered as of 'intermediate turbidity' according to WFD criteria in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to 'turbid'. However, SSC would return to background levels several days after dredging activity ceases.

21.6.11 The duration of the SSC plume is short-lived and transient; however, maintenance dredging increases the frequency of smaller scale impacts. Maintenance dredging would result in the plume reoccurring during the campaign period and throughout the construction phase.

21.6.12 The spatial extent of SSC elevation at >50mg/l, which would be equivalent to a WFD turbid classification (i.e. 100 – 300mg/l) when considered in addition to mean SSC background concentration during most of the year, would be 248ha. An area of 248ha is <2% of the Suffolk Coastal waterbody area and is considered medium extent as is the amount of change and duration of the plume resulting in an impact magnitude of medium.

21.6.13 The sensitivity of water quality to increases in SSC is low as the waters off Sizewell are well mixed.

21.6.14 The impact of increased SSC resulting from dredging activities for the BLF is predicted to have a minor adverse effect on water quality. Effects are predicted to be short-lived and **not significant** relative to natural variation.

21.6.15 The potential exists for dredging activities to occur simultaneously at the site. The effects of increases in SSC is considered further as part of the inter-relationship effects assessment, provided in **section 21.6 v** of this chapter.

iii. Combined drainage outfall

During scoping, the pressures arising from construction activities at the combined drainage outfall with the potential for effects on marine water quality and sediment were identified in **Volume 2 Appendix 21A** of the **ES** and these are presented in **Table 21.12**.

Table 21.12: Pressures associated with combined drainage outfall activities during the construction phase with the potential to affect marine water quality and sediment.

Pressure	Activities resulting in pressure	Assessed	Justification
Changes in suspended sediments.	Capital dredging and disposal.	Yes	Dredging would cause temporary increases in SSC. Sediment concentrations are used to provide a context for assessing nutrient status of a waterbody and the potential for increases in phytoplankton productivity and biomass.
Pollution and other chemical changes.	Construction discharges of heavy metals.	Yes	Heavy metal contaminants in construction discharges including dewatered groundwater may exceed EQS and have the potential to exert toxicological effects.
Pollution and other chemical changes.	Nutrients	Yes	Nutrient discharges including all sources of DIN and phosphate during construction (discharges of treated sewage and groundwater) and commissioning discharges (including phosphate) have the potential to effect primary production. Therefore phytoplankton growth potential is assessed.
	Un-ionised ammonia.		Potential EQS exceedance and toxicological effects may arise from un-ionised ammonia from treated sewage and commissioning discharges.
Synthetic compound contamination.	Commissioning discharges of hydrazine. Discharges of drilling wastewater chemicals.	Yes	Commissioning discharges of hydrazine during cold-flush testing of reactor Unit 1 would be discharged through the CDO. The potential to exceed toxicological thresholds and to exert effects are assessed. TBM chemicals may be used during drilling of the cooling water intake and outfall tunnels. Drilling waste water containing small volumes of drilling chemical leachate would be discharged via the CDO. The potential for toxicological effects is assessed.

Changes in suspended sediment concentration: Combined drainage outfall

21.6.16 Dredging and local disposal for the installation of the CDO headworks would lead to elevated SSC. Plumes with instantaneous SSC of >50mg/l and >100mg/l above background levels are expected to form over areas of up to 152 and 89ha at the surface respectively. An instantaneous SSC of >1,000mg/l above background at the sea surface is expected to occur over 1ha (**Table 21.7**).

21.6.17 Ambient conditions at the site are highly variable, as seen in **section 21.4** of this chapter, and the water body is considered as of 'intermediate turbidity' according to WFD criteria (Ref. 21.27). The spatial extent of SSC elevation at >50mg/l, which would be equivalent to a WFD turbid classification (i.e. 100 – 300mg/l) when considered in addition to mean SSC background concentration during most of the year, would be 152ha. An area of 152ha is ca. 1% of the Suffolk Coastal waterbody area and is considered medium extent as is the amount of change and duration of the plume resulting in an impact magnitude of medium.

21.6.18 Dredging would temporarily increase the classification to 'turbid'. However, SSC would return to background levels several days after dredging activity ceases. The increase in SSC would occur once for the installation of the CDO head.

Water quality and sediment sensitivity to changes in suspended sediment concentration

21.6.19 Marine waters at Sizewell are well mixed such that localised elevations of SSC quickly redistribute and return to background levels. The sensitivity of waters off Sizewell to SSC status change due to dredging activity is therefore predicted to be low sensitivity**.**

21.6.20 The impact of increased SSC resulting from dredging activities for the installation of the CDO is predicted to have a minor adverse effect on water quality and sediment. Effects are predicted to be short-lived and **not significant** relative to natural variation.

Heavy metal contamination: Combined drainage outfall

21.6.21 During construction of the main development site, groundwater discharges would be made via the CDO. Exploratory boreholes across the main development site quantified the concentrations of dissolved metals within the groundwater. The worst-case construction discharges for trace metals would be during the initial 28-day dewatering drawdown of the cut-off wall around the main construction site. The dewatering phase would result in an estimated 300,000m^3 of groundwater being discharged at a rate of 124l/s.

After the initial dewatering phase nominal discharges of 15l/s would continue throughout the construction phase to remove rainwater and seepage through the cut-off wall.

21.6.22 In the dewatering phase, two groundwater metals, zinc and chromium failed initial EQS screening and CORMIX and General Estuarine Transport Model modelling were undertaken to determine the mixing rates and spatial extent of the impacts.

21.6.23 The mean background concentration of zinc in the environment is 15.12µg/l whilst the EQS is 6.8µg/l as an annual average. Since the background levels are in exceedance of the EQS, zinc discharges could not be assessed under standard procedures. Modelling predicted the point at which zinc concentrations could not be discriminated from background based on an analytical detection limit of 0.4µg/l. Therefore, the threshold value for zinc was set at 15.52µg/l - refer to **Appendix 21E** of this volume. Thus, the amount of change relative to baseline is approximately 2.5%. Modelling demonstrated that zinc concentrations above background would occur over a mean sea surface area of 0.11ha. At the seabed, zinc is not predicted to exceed background concentrations.

21.6.24 Chromium as a mean has an EQS concentration of 0.6µg/l and as a 95^{th} percentile has an EQS concentration of 32µg/l. Chromium background concentrations of 0.4–0.57µg/l are reported for the site. As a precautionary measure the higher background concentration was applied to give a mean EQS threshold of 0.03µg/l. Thus, the amount of change relative to baseline is approximately 5%. A sea surface area of 5.49ha exceeded the mean EQS, but at the seabed chromium did not exceed EQS concentrations. The 95^{th} percentile concentration (32µg/l) was not exceeded as seen in **Appendix 21E** of this volume.

21.6.25 The initial dewatering phase during which a higher discharge rate of 124 l/s is predicted, is a short-term activity (28 days). Areas impacted extend over a very limited spatial area and the amount of change is very small relative to the baseline conditions. The impact magnitude is assessed as very low.

21.6.26 A very small proportion of the water column within the GSB would be exposed to trace metal concentrations in exceedance of EQS thresholds or natural background concentrations. In the tidally dominated system, the duration of EQS exceedance would be very limited. Sensitivity is therefore evaluated as low.

21.6.27 Heavy metal discharges from the CDO are predicted to have negligible effects on water quality or sediment. Effects are **not significant**.

Nutrient enrichment: Combined drainage outfall

21.6.28 During construction and commissioning several contributions would be made to DIN and phosphorus.The most consistent nutrient enriching inputs would be from treated sewage and groundwater but also during cold commissioning of the reactors conditioning chemicals in the various circuits may be discharged. Nutrient discharges have the potential to enhance phytoplankton biomass particularly if they occur during periods of nutrient limitation. Potential effects on primary production within the GSB are assessed.

21.6.29 The peak nitrogen and phosphorus additions from the proposed development were compared to the daily exchange of water in the tidal system and the additional nutrient terms were modelled using the combined Phytoplankton and Macroalgae model.

21.6.30 Daily commissioning nitrogen discharges would represent ca 0.004% and phosphate at ca 0.1% of the daily exchange rates for GSB. Combined construction and commissioning nutrient discharges represent approximately 1% or less of the exchange rates and would be indistinguishable from background nutrient variation. The magnitude of impact is low.

21.6.31 The CPM model predicts that construction nutrient additions (this included the commissioning inputs) would increase annual gross primary production within the tidal excursion by <0.13%, as seen in **Appendix 22H** of this volume. Such changes are orders of magnitude below the natural variation in chlorophyll biomass and therefore sensitivity is evaluated as very low, as provided in **Chapter 22** of this volume.

21.6.32 Construction phase nutrient inputs are predicted to have negligible effects. Effects are **not significant** relative to natural variability in modelled phytoplankton biomass.

Un-ionised ammonia: Combined drainage outfall

21.6.33 Ammonia is a commonly occurring pollutant that enters waterbodies from several diffuse and point sources including sewage effluents. Ammonia exists as un-ionised (NH_3) and ionised ammonium (NH_4). The relative proportion of each form depends on the temperature, salinity and pH of the water. Higher temperatures and high pH favour un-ionised ammonia, whilst higher salinity favours ammonium (Ref. 21.36). Un-ionised ammonia is the most toxic form and has an established annual average EQS value of 21µg/l. Treated sewage effluent discharge during construction is a primary source of un-ionised ammonia but there is also a contribution from groundwater.

21.6.34 The highest routine sewage discharges are anticipated during Case D (**Plate 21.1**) and a worst-case un-ionised ammonia discharge would occur for Case D1 for short-duration maximum sewage only discharge for which a discharge rate of 30l/s is assumed. For the maximum discharge scenario dilution modelling predicts exceedance of EQS concentrations up to 6.3m from the point of discharge. EQS exceedance is within 4m of the discharge for all other construction scenarios - **Appendix 21E** of this volume.

21.6.35 During cold commissioning there is potential for discharge of un-ionised ammonia which is used in pH adjustment and circuit conditioning. This discharge combined with the maximum Case D1 construction discharge would contribute a total discharge volume of 155l/s. Comparisons against previous nearfield modelling using CORMIX suggest a 49-fold dilution is achieved within approximately 25m which would be enough to reduce the potential un-ionised ammonia concentration (for average water quality parameters) to ca. 50% of the EQS.

21.6.36 Although discharge could occur throughout the construction phase the magnitude of impact is assessed as very low as the extent of exceedance is very limited.

Water quality and sediment sensitivity to un-ionised ammonia

21.6.37 Ammonia is rapidly used in the marine environment and local conditions at the point of discharge mean that inputs will be rapidly mixed and diluted below the EQS such that areas of exceedance are very small and sensitivity is evaluated as low.

21.6.38 Un-ionised ammonia discharges from the CDO are predicted to have negligible effect on marine water quality and sediment. Effects are **not significant**.

Microbiological inputs: Combined drainage outfall

21.6.39 During construction estimated maximum sewage loadings are assumed to be the same as those predicted for the Hinkley Point C development at 240 x 10^6 *E.coli*/ 100ml and 13.6 x 10^6 intestinal enterococci – see **Appendix 21F** of this volume.

21.6.40 Tertiary treatment is planned and discharges would be made via the CDO with a total combined discharge rate of 72l/s.

21.6.41 The discharge plume would be fresh water and therefore would be buoyant. Based on expected treatment level (5.4 log reduction) in the faecal indicator organisms *E.coli* and intestinal enterococci, CORMIX modelling estimates of subsequent mixing and dilution indicate compliance with good bathing water standards within 1m of the point of discharge (500 *E.coli* and 200 intestinal enterococci per 100ml).

21.6.42 This assessment assumes that treated sewage is equivalent to the total 72l/s and is conservative as the treated effluent would likely be <50% of this volume.

21.6.43 Even for a conservative assessment of the rate of discharge the area of potential exceedance is very small and so magnitude is evaluated as very low.

21.6.44 The nearest designated bathing waters are 10km away from the discharge point and so sensitivity is considered to be low so microbiological inputs from treated sewage during construction are predicted to have negligible effects. Effects are **not significant.**

Tunnelling chemical discharges

21.6.45 Tunnelling would be subterranean, approximately 30m below the seabed. The excavated pressure if required would either be at ambient or slightly above ambient pressure similar to the existing conditions at such depths. Therefore, the potential for tunnelling operations to cause a break through and release of chemicals at the seabed under pressure 'frac-out' of tunnelling materials including chemicals poses minimal risks to the overlying marine environment and is not considered further. The potential for contamination in the waste-water is considered.

21.6.46 Tunneling would involve transporting spoil from the cutting face to a temporary stockpile for onward management. During the transport and processing of spoil material groundwater and potentially residual TBM chemicals would be produced in wastewater that would be discharged via the CDO.

21.6.47 For slurry tunnelling using bentonite the predicted concentration of bentonite in suspension that is potentially discharged following recovery is orders of magnitude lower than baseline SSC, with 95th percentile concentrations of 10µg/l restricted to sea surface areas of <11ha and mean concentrations of 10µg/l over <1.5ha as provided in **Appendix 21E** of this volume. In the tidally dominated environment characterised by high resuspension rates, the potential for sedimentation of fine materials to influence water quality status in terms of overall SSC is minimal. No further assessment is made.

21.6.48 The use of TBM chemicals at Sizewell has not been confirmed and chemical use and selection would be informed by survey of the underlying geology prior to tunnel excavation.

21.6.49 However to envelope representative tunnelling approaches, compounds assessed are based on those planned for use at Hinkley Point including the anti-clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M. A conservative tunnelling scenario would occur when two cooling water tunnels are being excavated (Case E; **Plate 21.1 and Table 21.13**)

Table 21.13: Areas of PNEC exceedance for different TBM discharges.

TBM chemical and active substance	PNEC (mean)	Discharge conditions (concentration and flow rate)	Mean surface exceedance (and 95th percentile)	Mean seabed exceedance (and 95th percentile)
BASF Rheosoil 143: sodium lauryl ether sulphate.	40µg/l	23.13mg/l at 34.4l/s	1.01ha (5.83ha)	0ha
CLB F5 M: mono- alkyl sodium sulphates 5.	4.5µg/l	7.71mg/l at 34.4l/s	3.14ha (25.0ha)	0ha

21.6.50 Modelling predicted that the mean sea surface area in exceedance of the BASF Rheosoil 143 PNEC was restricted to 1.01ha (95th percentile 5.83ha). The seabed is never exposed to concentrations above the PNEC (**Table 21.13**). The sea surface area exposed to CLB F5 M in exceedance of the PNEC was restricted to 3.14ha as a mean concentration (95th percentile 25.0ha). The seabed is never exposed to concentrations above the PNEC, as provided in **Appendix 21E** of this volume.

21.6.51 Tunnelling is predicted to be a medium-term impact lasting several years in total. The use of TBM surfactants in the tunnelling process remains to be confirmed and assessments present a precautionary approach enveloping conservative discharge concentrations for representative chemicals and discharge levels. A small mean spatial area is predicted to exceed the PNEC at the sea surface ca. 3.1ha (95th percentile 25.0ha). The seabed would not be exposed to concentrations above the PNEC.

21.6.52 The impact magnitude is assessed to be **l**ow.

5 Ethoxylated sulphates are another active substance considered but have a less precautionary PNEC (35µg/l).

Marine water quality and sediment sensitivity to tunnelling surfactants

21.6.53 Limited empirical evidence is available for the effects of TBM surfactants on marine species with much of the data derived from freshwater studies in support of risk assessment of detergent products (Ref. 21.54) and (Ref. 21.55).

21.6.54 However, derived PNECs indicate that higher concentrations than those predicted at Sizewell are required to cause toxicity and biodegradation of the two types of surfactants shown in **Table 21.13** is rapid.

21.6.55 The predicted areas in which TBM surfactants would be elevated are also very limited and dilution would be rapid such that water quality and sediment is predicted to have low sensitivity to the representative TBM discharges assessed.

21.6.56 TBM discharges are predicted to have minor adverse effects on water quality and sediment. Effects are **not significant.**

Commissioning discharges: Hydrazine (influence on surface waters and seabed)

21.6.57 During cold flush testing a number of chemicals would be released that required further investigation for potential water quality issues. Of these, hydrazine, used to prevent corrosion of the reactor units, failed the initial screening and is considered in more detail. Hydrazine would be applied to prevent corrosion of the reactor units. Based on the Rochdale envelope approach, modelling took the precautionary position of both reactors being commissioned simultaneously with hydrazine discharged into the receiving waters via the CDO. Discharge concentration of 15µg/l was evaluated as the upper bounding concentration. Based on a maximum daily volume of hydrazine wastewater from cold commissioning of two reactors, a 5.0h discharge pulse would be sufficient to empty the total volume of two storage tanks - **Appendix 21F** of this volume. There is no established EQS threshold for hydrazine. The marine chlorophyte *Dunaliella tertiolecta* has been shown to have the lowest acute toxicity to hydrazine with a six-day EC_{50} for growth inhibition of 0.4µg/l (Ref. 21.56). A chronic PNEC of 0.4 ng/l has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4 ng/l for short term discharges (represented by the 95^{th}percentile). These thresholds are considered as precautionary triggers for further ecological investigation. Assessments used in support of Canadian Federal Water Quality Guidelines for hydrazine indicate concentrations below 0.2µg/l (200ng/l) have a low probability of adverse effects for marine life. In the freshwater environment, where more data is available, a threshold of 2.6 µg/l has been applied (Ref. 21.57). **Table 21.14** shows the areas of exceedance for an upper bounding hydrazine release of 15µg/l. Based on the area of exceedance of the precautionary EQS values the impact magnitude is assessed as medium.

Table 21.14: Areas of PNEC exceedance for hydrazine discharge at 15µg/l release concentration in 5.0h pulses during commissioning.

Model run	Effect category	Concentration (ng/l)	95^{th} percentile surface (ha)	95^{th} percentile seabed (ha)	Mean surface (ha)	Mean seabed (ha)
5h release 15µg/l at 83.3l/s.	Chronic	0.4			30.50	2.92
	Acute	4	12.90	2.92		
		2000	0.34	0		

Marine water quality and sediment sensitivity to hydrazine

21.6.58 Commissioning is likely to last several years; however simultaneous discharges of hydrazine are considered unlikely and the assessment is precautionary.

21.6.59 Hydrazine is rapidly degraded in the marine environment and has a half-life based on laboratory studies of seawater from Sizewell of ca. 38 minutes and, in the tidally dominated system, the duration of EQS exceedance would be very limited.

21.6.60 Although acute and chronic PNECs are defined, a large body of supporting data indicates that these values are precautionary. Even based on these values areas of exceedance are low and result from a daily discharge of short duration.

21.6.61 The precautionary basis for PNEC derivation and the expected rapid mixing and degradation of hydrazine indicates sensitivity to be very low.

21.6.62 Hydrazine discharges during commissioning are therefore predicted to have minor effects. Effects are **not significant.**

Commissioning discharges: Hydrazine (influence on designated sites)

21.6.63 Sites with ecological receptors or supporting habitats relevant to the scope of this chapter with the potential to be affected are outlined in **Chapter 22** and relevant **Appendices 22A–F** of this volume. Water quality impacts on designated marine mammal species (including seals from the Wash and North Norfolk Special Area of Conservation (SAC) and Humber Estuary SAC) and indirect effects on the prey species of designated marine mammals and seabirds are included in the assessment in relevant sections of **Chapter 22** and **Appendix 22E** of this volume.

21.6.64 This section considers the potential for effects from changes in marine water quality on coastal habitats beyond MHWS including marshes, dykes, reedbeds and brackish lagoons. These habitats support a diverse range of invertebrates that provide a food source for nationally and internationally important wetland birds.

21.6.65 Sites within the ZoI for water quality:

- Minsmere to Walberswick Special Protection Area (SPA) and Ramsar site.
- Minsmere to Walberswick Heaths and Marshes Site of Special Scientific Interest (SSSI).

21.6.66 The potential for water quality issues associated with the proposed development to affect the Minsmere to Walberswick SPA, Ramsar site, Minsmere to Walberswick Heaths and Marshes SSSI, and the associated RSPB Minsmere reserve has been identified. Effects may result from direct entry into the Minsmere reserve through the Leiston drain when the Minsmere sluice is open. Alternatively, contaminants may percolate through the dune system or overtop during storm events or due to changes under future baselines.

21.6.67 In the case of overtopping such climate driven processes would not become apparent until the operational phase of the development. Chemical discharges associated with the operation of the proposed development would not intersect the Minsmere coast at concentrations that could induce ecological effects, as provided in **Appendix 22C** of this volume**.** These habitats are therefore scoped out of the assessment of operational effects.

21.6.68 During the construction and commissioning phase discharges would be made via the CDO, closer inshore. The potential for construction and commissioning contaminants to enter the Minsmere habitats is considered in here.

21.6.69 Monitoring conducted between July 2014 and May 2015 in a small brackish pond located between the seawall and the beach adjacent to Minsmere RSPB reserve to the north of the existing power stations indicated that it was brackish with salinity of 6–25 salinity units. There was no indication of overtopping, but the salinity variation indicates that there is some limited seawater input into the pond with saline water entering the pond slowly, mostly likely via slow diffusion through the dune system that lies between the pond and the coast.

21.6.70 During commissioning, hydrazine will be treated to reduce its concentration. An upper, bounding concentration of 15µg/l is assessed here. At the upper bounding concentration discharges of hydrazine are predicted to exceed PNEC levels (acute threshold 4ng/l as a 95th percentile) over a sea surface area of 12.9ha and 2.92ha at the seabed, however interaction with the coastline does not occur at these levels. Thus, the potential for percolation through the dune system is negligible, particularly when the rapid degradation rate of hydrazine is considered (ca. 38-minute half-life).

21.6.71 However, as a precautionary measure a time series was modelled at the position of the Minsmere sluice to determine the potential for the maximum instantaneous plume to enter RSPB Minsmere via this route.

21.6.72 The Minsmere sluice controls the sea water that can flow into various drainage channels including those used to periodically supply a saline input to the Minsmere salt marshes. Should hydrazine concentrations at ecologically relevant concentrations occur at times when the sluice is open, there is the potential it could effect the designated habitats associated with the RSPB Minsmere reserve within the Minsmere to Walberswick SPA and Ramsar site, as provided in **Chapter 22** of this volume and **Table 21.1**. The Minsmere sluice opens for half an hour after high tide, allowing saltwater to enter the system. At Sizewell the tide floods in a southerly direction. As the proposed development is south of the Minsmere sluice, discharges are only transported northward on an ebb tide, when water levels are lowering. During the ebb tide, the hydrazine plume is transported northward towards Minsmere. During the month-long model run the acute PNEC was not exceeded with the highest maximum instantaneous concentration of 0.12ng/l predicted at the surface and 0.11ng/l at the seabed for a 15µg/l discharge concentration during the worst-case model scenario . Magnitude of impacts are evaluated as very low.

21.6.73 The PNEC applied as a trigger for ecological investigation is highly precautionary. Assessments used in support of Canadian Federal Water Quality Guidelines for hydrazine indicate concentrations below 0.2µg/l have a ‘low probability of adverse effects for marine life’, whilst a threshold of 2.6µg/l has been applied for freshwater environments based on a greater availability of data (Ref.21.57). The highest instantaneous concentration modelled at the sluice is several orders of magnitude below the threshold for low probability of adverse effects and also complies with the very precautionary derived PNEC values. If hydrazine was to enter the sluice, the low concentration and rapid degradation rates indicate that ecological features are unlikely to be affected. Furthermore, hydrazine has a very low bioconcentration factor meaning the bioaccumulation potential is low (Ref. 21.57). Sensitivity to hydrazine is therefore evaluated as low. Therefore, effects are evaluated as negligible and **not significant** on site integrity.

iv. Cooling water infrastructure

21.6.74 This section describes the impacts associated with the installation of the cooling water intake and outfall headworks. Pressures with the potential to marine water quality and sediment are presented in **Table 21.15**.

Table 21.15: Pressures associated with cooling water intake and outfall installation activities during the construction phase with the potential to affect marine water quality and sediment

Pressure	Activities resulting in pressure	Assessed	Justification
Changes in suspended sediments.	Preparation dredging and disposal.	Yes	Dredging prior to the installation of the cooling water intake and outfall headworks would cause temporary increases in SSC. Reductions in light availability due to increases in SSC can affect phytoplankton productivity and biomass. SSC may affect zooplankton through mechanical stress or reductions in feeding efficiency.
	Drilling of vertical connecting tunnels.	No	Drilling for the vertical connection shafts would result in SSC plumes that would be indiscernable from background condistions. No further assessement is made.
Synthetic compound contamination.	Discharges of drilling wastewater chemicals.	Yes (see CDO)	TBM chemicals may be used during drilling of the cooling water intakes and outfall tunnels. Drilling waste water containing small volumes of drilling chemical leachate would be discharged via the CDO. The potential toxicological effects have been assessed as part of the CDO assessment.

Changes in suspended sediment concentration: Cooling water infrastructure

21.6.75 Dredging for the installation CWS intake and outfall headworks would lead to elevated SSCs. Plumes with instantaneous SSC of >50mg/l and 100mg/l above background levels are expected to form over an area of up to 553 and 291ha respectively at the sea surface. A depth averaged instantaneous SSC of >1,000mg/l above background levels is predicted to affect a smaller area of up to 14ha (34ha at the sea surface) (**Table 21.6**).

21.6.76 Ambient conditions at the site are highly variable. Mean surface SSC values at Sizewell during April to August are 31mg/l with maximum values of 80mg/l. During the winter (September to March) average mean SSC values of 73mg/l were recorded in the surface waters at Sizewell with average monthly maximum values of 180mg/l. Near-bed conditions are considerably more turbid with daily ranges in suspended load of approximately 300mg/l at 1m above the seabed and 500mg/l at 0.3m above the seabed, provided in **section 21.4** of this chapter.

21.6.77 Dredging would temporarily increase the classification of the surface waters to 'Turbid', i.e. the area (553ha) where SSC elevation is >50mg/l would be equivalent to a WFD turbid classification (i.e. 100 – 300mg/l) when considered in addition to mean SSC background. An area of 553ha is <4% of the Suffolk Coastal waterbody area and is considered medium extent as is the amount of change and duration of the plume resulting in an impact magnitude of medium.

21.6.78 However, SSC would return to background levels several days after dredging activities cease. The increase in SSC would occur a total of six times for the installation of Cooling Water System infrastructure (once for each intake and outfall head). The timings of the SSC plumes associated with the installation of each headwork would not overlap.

21.6.79 While increases in SSC would be relatively large compared to baseline conditions and occur multiple times, the transient nature of the plumes and their intermediate spatial footprint result in an impact magnitude of medium.

Marine water quality and sediment sensitivity to changes in suspended sediment concentration

21.6.80 The short duration and transitory nature of the plume mean that changes in turbidity levels (and WFD status class) of the waters off Sizewell are very short-lived, but recovery to natural background would be rapid following cessation of the dredging activity. The sensitivity to this influence is predicted to be low.

21.6.81 The impact of increased SSC resulting from dredging activities for the cooling water headworks is predicted to have a minor adverse effect on marine water quality and sediment. Effects are predicted to be short-lived and **not significant** relative to natural variation.

v. Fish recovery and return systems

21.6.82 Two FRR systems would be constructed, one for each reactor. The FRR tunnels would be drilled beneath the seabed with arisings transported to landward for disposal with potential for chemical discharges in wastewater evaluated for the CDO. This section describes the impacts associated with the installation of the FRR systems during the construction phase. Pressures with the potential to affect marine water quality and sediment are presented in **Table 21.16**.

Table 21.16: Pressures associated with FRR during the construction phase with the potential to affect marine water quality and sediment.

Pressure	Activities resulting in pressure	Assessed	Justification
Changes in suspended sediments.	Preparation dredging and disposal.	Yes	Dredging prior to the installation of the FRR headworks would cause temporary increases in SSC. Reductions in light availability due to increases in SSC can affect phytoplankton productivity and biomass. SSC may affect zooplankton through mechanical stress or reductions in feeding efficiency.
Synthetic compound contamination.	Discharges of drilling wastewater chemicals.	Yes (see CDO)	Drilling chemicals may be used during drilling of the FRR tunnels. Drilling waste water containing small volumes of drilling chemical leachate would be discharged via the CDO. The potential for toxicological effects have been assessed as part of the CDO assessment.

Changes in suspended sediment concentration: Fish recovery and return systems

21.6.83 It is likely that the FRR systems would be installed separately approximately one year apart in sequence with the reactor they are associated with (**Plate 21.1**). Therefore, modelling considered FRR dredging of the two headworks to be temporally distinct events. Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over areas of up to 89ha at the surface. An instantaneous SSC of >1,000mg/l above background levels is predicted to affect a small area of 1ha at the surface.

21.6.84 Ambient conditions at the site are highly variable as seen in **section 21.4** of this chapter, and the surface waters are considered as 'intermediate turbidity' according to WFD criteria as provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to 'turbid'. However, SSC would return to background levels several days after dredging activity ceases.

21.6.85 These increases in SSC would occur twice for the installation of the FRR systems (once for each head). The timings of the SSC plumes associated with the installation of each head would not overlap.

21.6.86 While increases in SSC would be large relative to baseline conditions, the transient nature of the plumes and their intermediate spatial footprint result in an impact magnitude of medium.

Marine water quality and sediment sensitivity to changes in suspended sediment concentration

21.6.87 The short duration and transitory nature of the plume mean that turbidity status of the waters off Sizewell is very short, but recovery to natural background would be rapid following cessation of the dredging activity. The sensitivity to this influence is predicted to be low.

21.6.88 The impact of increased SSC resulting from dredging activities for the cooling water headworks is predicted to have a minor adverse effect on marine water quality and sediment. Effects are predicted to be short-lived and **not significant** relative to natural variation.

vi. Inter-relationship effects

21.6.89 This section provides a description of the identified inter-relationships that have the potential to affect marine water quality and sediment from construction of the proposed development. These are the effects arising from construction work acting in-combination to form additive, synergistic or antagonistic effects. **Figure 21.3** shows potential extent and overlap of influences on water quality and sediment during the construction/commissioning period.

In-combination effects from simultaneous dredging activities

21.6.90 During the construction phase, there is the potential that simultaneous dredging activities could occur. Maintenance dredging for the BLF is anticipated to occur at approximately monthly intervals during the campaign period. As a worst-case, it is assumed there is a temporal and spatial coincidence of the plumes from maintenance dredging for the BLF (plough dredger) and dredging (cutter suction dredger) and disposal material from (a) cooling water infrastructure and (b) the southern FRR outfall.

21.6.91 The suspended sediment plumes from the BLF maintenance dredge and the cooling water infrastructure do not interact, forming two discrete plumes. Therefore, the concurrent activities result in a greater spatial area of impacts rather than interactive effects. Increases in the total size of the instantaneous SSC plume are minimal.

21.6.92 The suspended sediment plume from the BLF maintenance dredge and the FRR dredge plume do interact. At the sea surface the maximum instantaneous area exceeding 100mg/l increases to 111ha. This increase is greater than the sum of the two individual activities; however, the plume is highly transient and the total duration of increases in SSC would be reduced due to the temporal overlap. The total area likely to be affected by SSC elevated to 50mg/l at the surface above background (if BLF maintenance, CWS intake and FRR outfalls are simultaneously dredged) and that would be likely to raise the tubidity classification from intermediate to turbid and would represent an area equivalent to 5% of the Suffolk Coastal waterbody (this assessment considers absolute areas only as actual overlap of the CWS sediment plumes with this waterbody would be more limited). This area of exceedance would occur for <5% of the year assuming e.g. monthly maintenance dredging and dredging of six CWS intakes and outfalls. The original assessment of individual activities for each development component causing changes in SSC on marine water quality and sediment therefore remains unchanged. Effects are minor adverse and predicted to be **not significant** on the turbidity classification of waters off Sizewell.

In-combination effects discharges from CDO and thermal and chemical discharge from Sizewell B

21.6.93 During the construction phase discharges from the CDO would overlap with those from the cooling water discharge from Sizewell B see **Figure 21.3**.

21.6.94 Construction discharges containing metals and un-ionised ammonia (including commissioning discharges) and potentially surfactants from tunnelling have very small areas of EQS exceedance close to the CDO.

21.6.95 Chlorine and ammonia can react in seawater to form, predominantly, dibromamine which has higher toxicity than TRO alone. However, the TRO concentration derived from Sizewell B that would intersect the CDO discharges would be ca. 20µg/l and the ammonia concentration rapidly declines to background beyond 25m of the discharge meaning that the concentration of any combination products would be insignificant.

21.6.96 Although hydrazine discharges at PNEC concentrations extend over larger areas around the CDO, interactions with TRO from Sizewell B would be at very low concentrations and interaction if any may reduce hydrazine concentration but is likely to be insignificant.

21.6.97 Thermal elevation in proximity to the CDO discharge is several degrees above background and is considered low as evidence suggests elevation of at least 5°C would be required to cause significant increase in chemical toxicity - **Appendix 21E** of this volume, and so the assessment is the same for the individual discharges from the CDO and in combination with any thermal influence.

21.6.98 A negligible effect assessment is therefore made for the interaction of the CDO discharge (metals, the un-ionised ammonia, tunnelling surfactants or hydrazine) and Sizewell B cooling water discharge (including TROchlorination by-products thermal elevation) with individual chemical discharge assessments unchanged as minor adverse (**not significant**).

21.6.99 During cold commissioning there is potential for discharge of un-ionised ammonia which is used in pH adjustment and circuit conditioning. This discharge would contribute 83.3l/s.

21.6.100 The total loading of un-ionised ammonia considered for modelling was 12,000 µg/l.

21.6.101 Modelling was conducted using both the General Estuarine Transport Model and CORMIX but the latter was more appropriate for calculation of the near field dilution estimates.

21.6.102 A discharge of 12,000 µg/l was modelled at 83.3 l/s from the CDO with a freshwater salinity.

21.6.103 Comparisons against previous nearfield modelling using CORMIX suggest that taking account of background concentration of un-ionised ammonia, enough dilution is achieved within approximately 10m to reduce the un-ionised ammonia concentration to below the EQS.

c) Operation

21.6.104 This section considers the development components and associated activities that were identified during scoping, as provided in **Appendix 21E** of this volume, with the potential to cause significant effects on marine water quality and sediment.

i. Coastal defence feature

21.6.105 Maintenance of the coastal defence features may be required during the operational phase as provided in **Chapter 20** of this volume. Maintenance activities generally occur above MHWS.

21.6.106 No impact pathway for water quality and sediment is identified.

21.6.107 A Coastal Processes Monitoring and Mitigation Plan is proposed as a condition on the Marine Licence which would ensure any maintenance works do not cause environmental impacts.

ii. Beach landing facility

21.6.108 The BLF would facilitate occasional AIL deliveries during the operational life of the proposed development This section describes the impacts associated with the operation of the BLF during the operational phase. Scoping identified that dredging activities represents the primary activity with the potential to affect marine water quality and sediment. Relevant pressures associated with BLF activities during the operational phase are presented in **Table 21.17.**

Table 21.17: Pressures associated with BLF activities during the operational phase with the potential to affect marine water quality and sediment.

Pressure	Activities resulting in pressure	Assessed	Justification
Changes in suspended sediments.	Navigational dredging.	Yes	Navigational dredging would cause temporary increases in SSC. Increases in SSC can affect turbidity status of the waterbody and may influence ecology.

Changes in suspended sediment concentration: Beach landing facility

21.6.109 Sediments agitated by plough dredging would be removed by ambient flows away from the dredge area. AIL deliveries would occur approximately every 5–10 years. When the BLF is operational a maintenance dredge would be required prior to delivery.

21.6.110 The SSC plume would resemble that described in the construction phase. A plume with an instantaneous SSC of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. Maintenance dredging would result in up to 28ha of sea surface expected to experience >100mg/l above background SSC on each occasion.

21.6.111 Ambient conditions at the site are highly variable and the surface waters are considered as 'intermediate turbidity' according to WFD criteria, as provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to 'Turbid'. However, SSC would return to background levels several days after dredging activity ceases.

21.6.112 The duration of the SSC plume is short-lived; however, maintenance dredging increases the frequency of smaller scale impacts. The amount of change and extent of the plume results in an impact magnitude of medium.

Marine water quality and sediment sensitivity to changes in suspended sediment concentration: Beach Landing Facility

21.6.113 The short duration and transitory nature of the plume mean that turbidity status of the waters off Sizewell is very short, but recovery to natural background would be rapid following cessation of the dredging activity. The sensitivity to this influence is predicted to be low.

21.6.114 The impact of increased SSC resulting from dredging activities is predicted to have a minor adverse effect on turbidity status. Effects are predicted to be short-lived and **not significant** relative to natural variation in background SSC.

iii. Combined drainage outfall

21.6.115 Operational discharges are not anticipated from the CDO although the headwork is expected to remain in place.

iv. Cooling water infrastructure

Cooling water discharges

21.6.116 This section describes the impacts associated with the operation of the proposed development relating to cooling water discharges. Pressures with the potential to affect marine water quality and sediment are presented in **Table 21.18**.

Cooling water discharges: Temperature changes

21.6.117 At the point of discharge heated cooling water would be discharged at 11.6ºC above ambient at a rate of 132m^3/s. The plume would be buoyant due to its increased temperature resulting in stratification. At this stage heat is lost from the plume directly to the air and to some extent to the surrounding waters. As the thermal plume cools the buoyancy decreases and eventually mixing (due to tides, winds, waves) overcomes the vertical stratification. At this point full mixing of warm and cooler water occurs and heat is transferred by direct mixing to cause a general warming to the receiving waters. The rate of mixing is determined by the tidal flow and the level of turbulence within the system, thus the strong tides at Sizewell (>1m/s) and the interaction with the bathymetry shapes the plume profile and extent.

21.6.118 The behaviour of the thermal plume can be characterised in three zones:

- Near-field: Occurs at the point of discharge where the plume has restricted horizontal movement and mixes in a vertical profile.
- Mid-field: Vertical momentum decreases, and the plume begins to travel slowly with the ambient tidal flow. Shear with the seabed causes the ambient flow to be more turbulent and interact with the edge of the thermal plume causing heat losses.
- Far-field: The plume is integrated in the tidal flow and mixing is subject to differences in density gradients, wave energy and bathymetry, which can cause the plume to decrease in thickness and break into filaments and eddies.

Table 21.18: Pressures associated with cooling water discharges.

Pressure	Activities resulting in pressure	Assessed	Justification
Thermal discharges.	Cooling water discharges.	Yes	Discharges of heated cooling water effluent have the potential to increase the thermal uplift and absolute temperature. Temperature elevation of areas of the sea around Sizewell may result in them falling below Good status for water quality and there may be impacts upon the marine water quality and ecology. The effects of future climate change and warming sea temperatures in relation to thermal discharges is also considered.
Chlorinated discharges including TROs and chlorination by-products.	Cooling water discharges.	Yes	Seasonal chlorination of the cooling water system to prevent biofouling results in exceedance of EQS standards for total residual oxidanTROsts and the most abundant chlorination by-product, bromoform. Areas exceeding these thresholds in the sea around Sizewell may result in them falling below Good status for water quality and there may be impacts upon the marine ecology.
Discharges of hydrazine.	Cooling water discharges.	Yes	Daily hydrazine releases to prevent corrosion of critical plant. Areas exceeding these thresholds in the sea around Sizewell may result in them falling below Good status for water quality and there may be impacts upon ecology.
Nutrient discharges.	Cooling water discharges.	Yes	Nutrient inputs including all sources of DIN and phosphate during operation have potential to increase the nutrient status of waters around Sizewell leading to failure to achieve Good status with potential effects on marine water quality.
Thermal discharge.	Influence on physico chemical factors.	Yes	Proportion of un-ionised ammonia and dissolved oxygen concentration. The effects of climate change also considered.

21.6.119 There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters but a best practice approach is considered (Ref. 21.58). Recommended thermal standards exist for SACs, SPAs and WFD waterbodies.

21.6.120 WFD thermal standards are considered the most appropriate for assessing the impact magnitude of thermal uplifts on marine water quality and sediment. The WFD standards for absolute water temperature and thermal uplifts are:

- Annual 98th percentile of the absolute water temperature

T < 20˚C	=	High
20˚C < T ≤ 23˚C	=	Good
23˚C < T ≤ 28˚C	=	Moderate
T > 28˚C	=	Poor

- Annual 98th percentile uplift in water temperature

Uplift ≤ 2˚C	=	High
2˚C < Uplift ≤ 3˚C	=	Good
Uplift > 3˚C	=	Moderate

21.6.121 **Table 21.19** shows the results of applying these standards to the predictions from the Sizewell B and the Sizewell C Project thermal plume modelling and **Figures 21.4** and **Figure 21.5** show thermal plume areas for Sizewell B and Sizewell C Project for excess and absolute 98th percentiles. Areas of exceedance are shown for Sizewell B in combination with the Sizewell C Project and for the Sizewell C Project alone.

21.6.122 For Sizewell B and the Sizewell C Project in combination, absolute temperature of 28ºC occurs over a negligible area (0.11ha) at the sea surface. Absolute thermal values of >23ºC occurs over an area of 89.6ha at the surface and 25.6ha at the seabed as a 98th percentile during the operation of Sizewell B and Sizewell C. Thermal uplifts of > 2ºC occur over an area of 7,899ha at the surface and 6,241ha at the seabed as a 98thpercentile during the operation of Sizewell B and Sizewell C. The remaining area beyond the influence of the thermal footprint would be expected to be at least Good status (**Table 21.19** and **Figures 21.4** and **21.5**).

21.6.123 Model runs output instantaneous thermal fields at hourly resolution for a period of one year. Accordingly, a 98th percentile represents the cumulative spatial area that individual cells (25x25m) within the model domain exceed a threshold temperature for 7.3 days at any point during the year. The 98th percentile statistics are not necessarily consecutive and could be days or months apart. Further detail is provided in **Appendix 21E** of this volume and references therein.

21.6.124 The Sizewell B power station is expected to operate until 2035, with the potential for an extension of its lifetime for 20 years, to 2055. Following any extension period, thermal discharges from Sizewell B would cease. The Sizewell C Project-only plume results in smaller areas of thermal impact, as provided in **Appendix 21E** of this volume.

21.6.125 The impact magnitude is based on the worst-case scenario of Sizewell B and the proposed development discharging cooling water concurrently. Thermal discharges would occur throughout the operational life cycle of the proposed station and are long term impacts. Absolute thermal exceedance is constrained to a very small area (<1ha). Modest thermal uplifts (2ºC) can extend over instantaneous areas of thousands of hectares at the sea surface within the tidal excursion.

Table 21.19: WFD thermal standards and total areas of exceedance for absolute temperature and temperature uplift during the operation of Sizewell B in combination with the Sizewell C Project and of B and C alone (grey box area not determined or not relevant).

Model run	Absolute water temperature (as a 98th percentile).			Thermal uplift (as a 98th percentile).		
	Temperature	Status	Position	Uplift	Status	Position
Sizewell B only	20ºC - ≤ 23ºC	Good		> 2ºC	Good	Surface 2,433ha
						Seabed 2,127ha
	23ºC - ≤ 28ºC	Moderate	Surface 44.9ha	> 3ºC	Moderate	Surface 1,263ha
			Seabed 8.75ha			Seabed 668ha
	> 28ºC	Poor	Surface 0ha			
			Seabed 0ha			
Sizewell B + the Sizewell C Project (most conservative case for Impact)	20ºC - ≤ 23ºC	Good		> 2ºC	Good	Surface 7,899ha
						Seabed 6,241ha
	23ºC - ≤ 28ºC	Moderate	Surface 89.6ha	> 3ºC	Moderate	Surface 2,200ha
			Seabed 25.6ha			Seabed 1,553ha
	> 28ºC	Poor	Surface 0.11ha			
			Seabed 0ha			

Model run	Absolute water temperature (as a 98th percentile).			Thermal uplift (as a 98th percentile).		
	Temperature	Status	Position	Uplift	Status	Position
The Sizewell C Project only	20ºC - ≤ 23ºC	Good		> 2ºC	Good	Surface 1,551ha
						Seabed 170.6ha
	23ºC - ≤ 28ºC	Moderate	Surface 0ha	> 3ºC	Moderate	Surface 305.7ha
			Seabed 0ha			Seabed 0ha
	> 28ºC	Poor	Surface 0ha			
			Seabed 0ha			

21.6.126 The impact magnitude, assessed as moderate, is precautionary because absolute standards are exceeded over relatively small areas.

21.6.127 The effects of future climate change and warming sea temperatures in relation to thermal discharges are considered further. These assessments focus on absolute temperatures as thermal uplifts are predicted to be largely independent of ambient water temperature (Ref.21.58) and would remain the same as assessed here.

Marine water quality and sediment sensitivity to thermal discharges

21.6.128 In the near field of the plume, absolute thermal uplifts have the potential to cause impacts. The wider area temperature elevation is likely to have both positive and negative influences.

21.6.129 There are various thermal standards under WFD and Habitats Directive criteria. The thermal plume is predicted to exceed these criteria and therefore there is the potential to affect the quality. However, for the absolute standards exceedance area is a small percentage of the relevant designated areas. For the uplift standards larger areas are affected as 98th percentiles but elevation above thresholds is likely to be for relatively short periods at a given location within the ZoI. The resistance of marine water quality and sediment receptors to temperature changes is therefore predicted to be medium. Resilience is considered high as waters are well mixed so facilitating rapid equilibration with seasonal background. Therefore, sensitivity is evaluated to be low.

21.6.130 Overall the thermal influence on water quality and sediment is considered minor adverse (**not significant**) but requires further consideration for marine ecology receptors- refer to **Chapter 22** of this volume.

The effect of climate change on cooling water discharges: Temperature changes

21.6.131 The proposed development has a 60 year operational life cycle and the potential for warming sea temperatures could have implications for thermal standards.

21.6.132 The primary effect of future warming sea temperatures is the elevation of the background temperatures such that entrained species experience more frequent periods of the year in which the ambient + 11.6ºC uplift of Sizewell C exceeds lethal thresholds.

21.6.133 The potential for the temperature uplift to influence physicochemical parameters will be discussed in the sections on DO and un-ionised ammonia, in **section 21.6viii** (Inter-relationships) of this chapter.

21.6.134 The influence of sea temperature warming as a result of climate change interacting with thermal discharges has been considered based on the methodology detailed in **Appendix 21E** of this volume. Future climate was considered relative to current thermal standards of thermal uplifts above ambient and absolute temperature.

21.6.135 Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature. Therefore, thermal uplift areas are predicted to remain largely unchanged under future climate scenarios.

21.6.136 To ascertain absolute temperatures in the future, the influence of climate change was added to the predicted thermal uplifts due to the proposed development. The approach considered Sizewell B and the proposed development operating together up until 2055 as a worst-case. Sizewell C operating alone in 2055 and 2085 were also considered as well as an extreme (2110) hypothetical operating scenario.

21.6.137 The thermal uplift due to the UKCP09[6] monthly increase in mean temperature, centred on 2006, was applied to this contemporary annual baseline projecting forward to 2055, 2085 and 2110. This climate uplift (98th percentile occurring in August) and the 98th percentile ambient temperature (also occurring in August) was then applied to the mean excess temperature rise due to the power stations. This is considered precautionary as the mean uplifts due to thermal discharges tend to be lower in the summer months.

[6] Note: Future sea temperatures are not included in the current UKCP18 marine climate predictions.

21.6.138 The results indicate that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28ºC, which remain under 1ha for all scenarios tested. Following the decommissioning of Sizewell B, 28ºC as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of the proposed development operating in 2110. Therefore, thermal effects in the receiving waters are predicted to remain minimal.

21.6.139 During the operation of both stations, absolute temperatures of 23ºC increase from 89.6ha at the surface and 25.6ha at the seabed for the present day to a worst-case of 506.2ha at the surface and 264.4ha at the seabed in 2055, provided in **Appendix 21E** of this volume. In the likely event Sizewell B is no longer operational in 2055, the exceedance of the absolute 23ºC threshold is predicted to be just 5.38ha at the surface and 0ha at the seabed with Sizewell C operating alone.

21.6.140 By the extreme date of 2110, large areas exceed 23ºC as a 98th percentile; 7,080ha at the surface and 6,540ha at the seabed. However, the results are due to the influence of climate warming, which is predicted to be +3.045ºC as a 98th percentile across the model domain, hence a station uplift of just 0.56ºC is enough to exceed contemporary thermal standards.

21.6.141 In 2085, towards the end of the likely operational life cycle of the proposed development, seabed areas in exceedance of 23ºC are predicted to occur over just 0.22ha, whereas surface exceedance occurs over an area of 69.1ha. The total area of the thermal plume above 23ºC in 2085 is therefore smaller and further offshore than the contemporary predictions for the two power stations operating together, as provided in **Appendix 21E** of this volume.

21.6.142 Whilst climate change would act in-combination with the proposed development to increase areas of exceedance, receptors exposed would be acclimated to a modified thermal baseline. Furthermore, changes in species composition may have occurred independently of the proposed development. For species exposed to the thermal plume, effects would be like those predicted for the current baseline.

21.6.143 Confidence in predicting the exact effects of climate change and thermal discharges on species ability to adapt is reduced further into the future. However, once Sizewell B ceases operating the thermal footprint from the proposed development is predicted to be smaller than the present-day thermal footprint. Predictions of effects based on current baselines is considered valid considering future climate change.

Cooling water discharges: Chlorinated discharges

21.6.144 To control biofouling of critical sections of the plant during operation, intake water will be chlorinated (either by electrolysis of seawater or by the addition of sodium hypochlorite). SZC Co.'s operational policy for its existing UK fleet is to continuously dose during the growing season to achieve a TRO dose of 0.2mg/l in critical sections of the cooling water plant and at the inlet to the condensers. Chlorination would be applied when water temperatures exceed 10ºC, as seen in **Appendix 21E** of this volume.

21.6.145 The primary biocidal effects of seawater chlorination result from oxidants associated with water chemistry. These oxidants are measured and expressed as the TRO concentration. Accordingly, the sum of TROs, rather than simply chlorine, are measured. The TRO discharge concentration would be 0.15mg/l, discharged at a rate of 132m^3/s in the cooling water at a temperature of 11.6 °C above ambient, as provided in **Appendix 21E** of this volume.

21.6.146 The TRO result from the combination of chorine and organic material in the water, furthermore chlorination compounds are broken down to form chlorination by-products. This section considers the impact magnitude of TRO and chlorination by-product discharges.

Total residual oxidants: Impact magnitude

21.6.147 Experimental studies at Sizewell were used to model the TRO plume based on the seawater chemistry and applying an empirical demand/decay formulation coupled into the General Estuarine Transport Model at Sizewell. The EQS for TROs is 10µg/l as a 95thpercentile concentration. The TRO plumes from Sizewell C and Sizewell B are spatially distinct therefore Sizewell C is considered separately with Sizewell B part of the baseline (see **Figure 21.6**)

21.6.148 The modelled Sizewell C total residual oxidant plume is highly stratified, and concentrations exceed the EQS over a sea surface area of 338ha and a seabed area of 2.1ha as provided in **Appendix 21E** of this volume.

21.6.149 The impact magnitude for total residual oxidant discharges is assessed as medium.

Water quality sensitivity to total residual oxidants

21.6.150 The total residual oxidant concentrations that result from seawater chlorination do not persist and 50% degradation is in the order of minutes, so that any impacts are very localised. As the GSB hydrodynamic regime is classified as 'permanently mixed' (Ref. 21.59), there will be a high dilution factor to facilitate mixing of additional seawater with no chlorination products so further TRO concentration decrease would occur both by dilution and by increased decay. Resilience of water quality to TRO discharges is therefore considered to be high.

21.6.151 The resistance of marine water quality and sediment receptors to TRO is predicted to be 'medium' and sensitivity is evaluated as low.

21.6.152 The combination of low sensitivity and medium impact for TRO discharges results in a predicted minor adverse impact on receiving waters. Effects are **not significant**.

21.6.153 Chlorinated discharges would be associated with thermal discharges and the in-combination effects on water quality are considered further in **section 21.6 viii** of this chapter.

The effect of climate change on cooling water discharges: Chlorination

21.6.154 TRO discharges would occur for the operational life of the proposed development and would be continuous when water temperatures exceed 10ºC. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December. Future climate change may extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination under the current strategy. In the coastal waters at Sizewell, high levels of turbidity in the winter and early spring limit biological production and increases in the duration of annual chlorination is unlikely to extend considerably.

21.6.155 TRO decay will increase at elevated temperatures, but dosing is adjusted to ensure that the target TRO of 0.2mg/l is achieved in critical sections of the Cooling Water system. The residual oxidant level at the point of discharge is therefore unlikely to be reduced under climate change. The relative increase in temperature background in the wider environment is also unlikely to significantly increase TRO decay and consequently a conservative assessment is that the discharge plume size and magnitude are likely to be comparable to those predicted for the current baseline.

21.6.156 Several Oceanic Global Circulation Models have projected a pH reduction of 0.14 units below present values by 2050 and 0.3–0.4 below present units in 2100, as provided in **Appendix 21E** of this volume.

21.6.157 The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH: the percentage of hypochlorous acid is likely to increase relative to hypobromous acid following a pH reduction from a present baseline mean of 8.0 to around 7.8 to 7.6 for future baselines at 2055 to 2085. Although there may be some differences in the toxicity of the different oxidants this difference in relative proportions is unlikely to be significant.

Chlorination by-products: Impact magnitude

21.6.158 Depending on the water chemistry many chlorination by-products can be formed in addition to TROs.

21.6.159 The most abundant chlorination by-products in discharges from coastal power stations, and the only one detected in recent chlorination by-product decay studies using Sizewell seawater is bromoform, as provided in **Appendix 21E** of this volume. The major fate process that results in decrease in bromoform concentration is volatilisation to the atmosphere. Loss rates were therefore incorporated into the General Estuarine Transport Model for Sizewell to predict the extent of the bromoform plume.

21.6.160 There are no established EQS concentrations for bromoform and a PNEC of 5µg/l as a 95th percentile is applied here as the standard (Ref.21.60).

21.6.161 Bromoform is predicted to follow a similar trajectory to the TRO plume with a narrow, tidally transported plume forming parallel to the shore. The plume is highly stratified with PNEC concentrations exceeding 5µg/l over an area of 52ha at the surface and 0.15ha at the seabed. The Sizewell C plume is discrete from the Sizewell B plume.

21.6.162 Bromoform discharges would occur for the operational life of the proposed development and would be continuous when water temperatures exceed 10ºC.

21.6.163 The impact magnitude for bromoform discharges is assessed as medium.

Water quality and sediment sensitivity to bromoform

21.6.164 The average bromoform concentration within the discharge plumes of ten European power stations, including Sizewell A, has been shown to be 16.3µg/l and outfall concentrations range from 1–43µg/l (Ref. 21.61). Chlorination by-products associated with chlorination are predicted to have very limited toxicity once in the receiving waters (Ref. 21.60).

21.6.165 The limited likely toxicological effects of bromoform and ready volatilisation in the well mixed waters of the GSB indicate medium resistance and high resilience of water quality and support an evaluation of low sensitivity.

21.6.166 The combination of low sensitivity and medium impact for chlorination by-products result in a predicted minor adverse impact on receiving waters. Effects are **not significant**.

The effect of climate change on cooling water discharges: Chlorination byproducts (bromoform)

21.6.167 TRO discharges would occur for the operational life of the proposed development and would be continuous when water temperatures exceed 10ºC. Chlorination by-product production would occur following chlorination. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December. Future climate change may extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination and chlorination by-product formation under the current strategy. In the coastal waters at Sizewell, high levels of turbidity in the winter and early spring limit biological production and increases in the duration of annual chlorination and presence of chlorination by-products is unlikely to extend considerably.

21.6.168 For bromoform, the dominant chlorination by-product at Sizewell, the primary fate process is volatilisation with biodegradation having relatively little influence on reducing environmental concentrations. Increased temperatures are therefore expected to have minimal influence on chlorination by-product decay and consequently the discharge plume magnitude and extent are conservatively assessed to be like those predicted for the current baseline.

21.6.169 Bromoform is likely to occur at similar concentrations or possibly slightly reduce following a pH reduction from a present baseline mean of 8.0 to around 7.8 to 7.6 for future baselines at 2055 to 2085. For other chlorination by-products there may be a small relative increase with lowering pH. The difference in terms of the extent and magnitude of any effects is likely to be negligible, as provided in **Appendix 21E** of this chapter.

Cooling water discharges: Hydrazine

21.6.170 Most precautionary daily hydrazine discharges from Sizewell C have been modelled based on hydrazine discharges of 24kg per annum into the cooling water flow. Conservative decay rates were incorporated into the General Estuarine Transport Model, seen in **Appendix 21E** of this volume. Daily hydrazine discharge within the cooling water flow is modelled based on the two potential discharge scenarios dependent on whether the hydrazine load is distributed and discharged from one or two wastewater tanks; a) 69ng/l for 2.3h a day, and b) 34ng/l for 4.6h a day culminating in the same total annual load (24kg/yr).

21.6.171 The plume simulations showed that both strategies gave similar results. The hydrazine plume follows a narrow trajectory parallel to the shore. At the seabed, less than 1ha exceeds the chronic PNEC, irrespective of the release strategy. At the surface the area that exceeds the chronic PNEC is 158.1 and 156.8ha for the 69ng/l and 34ng/l releases, respectively (**Table 21.20**).

21.6.172 The acute thresholds were only exceeded in the 69ng/l release strategy over a very small area of the seabed (0.22ha). Surface exceedance extended to 17.4ha and 13.8ha in the 34.5ng/l and 69ng/l strategy, respectively, as provided in **Appendix 21E** of this volume and **Table 21.20**. Daily discharges would occur throughout the life of the proposed development.

21.6.173 The acute (4ng/l) and chronic (0.4ng/l) PNEC concentrations derived for hydrazine provide precautionary triggers for further ecological investigation and relatively small areas exceed these values particularly at the seabed so the impact magnitude is assessed as medium.

Water quality and sediment sensitivity to hydrazine

21.6.174 Hydrazine is rapidly degraded in the marine environment so reducing exposure duration.

21.6.175 Although an acute and chronic PNEC are defined a large body of supporting data indicate that these values are precautionary. Even based on these values areas of exceedance are low and result from a daily discharge of short duration.

21.6.176 Water quality and sediment of the receiving waters are therefore evaluated to be very low to hydrazine discharges.

21.6.177 Hydrazine discharges would have a minor adverse effect on water quality and sediment. Effects are **not significant**.

Table 21.20: Area of the hydrazine plume in exceedance of concentration thresholds

Hydrazine release strategy	PNEC threshold	Area of exceedance (ha)	
		Surface	Seabed
69ng/l for a duration of 2.32h a day	Chronic 0.4ng/l (mean)	158.11	0.56
	Acute 4ng/l (95th percentile)	13.79	0.22
34.5ng/l for a duration of 4.63h a day	Chronic 0.4ng/l (mean)	156.88	0.34
	Acute 4ng/l (95th percentile)	17.38	0

The effect of climate change on cooling water discharges: Hydrazine

21.6.178 Hydrazine discharges would occur for the operational life of the proposed development. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December.

21.6.179 For hydrazine, the primary fate processes in water are oxygen dependent chemical breakdown and biological breakdown (biodegradation). The former is dependent on the presence in water of appropriate catalysts e.g. copper and other factors with e.g. higher ionic strength, temperature and pH reducing the time taken for hydrazine to degrade, as provided in **Appendix 21E** of this volume. Biodegradation is also influenced by temperature with increasing temperature generally reducing the chemical concentration in a shorter time. Hydrazine half-life (time taken for concentration to decrease by 50% of its starting concentration) in natural seawater from Sizewell is very short ca. 38 minutes therefore increasing seawater temperatures is likely to reduce the discharge plume magnitude and extent, but a conservative assessment is that they remain comparable to those predicted for the current baseline.

21.6.180 Under future climate predictions, ocean acidification (pH reduction) may become an environmental concern around the UK. Although low pH is shown to reduce hydrazine decay rate this is only demonstrated at values below 4 so projected average reductions of future baseline pH i.e. ca., 7.8 to 7.6 are not expected to influence hydrazine discharge plume magnitude and extent, as provided in **Appendix 21E** of this volume.

Cooling water discharges: Nutrients

21.6.181 The maximum number of people on site during the operational phase occurs when there are refuelling outages. During refuelling, nitrate and phosphate loads are increased above background concentrations due to elevated contributions from treated sewage effluent. These contributions are represented by peak 24-hour loadings. The refuelling outages typically last four to six weeks but can occur at any time of year.

21.6.182 Maximum daily nitrate discharges represent approximately 2% of the total mass exchanged within the tidal system. The daily average is 0.2% of the exchange rate. For phosphates, maximum daily loadings reach 5%, whilst average annual loadings contribute a very small proportion of the daily exchange (0.03%). Phosphate is not a limiting nutrient within the GSB system and therefore the addition of more phosphate would not be expected to influence phytoplankton growth. Maximum loadings would be short term and small relative to the daily exchange of nutrients.

21.6.183 The impact magnitude of added nutrients during operation is considered to be low.

Marine water quality and sediment sensitivity to nutrient discharges

21.6.184 A combined Phytoplankton and Macroalgae model was used to predict the effects of nutrients on the annual gross primary production within the tidal excursion accounting for entrainment from Sizewell B and Sizewell C during the operational phase. The model predicted annual nutrients loadings would increase production within the GSB by 0.14%. More detail on model outputs is provided in **Appendix 22H** of this volume. Such changes are orders of magnitude below the natural variation in chlorophyll a biomass, as provided in **Chapter 22** of this volume.

21.6.185 Marine water quality and sediment within the GSB is evaluated as very low to operational nutrient additions.

21.6.186 Operational phase nutrient inputs are predicted to have negligible effects on marine water quality and sediment, so effects are **not significant** due to input concentrations and local exchange rates.

Microbiological inputs: Operation

21.6.187 Tertiary sewage treatment is planned for the proposed development and discharges would be made via the cooling water flow 132m^3/s.

21.6.188 The discharge plume would be buoyant and on the surface. Based on expected treatment level (5.4 log reduction) in the faecal indicator organisms *E.coli* and intestinal enterococci, immediate dilution within the cooling water flow from one EPR™ unit 66m^3/s would be enough to comply with Good bathing water standards (500 *E.coli* and 200 intestinal enterococci per 100ml) and so would be compliant at the point of discharge.

21.6.189 There is no predicted exceedance of the standard beyond the point of discharge so impact magnitude is very low.

21.6.190 The nearest designated bathing waters are 10km away from the discharge point and so sensitivity is considered to be low**.** Therefore, microbiological inputs from treated sewage during construction are predicted to have negligible effects. Effects are **not significant.**

vii. Fish recovery and return systems

21.6.191 This section describes the impacts associated with the operation of the FRR. The FRR system is designed to minimise impacts on impinged fish and invertebrate populations. However, some species are highly sensitive to mechanical damage caused during passage through the cooling water intakes, drum screens and FRR channels and incur high mortality rates.

21.6.192 The return of dead and moribund biota retains biomass within the marine system but represents a source of organic loading, with potential for increase nutrient inputs, increased un-ionised ammonia and reductions in DO are considered. Pressures with the potential to affect marine water quality and sediment are presented in **Table 21.21**.

21.6.193 The total biomass of moribund biota predicted to be discharged from the FRR has been estimated based on abstraction rates and information on the seasonal abundance of species along with length to weight distributions of the species impinged for the existing Sizewell B station (Ref. 21.62) and as described in **Appendix 21F** of this volume. These values are based on rates of impingement at Sizewell B and extrapolated to Sizewell C, however they do not account for Sizewell C mitigation (Low-Velocity, Side-Entry (LVSE) headworks survival rates). Furthermore, the assessments consider discharges of dead and moribund biota from a single point source. This adds a further precautionary factor to the assessment as the two FRR units, located approximately 300m apart, would allow a greater level of initial dilution with discharges split between two spatially separated points sources. As such, they are highly precautionary assessments applied primarily to determine the worst-case potential for water quality issues (deoxygenation and nutrient enrichment). The effects of estimated organic enrichment from the moribund biomass discharged from the FRR is considered in further detail in **Chapter 22** of this volume.

21.6.194 The data show seasonal variation in the discharge of moribund fish. The highest biomass of moribund fish occurs in March with a mean biomass of 3,442kg per day predicted to be discharged from the FRRs.

21.6.195 Between April to September biomass discharge predictions are lower at a mean of 405.2kg per day.

21.6.196 Value engineering has suggested moving the location of FRR2 outfall further south by ca. 46m as this would shorten the length of the tunnel slightly and move it away from close proximity to the CDO. Such a move would also have the benefit of slightly reducing transit times for fish. The modelling of environmental impacts from dead and moribund fish being discharged from the FRR is very low to such a small southerly movement in the discharge point given the large scale of the system and the environmental impact assessment is considered robust for either location of FRR2.

Table 21.21: Pressures associated with discharges from the FRR.

Pressure	Activities resulting in pressure	Assessed	Justification
Reductions in DO.	Discharge of dead and moribund biota.	Yes	Decaying biomass would increase the biochemical oxygen demand (BOD) and has the potential to reduce DO levels. The waters off Sizewell are well mixed vertically facilitating reaeration at the surface and the rate of water exchange within the GSB would limit the extent and duration of any oxygen reduction. Background dissolved oxygen concentrations conforms to 'high' status within the WFD waterbody and includes the influence of Sizewell B. The BOD from biomass discharged from the FRRs is predicted to have a negligible effect on water quality.
Increases in nutrient inputs.	Discharge of dead and moribund biota.	Yes	The breakdown of organic material would release nitrogen and phorporous into the system. During periods of nutrient limitation increases in nutrient availability has the potential to enhance phytoplankton biomass.
Increases in un-ionised ammonia	Discharge of dead and moribund biota.	Yes	Decaying biomass would release ammonia into the sytems. The ambient conditions and rate of discharge would influence the levels on un-ionised ammonia. Assessments consider seasonal un-ionised ammonia inputs

Fish recovery and return: nutrient inputs

21.6.197 The decay of organic material would release nutrients to the GSB. Increases in nutrients would have the greatest potential effects on marine water quality during the growing season when light is not limiting.

21.6.198 Between April to September mean biomass discharges are predicted to be 405.2kg per day, and for much of this period (mid-May to August) the GSB experiences nutrient limitation, as provided in **Appendix 22H** of this volume.

21.6.199 Nutrient inputs were calculated based on wet weight mass conversions of 3.5% and 0.5% for nitrogen and phosphorus, respectively. This results in daily loadings of approximately 14kg nitrogen and 2kg phosphorus, as provided in **Appendix 21F** of this volume.

21.6.200 Operational nitrogen inputs from the proposed development are estimated to be 32kg per day, which represents 0.2% of the daily exchange for

Sizewell Bay. The additional inputs of nitrogen from decaying biomass represent an increase to a value of 0.4% of the daily exchange.

21.6.201 The daily average operational phosphorus loading is low at ca. 0.71kg or 0.03% of the daily exchange for Sizewell Bay and the biomass input from the FRR represents a relatively high addition to this. Nevertheless, the additional inputs from the FRR result in combined operational phosphorus inputs of 0.25% of the daily exchange which is still low. Phosphate is rarely a limiting nutrient within the GSB system and low-level increases would not be expected to perturb the system, as provided in **Chapter 22** of this volume.

21.6.202 Impact magnitude is evaluated as low.

21.6.203 A combined Phytoplankton and Macroalgae model predicted that annual nutrients loadings due to operational nutrient discharges from Sizewell B and the proposed development would increase production within the GSB by 0.11%, as provided in **Appendix 22H** of this volume.

21.6.204 Nutrient additions from the FRR represent a small additional increase and may increase production to a modest level of <0.3% in annual gross primary production.

21.6.205 The GSB is well mixed and is expected to have a high resistance to nutrient additions and high resilience and so sensitivity of marine water quality and sediment to nutrient additions from decaying biomass is evaluated as very low.

21.6.206 FRR nutrient inputs are predicted to have negligible effects on marine water quality and sediment. Effects are **not significant** and predicted to have insignificant influence on the natural variation in chlorophyll a biomass, as provided in **Chapter 22** of this volume.

21.6.207 This assessment is highly precautionary as it assumes that none of the fish are predated upon and that the tissue nutrient content makes an immediate contribution to nutrient levels when nutrients would be expected to be released over longer periods of time following tissue decay, as provided in **Appendix 21F** of this volume.

Fish recovery and return: un-ionised ammonia

21.6.208 The decay of biomass released from the FRR has the potential to cause an increase in un-ionised ammonia. The tissue ammonia content for fish and seasonal physicochemical conditions were incorporated into the un-ionised ammonia calculator in **Appendix 21F** of this volume. Un-ionised ammonia was calculated for summer and winter when fish discharges and ambient conditions differ.

21.6.209 During the period April-September, daily discharges of 405.2kg per day of dead or moribund biota would have the potential to cause un-ionised ammonia concentrations to exceed the EQS (21µg/l) over an area of 1.4ha (under average conditions).

21.6.210 To account for summer conditions, 95th percentile temperature and pH, and average salinity was considered. Under this scenario the EQS would be exceeded over an area of 3.8ha.

21.6.211 During the winter (December-April) the release of dead and moribund biota is higher, salinities may be lower during periods of heavy rainfall favouring un-ionised ammonia concentrations, but the temperature would also be low which reduces the un-ionised ammonia proportion.

21.6.212 To account for the most conservative scenario the highest daily discharge value (3,442kg per day in March) was applied using a 5th percentile salinity, average temperature for March and average annual pH. Under these conditions the exceedance of the EQS would occur over an area of 5.3ha, as provided in **Appendix 21F** of this volume.

21.6.213 The maximum spatial scale of the impacts differs seasonally but is low. Discharges would occur throughout the operational phase of the proposed development; therefore, the duration is high and the amount of change seasonally variable.

21.6.214 The impact magnitude is assessed as medium.

Marine water quality and sediment sensitivity to un-ionised ammonia

21.6.215 Small areas within the GSB would be exposed to un-ionised ammonia concentrations in exceedance of EQS thresholds and in the tidally dominated system exposure would be brief.

21.6.216 Due to the localised and seasonal exposures to un-ionised ammonia resilience is evaluated as high and resistance as medium with overall sensitivity evaluated as low.

21.6.217 Un-ionised ammonia discharges from the FRR are predicted to have minor adverse effects on marine water quality and sediment. Effects are **not significant**.

Fish recovery and return: biomass influence on dissolved oxygen levels

21.6.218 The decaying fish biomass discharged from the FRR is also likely to contribute to the biological oxygen demand.

21.6.219 Based on the oxygen demand of organic matter inputs from fish cages coupled to the annual average daily biomass loading an estimate of biochemical oxygen demand was made.

21.6.220 The average daily BOD contributed by decaying fish tissue is estimated to be 1342kg/day which is calculated to result in an oxygen draw down of 447kg/day.

21.6.221 This potential oxygen requirement is equivalent to 0.2% of the daily exchange for GSB and deficits would also be met by daily reaeration at the sea surface.

21.6.222 The impact magnitude is assessed as medium.

Marine water quality and sediment sensitivity to biochemical oxygen demand

21.6.223 As the GSB is well mixed and reaeration rate is high, resistance and resilience to BOD are both evaluated as high and sensitivity as very low.

21.6.224 The effect of BOD from decaying biomass from the FRR on marine water quality and sediment is evaluated as minor adverse and **not significant**.

viii. Inter-relationship effects

21.6.225 This section provides a description of the identified inter-relationship effects that are anticipated to occur on marine water quality between the individual environmental effects arising from operation of the proposed development. **Figure 21.7** shows the extent and overlap at the seabed and surface of various operational discharges and **Figure 21.8** shows the overlapping influence for the same discharges in relation to the coralline crag feature.

Cooling water thermal influence on dissolved oxygen

21.6.226 This section describes the impacts associated with the operation of the cooling water infrastructure relating to thermal discharge. The primary effects on marine water quality and sediment from cooling water discharge relate to thermal uplifts of 11.6°C.

21.6.227 The elevated temperature has the potential to reduce the oxygen carrying capacity of the seawater and to lower oxygen concentration.

21.6.228 Discharge would occur throughout the life cycle of the power station and is considered a long-term impact.

21.6.229 Modelling with General Estuarine Transport Model was used to assess the potential reduction in oxygen concentration in the seawater discharged from

Sizewell C alone and from Sizewell C and Sizewell B operating together at an elevated temperature.

21.6.230 Although the influence of the thermal discharge from Sizewell C will continue for the life of the station, oxygen concentration of the seawater is high throughout the year and the assessed thermal uplift is not predicted to reduce any areas influenced by the discharge to below high status.

21.6.231 The impact magnitude is therefore assessed as low.

Water quality and sediment sensitivity to discharge thermal elevation influence on oxygen concentration

21.6.232 This section considers the evidence of the sensitivity of water quality and sediment to primary entrainment thermal elevation and reduction of oxygen carrying capacity of the seawater.

21.6.233 Water quality off Sizewell in terms of DO status is predicted to be high resistance to thermal uplift from Sizewell C and Sizewell B as the waters are of high status and resilience is also high as they are well mixed so facilitating rapid reoxygenation. Sensitivity is judged to be low.

21.6.234 Warming of discharged water is predicted to have negligible effects on DO levels within the GSB. Effects are **not significant** relative to high levels of oxygenation, mixing and reaeration and level of exchange within the GSB.

Cooling water discharge thermal elevation influence on proportion of un-ionised ammonia

21.6.235 Operational discharges contain ammonia from treated sewage and from process discharges and temperature elevation will increase the more toxic un-ionised ammonia proportion relative to that of ammonium.

21.6.236 Temperature fields generated by the General Estuarine Transport Model and the relevant physicochemical data and total ammonia concentration for Sizewell C, and Sizewell C and Sizewell B in combination, was used to assess the potential increase in the proportion of un-ionised ammonia in the cooling water due to thermal elevation.

21.6.237 Annual mean increases in un-ionised ammonia concentration predicted at the surface for Sizewell Bay were derived and no areas exceed the EQS of 21µg/l as an annual mean and the predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS.

21.6.238 Although the influence of the thermal discharge from Sizewell C will continue for the life of the station the ammonia concentration is low and ammonia is rapidly used up so the thermal influence will not result in un-ionised ammonia reaching levels of concern.

21.6.239 The impact magnitude is therefore assessed as low.

Water quality and sediment sensitivity to discharge thermal elevation influence on proportion of un-ionised ammonia

21.6.240 Water quality off Sizewell in terms of un-ionised ammonia concentration is predicted to be relatively resistant to thermal uplift from Sizewell C and Sizewell B as the waters have a low background concentration of ammonia and relatively low additions of ammonia occur through operation. Resilience is evaluated as high as waters are well mixed so facilitating rapid use of ammonia by marine organisms. Sensitivity is evaluated to be low.

21.6.241 Thermal elevation of the cooling water discharge is predicted to have minor adverse effects on the proportion of un-ionised ammonia within the GSB for Sizewell C alone and in combination with Sizewell B. Effects are **not significant** relative to low levels of total ammonia and high levels of mixing.

Synergistic effects of chlorinated discharges and treated sewage in the cooling water system

21.6.242 During operational phase, seasonal chlorination would be applied to protect critical plant from biofouling. Chlorination of seawater results in the liberation of a range of TROs and chlorination by-products depending on the water chemistry.

21.6.243 Ammonia discharges from plant conditioning chemicals and the on-site sewage treatment would also be discharged via the cooling water outfalls. The level of total ammonia discharged including current background levels is low and represents an increase of ca.30% of the present mean background total ammonia.

21.6.244 The synergistic effects of chlorination and ammonia discharges may result in the formation of additional combined products.

21.6.245 Seawater chlorination with the ammonia present is likely to form different residual oxidants dependent on the ammonia to chlorine ratio.

21.6.246 Dibromamine is one of the primary formation products and has a generally higher toxicity that uncombined oxidants of chlorine or bromine although it is of very low persistence. However, as total ammonia is very low and only around one third of the background ammonia, any increase in toxicity above that due to chlorination alone is expected to be very small.

21.6.247 The synergistic effects of chlorination and ammonia discharges are not predicted to alter the assessment of toxicological effects.

21.6.248 The assessment remains unchanged from that of TRO alone with minor adverse effects predicted on water quality and sediment within the GSB as a result of the addition of small quantities of ammonia to the chlorinated cooling water discharge. Effects are **not significant**.

In-combination effects in the thermo-chemical plume

21.6.249 This section considers the interactive effects of temperature and chemical discharges for water quality and sediment.

21.6.250 Increase in temperature is known to increase chemical toxicity including that of chlorine. For example, a 5°C increase in temperature more than halved the effect concentration of free chlorine and chloramine for various marine species (Ref. 21.63).

21.6.251 The main potential for synergistic effects of temperature and toxicity of the chlorinated seawater is to species experiencing entrainment. The acute effects of this exposure would diminish rapidly upon discharge of the cooling water with rapid loss of temperature and reduction in oxidant concentration as the plume mixes and reaches the sea surface.

21.6.252 The thermal uplift in combination with the toxicological effects of chlorination is not expected to change the assessment of the chlorination discharge or thermal plume considered separately. Combined chlorination and thermal plumes are predicted to have a minor adverse effect on water quality and sediment within the GSB. Effects are **not significant**.

21.7 Mitigation and monitoring

a) Introduction

21.7.1 Where possible, mitigation measures are proposed to minimise the likelihood of a significant effect. Primary and tertiary mitigation measures which have already been incorporated within the design of the proposed development are summarised in **section 21.5** of this chapter and more detail is provided in **Chapters 2, 3** and **4** of this volume.

21.7.2 No further mitigation beyond primary and tertiary measures is required because no significant effects have been identified.

21.7.3 This section also describes any required monitoring regimes, including monitoring of specific receptors/resources, or monitoring the effectiveness of a mitigation measure. The requirements, scope, frequency and duration of a given monitoring regime are set out, as far as possible, in this section.

b) Monitoring

21.7.4 Various discharges during construction/cold commissioning and during operation would be subject to the relevant WDA permit conditions and would need monitoring as appropriate to ensure that these are met.

21.7.5 A Marine Licence condition for dredging activities includes the obligation to monitor sediment contamination levels to ensure material is deemed acceptable for the proposed disposal route. Ongoing dredging activities would require sediment monitoring to ensure environmental acceptability of the dredge material.

21.7.6 For the FRR discharges of moribund biota have the potential to affect water quality parameters. Therefore, water quality parameters including DO, pH, temperature, un-ionised ammonium, total oxidizable nitrogen, nitrite, silicate and phosphate and temperature would be sampled.

21.7.7 Water quality samples would be collected throughout the water column at sites as close to the FRR headworks as operationally feasible and at control sites. Samples would be collected quarterly for one year to capture seasonal variation in FRR discharges and ambient water quality. Sampling should focus on periods of full operational power once both systems are commissioned to determine the potential worst-case seasonal scenarios. Should reductions in water quality be identified, monitoring may be extended, however monitoring near the existing Sizewell B outfalls has not detected significant changes in the parameters described.

21.8 Residual effects

21.8.1 The following tables (**Tables 21.22** and **21.23**) present a summary of the marine water and sediment quality assessment for each of the main development phases. The level of effect and where the effect is deemed to be significant are identified together with proposed mitigation and the resulting residual effect.

Table 21.22: Summary of effects for the construction and commissioning phase.

Impact	Impact detail	Primary or tertiary mitigation	Assessment of effects	Additional mitigation	Residual effects
Changes in SSC	Resuspension of sediment increasing SSC during individual dredging, dredge disposal activities and installation of: CDO; FRR(x2); cooling water headworks (x6); plough dredging for BLF navigational channel (including maintenance—no disposal).	None	Marine waters at Sizewell are well mixed such that localised elevations of SSC quickly redistribute and return to background levels. SSC status (turbidity) based on annual value unaffected by very short-term elevation. Minor adverse effect (**not significant**).	Subject to Marine Licence and monitoring defined therein.	Minor adverse effects (**Not significant**).
Changes in SSC	In-combination effect of concurrent dredge activities increasing SSC.	None	Concurrent dredging activities increase the spatial footprint of impacts. However initial assessments of effects remain valid. Minor adverse effects (**not significant**).	Subject to Marine Licence and monitoring defined therein.	Minor adverse effects (**Not significant**)
Transition elements & organo-metals contamination	Heavy metal (zinc and chromium) contamination from CDO discharges of groundwater during main development site dewatering	None	Contaminant levels exceed thresholds over small areas for a short period (1 month). Negligible effects **(not significant**).	Subject to WDA permit and monitoring defined therein.	Negligible effects (**Not significant**)

Impact	Impact detail	Primary or tertiary mitigation	Assessment of effects	Additional mitigation	Residual effects
	phase.				
Nutrient enrichment.	Nutrient (nitrogen and phosphorus) input from treated sewage, groundwater and commissioning chemicals via the CDO during the construction and commissioning phase.	Sewage treated to tertiary level and siltbusters used will remove some associated nutrient.	Low level of nutrient additions are predicted to have a negligible effect on the nutrient status of the GSB (**not significant**).	Subject to WDA permit and monitoring defined therein.	Negligible effect (**Not significant**)
Introduction of other substances (solid, liquid or gas)	Un-ionised ammonia discharges from the CDO from treated sewage, groundwater and commissioning discharges.	Sewage treated to tertiary level.	The extent of exceedance of the un-ionised ammonia EQS is close to 6m for the most extreme discharge of treated sewage and groundwater. Inputs from commissioning are higher but also comply well within 25m—effects are evaluated as negligible (**not significant**).	Subject to WDA permit and monitoring defined therein.	Negligible effect (**Not significant**)
Introduction of microbial pathogens	CDO—treated sewage discharge.	Tertiary-treatment following secondary treatment.	*E. coli* and intestinal enterococci numbers would be significantly reduced by secondary and tertiary sewage treatment and comply with bathing water standards within 1m of the discharge effects judged negligible and **not significant**.	Subject to WDA permit and monitoring defined therein.	Negligible effect (**Not significant**)
Synthetic	TBM surfactant	Most TBM surfactants	TBM chemical assessment based on Hinkley	Subject to WDA permit and	Minor adverse effects

Impact	Impact detail	Primary or tertiary mitigation	Assessment of effects	Additional mitigation	Residual effects
compound contamination	chemicals BASF Rheosoil 143 and CLB F5M.	would adhere to the tunnelling spoil and be transported landward to the muck bay for disposal. CDO discharges would be treated with a siltbuster to reduce sediment an oil separators with both measures contributing to reduction of sediment or oil associated chemicals being discharged.	Point C details for conservative assessment- low volumes mean limited extent of effect and GSB well mixed -minor adverse (**not significant**).	monitoring defined therein.	(**Not significant**)
Synthetic compound contamination	In-combination effect of discharges from the CDO and TRO and chlorination by-products plume from Sizewell B.	None	Overlap between the chemical discharges from the CDO which include metals, unionised ammonia, potentially surfactants from tunneling and hydrazine from commissioning would overlap with discharges of TRO and chlorination by-products from Sizewell B. However discharges from the CDO are at very low concentration over small areas and the effects of any interaction are not evaluated as changing the individual assessments of effects which remain valid. The interaction has negligible effect so the assessment remains at minor adverse effects (**not significant**).	None required.	Minor adverse effects (**Not significant**)

Table 21.23: Summary of effects for the operational phase.

Impact	Impact detail	Primary or tertiary mitigation	Assessment of effects	Additional mitigation	Residual effects
Changes in SSC	Increases in SSC resulting from plough dredging for the BLF navigational channel (including lower magnitude maintenance dredging).	None	Marine waters at Sizewell are well mixed such that localised elevations of SSC quickly redistribute and return to background levels. SSC status (turbidity) based on annual value unaffected by very short term elevation. Minor adverse effect (**not significant**).	Subject to Marine Licence and monitoring defined therein.	Minor adverse effect (**Not significant**)
Deoxygenation	In-combination effect thermal elevation during abstraction uplifts of 11.6°C reduce oxygen concentration.	None	Influence is long term but well mixed local waters have high natural oxygen concentration—minor adverse effects (**not significant**).	Subject to WDA permit and monitoring defined therein.	Minor adverse effects (**Not significant**).
Synthetic compound contamination	In-combination effect thermal elevation during abstraction uplifts of 11.6°C increase proportion un-ionised ammonia.	None	Influence is long term but well mixed local waters have low natural background total ammonia and inputs are low such that proportion of un-ionised ammonia far below EQS—minor adverse effects (**not significant**).	Subject to WDA permit and monitoring defined therein.	Minor adverse effects (**Not significant**).

Impact	Impact detail	Primary or tertiary mitigation	Assessment of effects	Additional mitigation	Residual effects
Temperature changes.	Thermal elevation uplifts and exceedance of absolute standards.	None	Influence is long term. Absolute thermal exceedance for both stations in combination is constrained to small areas (<90ha at the surface and <26ha at the bed). Modest thermal uplifts (2ºC) can extend over instantaneous areas of thousands of hectares at the sea surface within the tidal excursion. Effects are evaluated as minor – **not significant**.	Subject to WDA permit and monitoring defined therein.	Minor adverse effects (**Not significant**).
Synthetic compound contamination.	TRO discharges during operation.	Seasonal chlorination of the cooling water system when temperatures are >10°C to prevent biofouling.	Influence is long term. TROs concentration rapidly decay and system is well mixed GSB further facilitating dilution and decay effects are evaluated as minor adverse.	Subject to WDA permit and monitoring defined therein.	Minor adverse (**Not significant**)
Synthetic compound contamination	Bromoform discharges during operation.	Seasonal chlorination of the cooling water system when temperatures are >10°C to prevent biofouling.	Influence is long term. Bromoform is volatile and readily lost to atmosphere so low persistence. Further dilution and decay in well mixed GSB further facilitaing dilution and decay effects are	Subject to WDA permit and monitoring defined therein.	Minor adverse (**Not significant**).

Impact	Impact detail	Primary or tertiary mitigation	Assessment of effects	Additional mitigation	Residual effects
			evaluated as minor adverse.		
Synthetic compound contamination.	Hydrazine discharges during operation.	Discharges would be directed to a wastewater tank prior to controlled release. Tank aeration to faciltate hydrazine decay and short half-life on mixing with seawater.	Two discharge concentrations modelled: - 34.5ng/l and 69ng/l. limited extent, rapid decay and precautionary PNEC value indicate effects negligible. Effects are evaluated as minor adverse.	Subject to WDA permit and monitoring defined therein.	Minor adverse (**Not significant**)
Nutrient enrichment.	Cooling Water outfalls—nutrient enrichment.	Sewage treated to tertiary level.	Low level of nutrient additions are predicted to have a negligible effect on the nutrient status of the GSB.	Subject to WDA permit and monitoring defined therein.	Negligible effect (**Not significant**)
Introduction of microbial pathogens.	Cooling Water outfalls—treated sewage discharge.	Tertiary following secondary treatment.	*E. coli* and intestinal enterococci numbers would be significantly reduced by secondary and tertiary sewage treatment and comply with bathing water standards within the cooling water flow the discharge effects judged negligible and **not significant**.	Subject to WDA permit and monitoring defined therein.	Negligible effect (**Not significant**)
Nutrient enrichment	FRR discharges dead biota.	None	The maximum spatial scale of the impacts is low and differs seasonally, but only small areas would be exposed to	Subject to WDA permit and monitoring defined therein.	Negligible effect (**Not significant**)

Impact	Impact detail	Primary or tertiary mitigation	Assessment of effects	Additional mitigation	Residual effects
			elevated nutrient levels and the effects are assessed as negligible (**not significant**).		
Deoxygenation	FRR discharges dead biota.	None	The maximum spatial scale of the impacts is low and differs seasonally, but only small areas would be exposed to reduced oxygen levels and high background means effects are assessed as negligible (**not significant**).	Subject to WDA permit and monitoring defined therein.	Negligible effect (**Not significant**)
Organic enrichment	FRR discharges dead biota.	None	The maximum spatial scale of the impacts is low and differs seasonally, but only small areas would be exposed to un-ionised ammonia >EQS effects are assessed as minor adverse (**not significant**).	Subject to WDA permit and monitoring defined therein	Minor adverse (**Not significant**)

References

21.1 Environment Agency. Catchment Data Explorer. Available from: Https://Environment.Data.Gov.Uk/Catchment-Planning/. Available from: https://environment.data.gov.uk/catchment-planning/. 2019

21.2 Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive). 1992. Official Journal of the European Communities.

21.3 European Parliament and of the Council. Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (Bird Directive). 2009. Official Journal of the European Union.

21.4 UNESCO. 1971. The Convention on Wetlands of International Importance (Ramsar Convention). Available from: https://www.ramsar.org/about-the-ramsar-convention [accessed August 2019]

21.5 Oslo and Paris Convention. Convention for the Protection of the marine Environment of the North-East Atlantic (the 'OSPAR Convention'). 22nd September 1992.

21.6 European Commission. Water Framework Directive (WFD). Common implementation strategy for the water framework directive (2000/60/EC): Transitional and coastal waters – Typology, Reference conditions and classification systems, Guidance Document No 5. Office for official publications of the European Communities, 2003

21.7 Bathing Water Directive (2006/7/EC) of the European Parliament came into force in March 2006 and replaces the current Bathing Water Directive (76/1160/EEC).

21.8 Directive 2006/113/EC of the European Parliament on the environmental quality of shellfish waters.

21.9 Marine Strategy Framework Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy.

21.10 Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 and 2016 amendment for inclusion of shellfish waters

21.11 Legislation.gov.uk. Bathing Waters Regulations (2013. No. 1675).

21.12 Legislation.gov.uk. The Wildlife and Countryside Act 1981 (as amended) available from: http://www.legislation.gov.uk/ukpga/1981/69 [accessed August 2019]

21.13 GOV.UK. Marine and Coastal Access Act 2009. https://www.legislation.gov.uk/ukpga/2009/23/contents [accessed September 2019]

21.14 GOV.UK. The Conservation of Habitats and Species Regulations (2017). Available from: http://www.legislation.gov.uk/uksi/2010/490/contents/made [accessed August 2019]

21.15 Legislation.gov.uk. Salmon and Freshwater Fisheries Act 1975

21.16 Department of Energy and Climate Change, DECC. Overarching National Policy Statement (NPS) for Energy (NPS EN-1). 2011. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf [Accessed July 2019]

21.17 Department of Energy and Climate Change, DECC. National Policy Statement for Nuclear Power Generation (NPS EN-6). 2011. Available from: https://www.gov.uk/government/publications/national-policy-statements-for-energy-infrastructure [Accessed July 2019]

21.18 HM Government. UK Marine Policy Statement available from: https://www.gov.uk/government/publications/uk-marine-policy-statement [Accessed October 2019]

21.19 East Inshore Marine Plan available from: https://www.gov.uk/government/publications/east-inshore-and-east-offshore-marine-plans [accessed August 2019]

21.20 "DEFRA, Anglian RBD Eel Management Plan, 2010".

21.21 Suffolk Coastal District. 2013. Suffolk Coastal District Local Plan. Core Strategy and Development Management Policies. Available from: http://www.eastsuffolk.gov.uk/planning/planning-policy-and-local-plans/suffolk-coastal-local-plan/existing-local-plan/ [accessed October 2019].

21.22 CIEEM. Guidelines for ecological impact assessment in Britain and Ireland: Terrestrial, Freshwater, Coastal and Marine. 2018. Available from: http://www.cieem.net/data/files/Resource_Library/Technical_Guidance_Series/EcIA_Guidelines/Final_EcIA_Marine_01_Dec_2010.pdf.

21.23 JNCC. Progress towards the development of a standardised UK pressure-activities matrix. Healthy and Biologically Diverse Seas Evidence Group. 9th-10th October 2013.

21.24 OSPAR. Pressure list and descriptions. In Paper to ICG-COBAM (1) 11/8/1 Add.1-E (amended version 25th March 2011) presented by ICG Cumulative Effects. OSPAR Commission, London. http://jncc.defra.gov.uk/PDF/20110328_ICG-C_Pressures_list_v4.pdf (last accessed on 22/11/2017). 2011 Available from:http://jncc.defra.gov.uk/PDF/20110328_ICG-C_Pressures_list_v4.pdf (last accessed on 22/11/2017).

21.25 H. Tyler-Walters, H.M. Tillin, E.A.S. D'Avack, F. Perry, and T. Stamp. Marine Evidence-Based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth. 2018

21.26 M.E. Roberts. Causes and ecological effects of resuspended contaminated sediments (RCS) in marine environments. Environment International Volume 40, Pages 230-243. April 2012.

21.27 Defra. The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 CONTENTS, 40. Available from: http://www.legislation.gov.uk/uksi/2015/1623/pdfs/uksiod_20151623_en_auto.pdf.

21.28 Defra. 2014. Water Framework Directive implementation in England and Wales: new and updated standards to protect the water environment. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307788/river-basin-planning-standards.pdf.

21.29 G. Mance, A.R., O'Donnell & P.R.Smith. Proposed environmental quality standards for List II substances in water: Boron. Water Research Centre (Technical Report No. 256). 1988.

21.30 European Union Technical Guidance Document in support of commission directive 93/67/EEC on risk assessment of new identified substances and commission regulation (EC) no. 1488/94 on risk assessment for existing chemical substances, EC-1996, revised 2003.

21.31 European Commission Common Implementation Strategy (CIS) for the Water Framework Directive (2000/60/EC) Guidance Document No. 27 Technical Guidance for Deriving Environmental Quality Standards. ISBN: 978-92-79-16228-2. DOI: 10.2779/43816. 2011.

21.32 GOV.UK. Clearing the Waters for All Guidance. Defra 2016. Last updated 9 November 2017. Available from: https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters.

21.33 CORMIX US EPA supported mixing zone model. CORMIX Version 10.0GT HYDRO1 Version 10.0.1.0 April 2017.

21.34 BEEMS. Sizewell Thermal Plume Modelling GETM Stage 3 Results with the Preferred SZC Cooling Water Configuration. Edition 3. Technical Report TR302. Lowestoft, UK: Cefas, 2016

21.35 Cefas Coastal Temperature. https://www.cefas.co.uk/cefas-data-hub/dois/cefas-coastal-temperature-network. 2013.

21.36 Environment Agency. Proposed EQS for Water Framework Directive Annex VIII substances: ammonia (un-ionised). SNIFFER Report: WFD52(ii). Bristol, UK. 78 pp. 2007a.

21.37 S.L. Clegg and M. Whitfield. A chemical model of seawater including dissolved ammonia, and the stoichiometric dissociation constant of ammonia in estuarine water and seawater from -2° to 40 °C. Geochim. et Cosmochim. 1995, Acta 59, 2403-2421.

21.38 Galloper Wind Farm Project Environmental Statement—Non Technical Summary. Document Reference—5.1. October 2011. Available from: http://www.galloperwindfarm.com/assets/images/documents/GWF%20Environmental%20Statement/ES_Non-Technical_Summary.pdf

21.39 D.D. MacDonald, R.S. Carr, F.D. Calder, E.R. Long, C.G. Ingersoll. Development and evaluation of sediment quality guidelines for Florida coastal waters. Ecotoxicology, 1996, 5, 253–278.

21.40 D. Sheahan, J. Maud, A. Wither, C. Moffat and C. Engelke. Impacts of climate change on pollution (estuarine and coastal). MCCIP Science Review 2013, 244-251, doi:10.14465/2013.arc25.244-251

21.41 Guidance for Pollution Prevention. Available from: GPP5 Works or maintenance in or near water. https://www.netregs.org.uk/media/1418/gpp-5-works-and-maintenance-in-or-near-water.pdf

21.42 GOV.UK. Pollution Prevention for businesses. Available from: https://www.gov.uk/guidance/pollution-prevention-for-businesses#activities-that-produce-contaminated-water

21.43 Guidance for Pollution Prevention, GPP6 Working at construction and demolition sites. Available from: https://www.netregs.org.uk/media/1672/ppg-6.pdf

21.44 GOV.UK. Construction inspection and maintenance. Available from: https://www.gov.uk/guidance/pollution-prevention-for-businesses#construction-inspection-and-maintenance

21.45 Guidance for Pollution Prevention, GPP2. Above ground oil storage Guidance for Pollution Prevention available from:https://www.netregs.org.uk/media/1475/gpp-2-pdf-jan-2018.pdf

21.46 GOV.UK. Oil storage Regulations for Businesses. Available from: https://www.gov.uk/guidance/storing-oil-at-a-home-or-business

21.47 Guidance for Pollution Prevention, GPP22 Dealing with spills available from: https://www.netregs.org.uk/media/1643/gpp-22-dealing-with-spills.pdf

21.48 GOV.UK. Pollution incident response plan available from: https://www.gov.uk/guidance/prevent-groundwater-pollution-from-solvents#prepare-for-emergencies-create-a-pollution-incident-response-plan

21.49 IMDG International Maritime Dangerous Goods Code, 2018 Edition (inc. Amdt 39-18) available at: http://www.imo.org/en/Publications/Documents/IMDG%20Code/IMDG%20Code,%202018%20Edition/IL200E.PDF

21.50 Control of Substances Hazardous to Health (COSHH). 2002. Available from: http://www.hse.gov.uk/coshh/index.htm

21.51 REACH Enforcement Regulations. UK Statutory Instruments 2008 No. 2852 PART 1

21.52 European Parliament Regulation (EC) No 1272/2008 - classification, labelling and packaging of substances and mixtures (CLP) 16 December 2008. Accessed at: https://osha.europa.eu/en/legislation/directives/regulation-ec-no-1272-2008-classification-labelling-and-packaging-of-substances-and-mixtures

21.53 Offshore COSHH Essentials Storing Chemicals accessed at available from:http://www.hse.gov.uk/pubns/guidance/ocm8.pdf

21.54 HERA. Human & Environmental Risk Assessment on ingredients of European household cleaning products: Alcohol Ethoxysulphates (AES) Environmental Risk Assessment. 2004.

21.55 HERA. Human & Environmental Risk Assessment on ingredients of European household cleaning products: Alkyl Sulphates (AS) Environmental Risk Assessment. 2002.

21.56 P.S. Dixon, J. Scherfig, and C.A. Justice. Environmental Quality Research, Use of Unicellular Algae for Evaluation of Potential Aquatic Contaminants. Fourth Annual Report. Irvine, California:1979

21.57 Environment Canada. Canadian Environmental Protection Act, 1999 Federal Environmental Quality Guidelines: Hydrazine. 2013,11 pp. Available from: http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=D66353C2-1.

21.58 BEEMS Scientific Advisory Report. BEEMS Expert Panel. Thermal Standards for Cooling Water from New Build Nuclear Power Stations. Scientific Advisory Report SAR008. Lowestoft, UK:2011

21.59 S. Van Leeuwen, P. Tett, D. Mills, and J. Van Der Molen. Stratified and Nonstratified Areas in the North Sea: Long-Term Variability and Biological and Policy Implications. Journal of Geophysical Research C: Oceans, 2015, 120 (7)

21.60 C.J.L. Taylor. The Effects of Biological Fouling Control at Coastal and Estuarine Power Stations. Marine Pollution Bulletin, 2006, 53 (1), pp. 30–48.

21.61 H.A. Jenner, C.J.L. Taylor, M. Van Donk, and M. Khalanski. Chlorination By-Products in Chlorinated Cooling Water of Some European Coastal Power Stations. Marine Environmental Research, 1997, 43 (4), pp. 279–293.

21.62 BEEMS. Sizewell C: Comprehensive Impingement Monitoring Programme 2014-2017. Cefas Technical Report TR339. Lowestoft, UK: Cefas 2019.

21.63 J.M. Capuzzo. The Effect of Temperature on the Toxicity of Chlorinated Cooling Waters to Marine Animals - A Preliminary Review. Marine Pollution Bulletin, 1979, 10 (2), pp. 45–47.