TR306 Sizewell Marine Water and Sediment Quality Synthesis Report MSR2/5

BEEMS Technical Report TR306 Edition 5

Table of contents

List of Tables and Figures

Tables

Please note that the red line boundary used in the figures within this document was amended after this document was finalised, and therefore does not reflect the boundaries in respect of which development consent has been sought in this application. However, the amendment to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Figures

Executive summary

The Centre for Environment, Fisheries and Aquaculture science (Cefas) supported by a network of subcontractors has been contracted by SZC Co to undertake the necessary marine studies to provide the evidence base for the Sizewell C project Development Consent Order (DCO) application via a comprehensive set of studies known collectively as the BEEMS programme for Sizewell C. This report provides a synthesis of the marine water and sediment quality evidence relevant to the Environmental Impact (EIA) and Water Discharge Activity (WDA) Environmental Permit assessments. Specific evidence for the Sizewell C Water Framework Directive (WFD) assessment and the shadow Habitat Regulations Assessment (HRA) is presented in BEEMS Technical Report TR483 and is referenced in this report. Further detail can be found in the cited BEEMS Technical Reports that underpin this document.

The Sizewell C EIA scoping report (SZC Co, 2014a) lists the elements of the Main Development Site that could impact on marine water and sediment quality as follows:

During construction and commissioning

- Changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column during the construction of the cooling water intake and outfall vertical shafts and head structures, the construction drainage outfall (CDO), the fish recovery and return system (FRR) and the beach landing facility (BLF);
- Discharges to surface waters that enter the marine environment that include surface water drainage, and groundwater containing suspended sediment and contaminants. Added to these discharges at different rates at different times may be treated sewage effluent, chemicals used in tunnelling. All such discharges would be subject to permit and would have an appropriate level of treatment before discharge to the marine environment to meet permitted levels; and
- Potential changes to marine water quality because of chemicals that are used in the cold commissioning of Sizewell C and discharged via the CDO before there is a fully functional cooling water system.

During operation

- Discharge of treated sewage effluent to sea would occur via the cooling water system;
- The elevated temperature of the cooling water effluent would alter the thermal regime in the vicinity of the discharge point;
- Potential changes may occur to marine water quality because of process chemicals that will be used in the operation of the main development site and that are discharged in the cooling water effluent;
- Chemical and physical changes that may occur due to decay of any fish discharged from the Fish Recovery and Return system that do not survive passage through the system; and
- The occasional need to access the beach landing facility to receive deliveries of Abnormal Indivisible Loads (AILs) by sea during the operational life of the power station may result in localised changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column from dredging operations and vessel movements.

This report describes the potential effects of each of these elements and is set out as follows:

- Description of the area of assessment for the EIA;
- Description of relevant water and sediment quality standards
- Description of the water and sediment quality of the greater Sizewell Bay;
- Description of the marine components of the proposed Sizewell C development;
- Potential effects of the development on marine water and sediment quality;

- Effects of the proposed Sizewell C development activities acting in-combination;

Some of the potential effects of the main development site on marine water and sediment quality are dependent upon the engineering designs of specific coastal infrastructure. SZC Co have not finalised the detailed design of this infrastructure and will not be able to do so until engineering contractors have been selected to build the station. Some of the detailed analyses contained in this report are therefore subject to change. This report reflects engineering designs and proposed construction sequencing as at **March 2020** and where necessary adopts a Rochdale Envelope approach to bracket engineering uncertainties.

There are three main areas of activity for the proposed new build power station Sizewell C that are assessed for the potential to affect marine water and sediment quality:

I. Construction activities in the marine environment;

II. On site construction activities including cold commissioning for which there may be chemical discharge (these are considered for different Cases or examples of the combined discharges for groundwater, sewage and other construction inputs that vary across the construction period);

III. On site operation activities for which there may be a thermal inputs and chemical discharge

Tables A1 to A10 summarise the key assessments and significance of effects described to marine water quality and sediment that could be associated with the Proposed Development.

Changes to this Report

Changes in Edition 5 dated 4/3/20202

Dredging activities are considered separately and in combination. Hydrazine cold commissioning discharge level has been revised to better reflect expected discharge level for permitting. An additional load assessment for trace metal contamination (cadmium and mercury) of raw materials used for water treatment has been added. A section has been added on inter relationship effects of discharges from the CDO and those from Sizewell B cooling water outfall (section 5.14). An inter-relationships section has also been added to consider interaction of discharge sources in the cooling water discharge for Sizewell C and interaction with temperature. Corrections have been made to some of the loading values for operational chemicals as more information has become available none of the changes has had significant implications for predicted impacts.

Changes in Edition 4. 17/10/2019

The sediment plume data has been updated and individual dredging campaigns are considered separately for modelling to more accurately reflect sequence and overlap of activities. This report includes an assessment of tunnelling and commissioning discharges. Phytoplankton modelling is included to assess the combined influence of nutrients from construction and cold commissioning. A section has been added on the potential influence of climate change on thermal effects of the cooling water plume. The potential influence of dead fish from the Fish recovery and return system is also included and an assessment made. Corrections have been made to some of the loading values for operational chemicals as more information has become available none of the changes has had significant implications for predicted impacts.

Changes in Edition 3. 7/06/2019

The report has been restructured so that construction description and assessment sections follow each other as do those for commissioning and for operation. These changes are to improve readability in response to regulator comments on the previous draft of this report and from the MTF in March 2019.

The methodology for screening and assessment of large cooling water discharges has been fully adopted for the operational assessment and the results of screening assessments updated accordingly.

A further modelling assessment was conducted to assess nutrient inputs and the results are included. Further work is underway to provide an assessment of potential discharges from tunnelling and from commissioning. The sediment plume assessment will also be updated with assessments that separate out individual dredging campaigns for modelling to more accurately reflect sequence and overlap of activities. This is not expected to increase the impact indicated in the present assessment.

Changes in Edition 2. 8/03/2019

The model runs for Sizewell B for chlorination (Total residual oxidants, TRO) and for bromoform have been repeated due to some inconsistencies in calculation of areas affected for initial runs and are provided in this report. This is has led to small changes in the predicted areas affected for the Sizewell B only run. Small differences in the prediction for Sizewell C area affected also resulted and have been corrected.

Section 6.2.3 ammonia in groundwater and sewage during construction - ammonia source data there are some small changes in derived values due to the use of 50%ile rather than mean values for pH and salinity. This change made to ensure consistency of approach throughout. Resultant changes to derived un-ionised ammonia are insignificant. The small change in the percentage mixing of construction discharge with seawater upon discharge that result has led to small revisions of distance to achieve dilution below the un-ionised ammonia EQS.

In section 6.2.1 a fuller explanation of the thermal elevation of different component sources that make up the cooling water discharge is provided.

Table 18 ammonia source data there are some small changes in derived values. This change resulted from a correction to use a 50%ile pH value rather than a 95%ile in the un-ionised ammonia calculation.

Section 6.2.4.1 localised effect of DIN the case E volume discharges were incorrect in the text although the correct values were used to derive relevant load figures.

Section 6.2.4.4 the assessment of BOD has been made consistent across construction and operation and with previous assessments and more detail is provided.

Table A1 Scale of construction activities in the marine environment with potential to influence sediment and water quality.

Structure	Activity	Influence of activity
Sediment	Disturbance	The sandy nature of the material and levels of contamination below Cefas Action Level 2 found in the marine sediment at Sizewell, there is a low risk of bioavailable contaminants. Sediments associated with dredging for the Planned Development are therefore considered to be uncontaminated and the effects of resuspension of contaminants on marine water quality and ecology receptors is not considered further.
Beach Landing Facility	Dredging	Capital dredging of the BLF would remove a total dredge volume of 4,600m^3. Modelling indicates sediment only settles on the bed over a relatively small area close inshore. Depth average location maximum SSC of more than 100mgl^{-1} above daily maximum background extend approximately 5 km north and south of the dredge site over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. Plume quickly disperses after dredge – low concentrations 20mgl^{-1} above background over three days. For maintenance dredging plumes of SSC of 100mg/l would affect an area of 108ha at the surface and 28ha at the bed but this elevation in SSC would relatively short-lived. Changes in SSC are not of sufficient duration and magnitude to alter the SSC status of the Suffolk Coastal Waterbody
Cooling water intake	Dredging	For intakes elongate area 13km north, 22km south ~2 km east-west affected by increases in SSC >100mgl^{-1}, depth averaged peak at >1,000mgl^{-1} above background. Elevated concentrations are short lived, with more typical SSC of 100mgl^{-1}. Following dredging, the plume quickly dissipates –ca., two days until at background. Changes in SSC not significant for marine water quality. Dredging for outfall similar SSC elevation and time to return to background.
	Drilling and shaft insertion	During the drilling of the bedrock at the intake structures, a very diffuse plume with SSC of around 5mgl^{-1} relative to background may occur– Changes in SSC not significant for marine water quality
	Installation head	Head is lowered into place, not cast in-situ so no predicted foreign material release effects to the water and sediment quality of the local area
Cooling water outfall	All activities	As for intake
FRR and CDO	Dredging	No areas are subjected to increased surface SSC of more than 50mg/l for more than 6 hours.
	Drilling	Tunnel approximately 0.8m diameter directionally drilled from onshore with drill cuttings returned to land no predicted sediment resuspension effects to the water. There are no details available for chemical selection and quantities required for tunnelling but conservative values for products assessed for use at HPC are evaluated for Sizewell. Changes in SSC not significant for marine water quality
	Installation of head	Head lowered into place, not being cast in-situ so negligible predicted foreign material release effects to the water and sediment

Table A2 Construction discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Metals load	Combined discharges for groundwater were assessed for contribution against the annual load limits for the priority hazardous substances cadmium and mercury of 5kg and 1kg cumulative loads. These values are not exceeded by the discharges during any phases of construction. Consideration also made of potential additional inputs from trace metal contamination of water teatment chemicals used for demineralisation of water and these combined additions did not exceed annual load limits.
Metals thresholds	Several metals are present in groundwater. Chromium and zinc fail screening and were modelled. Chromium plume is below EQS at<25m and zinc is undetectable above background at<3m from the CDO outfall. Not significant.
Ammonia	Maximum ammoniacal nitrogen contributions from groundwater and sewage for the construction period were evaluated. Exceedance of the EQS for un-ionised ammonia (21µgl^{-1}) maximum only occurs within 6.3m of the point of discharge. Not significant
Nutrients DIN and phosphorus	Maximum dissolved inorganic nitrogen and phosphorus contributions from groundwater and sewage were combined with the nitrogen and phosphorus loading used during commissioning. These loadings provided source terms for input to a combined phytoplankton and macroalgae model. Run over an annual cycle the model showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.13% for maximum construction and commissioning inputs of DIN and phosphorus. Not Significant
BOD	Using 13.3ls^{-1} and BOD of 40mgl^{-1} and taking account of groundwater contributions a maximum daily BOD of 121kg was calculated. This represents an oxygen requirement of 40.6kg/day. This amount of oxygen would be transferred across 1.2ha in a day and reaeration at the sea surface would also contribute. There is therefore considered negligible impact on the well mixed and well oxygenated waters off Sizewell from this discharge. Not Significant
Microbiological	*E.coli* meets bathing water standards <1m of the outfall with UV treatment and intestinal enterococci are ≤200 cfu/100ml at discharge the nearest Bathing water is 10k North of the discharge. No impact.
Tunnelling wastewater and chemicals	The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. Three chemicals used to facilitate tunnelling and that might be discharged at Sizewell were evaluated in terms of significance of discharge concentration. Conservative scenarios were modelled for a clay mineral (bentonite) that may be required at Sizewell and based on Hinkley Point information for two surfactant chemicals. The low toxicity of bentonite, the small areas affected (concentrations of 10µgl^{-1} restricted to sea surface areas of mean 1.35ha and a 95th percentile area of 10.8ha) and the low discharge concentrations are likely to have negligible effects on water quality. For both surfactants assessed no exceedance of the EQS occurred at the seabed and the maximum area of exceedance at the surface was small with highest mean exceedance of 3.14 ha and 25ha as a 95th percentile. Not significant for marine water quality.

Table A3 Commissioning discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Commissioning discharges	For commissioning the predicted discharge concentrations of phosphate were already assessed in combination with construction discharges. The circuit conditioning chemical ethanolamine passed the H1 test 5 dilution screening test and hydrazine and un-ionised ammonia were evaluated using GETM discharge modelling via the CDO. Hydrazine would be treated to achieve a maximum discharge concentration of 30µgl^{-1}. This discharge was assessed in terms of areas of exceedance for the acute and chronic hydrazine PNEC and intersection with the Minsmere sluice, the Coralline Crag and the foraging area for three SPA breeding colonies of birds. Hydrazine only intersects the sluice on the ebbing tide when it is likely to be closed. Passage of species like Eel that move to and from the saltmarsh via the sluice are not expected to have a significant affect as the peak concentrations are 800,000-fold less than levels shown to cause sublethal effects in fish. Peak hydrazine concentrations over the coralline crag do not exceed the precautionary chronic PNEC. The hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. The hydrazine plume does intersect foraging areas for the Minsmere Little Tern colony. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging range, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours a day. These changes are evaluated not significant for marine water quality, but further assessment is relevant for specific receptors. The un-ionised ammonia discharge during commissioning is rapidly reduced by the changing pH and salinity as well as by dilution as it mixes with seawater. Exceedance of the annual average EQS for un-ionised ammonia is predicted to only to occur in the direct vicinity of the discharge point and to be below the EQS 25m from the point of discharge. This change is not considered significant for marine water quality. As for the construction discharge assessment the total ammonium concentration at the point of mixing described above is at background for total ammonia and well below levels of concern.

Table A4 Inter-relationship effects during the construction period

Determinand	Influence of discharge
Overview	This section provides a description of the identified inter-relationships that have the potential to affect marine water quality and sediment from construction and cold commissioning of the proposed development. Activities include potential for overlapping dredging for different infrastructure. Assessment of the construction discharges have already accounted for maximum potential inputs of the same substances from different phases of construction and cold commissioning. Here the interaction of the effects of the discharge from the CDO and the Sizewell B cooling water discharge plume are also considered.
Dredging activity	Simultaneous dredging activities may occur for some elements of the development. 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. 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. The plume is highly transient and the total duration of increases in SSC would be reduced due to the temporal overlap. Simultaneous overlap of BLF maintenance, CWS intake and FRR outfalls would represent an area equivalent to 5% of the Suffolk Coastal waterbody 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.
CDO chemical discharge and thermal elevation Sizewell B	CDO chemical discharges have a small area of exceedance at EQS levels <25m so the influence of thermal elevation at ca. 5°C above background would be very limited and insignificant.
Chlorinated discharge Sizewell B and ammonia input CDO	Chlorine and ammonia at similar molar concentrations and at low concentration can react in full strength seawater to form, predominantly, dibromamine which has higher toxicity than TRO alone. However, TRO typically at ca 20µg/l and ammonia NH4-N rapidly decreases to ca., 11µg/l at around 25 metres of the discharge meaning that the concentration of any combination products would be at very low concentrations and within a limited area around the CDO.

Table A5 Operation activities and discharges (cooling water thermal input) with potential to influence marine temperature and dissolved oxygen saturation.

Type of discharge	**Influence of discharge**
Cooling water – Thermal SPA	The absolute areas of exceedance for each thermal standard that applies to the SPA were assessed: For the 2˚C uplift threshold based on a maximum excess (100th percentile) the absolute areas of exceedance range between a minimum area of 5,219ha at the seabed for Sizewell B to 22,464ha at the surface for Sizewell B + Sizewell C. The second criteria for SPAs concern the 98th percentile of the absolute temperature. The predicted absolute areas where the plume temperatures exceed 28˚C are all below 1ha based on a calculated mean excess of >8.6˚C added to the 98%ile for Sizewell. In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
Cooling Water Thermal WFD	The absolute areas of exceedance for each thermal standard that applies to the WFD waterbodies was assessed: For the 2˚C uplift threshold based on a 98th percentile of >23˚C the absolute areas of exceedance range between a minimum area of 8.75ha at the seabed for Sizewell B to 89.6ha at the surface for Sizewell B + Sizewell C. For excess temperatures of 2˚C as a 98th percentile this was exceeded for a minimum of 2126.71ha at the seabed for Sizewell B and 7899.17ha at the surface for Sizewell B +Sizewell C In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality but individual receptor assessments are warranted.
Cooling water – Thermal effect on Oxygen WFD	The effect of the thermal discharge on the oxygen saturation of the surrounding area has been derived using modelling. GETM runs show the area calculated that is beneath various DO concentrations for the entire model domain. The derived average DO concentration for the model domain for both Sizewell B and Sizewell C and Sizewell B alone is>5.77mgl^{-1} as a 5th percentile which is at or above the WFD threshold for High Status of 5.7mgl^{-1}. The influence of this change on marine water quality is not evaluated as significant
Cooling water – Thermal effect on percentage un-ionised ammonia WFD	The calculated mean ammonia discharge concentration was added to either the mean or 95 percentile un-ionised ammonia regional background value derived using the temperature fields generated by GETM and the relevant physicochemical data and total ammonia concentration for each scenario to derive the un-ionised ammonia calculation. The predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS of 21μgl^{-1}. The influence of this change on marine water quality is not evaluated as significant

Table A6 Operation activities and discharges (cooling water chemical input, TRO, CBP and hydrazine) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Cooling water - TRO	For the Sizewell C discharge plume there is a small area of 2.13ha that exceeds the TRO EQS 95th percentile of 10µgl^{-1} for Sizewell C at the seabed and over ~337ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. (The absolute values for Sizewell B and Sizewell C in combination exceed the TRO EQS 95th percentile of 10µgl^{-1} over 726ha at the surface and 167ha at the seabed. In some cases, large areas are influenced by TRO concentrations above the EQS but as TRO is not persistent the effects are not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
FRR - TRO	An initial assessment of discharge of chlorinated seawater from this system was made in BEEMS TR333 and all the potential tunnel locations passed the assessment. However, intakes and tunnels will not be chlorinated.
Cooling water – CBP's	The Bromoform discharge was modelled for 132m^{3}s^{-1}. The Bromoform plume area that exceeds the applied EQS (PNEC 5µgl^{-1} as a 95th percentile) for Sizewell C only at the seabed is ca., 0.15ha and ca.,52ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. The combined plumes for Sizewell B and Sizewell C result in an area of ca., 357ha at the surface and ca.,130ha at the seabed. In some cases, large areas are influenced by bromoform concentrations above the EQS but based on toxicity and persistence the effects are not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
Cooling water - Hydrazine	Hydrazine discharges exceed the acute and chronic quality standard (PNEC) values for discharge concentrations derived from both 24-hour and annual loadings. The chronic PNEC 0.4ngl^{-1} is exceeded at the surface and at the seabed, although in the latter case, an area of less than 1ha is affected for both discharge scenarios. The acute PNEC 4ngl^{-1} is exceeded at the surface (for less than 18ha) and at the seabed, but only in the case of the 69ngl^{-1} release for an area of 0.13ha. Relatively small areas are influenced by hydrazine concentrations above the acute or chronic EQS. These values are precautionary and so the effects are evaluated as not significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
Various substances screened out	Various substances (copper, zinc, chromium) exceeded the 24 hour or annual discharge assessment but this resulted from high background concentrations and predicted discharge concentration for these substances would be below detection limits, so they were screened out. Other substances that have no PNEC and reference site background cannot be effectively assessed but again most are below detection limits so again are screened out of further assessment

Table A7 Operation activities and discharges (Un-ionised ammonia, dissolved inorganic nitrogen, phosphorus and microbiological parameters) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Un-ionised ammonia	During operation the concentration of ammonia predicted in the discharge has been added to the site background and predictions of un-ionised ammonia concentrations derived for the discharge to Sizewell Bay. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of $21\mu gl^{-1}$ NH_3-N as an annual mean. Evaluated as not significant for marine water quality.
DIN	The predicted DIN loading during operation 332kg represents ca., 2% of the exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with PO_4-P a phytoplankton and macroalgal growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluation evaluations are considered in the Marine Ecology Environmental Statement Chapter 21.
Phosphorus	The predicted phosphorus loading during operation PO_4-P gives a value of 114.8kg. This loading represents ca., 5% of the PO_4-P exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with DIN a phytoplankton growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluation evaluations are considered in the Marine Ecology Environmental Statement Chapter 21.
Microbiological parameters	During operation the maximum number of staff on site is estimated at 1900 based on HPC. If UV treatment is applied to the predicted sewage effluent volume discharge and assuming a 5.4 log reduction in specific microorganisms compliance would be achieved at the point of discharge. Evaluated as not significant for marine water quality.

Table A8: Discharges of moribund fish from the FRR with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
FRR moribund fish influence on nutrient status	Nitrogen and phosphorus concentrations from decaying fish biomass predicted to be discharged from the unmitigated FRR and based on annual average fish loadings were assessed in a model run in combination with operational inputs using a Combined Phytoplankton and Macroalgae Model. A model run over an annual cycle predicts a less than 0.29% difference in annual gross production of carbon and this level of change would not be discriminated above natural background variation. Evaluated as not significant for marine water quality but evaluations for marine ecology receptors are considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on un-ionised ammonia	The un-ionised ammonia input from decaying biomass from the unmitigated FRR was derived for the maximum annual biomass loading. Relevant seasonal pH and temperature which influence the proportion of un-ionised ammonia were also accounted for an equivalent area of 6.7ha would potentially exceed the un-ionised ammonia annual average EQS. This area of exceedance is considered to be low relative to the potential for mixing and exchange of water across the GSB. Evaluated as not significant for marine water quality but further considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on dissolved oxygen	The effect of biomass decay on dissolved oxygen was also derived. The calculated annual mean daily biomass oxygen demand represents 0.2% of the oxygen available in the volume of water exchange across the Greater Sizewell Bay. Reaeration at the surface would also resupply oxygen with typical values of surface exchange for this area providing an equivalent loading to that consumed by the biomass discharge over an area of ca., 14ha. For the maximum predicted discharge of biomass during March oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha. Evaluated as not significant for marine water quality but further considered in the Marine Ecology Environmental Statement Chapter 21.

Table A9: Influence of climate change on Operational discharges.

Type of discharge	Influence of discharge
Cooling water – Thermal	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. 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. 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.
Cooling water - TRO	TRO decay will increase at elevated temperatures, but dosing is adjusted to ensure that the target TRO of 0.2mgl^{-1} is achieved in critical sections of the CW plant. The residual oxidant level at the point of discharge is therefore unlikely to be reduced under climate change. The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH. Lowering pH could in theory reduce toxicity but the pH change and influence on ratio of hypobromous and hypochlorous acid is not considered significant so the assessment remains the same as for current conditions.
Cooling water – CBP's	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 CBPs 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
Cooling water - Hydrazine	Hydrazine half-life 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.

Table A10: Inter relationship effects Operation

Type of discharge	Influence of discharge
Synergistic effects chlorinated discharge and treated sewage effluent	Seasonal chlorination and un-ionised ammonia from treated sewage discharge have the potential to interact in the cooling water discharge. 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. The synergistic effects of chlorination and ammonia discharges may result in the formation of additional combined products. However, the low level of ammonia available to interact with chlorinated seawater would limit the byproduct formation to below levels of significance in terms of change to toxicological influence of the chlorinated seawater alone.
Synergistic effects of temperature and toxicity of chlorinated seawater	Beyond the immediate point of discharge ca 10-20m the residual oxidant exposure would be low at a few 10s of micrograms/litre and the thermal elevation would be a few degrees above background. Beyond this point the low level of thermal elevation and its influence on the toxicity of residual oxidants would be insignificant. The area affected with potential for synergistic effects of temperature on chlorinated seawater toxicity would therefore be very limited.

1 Background

SZC Co proposes to construct and operate a new nuclear power station (new nuclear build, or NNB) immediately to the north of the existing Sizewell B station on the Suffolk coast. Under the Planning Act 2008, this development, as with other nationally-significant infrastructure projects, requires a Development Consent Order (including, in the case of conservation areas, a Habitats Regulations Assessment) to be granted by the UK Government's Planning Inspectorate. The marine aspects of the development will also require regulatory permits for, amongst other activities, cooling water discharges and activities that disturb the seabed. Decisions on permissions will be taken based on an Environmental Impact Assessment (EIA) encompassing the key ecological features of the site and including all marine activities associated with the development.

In 2007, British Energy (now EDF Energy) commissioned Cefas to undertake a programme of marine studies to underpin the Sizewell C development. This programme, termed BEEMS, is tasked with providing authoritative scientific advice encompassing the whole of the marine ecosystem (marine ecology and fisheries, coastal geomorphology and hydrodynamics and marine water and sediment quality), in terms of construction and operation as well as the Development Consent Order and associated permits and licences.

This marine water and sediment quality synthesis is intended to provide detail on the potential impacts of the construction, commissioning, and operational activities of the proposed Sizewell C power station. It is intended to inform the EIA, Water Discharge Activity (WDA) Environmental Permit and Marine Licence assessments for the development. It does not include assessments for the Habitats Directive (HRA) or the Water Framework Directive (WFD) which are considered in BEEMS TR483. Decommissioning will be the subject of a separate environmental assessment when relevant details are known. The Environmental Statement (ES) will assess the potential in-combination (activities associated with Sizewell C) and cumulative effects (activities associated with Sizewell C plus activities from other relevant developments), this will be included in the ES. Zones of Influence (ZoI) are established for these assessments and the Planning Inspectorate guidance will be adhered to.

The marine components of the development site include:

1. Coastal Defence Features (CDFs);
2. Beach Landing Facility (BLF);
3. Cooling Water Infrastructure including Intakes and Outfall heads;
4. Fish Recovery and Return (FRR) systems, and;
5. Combined Drainage Outfall (CDO).

The elements of the Main Development Site that could impact on marine water and sediment quality are as follows:

During construction and commissioning

- Changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column during the construction of the cooling water intake and outfall vertical shafts and head structures, the fish recovery and return system, the CDO and the BLF;
- Discharges to surface waters that enter the marine environment that include surface water drainage containing suspended sediment, contaminants and treated sewage effluent. All such discharges would have an appropriate level of treatment before discharge to the marine environment; and
- Potential changes to marine water quality because of chemicals that are used in the commissioning of the Main Development Site.

During operation

- Discharge of treated sewage effluent to sea would occur via the cooling water system;
- The elevated temperature of the cooling water effluent would alter the thermal regime near the discharge point;
- Potential changes may occur to marine water quality because of process chemicals that will be used in the operation of the Main Development Site and that are discharged in the cooling water effluent; and
- The occasional need to access the beach landing facility to receive deliveries of Abnormal Indivisible Loads (AILs) by sea during the operational life of the power station may result in localised changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column from dredging operations and vessel movements.

Some of the potential effects of the Main Development Site on marine water and sediment quality are dependent upon the engineering designs of specific coastal infrastructure. SZC Co have not finalised the detailed design of this infrastructure and will not be able to do so until engineering contractors have been selected to build the station. Some of the detailed analyses contained in this report are therefore subject to change. This report reflects engineering designs and proposed construction sequencing as at **March 2020** and where necessary adopts a Rochdale Envelope approach to bracket engineering uncertainties.

1.1 Area of assessment for the EIA

The Greater Sizewell Bay (GSB) is considered as the initial reference area for the study site. The GSB extends to Walberswick in the north with the southerly extent bound by the geomorphic Coralline Crag formation at the apex of the Thorpeness headland in the south. The seaward boundary extends to the eastern flank of the Sizewell-Dunwich Bank and includes the proposed cooling water infrastructure on the east side on the bank. The landward limit of the marine study area is delineated by Mean High Water Springs (MHWS).

The GSB is not a closed system and water exchanges with the rest of the southern North Sea. The Zone of Influence (ZoI) for development impacts is therefore dependent on hydrodynamic processes. For the EIA, the potential ZoI is dependent on several factors including; the position and duration of the discharge, the behaviour and persistence and/or degradation rates of the discharge components, bathymetry, and the state of the tidal cycle. Construction and operational discharges are predicted to occur from different point sources and may act cumulatively with discharges from Sizewell B, as is the case for thermal inputs.

Sizewell B intakes and outfalls are located within the Sizewell-Dunwich Bank (Figure 1) and discharge into the receiving waters of the GSB. Construction discharges from the CDO and operational discharges from the FRRs associated with Sizewell C would also occur within the GSB and would be transported throughout the inner tidal excursion within the Sizewell-Dunwich Bank. This excursion has been determined through particle tracking and is approximately 20.8 km North-South and approximately 3.5 km east-west. More detail on the calculation of the inner tidal excursion is provided in Appendix A.

The Sizewell C cooling water intakes and outfalls are located 3km offshore, beyond the Sizewell-Dunwich Bank, and therefore operational discharges would be within a different and larger tidal excursion.

The proposed tidal excursion associated with the Sizewell C intake locations (BEEMS Technical Report TR385), is approximately 15.9 km, and 1.4 km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 31.8 km long and approximately 2.8 km wide. The area and volume based upon the average depth, of the associated ZoIs are shown in **Error! Reference source not found.** (Table 37 and the respective tidal excursions are shown in Figure 15). The calculated data provide similar approximate volume and area estimates to confirm those applied in TR385, to enable model predictions of the effect of Sizewell C on phytoplankton community biomass and these are the values used for this report.

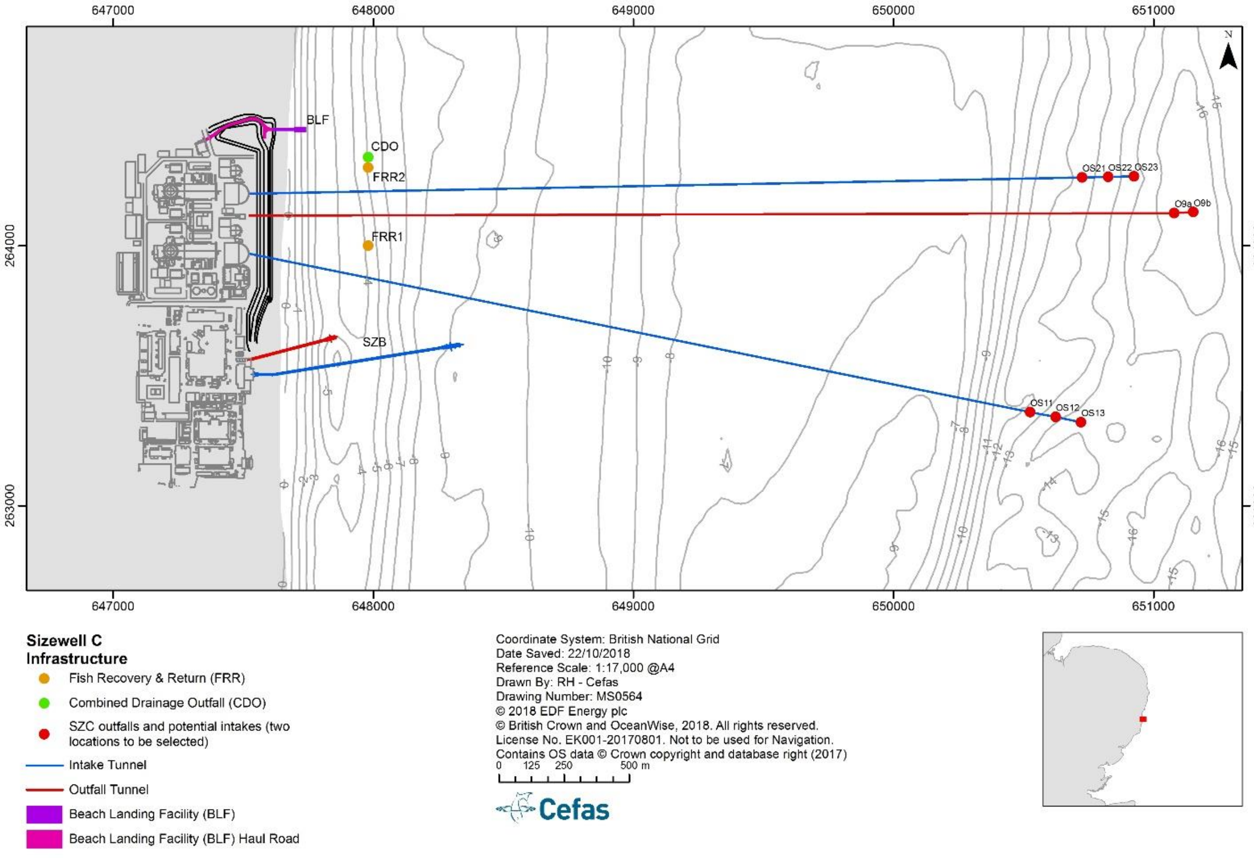

Figure 1: Schematic of development locations in the marine environment overlaid on bathymetry, blue indicates intake tunnels, red indicates outfall.

This report considers the influence of absolute areas of activity or discharge impact that exceed relevant water quality standards or applied values.

To prevent confusion with HRA and WFD assessments, this synthesis determines the absolute area of developmental impacts relative to hydrodynamically-relevant spatial and temporal scales, rather than considering effects within the specific WFD waterbodies or European designated sites. Marine water and sediment quality have no direct conservation value as they are not a designated features within this area. The area has some socioeconomic value as it contains recreational beaches and bathing waters (below MHWS).

The sea adjacent to the Main Development Site (MDS) is part of the Outer Thames Estuary Special Protection Area (SPA) and the Southern North Sea Special Area of Conservation (SAC) for harbour porpoises and the Suffolk Coastal waterbody and supporting elements. The evidence base for marine impacts of the development relative to WFD and Habitats Directive standards is addressed in BEEMS Technical Report TR483.

1.2 Marine water and sediment quality standards

1.2.1 Background

All direct cooled power stations require large quantities of cooling water to remove low grade waste heat resulting from the condensation of the steam used to drive turbo-generators. Where cooling water is abstracted from and discharged to surface waters, it is important that potential impacts on receiving water quality are carefully assessed. Some of the legislation requires that specific standards are not exceeded – these primarily relate to chemical parameters – but in other cases the requirement is that water quality status based on several biological and physical parameters is not negatively influenced by human activities. Good surface water status is one of the principal objectives for surface water bodies not designated as heavily modified or artificial under the Water Framework Directive. Those designated as heavily modified have a target of good ecological potential – that is, to achieve ecological quality that is as good as it can be, taking account of the modifications that give it heavily modified status. The other principal objective is to prevent deterioration of surface water status (UKTAG, Surface Water classification, 2007). In this latter case, particularly in relation to areas that are protected or that have special conservation status, there is greater uncertainty as to what constitutes acceptable levels of chemical and physical change to water quality and how this links to biological quality elements which can only be resolved by a detailed consideration of potential effects.

1.2.2 Thermal effects and standards

Table 1 summarises the legislation associated with thermal discharges. The primary change to cooling water discharged from power stations is increased temperature. The potential effects of a thermal plume are predominantly on sessile and sedentary benthic organisms that cannot avoid the plume. However, due to the plume buoyancy, appropriately designed thermal outfalls do not result in large areas of elevated seabed temperature. Planktonic organisms that drift with the tidal currents are only potentially at risk when they enter the mixing zone where the plume dilutes in the receiving water.

The potential effects of a thermal plume are predominantly:

- Acute effects – lethal effects where temperatures approach critical thresholds for 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

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.

There is also a potential chronic effect at short ranges from some cross-shore outfall designs due to daily temperature fluctuations caused by the passage of large magnitude thermal fronts over benthic organisms, but this effect would not be expected to occur near the proposed relatively deep-water Sizewell C discharge.

The EU Water Framework Directive (WFD) was transposed into law in England and Wales by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003. To meet the requirements of the WFD, the competent authority (the Environment Agency) has set Environmental Objectives for each water body. A default objective in all water bodies will be to prevent deterioration in either the 'Ecological Status' (for natural water bodies) or the 'Ecological Potential' (for heavily modified or artificial water bodies). The ecological status of a surface water body is assessed according to:

a. The condition of relevant biological elements, for example fish, benthic invertebrates, phytoplankton, and other aquatic flora;
b. The condition of supporting physico-chemical elements, for example temperature, pH, oxygenation salinity and concentrations of nutrients;
c. The concentrations of specific pollutants; and

d. The condition of the hydromorphological quality elements, including morphological condition, hydrological regime, and tidal regime (coastal waters only).

The Water Framework Directive (WFD) process has developed water quality standards for temperature suitable for application to UK water bodies. These supersede UK standards based on the European Freshwater Fish Directive (78/659/EEC), which arose from European Inland Fisheries Advisory Commission (EIFAC) water quality criteria first published in the 1960s (Alabaster and Lloyd, 1980). Other relevant thermal criteria are associated with the Shellfish (Directive79/923 Shellfish Waters Directive, Article 22 of the WFD repeals Directive 78/659/EEC and Directive 79/923/EEC,22 December 2013.), for which a guideline value recommends that for shellfish waters, no more than a 2°C rise above natural background should result from a thermal input.

In interim guidance on marine protected sites (WQTAG 160,Guidance on assessing the impact of thermal discharges on European Marine Sites cited in Turnpenny and Liney, 2006) a 2ºC rise was stated as the maximum allowable increase at the edge of a mixing zone for Special Protected Areas and Special Areas of Conservation.

For WFD assessements, guidance issued by UKTAG (2008a and b) recommends that maximum temperatures at the edge of the mixing zone should not exceed 23ºC with maximum uplift of 3ºC. The principal issues for water quality in terms of temperature increase are set out in detail in Table 1 and are summarised as:

- the acceptable maximum temperature and maximum increase/decrease in temperature in relation to the status class of the water body concerned and with respect to specific environmental sensitivities, and the potential for thermal barriers to limit fish movement in the estuary

- the interaction of oxygen concentration and temperature – warmer water at standard air pressure will hold less oxygen than it would at lower temperature – leads to the recommendation in waters where DO is less than 5mg DO l^{-1}, that the maximum allowable water temperatures should be reduced by 4ºC for every 1mg of dissolved oxygen per litre below 5mg DO l^{-1}.

- the interaction of temperature, dissolved oxygen levels, pH change and ammonia toxicity where there is potential for impact upon a protected feature or for the development of water conditions that create barriers to the passage of migrating or juvenile fish

- the effect of temperature increase upon the release and bioavailability of sediment contaminants.

Temperature standards may be applied both temporally and spatially and compliance assessed accordingly:

- temperature may be allowed to exceed a standard value within a given mixing zone from the point of discharge

- temperature may be allowed to exceed a standard value for a given period of time

- temperature may be allowed to exceed a standard value over a fixed area of a water body (this may apply to surface area and cross section).

Guidance on mixing zones that is more readily applied to tidal waters was finalised in 2010 (Common implementation guidance, on setting mixing zones, 2010) with a focus on chemical inputs. The principle of mixing zones acknowledges that a standard for a chemical or a physical parameter may be exceeded in a discharge, providing dilution is sufficiently rapid to avoid an impact upon the biology of the receiving water beyond the point of initial dilution. In this context, the footprint of a discharge for temperature in which a standard is exceeded could be considered equivalent to the mixing zone when the area potentially impacted meets good practice guidance on cross-sectional area, does not result in the failure of standards set in terms of overall temperature increase in a water body, and temperature elevation with respect to particular sensitivities does not impact upon a significant percentage of a given habitat type.

Table 1: Summary of legislation primarily triggered by the direct and indirect impacts of thermal plumes (prolonged elevated temperatures).

POTENTIAL ACTION BY POWER PLANT: Thermal Discharge				
Activity	**Measurement**	**Threshold**	**Consequence**	**Directive**
Thermal plume, increase in temperature	Temperature of surface water	Set against WFD status thresholds not > (defined value) for more than 5% of time	Temperature and DO part of the ecological classification. Potential to directly impact on the health of biological elements. Classification integrated into overall ecology. Failure of temp or DO results in failure of water body	WFD assessment from 2009. Will continue to 2030
Decrease in Dissolved Oxygen (DO)	DO monitoring (high frequency)	DO value no less than 4 mgl^{-1} for more than 5% of time		WFD assessment from 2009. Will continue to 2030
Fish behaviour, fish mortality	Sub-metrics under the fish classification scheme in WFD	Failure of ecological quality ratios (EQR) in the overall sub-metrics	Changes in fish behaviour relating to migration patterns and spawning are identified in the fish classification scheme. Change in fish species composition must relate to a pressure	WFD assessment from 2009. Will continue to 2030
Benthic invertebrates	Temperature effects on benthic invertebrates: Acute effects temperatures near lethal levels; Stress caused by short-term fluctuation; chronic effects exposure for significant period of life cycle BEEMS SAR008 v2		More information needed	
Change in phytoplankton community	Sub-metrics under the phytoplankton tools	Failure of ecological quality ratios (EQR) in the overall sub-metrics	Significant deviation in community composition is part of the normative definitions and will be identified in the phytoplankton classification tools	WFD assessment from 2009. Will continue to 2030
Impact on SAC biological element	Measurable change in a protected species or conservation area	Measurable change in features extent or condition	Measurable change in a species or conservation area could impact on the high conservation species or area by altering the site integrity	Habitats Directive

1.2.2.1 Thermal standards in transitional and coastal waters (TraC)

Under the Habitats Directive and the Water Framework Directive indicative thermal boundaries have to be established to protect the most sensitive taxa, which have been discussed and agreed with the Environment Agency and Natural England. Existing thermal guidelines have mostly been derived from data on fish (Table 2 and Table 3).

The Habitats Directive has no specific temperature requirements but requires that European protected habitats and species be maintained or restored with strict protection of Annex IV species.

In 2006 WQTAG 160,"Guidance on assessing the impact of thermal discharges on European Marine Sites" cited in Turnpenny and Liney, 2006 recommended interim thermal standards for assessing SAC/SPA sites in estuarine and coastal sites under the Habitats Regulations based upon standards contained within the Freshwater Fish Directive (summarised in Table 2). To avoid impacts on migratory species in line with international good practice it is also recommended that the mixing zone should not occupy more than 25% of the cross-sectional area of an estuarine channel as a 95th percentile (BEEMS Science Advisory Report SAR008 v2). Temperature uplifts at the edge of thermal plume mixing zones had been described in the Freshwater Fish Directive, with values of 1.5 – 3.0ºC, dependent upon the species being protected. In the review and development of temperature standards for marine and freshwater environments, Turnpenny and Liney (2006) recommend that "for water of high ecological status an uplift of 2ºC be applied". This value being consistent with that set as a maximum allowable temperature for the edge of the plume mixing zone for Special Areas of Conservation that include sensitive migratory species such as salmonids (Turnpenny and Liney, 2006).

Table 2: Recommended interim thermal standards in WQTAG 160 (2006), Turnpenny and Liney (2006), SAR 008 (2011) for assessing SAC/SPA sites (when a site is both a SPA and a SAC the most stringent apply).

Designation	Deviation from ambient	Maximum temperature
Special Protected Area	2°C as a Maximum Allowable Concentration (MAC) at the edge of the mixing zone	28°C as an annual 98 percentile at the edge of the mixing zone
Special Area Conservation (any designated for estuary or embayment habitat and/or salmonid species)	2°C as a MAC at the edge of the mixing zone Cross-sectional guidance ≤2°C 25 % of the estuary for 98% of the time	Not >21.5°C as an annual 98 percentile at the edge of the mixing zone[1]

Recommended thermal thresholds for SACs designated for estuarine or embayment habitat and/or salmonid species, apply absolute temperature thresholds of 21.5ºC as a 98th percentile (BEEMS SAR008 v2). These criteria are not applicable to fish assessments for the proposed development as salmonids are not designated features of the EMS within the ZoI of the thermal plume and the Southern North Sea SAC, directly adjacent to the proposed development is designated for harbour porpoise. As such, SPA absolute temperature criteria are applied.

The Water Framework Directive, WFD (2000/60/EC) is intended to provide a mechanism by which disparate regulatory controls on human activities that have the potential to impact on water quality may be managed in an effective and consistent manner. It supercedes the Freshwater fish directive which was repealed in 2013. UK TAG (2008a and b) produced draft standards for rivers that it was suggested could be used on an interim basis for transitional and coastal waters: Under this guidance, in order to achieve good status it is therefore necessary to ensure that maximum temperatures at the edge of the mixing zone do not exceed 23°C and that outside the mixing zone that temperature rises above ambient are limited to 3°C, Table 3.

Table 3: Recommended interim thermal standards in UK TAG 2008a and b for assessing sites under WFD.

Standard	High	**Good**	Moderate	Poor
Maximum temperatues (as an annual 98 percentile) allowed at the edge of the mixing zone	20°C	**23°C**	28°C	30°C
Deviation from ambient outside of mixing zone	2°C	**3°C**	3°C	3°C

1.2.2.2 *Interpretation of thermal standards for TraC waters*

The interim 2006 thermal guidelines for SACs were derived by transposition of thresholds in the Freshwater Fish Directive to marine waters without any substantial evidence base on their suitability. The 21.5°C was set as an absolute limit as a 98th percentile to protect SACs designated for estuarine or embayment habitat and/or migrating salmonid fish. Later recommendations. However, these criteria are not applicable to the Southern North Sea SAC designated for harbour porpoise. Absolute temperature thresholds for marine mammal sensitivity assessments consider SPA thresholds (28ºC as a 98th percentile). Turnpenny and Liney, 2006, based on a comprehensive review of temperature effects recommended that a cross sectional area criteria should be set to prevent thermal barriers to fish migration within river and estuarine channels. For fish species, a conservative thermal uplift of 3°C is considered a more appropriate avoidance threshold (BEEMS Technical Report TR483). Thus, 3°C will be taken into account for indirect effects.

In 2010 The Environment Agency issued "Guidance on Temperature Standards and Environmental Permit Requirments – informal guidance pending UKTAG decisions on TraC temperature standards". This document, which was intended to guide both EA staff and NNB developers, states that the Environment Agency will use the cold water UKTAG (WFD) standards of 2008 as the basis for determining conditions for environmental permits for cooling water discharges from new nuclear power stations. The document also states that "in addition to the draft WFD standards, other temperature standards may need to be considered in relation to conservation designations and specific conservation objectives"

Unlike chemical standards which normally have a clear evidence link to ecological effects, thermal standards are not always evidence based due to a lack of reliable data (BEEMS Scientific Advisory Report SAR008 v2). In order to be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis and, as such, they act as trigger values for further investigation of potential ecological effects.

BEEMS Scientific Advisory Report SAR008 v2 reviewed the available evidence on thermal effects and concludes:

> *"The available data confirms that adverse effects of CW outfalls are restricted to an area close to the plume, that temperature rises up to 3°C appear to be tolerable, and that resulting temperatures of less than 27°C have no clear deleterious impact on species in the receiving waters, but, in the longer term, changes in the local community may result as species with differing tolerances of elevated temperature show differing survival, growth and patterns of reproduction from those expressed under ambient conditions. Furthermore, populations that persist adjacent to a heated CW effluent will acclimate to those new local conditions and evolve in response to them"*

Two threshold values are recommended as trigger assessments for SPAs:

1. Temperature uplift ≤2˚C as a Maximum Allowed Concentration (MAC) at the edge of the mixing zone
2. 98th percentile of the absolute temperature ≤28˚C

The uplift criteria is defined as a Maximum Allowed Concentration. In ecotoxicity studies MACs are normally defined as 95th or 98th percentiles but the SPA uplift threshold is specified as a 100th percentile i.e. a maximum temperature value. This metric is, therefore, very dependent on how the observations or model simulations are done and the time period considered.

The absolute temperature standard for SPAs of ≤28°C as a 98th percentile does have a better evidence link as it is known than the upper lethal temperature for many benthic organisms is in the range 30-33°C (BEEMS Scientific Advisory Report SAR008 v2).

BEEMS Science Advisory Report SAR008 v2 prepared by the independent BEEMS Expert Panel presented evidence that the UKTAG 2008a and b WFD recommendations should be adopted for TraC waters with the single exception that the maximum temperature for High Status should be set at 23°C not 20°C.

Sizewell C modelling results in this report are assessed against the standards shown in Table 4.

Table 4: Water quality thermal assessment criteria applied in this report[1].

Designated Areas	Thermal thresholds (at the edge of the agreed mixing zone)
For SACs and SPAs	a.2006 WQTAG 160 interim guidleines for absolute and uplift temperatures (28°C[1] and 2°C respectively)
Special Area Conservation (any designated for estuary or embayment habitat and/or salmonid species)	b. the maximum cross sectional area criteria (estuaries should not be subject to temperature increase of >2°C across >25% of a cross section for >5% of the time).[2]
For WFD waterbodies	UKTAG 2008a and b cold water standards to achieve Good status of 23°C absolute[1] and 3°C uplift.

[1] Absolute temperatures from the GETM modelling cannot be reliably used as they produce overestimates. So more reliable prediction of 98th percentile absolute temperature can be derived at any location by adding the predicted mean temperature uplift due to the plume (i.e. the annual mean excess plume temperature) to the observed 98th percentile seawater background temperature;[2] Recommended thermal thresholds for SACs designated for estuarine or embayment habitat and/or salmonid species, apply absolute temperature thresholds of 21.5°C as a 98th percentile (BEEMS SAR008 v2). These criteria are not applicable to fish assessments for the proposed development.

1.2.2.3 *Dissolved oxygen*

The presence of dissolved oxygen at sufficient levels in all waterbodies including estuaries and coastal waters is essential to the survival and normal functioning of biological communities.

Oxygen depletion may occur over a number of timescales influenced by both seasonal and anthropogenic factors (Kemp *et al*. 2009). The solubility of oxygen varies with salinity, temperature and pressure (Garcia and Gordon, 1992) and an increase in water temperature will lead to a decrease in oxygen saturation. The other major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen. The proposed provisional Water Framework Directives standards for dissolved oxygen shown in Table 5 reflect these issues, while remaining generally compatible with previous recommendations. They are all 5th percentile, i.e. they should be exceeded for 95 % of the time.

The thermal influence of the Sizewell C cooling water discharge on the dissolved oxygen concentration and saturation of the relevant waterbody and habitats will be assessed with reference to the relevant standards that apply.

Table 5: Dissolved oxygen standards for transitional and coastal waters [from UKTAG, 2008a and b].

WFD Status	Freshwater 5%ile (mg l^{-1})	Marine 5%ile (mg l^{-1})	Description
High	7.0	5.7	Protects all life stages of salmonid fish
Good	5.0–7.0	4.0–5.7	Resident salmonid fish
Moderate	3.0–5.0	2.4–4.0	Protects most life stages of non-salmonid adults
Poor	2.0–3.0	1.6–2.4	Resident non-salmonid fish, poor survival of salmonid fish
Bad	2.0	1.6	No salmonid fish. Marginal survival of resident species

1.2.3 Chemical effects and standards

During construction of Sizewell C there will be activities that have the potential to release chemicals to the environment.

- Wastes produced in the early phase of construction when no route for marine discharge is available will be tankered off site for appropriate disposal
- Surface water drainage potentially containing contaminants from construction processes
- Effluent from potable supply and from the treatment of sewage (grey and black water respectively) by the on-site treatment works;
- Water containing trace levels of various contaminants pumped from both groundwater and excavations during construction dewatering activities.
- Wash water from cleaning concrete production equipment.
- Waste water from horizontal cooling water system tunnelling operations (during construction).

In addition, when the cooling water system is commissioned a range of tests will be conducted and conditioning of the entire plant will be undertaken with demineralised water and various chemical additives. This process will generate waste water containing several chemicals that will be discharged through the construction drainage system. Chemicals known to be present in the commissioning discharge effluent will need to be at sufficiently low level so that upon discharge and dilution in the marine environment the mixing zone within which there is exceedance of any EQS (or applied value), and that overlaps with waterbody and habitat designations, is sufficiently limited.

During operation of the power station large volumes of cooling water will be discharged through the main cooling water system. Waste chemicals from various operations will contribute to the discharge as will chlorine produced oxidants and by-products resulting from chlorination of the system to prevent biofouling. As for the construction discharge the mixing zone within which there is exceedance of any given EQS or applied value must be sufficiently limited.

1.2.3.1 Chemical standards of relevance to the site

Under the Water Framework Directive, chemical status is assessed by compliance with environmental standards for priority chemicals and other substances that are listed in the EC Environmental Quality Standards Directive (2008/105/EC) as amended by Directive 2013/39/EU (implemented by the Water Framework Directive (Standards and Classification) Directions (England and Wales, 2015) which increased the list of priority chemicals to 45. Chemical status is recorded as 'good' or 'fail'. The chemical status classification for the water body is determined by the worst scoring chemical.

For the Water Framework Directive, certain substances that are regarded as the most polluting were identified in 2001 as Priority Hazardous Substances by a Decision of the European Parliament and the Council of Ministers (Decision 2455/2001/EC). This first list of substances became Annex X of the WFD. This first list was replaced by Annex II of the Directive on Environmental Quality Standards (Directive 2008/105/EC) (EQSD), also known as the Priority Substances Directive and this was further updated in 2013, Directive 2013/39/EU. For Sizewell the relevant priority substances are cadmium, lead, mercury and nickel. Environmental Quality Standards (EQS) are determined at the European level, and these apply to all Member States.

For other substances, standards may be derived by each Member State, and they should lay down, where necessary, rules for their management. This list of compounds or Specific Pollutants is defined as substances that can have a harmful effect on biological quality, and which may be identified by Member States as being discharged to water in “significant quantities”.

EQSs are concentrations below which a substance is not believed to be detrimental to aquatic life. These were originally developed for the EC Dangerous Substances Directive (76/464/EEC). The concept is now well established and is incorporated into the Environmental Quality Standards directive(2008/105/EC) which is a daughter directive of the Water Framework Directive (60/2000/EC). EQSs are derived using acute toxicity tests on organisms at different trophic levels. To provide a safety factor, the EQS is set substantially below the concentration observed to have a toxic effect on the test organisms. EQSs vary for each substance and can be different for fresh, estuarine or coastal waters. They may also be adjusted for individual waterbodies dependent upon the level of other local factors such as dissolved organic carbon concentration.

In the marine environment both ammonia in its ionised NH_4 and un-ionised NH_3 form may contribute to toxicity although it is the un-ionised form that is the most toxic. Ammonia may be lost from water by volatilisation or under aerobic conditions may be oxidised to nitrite and then nitrate. Various water quality parameters influence the toxicity of ammonia mainly by increasing the proportion of the most toxic, unionsed, form of ammonia. The pH of seawater has the most influence on ammonia toxicity, increasing it by 1 unit (e.g. pH 7 to 8) at 10˚C produces about a 10 fold increase in NH_3 concentration while increasing the temperature by 10˚C (10 to 20˚C) approximately doubles the NH_3 concentration. Increasing salinity from 0.5 to 32 ppt at 10˚C reduces the NH_3 concentration by about 15% (Eddy, 2005). The influence of the thermal input from Sizewell C upon the relative proportion of unionsed ammonia present within a given area of the relevant associated waterbodies and habitats will also need to be assessed with reference to the relevant standard that applies.

Nutrient inputs from agricultural areas and sewage discharges can have significant effects upon estuarine and coastal waters. The major concern for increased inputs of nutrients mainly nitrogen (nitrate) and phosphorus (phosphate) is the enhanced growth of attached and planktonic plants which if it reaches excessive levels can lead to oxygen depletion. For this reason, under the Water Framework Directive, dissolved inorganic nitrogen (DIN) thresholds are set for classification of WFD waterbodies. The assessment of nutrient status considers waterbody turbidity as more turbid waters limit light penetration and the depth within which phytoplankton can readily grow. So, in more turbid conditions a higher DIN threshold may be considered to represent Good status as it is less likely to result in undesirable increases in plant growth relative to a waterbody that is less turbid. DIN measurements for a waterbody are normalised to a salinity of 32 for coastal waters to allow different waterbodies to be compared and to take account of the fact that nutrient concentrations generally decrease from areas closer inshore that are influenced by riverine inputs relative to those further offshore.

The dissolved inorganic nitrogen (DIN) value referenced in Table 6 is based on the 99th percentile of the winter DIN values for waterbodies of intermediate turbidity. The threshold value shown in Table 6 is based on the annual average suspended particulate matter (SPM) levels which mean that under WFD for the Suffolk coastal waterbody to be considered at good status it would need be below or equal to an associated threshold 99th percentile winter DIN values for coastal waters of 980µgl^{-1} for Good and 1470µgl^{-1} for Moderate status (Water Framework Directive Standards and Classification Directions, 2015). The Suffolk coastal waterbody has been classified as of moderate status for DIN (2013-2016, Environment Agency Catchment data explorer, 2019). However, regional sea area 2, the Southern North Sea (Defra, 2010) within which the area off Sizewell is included is not considered a problem area for eutrophication under the OSPAR common procedure (UK National Report, 2017).

To safeguard human health, legislative measures require the monitoring of faecal indicator organisms (FIO) concentrations in recreational and shellfish waters. The bathing water regulations (2013) classifies coastal bathing waters as of Good status based upon a 95%centile evaluation if intestinal enterococci are present at ≤200 colony forming units per 100ml sample volume and *Escherichia coli* are present at ≤500 colony forming units per 100ml sample volume. The Shellfish Water Protected Areas (England and Wales) Directions 2016 set standards for concentraion of FIO in shellfish flesh but the nearest shellfishery is over 40 kilometres South of Sizewell at Butley and so the focus was on bathing waters only.

There are no assigned marine EQS values for suspended solids, Biochemical Oxygen Demand (BOD) or petroleum hydrocarbons.

During the commissioning phase it is assumed that all Sizewell C conditioning chemicals will be discharged through the combined drainage outfall. All operational discharges will be via the cooling water system. For other chemicals likely to be present during these phases of development but for which there are no available EQS values a surrogate value has been derived. These chemicals include hydrazine, morpholine and ethanolamine. For the chemicals associated with the sequestering agents used in the demineralisation water plant (see BEEMS Technical Report TR193), there are currently no saltwater EQS or EDF validated PNEC values available. Therefore, ecotoxicity data (sourced from peer-reviewed publications and non-peer review literature such as industry reports) have been used with the recommended approach in the CIS guidance, 2003 to derive PNEC values that are used as environmental acceptance levels. The chemicals concerned are Amino tri-methylene phosphonic acid based sequestering agent (ATMP) or a sodium polymer-based compound (which comprises alkyl phosphonic acid and sodium polyacrylate). Breakdown products of alkyl phosphonic acid are acetic acid, phosphoric acid and Hydroxyethylidene Diphosphonic acid (HEDP). For some substances where no toxicity data can be sourced discharge concentrations are compared to environmental backgrounds identified during recent monitoring work (BEEMS Technical Reports TR189 and TR314). EQS or surrogate values used as environmental assessment levels are shown for all substances in Tables 45 and 46.

Table 6: Marine water quality standards referenced in assessment of planned discharges during the Sizewell C development – these represent Environmental Quality Standards (EQS) for other surface waters (TraC Waters) for priority hazardous substances and other pollutants (Directive 2013/39/EU) and for specific substances (Defra, 2014).

Determinands	WFD EQS Annual average values ($\mu g l^{-1}$)	WFD EQS Maximum Allowable Concentration (MAC) values (as 95 percentile) ($\mu g l^{-1}$)
Cadmium and its compounds (PS)	0.2	1.5
Lead and its compounds (PS)	1.3	14
Mercury and its compounds (PS)	-	0.07
Nickel and its compounds (PS)	8.6	34
Chromium VI (dissolved) (SP)	0.6	32
Arsenic (dissolved) (SP)	25	Not applicable
Copper (dissolved) (SP)	3.76 (2.677 x ((DOC/2) - 0.5)) $\mu g l^{-1}$ dissolved, where dissolved organic carbon (DOC) > $1 mg l^{-1}$	Not applicable
Iron (dissolved) (SP)	1000	Not applicable
Zinc (SP)	6.8 (plus ambient background 1.1 in salt water)	Not applicable
Boron (Total)	7000 (pre Water Framework recommended standard)[1]	-
Chlorine (SP)	-	10
Un-ionised ammonia (NH_3) (SP)[2]	21	-
Winter dissolved inorganic nitrogen (DIN)		980[3]
Escherichia coli		≤500 colony forming units/100ml[4]
Intestinal enterococci		≤200 colony forming units/100ml[4]

PS priority substance and SP – specific pollutant; 1 Mance et al. 1988; 2 Total ammonia values of 1100 (annual average) and 8000µg/l NH4-N are also recommended for habitats consideration (WQTAG086, 2005). 3 99% (70µmol) standard for period 1st November – 28th February for dissolved inorganic nitrogen for Good status for a waterbody of intermediate turbidity (between 10<$100 mg l^{-1}$ suspended particulate matter) Appendix B. It should be noted that a more specific methodology for deriving 99th percentile values based on a relationship between SPM and DIN is recommended in draft Environment Agency guidance and for an annual average SPM of 55.2 $mg l^{-1}$ would give a slightly lower value of $952 \mu g l^{-1}$ as a 99th percentile but the screening here would only slightly change. 4 This assessment is from bathing water regulations (2013. No. 1675) for coastal and transitional waters and represents Good standard

1.2.4 Marine Sediment standards

During the construction and operational phases of Sizewell C there are several proposed seabed disturbance activities include dredging, piling installation, anchoring of vessels, vessel movements (tug boat manoeuvring) and scour. Sediments act as a net sink for anthropogenic contaminants in marine ecosystems and contaminated sediments may have a range of toxicological effects on benthic fauna and associated species (Roberts, 2012).

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. These contaminant disposal limits are regulated in England by the Marine Management Organisation under the Marine and Coastal Access Act 2009. The aim of these limits is to prevent accumulation of high levels of contamination in offshore sediments and to avoid direct toxic effects on marine flora and fauna. Levels of contamination in dredged sediment are assessed against Cefas Action Levels (OSPAR, 2008). The Canadian Interim Sediment Quality Guidelines (ISQGs), although not specific to the UK are commonly also used to assess sediment quality.

The marine water chemical standards ensure that any pollutants discharged do not increase the contamination of sediments above a toxic level. This is because, the EQS for a substance is set substantially below the concentration observed to have a toxic effect on the test organisms.

1.2.4.1 Cefas Action Levels

Cefas Action Levels are used as part of a 'weight of evidence' approach to assessing dredged material and its suitability for disposal to sea. These values are used in conjunction with a range of other assessment methods e.g. bioassays, as well as historical data and knowledge regarding the dredging site, the material's physical characteristics, the disposal site characteristics and other relevant data, to make management decisions regarding the fate of dredged material. The Cefas Action Level limits for contaminants are shown in Table 7, these were set in 1994.

Table 7: Cefas Action Levels in sediments (MMO, 2015a).

Contaminant or compound	Action Level 1 (mg/kg dry weight (ppm))	Action Level 2 (mg/kg dry weight (ppm))
Arsenic	20	100
Mercury	0.3	3
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200
Lead	50	500
Zinc	130	800
Organotins (TBT, DBT, MBT)	0.1	1
PCBs – sum of ICES 7	0.01	None
PCBs – sum of 25 congeners	0.02	0.2
PAHs	0.1	None
DDT	*0.001	
Dieldrin	*0.005	

Sediment contamination is assessed as follows:

- Below Cefas Action Level 1 limit - In general, contaminant levels in dredged material below Cefas Action Level 1 are of no concern and are unlikely to influence the licensing decision.
- Between Cefas Action Level 1 and Cefas Action Level 2 limits - Dredged material with contaminant levels between Cefas Action Levels 1 and 2 requires further consideration and testing (where appropriate) before a decision can be made.
- Above Cefas Action Level 2 limit - Dredged material with contaminant levels above Cefas Action Level 2 is generally considered unsuitable for sea disposal.

1.2.4.2 Canadian Interim Sediment Quality Guidelines

The Interim Canadian Sediment Quality Guidelines (ISQGs), although not specific to the UK are commonly used to assess sediment quality. The guidelines were developed by the Canadian Council of Ministers of the Environment as broadly protective tools to support the functioning of healthy aquatic ecosystems (CCME, 2001). They are based on field research programmes that have demonstrated associations between chemicals and biological effects and supplementary data derived from spiked sediment toxicity studies.

The guidelines consist of threshold effect levels (TELs) and probable effect levels (PELs), these are shown in
Table 8. The TELs and PELs are used to identify the following three ranges of chemical concentrations based on biological effects:

- Below TEL - Minimal effect range within which adverse effects rarely occur.
- Between TEL and PEL - Possible effect range within which adverse effects occasionally occur.
- Above PEL - Probable effect range within which adverse effects frequently occur.

Table 8: Canadian Sediment Quality Guidelines (CCME, 2001).

Substance	Units	ISQG/TEL	PEL
Metals			
Arsenic	mg.kg-1	7.24	41.6
Cadmium	mg.kg-1	0.7	4.2
Chromium	mg.kg-1	52.3	160
Copper	mg.kg-1	18.7	108
Lead	mg.kg-1	30.2	112
Mercury	mg.kg-1	0.13	0.7
Zinc	mg.kg-1	124	271
Polychlorinated byphenyls (PCB)			
PCBs: total PCBs	mg.kg-1	21.5	189
Polyaromatic hydrocarbons (PAH)			
Acenaphthene	µg.kg-1	6.71	88.9
Acenaphthylene	µg.kg-1	5.87	128
Anthracene	µg.kg-1	46.9	245
Benz(a)anthracene	µg.kg-1	74.8	693
Benzo(a)pyrene	µg.kg-1	88.8	763
Chrysene	µg.kg-1	108	846
Dibenz(a,h)anthracene	µg.kg-1	6.22	135
Fluoranthene	µg.kg-1	113	1494
Fluorene	µg.kg-1	21.2	144
2-Methylnaphthalene	µg.kg-1	20.2	201
Naphthalene	µg.kg-1	34.6	391
Phenanthrene	µg.kg-1	86.7	544
Pyrene	mg.kg-1	153	1398

1.2.4.3 Radionuclides in sediments

The UK government is a signatory to the London Convention (1972)[1] that prohibits the disposal of radioactive material at sea unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA). If both the following radiological criteria are satisfied:

- The effective dose expected to be incurred by any member of the public or ship's crew is of the order of 10 µSv or less in a year.
- The collective effective dose to the public or ship's crew is not more than 1 man Sv per annum

Then the material is deemed to contain *de minimis* levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under the Convention. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 µSv/a (Cefas, 2006).

1.2.4.4 Marine suspended sediments standards

In the UK there are no standards for levels of suspended sediment in TraC waters. The Marine Life Information Network (MARLIN) (Tyler-Walters *et al.* 2017) identified benchmark definitions of change in suspended particulate matter that are used as supporting information for Water Framework Directive assessment of nutrient status of a waterbody (Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015). There are four WFD Waterbody 'Types' defined by annual mean concentration of suspended particulate matter (see Appendix B). The benchmark for suspended sediment is a change from one waterbody type for a period of one year.

Construction activity that disturbs marine sediment is normally regulated to minimise potential effects on marine ecology via sedimentation (i.e. potential smothering of sensitive benthic ecology) and potential remobilisation of any contaminants in the sediments. Consideration of potential effects on mobile organisms (e.g. fish) is not usually a regulatory focus as it is assumed that such organisms are able to avoid suspended sediment plumes. However, in coastal areas within the foraging range of protected birds the potential effects of increased suspended sediments on the bird prey needs to be considered. In practice such an assessment has to consider the increase in suspended sediment and the duration of such events in the context of the natural variability of the suspended sediment climate at the site.

1.2.5 Outline of what is covered in this synthesis report

This synthesis presents the evidence behind, and the effects of, the construction, commissioning and operation of the proposed Sizewell C development on marine water and sediment quality. Only the specific information for the effects of the development are included in this report. References to the underlying detailed scientific works are included if further detail is needed. As this report focuses on the absolute areas where a standard or applied value is exceeded there will be no assessment of the significance of in combination effects at this stage. The remainder of this report is divided into the following sections:

- Description of the water and sediment quality of the greater Sizewell Bay;
- Description of the marine components of the proposed Sizewell C development;
- Potential effects of the development on marine water and sediment quality

In December 2016, the Environment Agency released new guidance on how to assess the impact of any activity in transitional and coastal waters, "Clearing the Waters for All". The process consists of three stages (screening, scoping and impact assessment). For the planned Sizewell C this report considers each of the three assessment stages for the discharges to the marine environment during construction, commissioning and operation.

[1] Available from: http://www.imo.org/en/OurWork/Environment/LCLP/Documents/LC1972.pdf

2 Description of the Water and Sediment Quality of the Greater Sizewell Bay

2.1 Aim

This section summarises the baseline water quality of the greater Sizewell Bay, for the proposed Sizewell C marine development. For a detailed description of the baseline water quality at Sizewell reference should be made to BEEMS Technical Reports TR189 and TR314. Work undertaken that relates specifically to effects of the Sizewell C development on the marine environment is listed in the subsequent sections.

2.2 Feeder Reports

The Sizewell water quality synthesis is primarily based on information gathered by Cefas under the BEEMS marine evidence programme (the BEEMS Technical Reports, or ‘feeder reports’). For this synthesis the key BEEMS reports and their interrelationships are shown in Figure 2.The reports forming the basis of the assessments are those of the marine water quality series produced between 2014 and 2016, the coastal geomorphology and hydrodynamics synthesis and selected modelling reports. These, in turn, reference earlier BEEMS Technical Reports containing detailed methods and data analyses from the BEEMS surveys, experiments and modelling.

The main BEEMS feeder reports are:

- Sizewell coastal geomorphology and hydrodynamics synthesis. Technical Report TR311.
- Sizewell Thermal Plume Modelling: GETM Stage 3 results with the preferred Sizewell C cooling water configuration. Technical report TR302.
- Sizewell Chemical Plume Modelling: TRO, CBP’s, Hydrazine, DO and Ammonia. Technical Report TR303
- Sizewell C Discharges H1 Type assessment - supporting data report. Technical Report TR193.
- Sizewell Water Quality Literature Report. Technical Report TR131.
- Sizewell Marine Sediment Quality Report. Technical Report TR305.
- Sizewell supplementary water quality monitoring data 2014/2015. Technical Report TR314.
- Sizewell Marine Water Quality Monitoring Final Summary Report. Technical Report TR189.

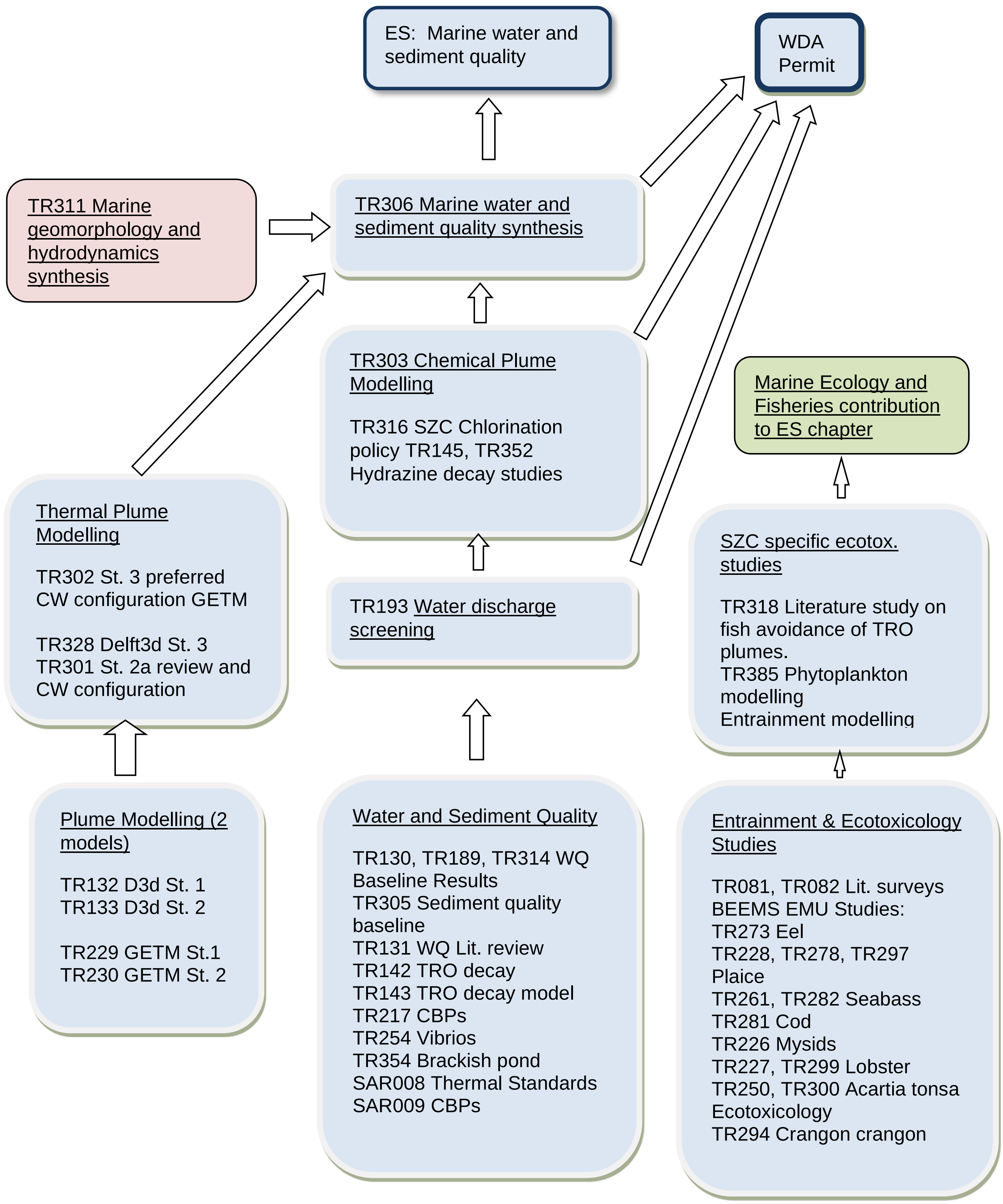

Figure 2: Feeder Reports.

2.3 Water Quality of the Greater Sizewell Bay

Supporting data used in this assessment are derived from four main sources. Historic data relating to marine water quality were sourced from the scientific literature. Most of the data from this source focussed on the quality of estuaries discharging into the Suffolk coastal waterbody. Data on coastal sea surface temperatures were collated into time-series over 48 years based on data provided on behalf of Cefas, by councils, companies and other organisations. In addition, water quality data were obtained from Environment Agency surveys. Finally new data were obtained from a Cefas monitoring programme focussed on current and planned cooling water discharge locations off Sizewell. The temperature and monitoring data are reported in detail in BEEMS Technical Report TR131 Sizewell Water quality literature review. As the data extracted from the scientific literature do not specifically focus on the Suffolk waterbody most reliance in the following sections is placed on the other data sources.

2.3.1 Historic data

2.3.1.1 Temperature data

Temperature records from sources relevant to the Sizewell power station have been collated into time-series for the previous 48 years. Individuals on behalf of Cefas, councils, companies and other organisations have obtained records of coastal sea surface temperatures, for some stations, of more than 100 years duration. Approximately half of the stations started recording coastal temperatures in the mid 1960s. Datasets include records for Lowestoft, Southwold, Sizewell Power station. Near surface temperature and salinity samples have also been collected by ferries. Based on the range of temperature data for these four locations in the Suffolk coastal waterbody from 1963 – 2013, yearly averages were derived from those years which have a complete set of monthly values. Monthly mean sea temperatures for the four sites used to derive temperature information and for which years are shown in Figure 3.

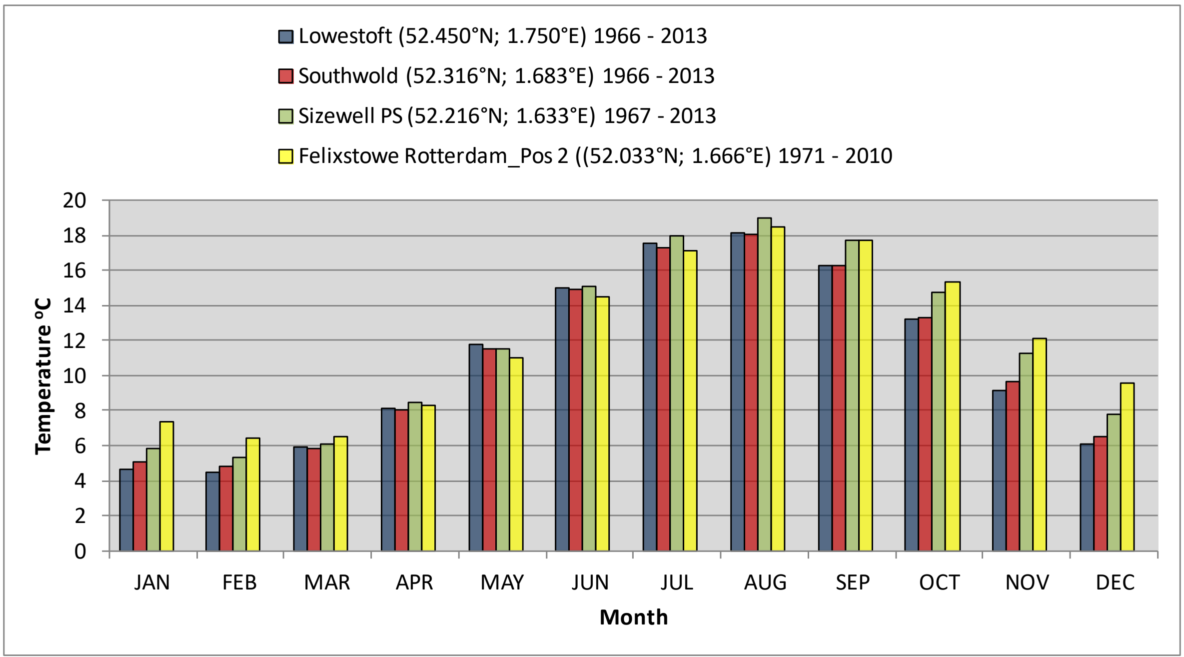

Figure 3: Monthly mean Sea Temperatures (°C) for four locations in the Suffolk coastal water 1966 -2013 (BEEMS Technical Report TR131).

The main concern regarding water temperature elevation from cooling water input to suffolk coastal water is that exceedance of specific standard values may result, or there may be an impact on the biology to the extent that (as this area is classified as heavily modified based on coastal protection) good ecological potential cannot be attained under the Water Framework Directive, or that protected species or habitats are impacted. Taking account of the recent temperature data covering the five year period between 2009 -2013 the 98 percentile is 19.4°C. Elevation of receiving water temperature due to the discharge of cooling water from Sizewell C is considered in relation to this value.

2.3.1.2 Contaminant concentrations

This section describes Environment Agency monitoring surveys for compliance and therefore the sites chosen, type of analysis and detection limits are set in this context. The data for dissolved metals cover the period 1989 to 2006 and include data for sites from off Felixstowe to just off the river Yare (Figure 4). Four of the nine locations sampled in the original survey are within the Suffolk coastal waterbody and these are referred to below.

Nutrients and inorganics data include samples collected between 1983 and the early part of 2014. The EQS are derived from Directive 2013/39/EU as regards priority substances, cadmium, lead, nickel and mercury. For the concentrations of metals in seawater in the historic dataset from various sites within the Suffolk waterbody only zinc exceeded its EQS at locations Off the Alde/Ore although high values were also measured in samples Off Dunwich. There is no clear trend in concentrations measured and values below detection are interspersed with high values.

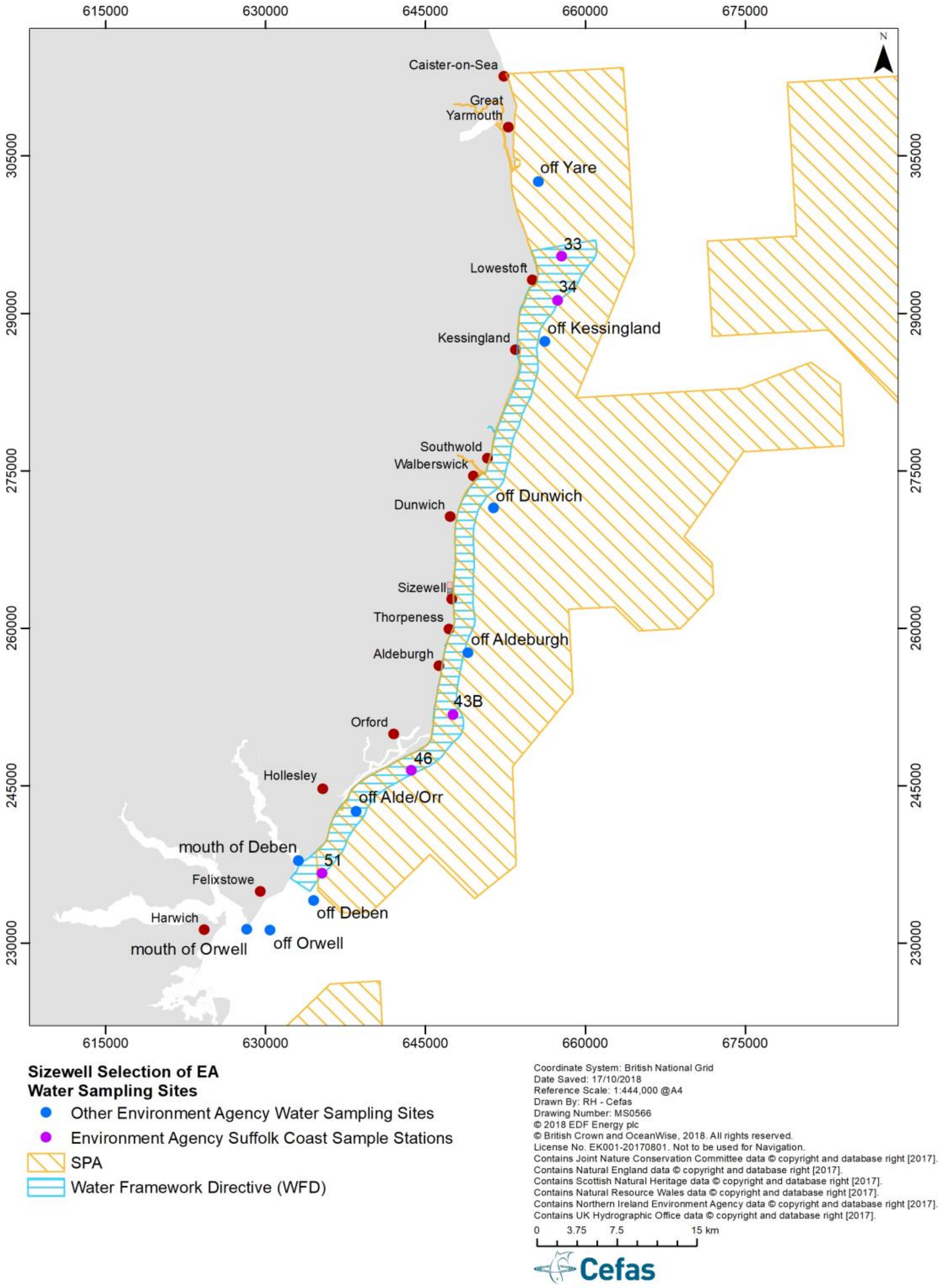

Figure 4: Environment Agency (EA) sampling stations shown in relation to Sizewell Power Station. The numbered sample locations are the Suffolk Waterbody sampling points and the Suffolk Waterbody is delimited by the green hatched area near to shore. The brown hatched area - upper part of the Outer Thames Estuary SPA. Other EA sampling points - blue circles. The red dots are geographical locations.

2.3.2 BEEMS water quality monitoring data

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 a range of time scales. The initial programme ran from February 2010 to February 2011, and the results are presented in BEEMS Technical Report TR189. Further monitoring surveys were conducted in 2014-2015 (BEEMS TR314). This latter survey allowed more reliable data to be collected for nutrients and some metals (detection limits were not adequate for these parameters in earlier work). However, the tidal cycle surveys in the earlier work in 2010 and 2011 provides a useful perspective of daily variation in physicochemical parameters in the marine environment off Sizewell. Sampling was organised to establish the variability in analyte concentrations over several different
spatial and temporal scales (BEEMS Technical Report TR189):

- A spatial survey acquired surface and near-bed water samples from 12 stations (Figure 5) extending approximately 12 km to the north and south of the Sizewell B cooling water outfall and 3 km offshore. Maximum concentrations of compounds from the cooling water are expected to be found in surface waters due to the thermally buoyant nature of the outfall plume. Surface waters were therefore intensively sampled. To ensure that the full water column was investigated, certain stations were selected for the acquisition of near-bed samples in addition to surface water samples.
- A tidal cycle survey acquired hourly surface water samples from a vessel anchored as close as possible to the cooling water outfall (Station 5) during an ebb/flood cycle on spring tide conditions.
- A seasonal survey acquired surface water samples at the cooling water outfall (Station 5) and a reference site (Station 11) at intervals of approximately two weeks from February 2010 to February 2011.

The required sample analyses were subcontracted to several accredited UK and European laboratories. Conductivity, temperature and depth sensor (CTD) profiles showed that the waters sampled were well mixed regarding salinity. The temperature profiles indicated the presence of a thermally buoyant plume of water at the sea surface. Many of the chemical analyses gave negative results, indicating that the analytes were either absent or present at concentrations below the limits of detection. There were few differences between results from inshore of Sizewell Bank (stations 1 to 9) and offshore (stations 10 to 12).

Concentrations of dissolved copper, arsenic, zinc, mercury and cadmium exceeded EQS levels on occasions. Some exceedance of the Environmental Quality Standard (EQS) concentrations for these metal and 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 polycyclic aromatic hydrocarbons (PAHs), biphenyl and bis (2-ethylhexyl) phthalate (DEHP), 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. These exceedances of organic EQSs were observed in samples acquired on three sampling dates: 7th and 8th April and the 19th May 2010.

Total residual oxidant (TRO) concentrations varied between 0.01 and 0.16mgl^{-1}. The EQS for TRO is 0.01mgl^{-1} (10μgl^{-1}). The mean of all TRO measurements (n = 725) was 0.04mgl^{-1}, with a value of 0.01mgl^{-1} (half the limit of detection) used to represent negative results. Slight localised elevation of TRO was observed near the Sizewell B 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 was 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.

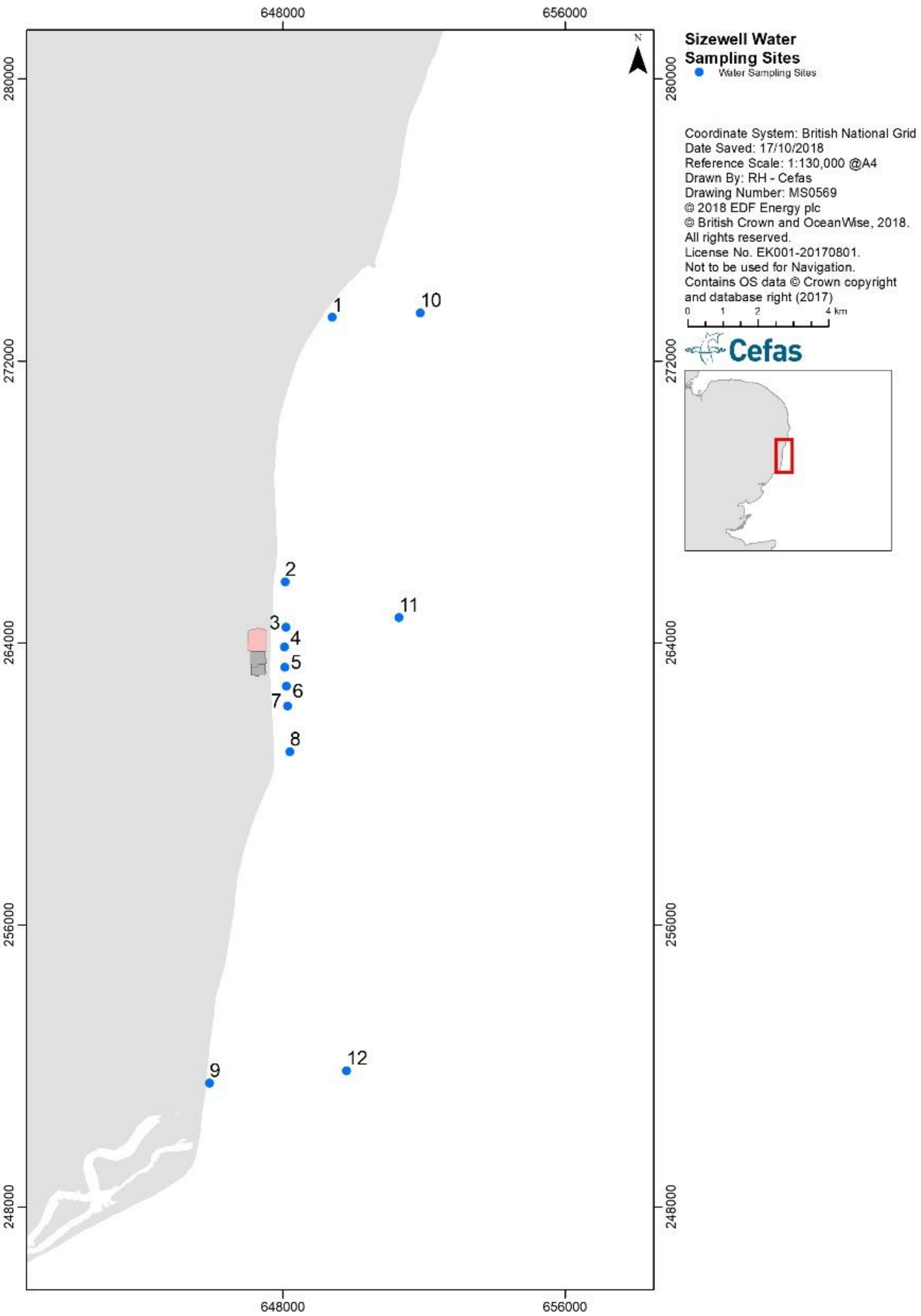

Figure 5: Location of the BEEMS sampling sites in the 2010 Sizewell water quality monitoring programme.

Analysis of some samples indicated the presence of Hydrazine (N_2H_4), an ammonia-derived compound that is an oxygen scavenger and is used in power plants to inhibit corrosion in steam generation circuits. Hydrazine is used to condition the secondary circuit of PWR power stations and is also used in the primary circuit during start up. However, doubts about the validity of the ultraviolet-visible spectrophotometry results, based on the limits of quantification of the technique and potential interference, led to the use of an alternative analytical method. For the final three months of the programme a gas chromatography mass spectrometry (GC-MS) technique was used on water samples to measure hydrazine concentrations in addition to the spectrophotometric technique. The GC-MS technique was far more sensitive and indicated that hydrazine concentrations were generally below the limit of detection ($0.01 µg l^{-1}$). Prior hydrazine results are therefore not considered valid.

Three positive results above the limit of detection were also obtained from morpholine analyses conducted on water samples from stations 5 and 11. However, morpholine is not used by Sizewell B power station and as morpholine does not occur naturally and only relatively few positive values were obtained with no obvious pattern or trend it is unclear the origin of these elevated values.

No other concentrations of environmental concern were measured in the analyses carried out on water samples acquired at stations 5 and 11. All radionuclide concentrations measured in seawater samples were very low and were consistent with routine local radionuclide monitoring by the Environment Agency.

The results of the marine water quality monitoring programme (BEEMS Technical Report TR189) show that the concentrations of many elements and compounds are relatively uniform in the programme area. A small percentage of the samples acquired indicate that EQSs may occasionally be exceeded, but there is no indication that these are caused by the Sizewell B power station.

The measured ammonia concentrations from the 2009/10 water quality monitoring programme reported in BEEMS Technical Report TR189 were subsequently regarded as suspect and found not to agree with WFD measurements undertaken by the Environment Agency in the Suffolk coastal waterbody (but with no measurements taken in Sizewell Bay) which indicated mean ammonia values of approximately 20 - $27 µg l^{-1}$ NH_4-N (BEEMS Technical Report TR131) compared to a mean value of $420 µg l^{-1}$ NH_4-N reported in TR189. A subsequent monitoring programme was undertaken from February 2014 to January 2015 to provide additional data primarily for nutrients (including ammonia) but also to supplement information on metals concentrations in seawater, water temperature, salinity, dissolved oxygen and levels of chlorine produced oxidants present as a result of the existing Sizewell B discharge (BEEMS Technical Report TR314). Sampling was conducted spatially over 4 sites in the Sizewell area and temporally over two annual seasonal cycles.

Except for zinc, the mean measured concentrations of all the metals in the water samples were below their respective environmental quality standards.

Under the Water Framework Directive, the 99^{th} percentile winter dissolved inorganic nitrogen (DIN) ($425 µg l^{-1}$, or $30.36 µmol\ l^{-1}$) value was within an acceptable range for waterbodies of intermediate turbidity. The mean phosphate concentration was relatively high ($33.48 µg l^{-1}$, $0.35 µmol\ l^{-1}$) but will be considered as a site background also in the context of the local suspended particulate levels. Ammonia concentrations were relatively low and mean and 95 percentile values together with relevant pH, salinity and temperature data will be used to derive the background concentration of un-ionised ammonia as part of the discharge assessment.

Most of the chlorine produced oxidant concentrations measured (over 80%) were $\leq 0.04 mg l^{-1}$. Unsurprisingly samples taken from the outfall at Sizewell B show the highest values.

For the monitoring studies reported in TR314 dissolved oxygen concentrations were between 6.96 and 11 $mg\ l^{-1}$ which was well above the requirement for High status ($5.7 mg l^{-1}$). Lowest measured values were in summer with 6.96 -7.04 $mg\ l^{-1}$ recorded in July 2015.

2.4 Sediment Quality of the Greater Sizewell Bay

Sediments act as a net sink for anthropogenic contaminants in marine ecosystems and contaminated sediments may have a range of toxicological effects on benthic fauna and associated species (Roberts, 2012). There are no statutory thresholds in order to assess the quality of marine sediment in the UK, however the levels of contamination in dredged sediment are assessed against Cefas Action Levels in order to help reduce any impacts (OSPAR, 2010). These contaminant disposal limits are regulated in England by the Marine Management Organisation under the Marine and Coastal Access Act 2009[2]. The Interim Canadian Sediment Quality Guidelines (ISQGs) provide supporting information on sediment quality, however they are not specific to UK and are not regulated by the Marine Management Organisation under the Marine and Coastal Access Act 2009.

As part of the Sizewell C 2015 geotechnical survey (Fugro, 2015) that collected vibrocores from a number of locations samples were taken from a subset of 14 vibrocores at or close by areas likely to be dredged (

Figure 6) that were analysed for chemical and heavy metal contaminants; 5 of those cores were also sampled for radionuclide composition. Sediment samples were analysed by various laboratories (sampling and analytical methods described) for the following contaminants:

- Heavy metals and insecticides – Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), Zinc (Zn), DDT and Dieldrin.
- Organotin and Particle size – Monobutyl-tin (MBT), Dibutyl-tin (DBT), Tributyl-tin (TBT) and Particle Size Analysis (PSA).
- Organic and chlorinated compounds – Polyaromatic Hydrocarbons (PAHs), Total Hydrocarbon Content (THC) and Polychlorinated biphenyls (PCBs).
- Radionuclides.

The sediment samples collected at Sizewell indicate that organotin and some heavy metals were below Cefas Action Level 1 (Table 5.12) 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 ISQG PEL concentrations (Table 9). 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). High levels of arsenic have been reported in the region under similar studies (for example see Galloper Wind Farm Limited 2015). 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 representative of the natural geology and not anthropogenic contamination.

PCBs and organotin were below detection levels in most samples and where detected were considerably below the relative Action Level 1. The results from the sediment quality data analysis, show that the material is likely to be acceptable for disposal to sea based on the Cefas Action Levels for each determinand.

Based on the Canadian ISQGs, there are some areas that are in the probable effect range within which adverse effects occasionally occur on biota from several determinands. The results show that there are areas where the sediment is in the probable effect range within which adverse effects may occur on biota from arsenic (VC 18 at 2.00 – 2.20 m and VC 30 at 5.00 – 5.20 m) and dimethyl naphthalene's (in eleven samples) (see Table 9). T The vibrocore 30 location with arsenic above the probable effect range coincides with the proposed BLF access channel (Figure 6). As the levels of arsenic found across the site are below Cefas AL2, there is a low risk of bioavailable contaminants and the material is likely to be deemed acceptable for disposal to sea.

Figure 6). The naphthalene concentration was elevated above Cefas Action level 1 and also exceeded PEL in several samples but the levels determined are comparable with location background concentrations typically found in this area (0.932 $mgkg^{-1}$ for naphthalene, Kelly *et al.* 2002) and as the ISQG is a conservative value, there is not a concern in relation to PAH contamination. A further method to examine PAHs in marine sediments involves assessing levels of grouped PAHs based on their origin and effects characteristics, to published effects ranges. Hydrocarbons can be grouped into low molecular weight (LMW) and high molecular weight compounds; LWM 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. HMW are typically derived from 'pyrolytic' sources (e.g. burning of fossil

[2] Available from: http://www.legislation.gov.uk/ukpga/2009/23/contents

fuels) they are more pervasive. with low volatility, are often bound to particulates in air or sediment and are more persistent in the environment. Effects ranges typically used for assessment include the ‘effect range low’ (ERL) and the effects range medium (ERM). Effects on biota at concentrations below the ERL are rarely observed however at levels above the ERM effects are generally or always observed. The ERL and ERM values for LWM and HMW PAHs are given in (Buchman, 2008) as; 552ng/g (ERL) and 3,160ng/g (ERM) for LWM and 1,700ng/g (ERL) and 9,600 (ERM) for HWM. All values for the sediment samples were below the relative ERM values and all expect two samples were below the ERM values. Samples VC10 (surface) and VC24 (surface) marginally exceed the ERL for LWM PAHs (levels of 725ng/g and 793 ng/g respectively), however these exceedances are marginal and the ERL should be considered a low point on a continuum of possible effects, furthermore these two locations represent the highest proportions of fines in the surface sediments and therefore can be expected to adsorb relatively higher levels of organic compounds compared to coarser sediments.

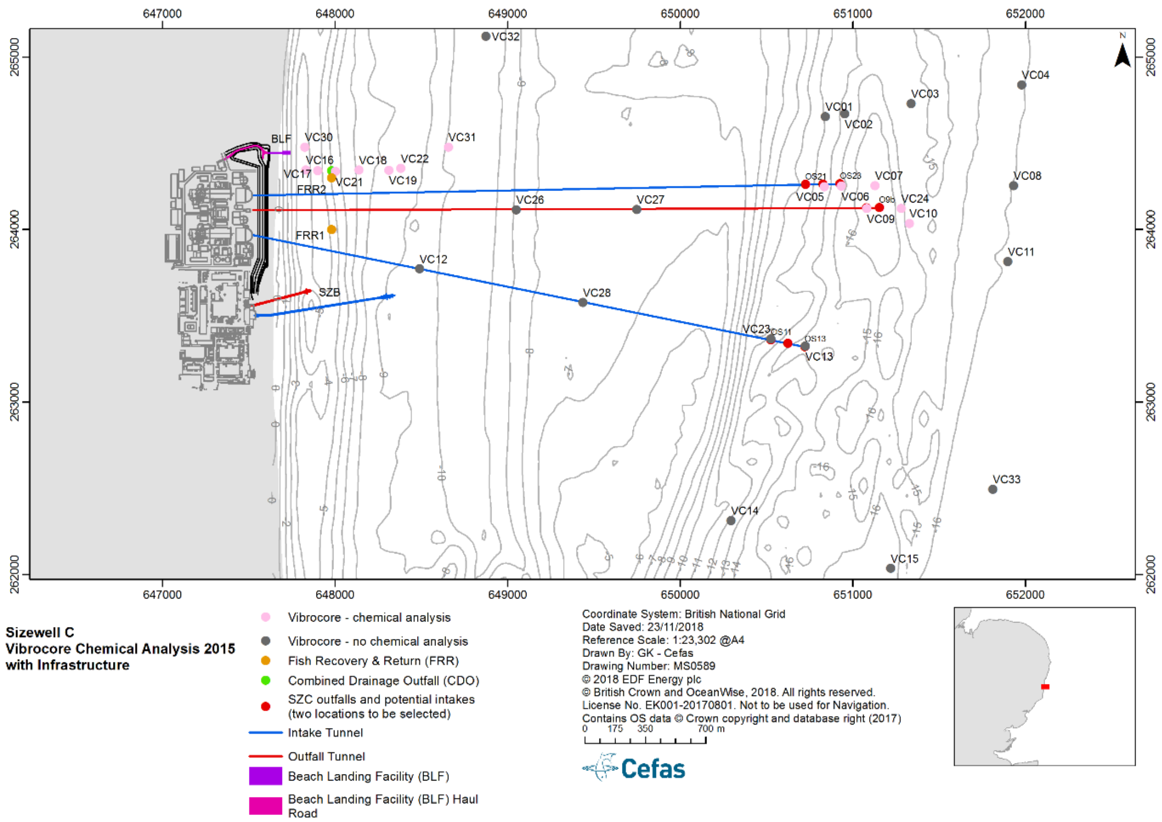

Figure 6: Position of Sizewell C 2015 vibrocore sampling stations from the geotechnical survey and selected cores from which samples were taken for chemical analysis in relation to Sizewell C infrastructure.

Table 9: Vibrocore results in the probable effect range within which adverse effects may occur on biota, based on Canadian ISQGs.

Sample	Depth (m)	As*	dimethyl naphthalenes*
		$mgkg^{-1}$	$mgkg^{-1}$
Cefas AL1		20	0.1
Cefas AL2		100	
Canadian TEL		7.24	0.0202
Canadian PEL		41.6	0.201
VC18	2.00 - 2.20	84.7	
VC30	5.00 - 5.20	91.5	
VC05	0.00 - 0.20		0.227
VC05	3.00 - 3.20		0.224
VC07	0.00 - 0.20		0.39
VC09	0.00 - 0.20		0.274
VC10	0.00 - 0.20		0.369
VC10	2.00 - 2.20		0.342
VC17	2.00 - 2.20		0.263
VC21	2.00 - 2.20		0.252
VC24	0.00 - 0.20		0.631
VC30	3.00 - 3.20		0.22
VC30	4.00 - 4.20		0.237

The radionuclide results show that radionuclide concentrations in marine sediment at Sizewell are low (with many values below the limit of detection) and consistent with routine local radionuclide monitoring (Environment Agency *et al*. 2015). *The action levels and Canadian TEL and PEL are colour coded to show which sediment locations and contaminants are at a given action level or TEL/PEL.

The analysis of contaminants from the core samples indicates 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 could be anticipated. 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. The locations of elevated arsenic are >160m from the currently proposed dredging site (FRR2), dredging at this site is expected to cover a footprint of 9m by 23m, and therefore it is currently considered unlikely that these sediments would be disturbed by the proposed works. Furthermore, the acceptability of material for dredging and disposal will require a contemporary assessment at the time of dredging which will consider the specific details of the dredging requirement and, if necessary, obtain and interpret new sediment samples

The sediments are therefore considered to be uncontaminated and the effects of resuspension of contaminants on marine ecology receptors is not considered further.

Particle size analysis (PSA) 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) Particle Size Analysis (PSA) results show that most of the samples (79 %) are comprised mainly of sand (approximately 65 – 99 % sand).

Therefore, due to the sandy nature of the material and levels of contamination below Cefas AL2 found in the marine sediment at Sizewell, there is a low risk of bioavailable contaminants. The Sizewell results are consistent with the results of the UK National Marine Monitoring Programme (Cefas, 2004), which did not identify any areas off the Suffolk coast that had high levels of contamination.

2.4.1 Suspended sediment concentration in Sizewell Bay

Sediments in sea water are the result of both natural processes (e.g., coastal erosion, catchment runoff and resuspension of sea bed sediments) and human activities (e.g., fishing, shipping, aggregate extraction, dredge disposal, marine construction). The amount of sediment in sea water, or 'turbidity', is one of several factors that define coastal ecosystems and the organisms that can survive there. Several monitoring studies have measured the suspended sediment regime off Sizewell (BEEMS Technical Reports TR189, and Dolphin, Silva and Rees, 2011 for a project evaluating natural sediment variability in Regional Environmental Assessment areas in the North Sea and English Channel. From satellite data for the period 1/7/2002 to

31/5/2010 monthly mean, maximum and standard deviation of suspended particulate matter (SPM) were derived. SPM data showed an average mean value at Sizewell during April to August of 31mgl^{-1}(and average monthly maximum 80mgl^{-1}) and during September to March 73mgl^{-1}(and average monthly maximum 180mgl^{-1}). An annual mean SPM for these data was 55.3mgl^{-1}. The data had previously been compared with measurements of turbidity from research cruises and the Cefas SmartBuoy network for several UK coastal and offshore sites and showed a good correlation. With reference to the suspended sediment levels associated with WFD nitrogen standards (Appendix B) and based on the satellite data and previous monitoring surveys Sizewell is classed as of intermediate turbidity. Additional surveys of suspended particulate matter conducted over a tidal cycle at Sizewell in July and August showed a mean and range for July of 25.2 (8.65 – 68.35) mg l^{-1}, and for August of 16.67 (7.21 – 38.38) mg l^{-1}. Previous satellite data produced a mean and range SPM for July of 18.3 (8.6 – 49.5) mg l^{-1} and for August of 29.7(10.2 – 94.0) mg l^{-1}. These data suggest a broad comparability between satellite data and actual measurements.

3 Description of the marine components of the proposed Sizewell C development

This section details the development's marine components - the beach landing facility (BLF), cooling water system, and associated activities for their construction and operation. Our understanding of these marine components as at March 2020, with relevance to water quality, is set out below with more detail of relevance to Ecological receptors and geomorphic features provided in BEEMS Technical Report TR311.

The development includes a hard and soft coastal defence feature (SCDF) (Figure 7). Design and maintenance of the SCDF is discussed in ES Appendix 20A. In summary, the SCDF would be maintained for as long as mitigation was active. Maintenance of the SCDF would require vehicular access and works close to the shoreline. To avoid any impact on water quality adoption of series of measures under construction code of practice a would be adopted to mitigate against any impacts upon marine water quality.

The following components of the development that may have an effect on the marine environment and are potentially relevant to water quality are:

(i) A beach landing facility (BLF) for the station construcion and operation

A Beach Landing Facility (BLF) would be used to import rock armour, Abnormal Indivisible Loads (AILs) and receive some marine freight during the construction phase and be retained through operation for delivery of occasional AILs over the operational life of the site. During the power station's operational life, cross-shore works would be constrained in space and time to the occasional needs for AIL deliveries (estimated as once every 5-10 years). The BLF consists of a piled deck that will connect to the hard-coastal defence feature and the AIL haul road, plus additional fenders and ramp.

(ii) Cooling water system (including intakes, outfalls and fish recovery and return outfall)

The cooling water system would consist of two intake tunnels both >3km long, excavated under the seabed with a tunnel boring machine from landward with excavated arisings going to landward. These boring machines may be disposed of in-situ, just beyond the vertical shaft that connects to the intake and outfalls heads.

Two vertical shafts would be driven down to meet each tunnel offshore of the Sizewell Banks. A number of shafts connect the intake heads and outfall heads to the tunnels. It is proposed to dispose of the associated arisings locally.

The intake and outfall heads would be mounted at the end of the vertical shafts. The design of the intake heads is not finalised and is subject to further engineering studies. The outfall head is likely to have the same design as that proposed for Hinkley Point C.

Two Fish Recovery and Return (FRR) systems would also be part of the cooling water system. The exact position of the FRR outfalls is still subject to engineering design, however, assessment suggests that the optimal easting is between BNG Easting 647977 and 648127. The northing positions of each FRR are aligned with the two EPR forebays, allowing a minimum tunnel length of ca. 400m offshore from the HCDF. This location is away from the longshore bar systems and the bathymetric gradients are low and with a very low rate of elevation change. The tunnels would be directionally drilled from onshore with drill cuttings returned to land. Concrete headworks would anchor the FRR outfall heads to the subterranean tunnel.

(iii) **A combined drainage outfall (CDO) for the construction period**.

A discharge point will be required to discharge the treated sewage effluent and other wastes associated with construction and commissioning before the main Sizewell C cooling water system is available. Discharges from the CDO 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. The final discharge point for groundwater during operation is not confirmed, but if they pass the assessment for discharge via the CDO or have limited areas of exceedance then if they are routed via the cooling water discharge, they are unlikely to be of concern.

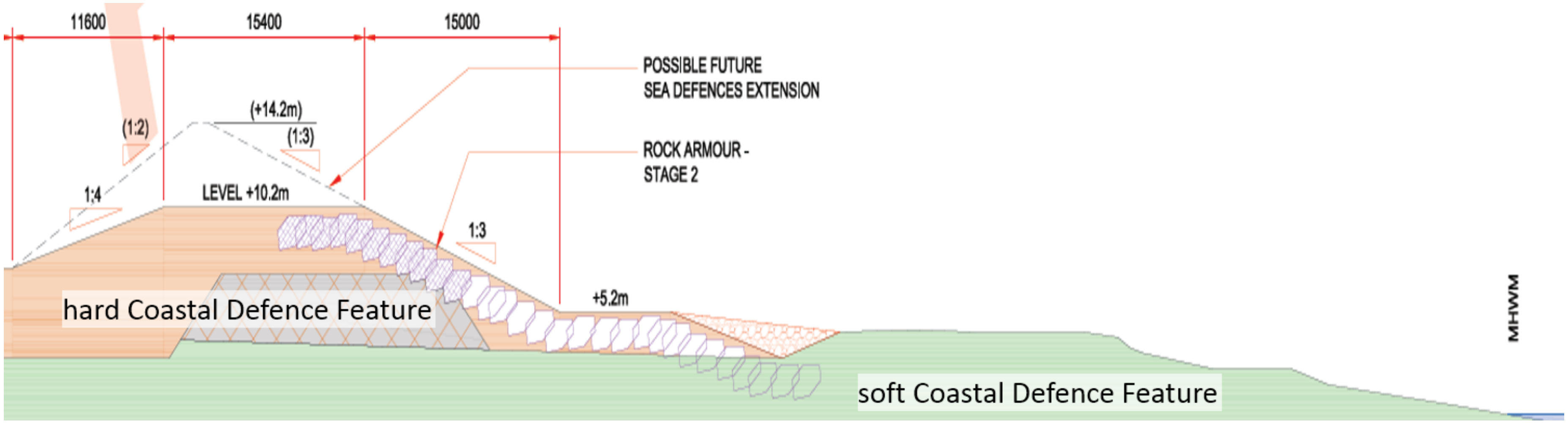

Figure 7 Cross-section of the proposed Coastal Defences at Sizewell C. Note that this drawing is indicative and does not presently include the correct foundation depths.

4 Potential effects of construction and commissioning phases of Sizewell C development upon marine water and sediment quality

This section details the potential effects of the development's marine components and their associated construction and commissioning activities on the marine water and sediment quality adjacent to the Sizewell C development site. The marine components with potential to cause effects relevant to water or sediment quality are:

i. the Beach Landing Facility (BLF);

ii. cooling water intakes;

iii. cooling water outfalls;

iv. fish recovery and return system outfall; and

v. combined drainage outfall (treated sewage and construction wastewater).

4.1 Potential sources of water and sediment contamination during construction that are screened out of further assessment

Several construction activities represent potential sources of contamination to marine water and sediment quality and are screened out of further consideration as follows:

4.1.1 Potential effects of chemical release from sediment resuspension

Except for the construction of the coastal protection features, all the construction activities listed in Section 3 present a risk of remobilising any contaminants present in the local seabed sediments although the largest disturbance would be primarily from dredging and drilling activity.

The marine sediment quality off Sizewell was characterised in terms of contamination in BEEMS Technical Report TR305. The report concluded that due to the sandy nature of the material and levels of contamination below Cefas AL2 found in the marine sediment at Sizewell, there is a low risk of release of contaminants to the water column.

With respect to the contribution of sediment disturbance to nutrient concentration in the water column studies from the scientific literature indicate that resuspension events are unlikely to have a significant effect on water column PO_4 concentrations, other than locally, where in the short term, there may be a temporary "spike" in concentrations until phosphates mobilised from sediment porewaters reassociate with suspended sediment particles and newly formed Fe-Mn oxyhydroxides or clay minerals, before settling out (Dunn *et al.* 2017 and Defforey *et al*. 2018). Marine sediment resuspension studies from the scientific literature have also shown that a relatively low percentage of sediment NH_4 may be released to the water column (0.58 – 5.50% of the depth integrated NH_4) and within a few hours the NH_4 concentration returns to levels prior to resuspension (Dunn *et.al.* 2017).

The proposed seabed disturbance activities associated with the construction and operational phases of Sizewell C are, therefore, considered unlikely to cause any chemical release effects to the water and sediment quality of the local area due to sediment composition and low level of contaminants (BEEMS TR305). The issue of sediment resuspension of contaminants is therefore not considered further.

4.1.2 Potential for effects from accidental chemical release from vessel movements

The potential for chemical and oil spills during vessel movements, whilst recognised, would be managed by compliance with IMO regulations. Therefore, any chemical release effects to the water and sediment quality of the local area would be minimised by compliance with regulations.

4.1.3 Potential for introduction of non-native species from ballast water

The potential for non-natives to be introduced during ballast water activities, whilst recognised, would be managed by compliance with the IMO Ballast Water Management Convention (adopted in 2004). All ships in international traffic are required to manage their ballast water and sediments to a certain standard, according to a ship-specific ballast water management plan. All ships will also have to carry a ballast water record book and an international ballast water management certificate. Therefore, no foreign material release effects to the water and sediment quality of the local area are expected.

4.1.4 Potential for harmful effects of chemicals leaching from marine structures and coatings

Any chemicals used in marine construction will be selected from the list of notified chemicals assessed for use by the offshore oil and gas industry under the Offshore Chemicals (Amendment) Regulations 2011. Any coatings or treatments must be suitable for use in the marine environment in accordance with best environmental practice (Guidance for Pollution Prevention). Therefore, negligible release effects from this source to the water and sediment quality of the local area are expected.

4.1.5 Temporary and variable construction discharges

Other temporary and more variable discharges to marine water may form part of the surface drainage strategy during the construction phase together with the range of expected discharges detailed above. The main expected contaminants in these discharges are suspended solids, Biochemical Oxygen Demand (BOD) and hydrocarbons. Assessment using the Environment Agency/Defra screening of contaminant contributions from surface drainage sources (Defra and Environment Agency Guidance, 2016) is not appropriate due to their highly variable nature over the construction period. Hydrocarbons can be removed from effluent prior to discharge by the incorporation of suitable oil separators within temporary drainage systems and any potential for chemical and oil spills during construction activities, whilst recognised, would be covered under the government waste management guidelines. Therefore, no chemical release effects to the water and sediment quality of the local area are expected from these variable sources and they are therefore screened out of further assessment.

4.2 Beach Landing Facility

4.2.1 Beach landing facility construction (dredging)

North Sea Barges (or similar) would be used to deliver freight (AILs, rock armour and potentially other materials) to the BLF for transfer onto the main development site or construction area as appropriate. A plough or scraper method would be used to gain clearance over the outer longshore bar and to flatten the inner bar so that barges can come safely aground, on a planar surface, on the falling tide after they dock onto the BLF deck.

The total dredge volume modelled for the BLF is 4,600m^3. The proposed plough dredge method does not extract material; however, banking of redistributed sediments may occur in the local vicinity causing burial of surficial sediments and associated biota.

On both spring and neap tides the sediment only settles on the bed over a relatively small area close inshore. Depth average location maximum SSC of more than 100mgl^{-1} above daily maximum background extend approximately 5 km north and south of the dredge area for the capital dredge over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. (satellite data show that the lowest SPM values are present at Sizewell during June with a mean average value of 12.1mgl^{-1} and range 6.9 to 27.5 highest SPM occurs in January with a mean average of 89.3, and range 10.4 - 217mgl^{-1}). A small area of up to 7ha would experience an instantaneous SSC plume of >1,000 mg/l above background levels. Ambient conditions at the site are highly variable and the surface waters are considered as of 'intermediate turbidity' according to WFD criteria. Following the completion of the dredge the plume quickly disperses. On spring tides material in suspension is at concentrations of less than 20mgl^{-1} above background within three days (BEEMS Technical Report TR480). During dredging and for several days following completion SSC would increase to a level that would be defined as 'turbid' (see Appendix B). 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. A single dredging event including the time required for SSC to be close to background would represent <0.1% of the year.

4.3 Cooling Water intake (Construction)

4.3.1 Cooling Water Intake - Dredging

The intake structures would be emplaced during the construction period and exist for the entire operational life of the station and a substantial part of the decommissioning period. The intake tunnels would be bored from landward. At the planned location of the intake/outfall heads, the sea bed sediments would be removed, connecting shafts drilled down through the bedrock and finally the intake heads lowered into place. The design of the intake heads has not yet been undertaken.

Any wastewater generated by drilling of the horizontal cooling water tunnels would be returned to land for treatment before discharge via the CDO (see section 4.6.2)

It is assumed that the head foundations would be installed to the bedrock. The sediment depth is likely to vary at each head location and the assumed dredge volume is based on a worst-case sediment depth of 6m. An excavated volume of 17,406.5m^3 per intake head has been calculated for a total of four heads.

During the dredging and associated local disposal of surficial sediments from the location of the CWS intake structures, an elongate area extending approximately 13km to the north, 22km to the south and a couple of km east-west is affected by increases in SSC of more than 100mgl^{-1}. SSCs within the plume, depth averaged SSCs within the plume peak at more than 2,000mgl^{-1} above background. These elevated concentrations are relatively short lived, with more typical SSC values of 100mgl^{-1} along the plume axis. The maximum instantaneous plume area with increases in depth average SSC of more than 100 mgl^{-1} is around 373 Ha. Following completion of the dredge, the plume quickly dissipates. The elevated concentrations are shown to decay to background levels within *circa* two days on neap tides and two days on spring tides after the completion of the disposal operations. Elevated SSC are not expected to occur for more than about eight days for the dredge scenarios modelled (BEEMS Technical Report TR480). 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. Dredging to establish all four heads including the time required for SSC to return to background would represent ca.,2% of the year.

4.3.2 Cooling Water Intake – Drilling and shaft insertion

Drilling the connecting shafts to a depth of 15m is estimated to take 3 weeks for each shaft. For the intake shafts with and external diameter of 8m, a total drill volume of 750m^3 is anticipated for each of the four shafts. The drill cuttings which will be mostly coarse material and are likely to be disposed of locally. The external diameter of the outfall shafts is likely to be 9m, giving a volume of 955m^3. Drill volumes are likely to be precautionary as they assume drilling from the seabed level. It is likely however, that dredging will remove the surface sediment layers (up to 6m).

The rate of release of drill arisings is derived from assuming 15 days of drilling, at 12 hours a day giving a discharge of 0.017m^3 s^{-1}. 90% of this is likely to be coarse material > 1cm diameter. 5% may be sand and a further 5% fine material <63µm. The bulk of the material will be (Coralline) Crag (sandy limestone) which has a relatively low density (BEEMS Technical Report TR311).

During the drilling of the bedrock at the intake structures, a very diffuse plume with concentrations of around 5mgl^{-1} relative to background develops. Concentrations at this level are around the annual monthly minimum values for satellite data. Based on measured SPM data over a tidal cycle in July which had a mean 8.5, and range 18.3 -49.5mgl^{-1} the plumes created during drilling of the bedrock are therefore unlikely to be discernible above background values (BEEMS Technical Report TR480).

4.3.3 Cooling Water Intake – Installation of Head

The intake heads would be lowered into place and are therefore not being cast in-situ and there are no predicted foreign material release effects to the water and sediment quality of the local area.

4.4 Cooling Water Outfall (Construction)

4.4.1 Cooling Water Outfall - Dredging

As with the intakes, the outfall has to be seismically qualified, which means that the overlying sediment has to be removed, connecting shafts drilled and the outfall head lowered into positon. There are two outfall heads, which are larger than the four intakes but carry the same volume of water.

Any wastewater generated by drilling of the horizontal cooling water tunnels will be returned to land for treatment before discharge via the combined drainage outfall (see section 4.6.2)

It is assumed that the head foundations would be installed to the bedrock. The sediment depth is likely to vary at each head location and the assumed dredge volume is based on a worst-case sediment depth of 6m. An excavated volume of 11,742m^3 per outfall head has been calculated.

Dredging would be similar to that for the intakes and 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. Dredging to establish both outfall heads including the time required for SSC to be close to background would represent ca.,1% of the year.

4.4.2 Cooling Water Outfall – Drilling and shaft insertion

Drilling the connecting shafts to a depth of 15m is estimated to take 3 weeks for each shaft. For the intake shafts with an external diameter of 8m, a total drill volume of 750m^3 is anticipated for each of the four shafts. The drill cuttings which will be mostly coarse material and are likely to be disposed of locally. The external diameter of the outfall shafts is likely to be 9m, giving a volume of 955m^3. Drill volumes are likely to be precautionary as they assume drilling from the seabed level. It is likely however, that dredging will remove the surface sediment layers (up to 6m). Drilling for the vertical connection shafts would result in SSC plumes that would be indiscernable from background conditions (BEEMS Technical Report TR480)

4.4.3 Cooling Water Outfall – Installation of Head

The outfall heads will be lowered into place and are therefore not being cast in-situ and there are no predicted foreign material release effects to the water and sediment quality of the local area.

4.5 Fish Recovery and Return System Construction

4.5.1 Fish Recovery and Return System – Dredging

The FRR outfall heads are assumed to comprise of a concrete block approximately 3m long, 4.5m high, and 3m wide (subject to final engineering design). To estimate a worst-case dredge volume the headworks and estimated scour protection is applied. Scour protection may be placed to limit downward scour and to ensure that scour generated from the structure keeps the area clear of sediment. The total surface footprint is ca. (9m x 23m) or 207m^2 for each FRR system. The dredge volume is approximately 3,690m^3 per FRR system.

It is likely that the FRR systems would be installed separately approximately one year apart in sequence with the reactor they are associated with. 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 instantaneous areas of up to 89ha at the surface. A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface. The area effected by sediment disturbed during the dredging and local disposal of sediment from the FRR outfalls extends north-south along the coast, with limited offshore extent. Following the completion of the dredge the plume quickly disperses. No areas are subjected to increased surface SSC of more than 50 mg/l for more than six hours (BEEMS Technical Report TR480).

4.5.2 Fish Recovery and Return System – Drilling

The FRR tunnel would be approximately 0.8m diameter and directionally drilled from onshore with drill cuttings returned to land (BEEMS Technical Report TR311), therefore there are no predicted sediment resuspension effects to the water and sediment quality of the local area.

4.5.3 Fish Recovery and Return System –installation of Head

The FRR heads will be lowered into place and are therefore not being cast in-situ and there are no predicted foreign material release effects to the water and sediment quality of the local area.

4.6 Main Site Combined Drainage Outfall (CDO) Construction

4.6.1 Combined drainage outfall - Dredging

The method of construction for the CDO has not yet been finalised but is likely to be like that of the FRR and include a directional drilled tunnel with a terminating outfall block. The design of the outfall head has not yet been undertaken but for this report has been assumed to comprise a concrete block like the FRR block. The position of the construction discharge outfall will be suitable for alignment with the sewage treatment system and constrained by the location the BLF, FRR and cooling water tunnel construction. The tunnel would be directionally drilled from onshore with drill cuttings returned to land.

The design of the CDO head has not yet been undertaken and is assumed to be similar dimensions to the FRR. It is assumed that dredge spoil will be disposed of on-site via a pipe that transports the dredge material 500m down drift. Sediment dispersal modelling has been completed based on these assumptions.

The area effected by sediment disturbed during the dredging and local disposal of sediment extends north-south along the coast, with limited offshore extent. Location maximum depth average SSC of more than

100mg $l^{-1}$are constrained to within 6.5 km to the north and 5.5 km to the south of the release location. The remainder of assessment as for FRR.

4.6.2 Waste water and treated sewage discharge via the CDO

Construction phase drainage that may be discharged to the marine environment includes:

- Surface water drainage
- Effluent from the treatment of sewage and from potable supply (black and grey water) by the on-site treatment works;
- Water pumped from both groundwater and excavations during construction dewatering activities.
- Wash water from cleaning concrete production equipment.
- Waste water from horizontal cooling water system tunnelling operations (during construction, see below).

The handling of the of waste water generated from construction of the CDO and potentially the Fish Recovery and Return tunnels has yet to be finalised but is likely to contribute much smaller quantities of groundwater and for a shorter period than those described and assessed in the following sections.

The CDO will be constructed by TBM and will be the primary discharge point for construction phase discharges of tertiary treated sewage, main site dewatering, TBM effluents and commissioning phase hydrazine releases. Discharges will be treated with a silt-buster or similar technology to minimise suspended solids being discharged into the receiving waters.

Wastewater volumes which include that used in various tunnelling processes as well as groundwater seepage are taken from those used for HPC. The construction discharge schedule developed for Hinkley Point C assumes as a worst case that tunnelling wastewater is primarily made up of groundwater only. Thus, the tunnelling wastewater and sewage discharges for HPC have been adapted to include the groundwater discharges expected for Sizewell C and the resulting volumes and discharge schedule are used in TR193. There are no details available for chemical selection and quantities required for the tunnelling schedule and those used at HPC may not be appropriate to the geology at Sizewell.

4.6.3 Indicative construction schedule

As different site discharges may be present at the same time the timing, duration and source concentrations of the likely discharges are important to determine. Prior to CDO completion construction effluents will be tankered off site for appropriate disposal.

A cut-off wall will be constructed around the main construction site and over a 28-day period, groundwater will be lowered within this at an estimated discharge rate of $124ls^{-1}$ or $446m^3hr^{-1}$. For the remainder of the construction period groundwater dewatering is estimated to occur at a rate of $15ls^{-1}$ or $54m^3hr^{-1}$. These discharges are anticipated to be via the CDO.

Package units for treatment of sewage and wastewater from welfare facilities would be established during the construction period with an estimated average discharge rate of $13.3ls^{-1}$ and potential maximum of $30ls^{-1}$ based on current plans at Hinkley Point.

Small amounts of concrete wash water are also likely to be discharged this is expected to contribute relatively small daily volumes up to $10m^3$ a day ($0.1ls^{-1}$).

For assessment, maximum loads are to be addressed within modelling scenarios. The issues of concern being, maximum loads of; heavy metals, Dissolved Inorganic Nitrogen (DIN), faecal coliforms from treated sewage effluent, metals and DIN from groundwater and any tunnel boring additives that are not recovered for reuse.

Five different discharge scenarios or Cases (A – E) are identified during the construction phase at Sizewell C which is scheduled over a 3.5-year period and these include inputs from different activities which potentially contribute different chemical contaminants. There is also a maximum case variation to Case D – D1 that includes a maximum volume contribution of treated sewage effluent which is unlikely to persist over prolonged periods but is included to help inform permitting. The volume discharges for these discharge cases are shown in Table 10.

The maximum discharges of flows that contain metals will occur during Case A. The maximum DIN input will be during Case D (between weeks 45 and 53 when the groundwater element reaches $42ls^{-1}$). Case D is relatively transitory. Case D1, which includes an extreme case of sewage discharge, is also likely to be highly transitory. Once the SCL works are complete (Case E) the total groundwater discharge falls to $15ls^{-1}$. The waste from the TBM soil conditioning chemicals if present is likely to make the largest contribution during Case E as two tunnel boring machines would be in operation and two volumes of makeup water containing conditioning chemicals would be employed. This assumption is based on the work conducted at HPC and it may be that conditioning chemical volume figures change when more is known regarding the tunnelling process required for Sizewell C. The total discharge volume during Case E is approximately $34ls^{-1}$.

Table 10: Construction discharge scenarios during different phases (Case A-E) of construction at Sizewell C.

Date and activity change	Main site Groundwater (ls^{-1})	Sewage (ls^{-1})	Tunnelling wastes (and associated) discharges (ls^{-1})	Case	Total Discharge (ls^{-1})	Comments
WK 1 discharge available 28-day duration						
	124	0	0	A	124	Worst Case Metals
WK 17 tunnelling start						
	15		7	B	22	
WK 26 permanent Sewage Treatment Plant			SCL ramp up			
	15	13.3	22	C	50.3	
WK 49			GW + soil conditioning 1 TBM			
	15	13.3	26.7	D	55	
WK 49		Occasional Max sewage	Made up of GW + (soil conditioning 1 TBM approx. $3ls^{-1}$)			
	15	30	26.7	D1	71.7	Worst Case Sewage
WK 81			2 TBMs			
	15	13.3	(approx. $6ls^{-1}$)	E	34.3	Worst Case TBM

For assessment, maximum loads are to be addressed within modelling scenarios. The issues of concern being, maximum loads of; heavy metals, Un-ionised ammonia, Dissolved Inorganic Nitrogen (DIN), Biochemical oxygen demand, faecal coliforms from treated sewage effluent, metals and DIN from groundwater and any tunnel boring additives that are not recovered for reuse.

The worst-case scenarios for each construction phase are:

- **Case A** is associated with the highest groundwater element over the first 28 days of construction when a cut off wall is constructed around the site and is the worst case for metals and will be screened at $124ls^{-1}$

- **Case D** is the most likely high discharge for DIN and ammoniacal nitrogen after the initial 28 days as it contains main site and tunnelling groundwater, and sewage at a discharge rate of $13.3ls^{-1}$ at a maximum ammoniacal nitrogen contribution of $20,000\mu gl^{-1}$. Additional contributions to N from hydrazine use during commissioning will also be included when known.
- **Case D1** provides the highest contribution of DIN and ammoniacal nitrogen as it is similar to Case D but represents an occasional maximum for sewage with a discharge rate of $30ls^{-1}$ and maximum ammoniacal nitrogen of $20,000\mu gl^{-1}$.
- **Case E** is the worst case for the TBM machines with the potential for 2 lots of ground conditioning chemicals to be discharged although recovery systems mean this is likely to be a negligible input. Less groundwater is contributed from tunnelling and the main site groundwater contribution is also low as is the sewage discharge rate.

In the screening stage those discharges and substances that are evaluated as having negligible likely effects are excluded from further scoping.

To assess the significance of specific chemical discharges the screening methodology applies existing Environmental Quality Standards (EQSs). Where no EQS is available approaches are described for derivation of an alternative reference value.

The focus of this report is the potential impact of activities upon water and sediment quality. Where relevant, more detailed chemical modelling of discharges is used to determine total areas of exceedance for those substances not screened out by preliminary assessment. Supporting information and additional detail for some of the assessments is provided in BEEMS Technical Report TR193. The same information but considering areas of overlap with the Water Framework waterbodies and Habitats are considered in BEEMS TR483 or for individual biology receptors will be considered in the Ecology section of the Environmental Statement (Volume 2, Chapter 22).

5 Assessment of construction discharge

5.1 Background

As part of a surface water risk assessment (Environment Agency and Department for Environment Food and Rural Affairs, 2016) the concentration of substances present in the discharge must be assessed against a list of specific pollutants and their Environmental Quality Standards (EQS). Some substances, termed priority hazardous substances have associated concerns for toxicity, accumulation and persistence in the environment therefore the quantities of these are strictly controlled and are subject to an assessment of annual load discharged

Further tests are conducted for all substances discharged to determine if the concentrations in the discharge exceeds their respective EQS. 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).

The EA 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 (MLWS) tidal level.

More detail on the approach to these assessments is provided in BEEMS TR193.

5.2 Total loads for Cadmium and Mercury.

As part of the surface water pollution risk assessment for environmental permit there are specific requirements for the minimisation of the annual loads of the priority hazardous substances cadmium and mercury. To determine significant loads for these contaminants the average discharge concentration is multiplied by the average flow and the quantity in kg per year is derived. Figure 8 shows that shows the discharge rate for groundwater left axis and blue line. Groundwater discharge is very high (above left axis maximum shown) in the first 28 days (124ls^{-1}) during the main dewatering on site and then decreases rapidly to around 15ls^{-1}. From around week 16 to 76 groundwater varies due to overlapping contributions from tunnelling of intake 1, the outfall and intake 2. Over this whole period the cumulative load of cadmium and of mercury derived from the groundwater is shown by the brown and red lines and the scale on the right-hand axis. Over this 3.5 year period the cumulative load for cadmium is 0.45kg and for mercury is 0.05kg. Both these load figures meet the requirement to not exceed a significant annual load of 1kg for mercury or 5kg for cadmium. Trace contamination of raw materials used in demineralisation of water used during cold commissioning may contribute additional loadings of mercury and cadmium but based on maximum annual loadings during normal operation when the systems are in full use the additional annual loadings, cadmium 0.37kg and mercury 0.099kg (Table 48) would not result in exceedance of the significant loads.

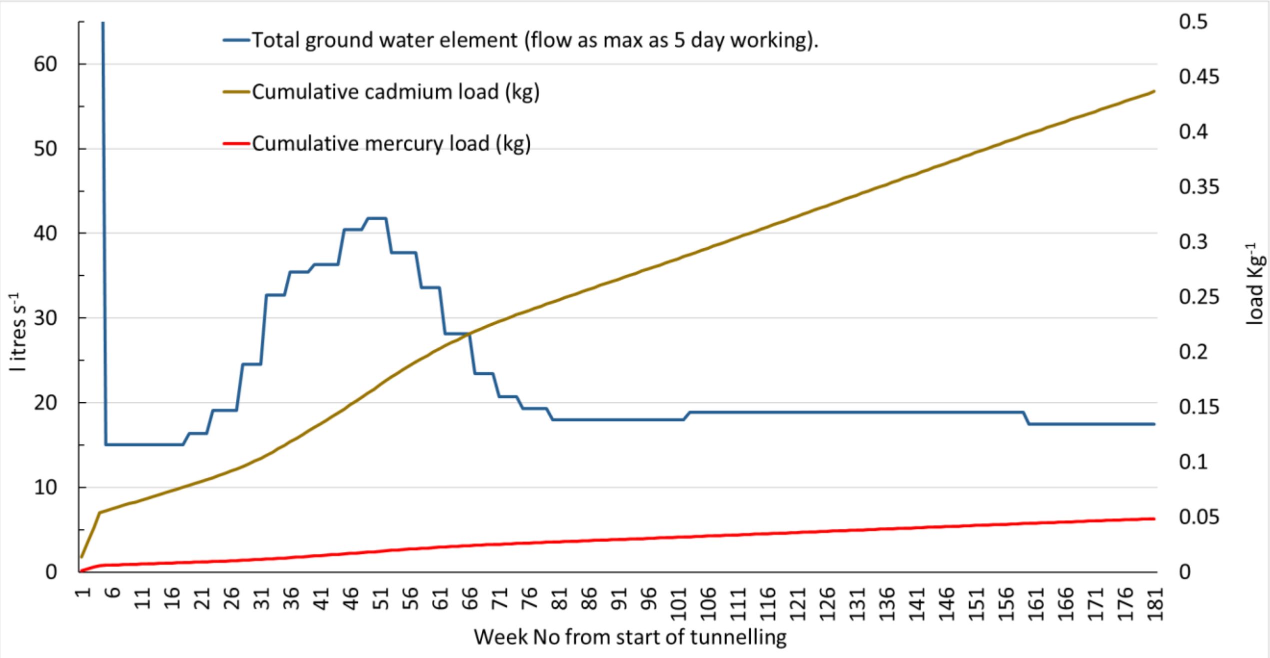

Figure 8: Just over three-year timeline of groundwater discharge (ls^{-1} left axis) and resulting cumulative load for Mercury and Cadmium (kg right axis).

5.3 Screening of chemical discharges

For the screening assessment tests 1 and 5 (as referenced in Clearing the Waters for All, Defra and Environment Agency Guidance, 2016) were applied to the predicted daily and annual discharge concentrations for chemicals likely to be discharged during the construction period. For test 1 the calculated concentration for a chemical is compared to its benchmark value that is either an EQS or PNEC, based on available toxicity data or refers to a background value from monitoring data for the site.

Discharge concentrations were calculated based on the quantity of various chemicals used in different processes and upon dilution in the relevant water flows. When calculating summary statistics for all substances, any values below the method detection limit were adjusted to a value equal to the detection limit. For metals, modelling tests use both total and dissolved concentrations to assess potential deterioration of surface water quality (Environment Agency, 2014). The total concentration of substances is used in the initial screen and in subsequent modelling to take account of uncertainty regarding the partitioning of substances into the dissolved phase as the groundwater mixes with the seawater. More detail on the handling of data and its analysis are provided in BEEMS TR193.

The updated guidance for surface water pollution (Environment Agency, 2016) recommends the application of an initial test (Test 1) for discharges to Transitional and Coastal (TraC) waters in which the discharge concentration is compared to the relevant quality standard or equivalent for that substance. Where the discharge concentration exceeds the standard concentration, further assessment is required. When the discharge concentration is divided by the EQS in Test 1 any values of 0.5 and above are taken forward to the next stage of screening. As this construction discharge will be subtidal and is over 50 metres offshore, a further test ("Test 5") is recommended. Test 5 divides the concentration of a substance and volume discharged (the discharge specific Effective Volume Flux, EVF) by its EQS minus background concentration (the location specific Allowable Effective Volume Flux, AEVF). If the EVF is not greater than the AEVF, then the discharge is insignificant and is screened out. The AEVF references the discharge depth and this value can be up to a maximum of 3.5 metres. For Sizewell the discharge depth for construction relative to chart datum is greater than 3.5 metres therefore 3.5 this is the AEVF used for comparison

5.4 Metals and other contaminants present in groundwater

The volume of water that would need to be disposed of during the initial dewatering phase will be around 300,000m^3 based on the hydraulic properties of the materials within the cut-off wall around the main construction site. It is estimated that to lower groundwater within the cut-off wall to the design level will take 28 days at a rate of 124ls^{-1}. Following the initial lowering of water levels there will be some nominal ongoing discharge throughout the construction phase to deal with nuisance water (rainfall, seepage through the cut-off wall) but the volumes will be very small at estimated values of 15ls^{-1}. Exploratory boreholes across the site showed different levels of contamination with dissolved metals and dissolved inorganic nitrogen (DIN) (Table 11). No other contaminants were detected (Atkins, 2016).

Table 11: Groundwater substance concentration range measured in Sizewell C construction site and relevant EQS values and marine background concentrations.

Substance	Mean dissolved concentration µgl^{-1}	95% dissolved concentration µgl^{-1}	Saltwater EQS AA µgl^{-1}	Saltwater EQS MAC µgl^{-1}	Marine Background concentration µgl^{-1}
Arsenic	3.55	11.5	25	-	1.07
Cadmium	0.10	0.18	0.2	1.5	0.05
Chromium	6.39	18.45	0.6	32	0.57
Copper	1.87	4.25	3.76	-	2.15
Lead	1.07	1.07[1]	1.3	14	-
Zinc	7.34	17.5	6.8[2]		15.12
Mercury	0.013	0.023	-	0.07	0.02
Iron	395	1500	1000	-	50
DIN	3.55	5636	980[3]	-	426

1: For lead only 3 of 151 values above detection limits results in a mean value higher than the 95th percentile which is at the detection limit therefore the higher mean value is used here, 2: The EQS for zinc may be adjusted to take account of local background, 3: 99% (70µmol) converted to N standard for period 1st November – 28th February for dissolved inorganic nitrogen for Good status, Appendix B. Based on unpublished guidance more specific DIN value may be derived based on site average SPM 55mg/l however the value is used for initial screening but a more thorough investigation is undertaken using modelling.

In initial screening of the contaminants present in the groundwater it can be seen from Table 12 that the 95th percentile dissolved concentrations exceed the respective EQS for chromium, copper, and DIN. The zinc 95 percentile concentration in the discharge exceeds the mean EQS for zinc. It is not possible however to evaluate the zinc discharge using the initial dilution test 5 as the background concentration data also exceeds the EQS.

A second screening test (Test 5) was applied considering discharge rate to chromium, copper and DIN. For metals which are predominantly present in the groundwater their concentration is greatest during the first 28 days when the dewatering rate is 124ls^{-1}. Calculation of AEVF for chromium, copper and DIN shows a failure of test 5 for chromium only. Chromium and zinc were therefore taken forward for a modelling assessment.

5.4.1 Modelling assessment of metals

Both zinc and chromium were modelled for Case A (124ls^{-1}) with a source concentration of 17.5µgl^{-1}and 18.45µgl^{-1}, respectively. A US EPA supported mixing zone model, CORMIX was used to predict the rate of chemical plume dilution and plume geometry from the CDO. Some comparisons were also run using the validated General Estuarine Transport Model (GETM) of Sizewell. The GETM set up parameters are described in BEEMS Technical Reports TR301 and TR302 for the thermal plume, and TR303 for the chemical discharges. GETM is a 3D hydrodynamic model with an inbuilt passive tracer to represent zinc and chromium. As a worst case, it was assumed that there was no loss of dissolved metals due to sediment absorption or biological uptake. Using these assumptions, concentrations can be scaled, as the modelled concentration was simply a function of dilution.

CORMIX Modelling shows that for zinc the outfall plume would no longer be detectable above background within 3m of the outfall. For chromium the outfall plume would fall below the EQS within 25m. The output data suggest an initial dilution, for both zinc and chromium, was 47-fold at 25m from the discharge (i.e. the same size as a single grid cell in GETM). GETM slightly under-predicts the initial dilution.

For GETM with the discharge volume of $124ls^{-1}$ entering the model surface layer the total volume in the upper grid cell is approximately $120m^3$. GETM shows a 40-fold dilution in the first 25m, meaning the plume extends slightly further. The mean surface area in exceedance of the EQS for chromium, predicted by GETM, is 0.34ha, or 5 grid cells. For zinc, the total surface area is 0.11ha, or 2 grid cells.

Both CORMIX and GETM are conservative estimates as they do not include additional mixing and dilution due to waves.

5.5 Ammoniacal nitrogen (NH_4-N) in combined construction discharge sources

Ammonia enters freshwater and marine water bodies from sewage effluent inputs, from industrial and agricultural activities and from the breakdown of organic matter. In the marine environment the toxicity of ionised ammonia (NH_4) should be considered. In waters, particularly at higher salinities, it has been shown that the ammonium ion can also permeate the gills, and so the concentration of total ammonia NH_4 can also be toxicologically significant. Total ammonia values of 1100 (annual average) and 8000µg/l NH_4-N (WQTAG086, 2005) are therefore set as guide values for habitats andthese are considered. In general, the un-ionised form of ammonia is more toxic than the ionised form. At higher pH values, un-ionised ammonia represents a greater proportion of the total ammonia concentration. Temperature increase also raises the relative proportion of un-ionised ammonia, but this effect is much less marked than for pH change, e.g. a temperature increase of 10°C (from 10 to 20°C) may double the proportion of un-ionised ammonia but change from pH 7 to pH 8 produces an approximately tenfold increase (Eddy, 2005). A greater percentage of ammonia will also be in the un-ionised form when the salinity is lower.
The concentration of un-ionised ammonia can therefore be derived from knowledge of the total ammoniacal nitrogen concentration (i.e. NH_4 as N), the salinity, the pH and temperature using the EA calculator (Table 13). Of these the pH is the most important with an approximate doubling in un-ionised ammonia concentration between pH 7.5 and 8.
The EQS for un-ionised ammonia is $21µgl^{-1}$ expressed as an annual average, however being consistent with the previous screening, this value is compared with the 95th percentile source contributions. The 95th percentile values used for the source terms were a groundwater ammonium concentration of $5557.2µgl^{-1}$ as N and a treated sewage effluent maximum concentration of ammoniacal nitrogen $20000µgl^{-1}$ as N. $20000µgl^{-1}$ as N represents the design standard of the sewage treatment plant. Source concentrations of ammonia were entered in the EA calculator with starting parameter values for groundwater for pH, temperature and salinity to derive the initial proportion of un-ionised ammonia. As the freshwater construction discharge from site mixes with seawater it becomes more saline and the pH increases. The ammonia concentration in the discharge decreases with dilution. The proportion of un-ionised ammonia also decreases with increasing salinity but the elevated pH of seawater increases the proportion of un-ionised ammonia. The changing proportion of un-ionised ammonia was calculated by producing a plot of dilution against un-ionised ammonia concentration taking account of changes in pH and salinity (BEEMS TR193).

The two components of the mixing relationship were:

a. freshwater, with salinity derived from the average pH (7.3) and 95th percentile of ammoniacal nitrogen (Atkins, 2016), and an average temperature of 11.43ºC (BEEMS TR131).

b. seawater, with a mean temperature of 11.43ºC, 50th percentile salinity 33.1 (BEEMS TR189) and 50th percentile seawater pH 8.05 (BEEMS TR189). The average ammoniacal nitrogen in the sea water background was $11.38µgl^{-1}$ as N (BEEMS TR314).

Cases Amax, D1max, Dmax and sewage only are considered (Table 12).

Table 12: Un-ionised ammonia concentrations for groundwater (GW), treated sewage (STW) and combined discharge derived using the EA calculator as a source term before mixing.

Discharge	Ammoniacal nitrogen (N) ($\mu g l^{-1}$)	Salinity	Temp °C	pH	Un-ionised ammonia ($\mu g l^{-1}$)
Case A	5,557	1	11.43	7.3	22.8
Case D	9,049	1	11.43	7.3	37.2
Case D1	11,600	1	11.43	7.3	47.6
Sewage discharge only	20,000	1	11.43	7.3	82.1

For some Cases small sources which would dilute the concentration, but which may not be present all the time have not been considered (e.g. in case D there could be 4 litres per second of additional water not containing DIN).

1) Case A total discharge is $124 l s^{-1}$ with a 95th percentile concentration of $5{,}557 \mu g l^{-1}$ ammoniacal Nitrogen as N.
2) Case D total discharge is $55 l s^{-1}$ with a 95th percentile concentration of $9{,}049 \mu g l^{-1}$ ammoniacal Nitrogen as N.
3) Case D1 total discharge is $71.7 l s^{-1}$ with a 95th percentile concentration of $11{,}600 \mu g l^{-1}$ ammoniacal Nitrogen as N.
4) Sewage only discharge is$13.3 l s^{-1}$ at a planned maximum of $20{,}000 \mu g l^{-1}$ ammoniacal Nitrogen as N.

Mixing of the different sources contributing ammoniacal nitrogen and the ratio of un-ionised to ionised ammonia upon mixing with seawater is evaluated using dilution rates specific to the Sizewell C construction discharge using CORMIX-US EPA supported mixing model (CORMIX Version 10.0GT HYDRO1 Version 10.0.1.0 April 2017) and these data are presented and discussed in section 6 with more detail provided in BEEMS TR193.

5.5.1 Modelling assessment of Ammoniacal nitrogen (NH4-N) in combined construction discharge sources (groundwater and sewage)

Ammoniacal nitrogen exists in both ionised and un-ionised form in the combined groundwater and sewage discharges from the construction site with the ratio of each determined by pH, temperature and salinity. Un-ionised ammonia is generally considered more toxic and has an annual average EQS of $21 \mu g l^{-1}$. A mixing figure was used to determine the ratio of un-ionised to ionised ammonia as the groundwater and sewage mix with seawater (BEEMS TR193). The derived values were considered in combination with the estimated dilution rates derived from the CORMIX modelling. Case A, Case D1 and Sewage only discharges have been modelled with CORMIX. As Case D is a lower flow rate and source input, its impact will be lower, and was not modelled.

It is evident from the derived data that there is exceedance of the EQS ($21 \mu g l^{-1}$) when less than 68% mixing has occurred for Case A, 84% mixing for Cases D, 88% for D1 and 94% for the sewage only case. In relation to Case A, a dilution factor of 2.13, (68% mixing) occurs after 3.67m for a discharge of $124 l s^{-1}$. For case D1, a dilution factor of 7.33 (88% mixing) occurs after approximately 3.89 m. The sewage only case which is unlikely to occur, would be compliant with a dilution factor of 15.67 (94% mixing). This dilution is likely to have occurred within 6.3 m of the discharge (BEEMS TR193). The total ammonium concentration at the point of mixing described above is at background 11.38µg/l NH_4-N and well below levels of concern at mixing distance 1100µg/l (WQTAG086, 2005).

5.6 Dissolved inorganic nitrogen (DIN) in combined construction discharge sources

The maximum concentration of DIN in the sewage discharge could be up to 23000µgl^{-1} as N (including all potential sources). The mean flow rate is 13.3ls^{-1} but flow may peak intermittently up to 30ls^{-1}. It should be stressed that the 95th percentile concentration of the sewage treatment plant is still 5000µgl^{-1}. This value has been used previously and is still a conservative estimate of the total loading discharged. Maximum discharge flow occurs during the first month at 124ls^{-1} but consists only of groundwater contributions to DIN (Table 13). Thereafter it is possible that maximum discharge flow could occur during the Case D period. Using mean conditions for concentration and total maximum combined flow, regime $D1_{mean}$, becomes 71.7ls^{-1} at 2680µgl^{-1} (as N). In a very unlikely case the maximum sewage flow (30ls^{-1}) and maximum concentrations for sewage (23000µgl^{-1}) and 95th percentile for ground water (5636µgl^{-1}), would be 71.7ls^{-1} at 12900µgl^{-1} (as N) referred to as D1. The latter stages of the construction/commissioning period are E and E_{max} with flow rates of approximately 28.3ls^{-1} (potential volume of 34.3 if tunnelling chemicals present) and concentrations of 2890µgl^{-1} and 5340µgl^{-1} respectively.

Table 13: DIN concentrations for groundwater (GW), treated sewage (STW) and combined discharge.

Case	Groundwater flow ls^{-1}	DIN concentration µgl^{-1}	Sewage Flow ls^{-1}	DIN concentration µgl^{-1}	DIN Discharge concentration µgl^{-1}
A	124	5636 (95%)	0	0	5636
D1 mean	41.7	1021 (mean)	30	5000	2686
D1	41.7	5636 (95%)	30	23000	12901
E mean	15	1021 (mean)	13.3	5000	2891
E	15	5636 (95%)	13.3	5000	5337

The discharges during construction that may contain DIN are likely to be of variable duration and concentration. Table 14 illustrates some potential cases. However, the highest most continuous daily loadings will be contributed during Case $D1_{mean}$, which includes a maximum sewage discharge rate and highest groundwater discharge rate (except for the initial dewatering period in the first month of construction). The total flow rate during $D1_{mean}$ is 71.7ls^{-1}and a concentration (represented by the 95th percentile for sewage) of 2680µgl^{-1} would lead to a discharge of 16.6kgd^{-1}.

During commissioning, ammonia is used (contributing approximately 0.66kgd^{-1} average daily discharge nitrogen) from the steam generator of the EPR and turbine hall and as this precedes construction/operation of the cooling water system the discharge will also occur through the CDO. Nitrogen input from commissioning is added to the groundwater and sewage loading derived for Case $D1_{mean}$ to provide a representative worst-case daily loading of 17.3kgd^{-1} DIN. This loading is therefore used for assessment of the potential impact on phytoplankton growth for the construction/commissioning period.

5.7 Phosphorus in combined construction discharge sources (groundwater and sewage)

Phosphorus is present in groundwater and treated sewage effluent and as these discharges will continue during commissioning of the EPRs any input of phosphorous from commissioning will be added to the total loading. A concentration 10,000µgg l^{-1} as P was derived for treated sewage from package units based on Natural England, 2016. For groundwater a 50th percentile value of 40µgg l^{-1} as TP was derived for Thames groundwater by Stuart and Lapworth, 2016. For the commissioning input reference was made to HPC-EDECME-AU-000-RET-000063, 2017 and a maximum discharge of phosphate per day based on a period of hydraulic testing and preservation of closed cooling circuits, chilled water and electrically produced hot water systems). A value of 594kg PO_4 over 85 days was used to derive a daily value of 6.99kg PO_4 or 2.28kg as P. Adding the commissioning load to that of treated sewage and groundwater (~26kg) gives a total load of 28.2kg. This phosphorus load was combined with the DIN inputs described in section 5.6 above and use to run a phytoplankton growth model (BEEMS TR385) and as briefly described in section 5.8.

5.8 Application of a phytoplankton box model to simulate growth under the influence of nutrient inputs during construction and commissioning

The effect of chlorination at Sizewell B on phytoplankton that pass through the power station was simulated with an emphasis on the spring bloom and summertime production using a phytoplankton box model. The combined loadings of nitrogen and phosphorus as previously described from the construction and commissioning inputs together with relevant inputs from SZB resulting from the use of conditioning chemicals and the discharge of treated sewage were assessed. For much of the year light availability limits phytoplankton growth and the addition of relatively small quantities of nutrients has no effect. In the summer, nitrate is a limiting nutrient (when light is not limiting) and is consumed rapidly. However, the exchange with the wider environment is much greater than the maximum proposed discharges, during construction, so that no change in phytoplankton growth beyond natural variability would be observed.

A model run over an annual cycle predicts a 0.13% difference in annual gross production (BEEMS TR385) of carbon and this level of change would not be discriminated above natural background variation.

5.9 Assessment of BOD discharges during construction

The sewage treatment works is expected to achieve a maximum concentration of Biochemical Oxygen Demand (BOD) of 40mgl^{-1} (i.e. over the 5-day BOD test). Based on the expected number of staff on site during the construction phase and waste water production of 100 litres/per head/per day (Based on Hinkley Point C) a more typical sewage discharge of 13.3ls^{-1} (Case D) is expected through most of the construction phase but a maximum of 30ls^{-1} is also considered as Case D1. Groundwater contribution is not yet confirmed so a value of 5mgl^{-1} BOD (representing Good status classification of surface waters of specific types) and this together with relevant groundwater flow rates is taken account of for Case A, D and D1 to allow assessment.

The background BOD near to the Sizewell B cooling water discharge based on monitoring from 2010 (BEEMS Technical Report TR189) has a mean value of 2mg l^{-1}. Dissolved oxygen levels at the site are 'high' with a mean DO concentration of 7.5mgl^{-1} (BEEMS Technical Report TR303) adjusted to an equivalent salinity of 35 this represents 6.27mgl^{-1} (Water Framework Directive Standards and Classification Directions, 2015). The waters off Sizewell are well mixed vertically. Draw down of oxygen will only occur if the rate of consumption due to BOD is greater than the oxygen transfer across the water surface. Typical values of oxygen flux are 100mmol m^{-2}d^{-1} (Hull, 2016) or 3.2gm^{-2}d^{-1}. Using 13.3ls^{-1} and BOD of 40mgl^{-1} and taking account of a groundwater contribution of 5mgl^{-1} a daily BOD of 121kg was calculated for Case D1, 64kg for Case D and 53kg for Case A. Every 1.5mgl^{-1} BOD is estimated to result in 0.5mgl^{-1} oxygen use (OSPAR Comprehensive studies report, 1997). Therefore, oxygen required to meet these BOD loadings would be D1 40.6kg/day, D 21.3kg/day and Case A 17.7kg/day. The maximum loading of oxygen would be transferred across 1.2ha in a day. For the more usual situation during construction (case D) this would be around 0.7ha. The maximum oxygen demand scenario is negligible relative to the high exchange rate across Sizewell Bay and the potential rate of reaeration at the sea surface. Therefore, these discharges would be expected to have a negligible impact on the well mixed highly oxygenated waters off Sizewell. Dissolved oxygen levels are likely to remain at high status. The discharges of BOD during construction are of negligible significance for dissolved oxygen modification.

5.10 Assessment of coliforms, enterococci – bathing water standards and shellfish

This assessment is based on bathing water regulations (2013. No. 1675) for coastal and transitional waters for which Good status requires that at the bathing water monitoring points the colony forming unit (cfu) counts for intestinal enterococci are ≤200 cfu/100ml and for Escherichia coli are ≤500 cfu/100ml. The nearest designated bathing waters are Southwold the Denes (latitude 52.32º N, longitude 1.679º E) and Felixstowe North (latitude 51.96º N, longitude 1.355º E) and are approximately 10km and 35km distant, respectively. To ensure that there is no impact on compliance at these locations it is necessary to confirm that treatment and dilution of the sewage effluents produced during the construction period meets the required standard.

Based on data in support of the Hinkley Point C development (pers. Comm., EDF), estimates were provided for maximum levels of faecal indicator organisms for the raw sewage input to the treatment plant. Secondary treatment implies a 100 factor (2 log) reduction in Coliforms and enterococci. If UV treatment is also applied a 5.4 log reduction is assumed. Following application of these different levels of treatment reduction the dilution factor required to reduce the coliforms to levels that would comply with bathing water standards and the distance from the point of discharge at which this would be achieved has been derived. The distance from the discharge point at which this dilution occurs has been estimated using the Cormix estimates of dilution rates relevant for the 13.3ls^{-1} sewage discharge (Section 6 and Appendix C). The maximum flow rate of 30ls^{-1} could potentially occur although only briefly, therefore dilution has also been conservatively estimated using the 30ls^{-1} simulation.

Following either sewage treatment at a secondary or tertiary (UV) level the distance from the CDO discharge point, at which enough dilution occurs to be below relevant microbiological standard levels, has been estimated using CORMIX for Case D (30ls^{-1}) sewage discharge and Case D1 (72ls^{-1}) (Appendix C). The discharge plume is buoyant and will be on the surface. CORMIX estimates show that the concentration of Intestinal Enterococci is likely to exceed the bathing water standard (200 cfu/100ml) only within 66m of the discharge for the 30ls^{-1} case, without UV treatment. For the larger discharge volume (72ls^{-1}) the bathing water standards are exceeded for 460m. With UV treatment, even at the higher discharge volume, exceedance is limited to within less than 1 metre of the discharge. Typically, the sewage discharge may not be discharged on its own, but as part of other discharges, these other discharges will add direct dilution which compensates for the inhibition of mixing. The discharge has been modelled using the total volume although the sewage component is only a percentage of this therefore the assessment is conservative. The discharge point is not in designated bathing waters. Treatment from the plant is sufficient to ensure that *E.coli* concentrations in discharged waters comply with bathing water standards within a maximum of 3.1km from the discharge point (without UV treatment) and <1m (with UV treatment).

5.11 Tunneling wastewater and chemicals

The waste from the TBM soil conditioning chemicals if present is likely to make the largest contribution during Case E as two tunnel boring machines would be in operation and two volumes of makeup water containing conditioning chemicals would be employed. This assumption is based on the work conducted at HPC and it may be that conditioning chemical volume figures change when more is known regarding the tunnelling process required for Sizewell C. The total discharge volume during Case E is approximately 34ls^{-1}of which ~6ls^{-1} is contributed by soil conditioning water and chemicals.
The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. Spoil from the cutting face of the TBMs would be removed by a screw conveyor, then transported by conveyor belt to the landward muck bay for licenced disposal.

Groundwater would be generated from digging the galleries allowing access to the tunnels. During the transport of spoil material, groundwater and TBM chemicals can leach from the conveyor belts and fall to the tunnel floor. Wastewater on the tunnel floor would be discharged via the CDO. Discharges would be treated with a silt-buster or similar technology to minimise sediment inputs.

Various chemicals may be required during the tunnelling process:

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

- ground conditioning.

Fuel and lubricants would be subject to management protocols and oil/chemical spills will be contained by appropriate treatment and disposal. Sealants and greases are impervious to water and will remain associated with the tunnel walls or be removed with the spoil.
The underlying geology at Sizewell differs from Hinkley Point and a bentonite slurry tunnelling method is anticipated at Sizewell. Bentonite is a clay mineral regularly used in construction and offshore drilling operations. Bentonite is included on the OSPAR list of PLONOR substances (pose little or no risk to the environment). Although bentonite recovery systems are used with TBMs (as bentonite is a valuable resource in the tunnelling process) the potential release of fine material into the receiving waters is assessed.

In some TBM soil conditioning applications several different surfactant chemicals may be required. The use and discharge of two surfactant chemicals the anti- clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M that are planned for use with the HPC tunnelling operation and that present higher risk quotients in terms of chemical properties are modelled. This approach has been taken to provide a representative upper bounding assessment of potential effects of discharges from this process.

As with the groundwater metals, the release and mixing of TBM chemicals in the construction discharge was modelled by considering them as passive tracers (no decay rate). As such, a single model run was carried out with single tracer at a release rate of 34.3 ls^{-1} with an initial concentration of 100 μgl^{-1}. The results were then scaled to the appropriate concentrations for each chemical, as the modelled concentration was simply a function of dilution. The discharge was modelled as a freshwater input with no thermal uplift. More detail on the model parameters is provided in BEEMS TR193.

A tunnelling discharge of bentonite at a concentration of 8.8mgl^{-1} was modelled using GETM (further details BEEMS TR193). The concentration of bentonite in suspension is orders of magnitude lower than baseline suspended sediments concentrations predicted during construction (BEEMS TR480), with 95th percentile concentrations of 10μgl^{-1} restricted to sea surface areas of mean 1.35ha and a 95th percentile area of 10.8ha. There was no exceedance at the bed above 6μgl^{-1}. Limited data on survival of organisms exposed to bentonite suspensions indicate that effects only occur when concentrations exceed 1gl^{-1} of suspended material (WHO, 2005). The low toxicity of bentonite, the small areas affected, and the low discharge concentrations are likely to have negligible effects on water quality.

For the soil conditioning chemical discharges, the total Rheosoil plume areas at the EQS (40μgl^{-1} as a mean and 95th percentile) were calculated. There was a small area of 1.01ha exceedance of the mean EQS at the surface and no exceedance of the EQS at the bed. CLB F5 M discharges did not exceed the EQS at the seabed and the areas at the surface exceeding the EQS were relatively small with 3.14ha and 25.01ha above the EQS for mean and 95th percentile assessments.

The most toxic of the active ingredients for BASF Rheosoil 143 Sodium lauryl ether sulfate was modelled for the tunnelling discharge and is an example of an alcohol ethoxysulphate. Although tunnelling would occur over several years only very small areas at the surface are predicted to exceed the EQS for Rheosoil and this group of surfactants are shown to be readily degradable with no indication for the formation of persistent or markedly toxic metabolites (HERA, 2004). The most toxic active component of CLB F5 M, mono- alkyl sodium sulphate is an example of an alkyl sulphate and experimental and field data also indicate this group to be readily degradable (HERA, 2002).

5.12 Construction discharge summary

Discharges during construction will be variable, of relatively low volume and will not continue at this level beyond the construction period. It is anticipated that to lower groundwater within the cut-off wall to the design level will take 28 days and will result in a discharge rate of 124ls^{-1}. During this period based on 95th percentile values of dissolved chromium and maximum estimates of the zinc concentration both metals are likely to exceed acceptable levels in the construction discharge. Assessment of mixing and dilution of the metals discharge using the CORMIX model and GETM (section 5.4.1) confirms that exceedance of the EQS for chromium is limited to within 25m of the discharge and that zinc would no longer be detectable above background at around the same point (More detail on the screening calculations is provided in BEEMS TR193).

Given the potential for dilution at the discharge point the maximum likely ammonia concentration and the equivalent contribution to nitrogen and to un-ionised ammonia input during construction are unlikely to represent a significant risk of deterioration in marine water quality. However, the effect of mixing with seawater on the proportion of un-ionised ammonia present in the discharge was assessed (section 5.5.1) by determining the proportion of un-ionised ammonia for a given percentage dilution and with reference to CORMIX dilution plots determining the distance required to reach a point at which the un-ionised ammonia concentration is below the EQS. For sewage only case representing the maximum ammonia contribution during construction the un-ionised ammonia would be below the EQS within 6.3 metres. Total ammonia concentrations would also be below annual average and maximum allowable concentrations based on habitats guidance at 6.3 metres for the sewage only case. The influence of the nutrients DIN and phosphorus present in construction discharges upon phytoplankton growth was assessed using a box model (BEEMS TR385). Run over an annual cycle the model showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.13% for maximum construction (and commissioning) inputs of DIN and phosphorus. Biochemical oxygen demand from combined groundwater and sewage inputs during construction (section 5.8.1) was shown to have a limited influence within a few hectares of the discharge.

The results of the microbiological assessment of the sewage effluent discharge are also presented and discussed in section 5.9. Taking account of effluent treatment at maximum sewage discharge rates during construction the discharge via the CDO would be meet the Good standard for bathing waters within 66m of the discharge if treated to secondary level and to within a few metres if UV treated. The nearest designated bathing waters are approximately 10km North of the discharge and so this would have negligible effect.

5.13 Commissioning discharges via the CDO

Commissioning of the UK EPR reactor is proposed to take place in two stages, namely (i) cold flush testing (CFT) and (ii) hot functional testing (HFT). The commissioning process for each unit would last for about 24 months. Both CFT and HFT processes will produce liquid effluents.

5.13.1 Cold Flush Testing

Prior to operation of the EPR units there would be a period of commissioning tests. Tests use demineralised water for preparing plant systems. This would include the substances shown in Modelling has been conducted to assess the potential interaction of any hydrazine discharge (BEEMS TR494) with designated areas and specific features (BEEMS TR494). The predicted phosphate load and nitrogen contribution from un-ionised ammonia discharged during commissioning is accounted for within the construction/commissioning assessment of phosphorus and DIN potential influence on phytoplankton growth (section 5.8). Other potential chemical discharges during commissioning include un-ionised ammonia, ethanolamine and hydrazine. Prior to the release of hydrazine from the holding tanks, hydrazine would be treated to reduce the discharge concentration. Various treatment options are under investigation and it is anticipated that a discharge concentration of 15µgl^{-1} would be achieved as a representative upper bounding concentration. As a discharge concentration of 15µgl^{-1} exceeds the EQS and fails the Test 5 dilution test this discharge concentration is modelled using GETM. Table 15 shows the H1 screening test 1 and 5 for the ethanolamine and un-ionised ammonia discharges. As un-ionised ammonia concentrations fail test 5 further modelling was also conducted for this discharge.

Table 14 and these figures which are based on HPC will be used in a modelling assessment. Testing of the primary and secondary circuits requires them to be filled and flushed several times each. The maximum daily discharge volume is 1500m^3d^{-1}, equivalent to the contents of the two 750m^3 tanks that serve this waste stream. NNB GenCo proposes to empty each tank once a day, although not at the same time. No operational cooling system will be available for the disposal and dilution of commissioning phase effluents during the cold flush testing (CFT) stage for the first unit to be constructed during the phased development of the Sizewell C site. Therefore, the only available discharge route for this wastewater stream will be through the CDO. If there is overlap in the period when each EPR is being commissioned this would increase discharge duration and load, but discharge concentration may be similar.

Cold flush testing mainly involves cleansing and flushing the various plant systems with demineralised water to remove surface deposits and residual debris from installation NNB GenCo's intention would be for CFT effluent to be discharged to the Sizewell Bay via the CDO serving the Sizewell C construction site. The discharges resulting from CFT will be subject to a separate, later water discharge activity permit application. Modelling has been conducted to assess the potential interaction of any hydrazine discharge (BEEMS TR494) with designated areas and specific features (BEEMS TR494). The predicted phosphate load and nitrogen contribution from un-ionised ammonia discharged during commissioning is accounted for within the construction/commissioning assessment of phosphorus and DIN potential influence on phytoplankton growth (section 5.8). Other potential chemical discharges during commissioning include un-ionised ammonia, ethanolamine and hydrazine. Prior to the release of hydrazine from the holding tanks, hydrazine would be treated to reduce the discharge concentration. Various treatment options are under investigation and it is anticipated that a discharge concentration of 15µgl^{-1} would be achieved as a representative upper bounding concentration. As a discharge concentration of 15µgl^{-1} exceeds the EQS and fails the Test 5 dilution test this discharge concentration is modelled using GETM. Table 15 shows the H1 screening test 1 and 5 for the ethanolamine and un-ionised ammonia discharges. As un-ionised ammonia concentrations fail test 5 further modelling was also conducted for this discharge.

Table 14: H1 Test 1 and 5 for discharges of ethanolamine and un-ionised ammonia during commissioning.

Substance	**Estimated discharge concentration µgl^{-1}**	**Saltwater AA EQS µgl^{-1}**	**Background concentration µgl^{-1}**	Effective volume flux Total flow 83.3 l/s	TraC Water test 5 EVF < 3.0 (Pass/Fail)
Ethanolamine	4000	160	-	2.08	Pass
Unionised ammonia	12000	21	0.2	47.6	Fail

5.13.2 Hydrazine cold commissioning discharge assessment

To investigate the potential interaction of the hydrazine discharge concentration with relevant environmental sensitivities the results for assessment against the acute and chronic PNEC are compared against three criteria:

The likelihood that hydrazine could enter the Minsmere Sluice and/or affect passage of migrating Eels; Levels of hydrazine at the seabed over the Coralline Crag; The area of intersection of the acute hydrazine plume with Little Tern foraging areas.

The Minsmere sluice controls the seawater that can flow into various drainage channels including those used to periodically supply a saline input to the Minsmere salt marshes.

The Coralline Crag is a geological formation of special ecological interest in the area of Aldeburgh and Orford (Suffolk

In addition to the two PNEC values considered in this report (acute and chronic), the area exceeding 200ngl^{-1} as a 95th percentile, as more recently set by the Canadian Federal Water Quality Guidelines for hydrazine was also evaluated (Environment Canada 2011).

The 95th percentile results show that the plume at the surface is shorter and thinner than the mean plume. The plume at the seabed shows a similar elongated narrow plume (BEEMS TR494). The area exceeding the derived acute and chronic PNECs is less at the bed than the surface. At the surface ca., 12.9 and 30.5ha exceed the acute (4ngl^{-1}) and chronic (0.4ngl^{-1}) PNEC respectively. At the surface the exceedance for the 200ngl^{-1} Canadian standard is 0.34ha, which represents three model grid cells (25 x 25 m) around and including the hydrazine discharge from the CDO.

The hydrazine plume is transported northward towards Minsmere during the falling tide, meaning that the sluice water supply that is periodically used to add additional saltwater to the Minsmere salt marshes is unlikely to be exposed to hydrazine. The likelihood of any hydrazine exposure in the sluice water would also be made considerably less likely due to rapid degradation of hydrazine with a half-life of ca.,30 minutes. The passage of Eels into or out of the saltmarshes via the sluice is unlikely to be affected by the presence of hydrazine as hydrazine plumes would only intersect the sluice during an ebbing tide when water levels would be falling, and the sluice would be closed. The predicted peak concentrations of hydrazine in proximity to the sluice in any case at 0.12ng/l are ca., 800,000 times below levels shown to cause sublethal behavioural avoidance effects in the freshwater bluegill fish (*Lepomis macrochirus*) (Fisher et al., 1980) so Eels moving to or from the saltmarshes in the vicinity of the sluice would also not be exposed to significant concentrations of hydrazine.

In terms of the coralline crag the peak hydrazine concentration at the seabed over the crag does not exceed the acute PNEC and only exceeds the chronic PNEC for 15 minutes a day. In the Greater Sizewell Bay.

The hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging range for the Minsmere little Tern colony, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours.

More details for these assessments are provided in BEEMS TR193.

5.13.3 Un-ionised ammonia cold commissioning discharge assessment

The discharge of un-ionised ammonia during the commissioning phase of the EPR construction was modelled using the validated GETM model of Sizewell. Ammonia is added to feedwater during commissioning to elevate pH and to reduce corrosion of ferrous metals. The maximum loading of ammonia planned during commissioning is expressed as a concentration of 12000µg l^{-1} un-ionised ammonia. The pH in various circuits during commissioning is ca.,10 and at this level this is equivalent to a total NH4-N concentration of 17,806µgl^{-1}. This ammonia concentration and the physicochemical conditions of the EPR commissioning demineralised water provide the starting point for calculation of a dilution curve as the effluent mixes with seawater. During mixing the reduction in pH from 10 to around 8 and the increasing salinity act together with dilution to change the concentration and ratio of unionised ammonia. A mixing level of 94.4% is enough together with the changing pH, and salinity that occurs as the wastewater mixes with seawater to reduce the unionised ammonia below its EQS and is equivalent to a 16.8-fold dilution.

Modelling using CORMIX indicates that this level of dilution is achieved within ca.,10m of the point of discharge. The modelling results from GETM show there is no plume in exceedance of the EQS for the un-ionised ammonia. In the direct vicinity of the outfall (<5m) the un-ionised ammonia of the discharge will exceed the EQS. But this behaviour is smaller than the model grid cell size (25m). Comparisons against previous nearfield modelling using CORMIX suggest a 16.8-fold dilution is achieved within approximately 10 m. As for the construction discharge assessment the total ammonium concentration at the point of mixing described above is at background 11.38µg/l NH4-N and well below levels of concern (WQTAG086, 2005) at mixing distance.

5.13.4 Hot functional testing

Hot functional testing begins following completion of CFT and when all the required systems are available. It takes place before fuelling the reactor and only once the cooling water infrastructure is in place and operational. The objective of HFT is to test the reactor and associated systems under pressure, temperature, flow and chemical conditioning as close to normal operating conditions as practicable without putting nuclear fuel at risk. The effluent produced during HFT would be diluted in the 132m^3s^{-1} cooling water flow within the cooling water system before being discharged via the outfall tunnel to the adjacent marine environment.

Due to the current stage of the project and the long lead time until commissioning takes place, detailed information on the nature of the discharges during HFT is limited, but it is assumed that HFT can be considered as running the systems under normal operating conditions. Therefore, the assessment for operational discharges would also apply to that during HFT.

5.13.5 Chlorination testing

Coastal power stations require a means of chlorine dosing for biofouling control. Based upon the known risk of biofouling at Sizewell, SZC Co would need to chlorinate the Sizewell C cooling water (CW) system to maintain control over biofouling of critical plant. At those sites where chlorination is required, EDF Energy's operational policy for its existing UK fleet (based upon experiments and operational experience) is to continuously dose during the growing season to achieve a minimum Total Residual Oxidant (TRO) dose of 0.2mgl^{-1} in critical sections of the CW plant and at the inlet to the condensers.

Testing of this system would be undertaken during commissioning, but it is assumed that this would only occur once the full cooling water system was in place and operational.

The chlorination strategy for Sizewell C is presented in BEEMS Technical Report TR316. This will be continuous dosing and will respect the operational needs of the plant, the Environmental Quality Standards and the Habitats Regulations thresholds. It is currently expected that the Sizewell C intake heads, tunnels and forebays will not be chlorinated.

The expected discharges from the chlorination process include:

- Residual oxidants measured as total residual oxidants and expressed in terms of chlorine equivalent concentration. Also, various chlorination byproducts the range and proportions of these are variable and relate to the presence of organic material and bromine or bromide concentrations in the sea water being treated.
- Trihalomethanes the most dominant of which in terms of concentration is bromoform at Sizewell.

It is assumed that during commissioning chlorine would be dosed to achieve a target TRO concentration of 0.2mgl^{-1}. Therefore, as this would be the same as for the operational phase the detailed modelling assessment for operational chlorine dosing described in section 5.3 would also apply to the chlorination tests.

5.14 Inter-relationship effects construction and cold commissioning discharges via the CDO

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 9 shows potential extent and overlap of influences on water quality during the construction/cold commissioning period. Various construction activities and including cold commissioning would produce discharges via the CDO. Thus far assessments have been conservative accounting for all potential sources for a given substance and making worst case assumptions regarding the overlap of different source discharges. This section considers the potential interaction of dredging associated with the establishment of infrastructure and separately considers chemical discharges from the CDO and potential interaction within the thermal and chemical discharge plume from Sizewell B.

5.14.1 In-combination effects from simultaneous dredging activities

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.

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.

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 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 the same.

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

Construction discharges containing metals and un-ionised ammonia and potentially surfactants from tunnelling have very small areas of EQS exceedance close to the CDO and therefore the interaction with the thermal and chemical plume from Sizewell B at concentrations above EQS or equivalent level is very limited.

Chlorine and ammonia at similar molar concentrations and at low concentration can react in full strength seawater to form, predominantly, dibromamine which has higher toxicity than TRO alone (Inman and Johnson, 1977). However, the TRO concentration derived from Sizewell B that would intersect the CDO discharges would be ca. 20µg/l and the concentration of ammonia NH_4-N rapidly decreases to ca., 11µg/l at around 25 metres of the discharge meaning that the concentration of any combination products would be at very low concentrations and within a limited area around the CDO.

Thermal elevation in proximity to the CDO discharge is predicted to be up to 5°C degrees above background.

Increase in temperature is known to increase chlorine toxicity, particularly when exposure temperatures approach the limits of a species' tolerance range (Taylor, 2006). Temperature dependent toxicity is suggested to be a result of increased uptake rates and physiology at higher temperatures. A 5°C increase in temperature more than halved the LC50 concentration of free chlorine and chloramine in 30-minute exposures in the rotifer Brachionus plicatilis, larvae of the American lobster Homarus americanus, and American oyster larvae Crassostrea virginica (Capuzzo, 1979). However, in the same studies the eurythermal copepod A. tonsa was unaffected by temperature increases. Chlorinated effluents typically dilute relatively quickly in receiving environments, as such the potential for synergistic interactions in the field would be reduced (Taylor, 2006).

In the case of the CDO discharges and overlap with the Sizewell B thermal plume the TRO concentrations would be at sublethal levels and in this case a temperature elevation of 5°C would not be expected to have a measurable effect on the toxicity of combined or free chlorine residuals and so the assessment is the same for the individual discharges from the CDO and in combination with any thermal influence.

A negligible effect assessment is therefore made for the interaction of the CDO discharge (metals, the un-ionised ammonia, tunnelling surfactants) and Sizewell B cooling water discharge (including TRO, CBP thermal elevation) with individual chemical discharge assessments unchanged.

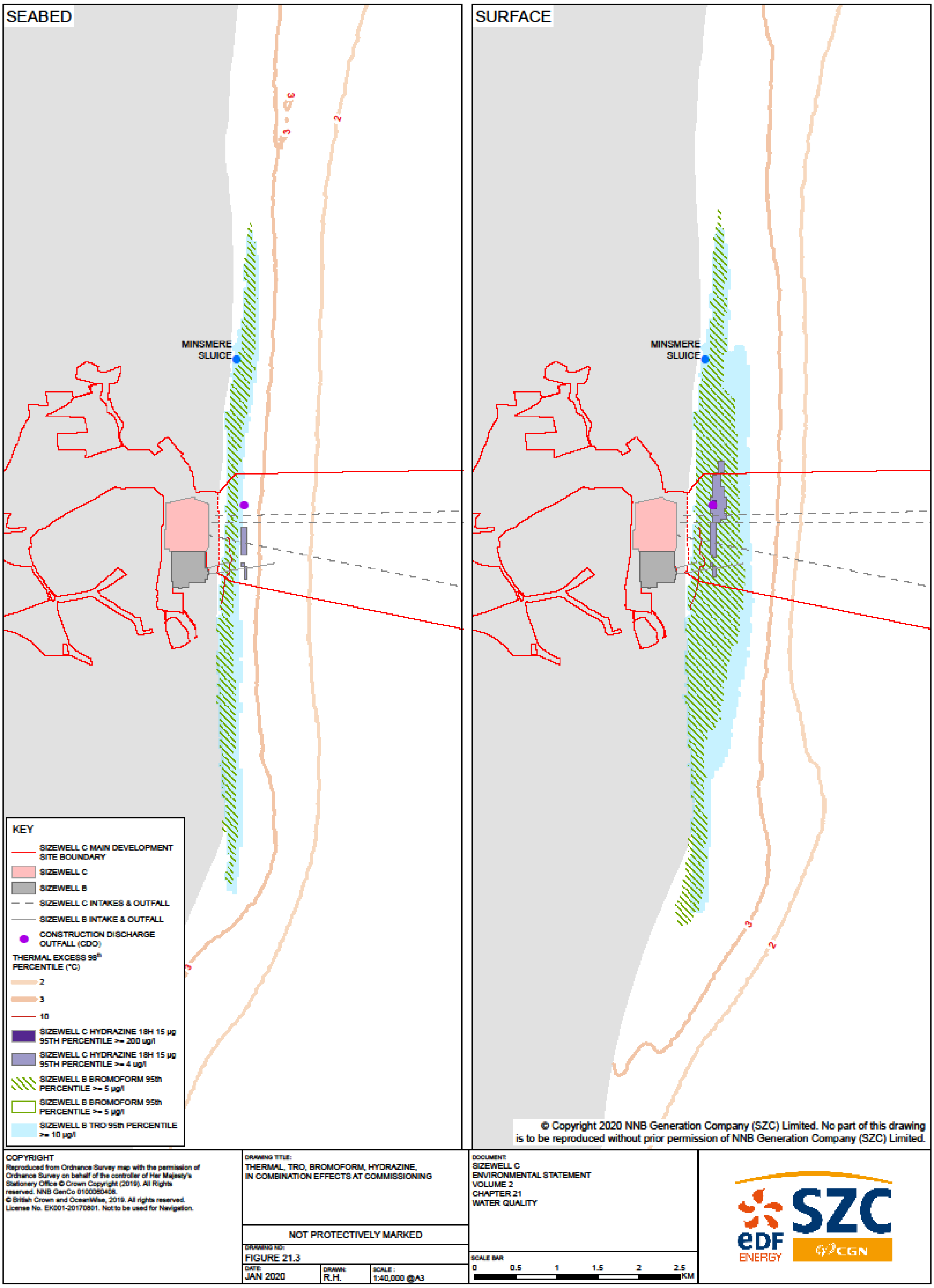

Figure 9: Overlap of thermal plumes from Sizewell B and chemical plumes from the CDO during construction/cold commissioning of Sizewell C.

6 Potential effects of the operational phase of the development on marine water and sediment quality

This section details the potential effects of the development's marine components and the associated operational activities on the receptors defined in the Sizewell C EIA scoping document (SZC Co, 2014a); namely the water and sediment quality of the greater Sizewell Bay. These marine components consist of:

i. the Beach Landing Facility (BLF);

ii. cooling water outfalls and

iii. fish recovery and return system outfall.

Expected effects of activities and discharges to local marine waters from Sizewell C during the operation may be broadly characterised as:

- Sediment disturbance
- Thermal elevation of the cooling water
- Surface drainage from across the developed site;
- Grey and black water drainage from on-site purification plants;
- Effluent from demineralisation plant;
- Chemicals discharged during the operation of the 2 units; and
- Discharges associated with chlorination
- Influence of thermal elevation on other parameters

6.1 Beach Landing Facility Operation

A Beach Landing Facility (BLF) will be used to import rock armour, AILs and receive marine freight during the construction phase, and occasional AILs over the operational life of the site. During the power station's operational life, cross-shore works would be constrained in space and time to the occasional needs for AIL deliveries (estimated as once every 5-10 years).

6.1.1 Dredging the BLF

North Sea Barges (or similar) will be used to deliver freight (AILs, rock armour and potentially other materials) to the BLF for transfer onto the main development site or construction area as appropriate. A plough or scraper method will be used to gain clearance over the outer longshore bar and to flatten the inner bar so that barges can come safely aground, on a planar surface, on the falling tide after they dock onto the BLF deck.

During establishment of the BLF the total dredge volume to be modelled is 4,600m^3. The proposed plough dredge method does not extract material; however, banking of redistributed sediments may occur in the local vicinity causing burial of surficial sediments and associated biota.

The capital dredging requirements of the BLF access channel and the subsequent disposal of dredge spoil present a risk of remobilising any contaminants present in the local seabed sediments. Maintenance dredge modelling simulates removal of 10% of the total capital dredge volume. Following the initial capital dredging event, a plume with an instantaneous suspended sediment concentration (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 >100mgl^{-1}, and 1ha expected to experience >1,000mgl^{-1} above background SSC on each occasion. The spatial extent of SSC elevation 248ha at >50mg/l 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. An area of 248ha is <2% of the Suffolk Coastal waterbody area

The marine sediment quality off Sizewell was characterised in terms of contamination in BEEMS Technical Report TR305. The report concluded that due to the sandy nature of the material and levels of contamination below Cefas Action Level 2 found in the marine sediment at Sizewell, there is a low risk of release of contaminants to the water column. The proposed seabed disturbance activities associated with the operational phases of Sizewell C are, therefore, considered unlikely to cause any chemical release effects to the water and sediment quality of the local area due to the sediment quality.

The potential for chemical and oil spills during vessel movements, whilst recognised, would be managed by compliance with IMO regulations. Therefore, no chemical release effects to the water and sediment quality of the local area are expected.

The potential for chemical and oil spills during operational activities, whilst recognised, would be covered under the Government Pollution Prevention Guidelines. Therefore, no chemical release effects to the water and sediment quality of the local area are expected.

As for the capital dredge of the BLF, plots of SSC (BEEMS TR480) show a plume with highest concentrations occurring in a relatively narrow band along the coast. The concentrations for the maintenance dredge are lower than those associated with the capital dredge as a result of the much lower volume of sediment release. Depth average location maximum SSC of more than 100 mg/l above background extend approximately 5 km north and south of the dredge area for the capital dredge. Following the completion of the dredge the plume quickly disperses. On spring tides material in suspension is at concentrations of less than 20mg l^{-1} above background within three days. On neap tides, the plume concentrations in suspension also quickly return to values which are close to background, however some resuspension of material is expected once the larger range spring tides occur. (BEEMS Technical Report TR480).

6.2 Cooling water discharge

6.2.1 Thermal plume assessment

The proposed Sizewell C power station would comprise a twin-unit European Pressurised Reactor (EPR), with a design cooling water outfall rate of 132m^{3}s^{-1} (2 x 65.9m^{3}s^{-1} during standard operation). A maximum of 8.6% of the total cooling water flow would supply the essential and auxiliary cooling water systems via band screens and the remaining 91.4% (120m^{3}s^{-1}) would supply the main cooling water systems (CRF) via the station drum screens. The thermal uplift of the 12m^{3}s^{-1} that supplies the essential and auxiliary cooling water systems would be 6.6°C ΔT. in the absence of full details on the design of the Sizewell C cooling water system, thermal modelling in 2015 assumed a total discharge of 125m^{3}s^{-1} would be discharged at 11.6°C ΔT (BEEMS Technical Report TR302. This is within 1.4% of the total heat flux of the estimated cooling water discharge of 131.8m^{3}s^{-1} at a net 11.15°C thermal uplift and the modelling reported in TR302 is, therefore, considered enough accuracy for thermal assessment purposes. The cooling water will be extracted from the Southern North Sea via two separate intake tunnels each with 2 intake heads and will be returned through one single outfall tunnel with 2 outfall heads. As Sizewell B will be operational until at least 2035 the in-combination effect of Sizewell B and Sizewell C needs to be considered. The thermal plume has been modelled taking account of mixing and dilution in a tidal regime.

6.2.2 Chemical plume screening assessment

Potential discharges to the marine environment have been assessed for the operational phase of the planned Sizewell C. For large cooling water discharges that are discharged to estuaries or coastal waters a specific screening assessment recommended by Defra and Environment Agency, (Clearing the Waters for All, 2016) is applied. More detail on these assessments is provided in BEEMS Technical Report TR193).

To assess the significance of specific chemical discharges the methodology uses as its reference existing Environmental Quality Standards (EQSs). Where no EQS is available for a given substance then any available toxicity test data are used to generate a Predicted No Effect Concentration (PNEC) as a reference for short term acute exposure and longer-term chronic exposure. Where insufficient or no toxicity data can be sourced then the marine background concentration for a substance from monitoring conducted adjacent to the Sizewell site is used.

Substances likely to be discharged in the cooling water are assessed as follows:

(i) Average background concentration for substance multiplied by average cooling water flow (to determine background load)

(ii) Average load of substance in process stream added to above load

(iii) Divide step (ii) result by total of average cooling water discharge volume and average process stream volume combined

(iv) Compare result of above to the EQS AA

A second assessment makes a comparison to the relevant EQS MAC

(v) Maximum background concentration for substance multiplied by minimum cooling water flow (to determine background load)

(vi) Maximum load of substance in process stream added to above load

(vii) Divide step (vi) result by total of minimum cooling water discharge volume and average process stream volume combined

(viii) Divide step (vi) result by total of minimum cooling water discharge volume and average process stream volume combined

(ix) Compare result of above to the EQS MAC

The aim of the process is to identify components of discharges that may contribute to the deterioration of a waterbody and so prevent achievement of target standards such as status objectives under the Water Framework Directive.

The guidance applies to continuous discharges and variable process discharges to freshwater and coastal waters ("surface waters").

Substances are assessed in two stages: screening and modelling.

For discharges where a simple assessment cannot be applied or where a potentially unacceptable area of exceedance of an EQS or equivalent is indicated then more detailed modelling is undertaken.

6.2.3 Chemical loading for discharges via the cooling water system

Operation of Sizewell C will require large volumes of cooling water to condense steam used in the turbines that generate electricity for export to the National Grid. The cooling water drawn from the Southern North Sea off Sizewell will be chlorinated to prevent fouling and passed through condensers to effect cooling and returned to the Southern North Sea.

The key systems and processes of the UK EPR nuclear power station with relation to effluent production are:

- Seawater cooling system;
- Primary system;

- Secondary system;
- Site oily water drainage system;
- Production of demineralised water; and
- Sanitary effluent treatment.

In addition to the cooling water discharge, trade effluents will be produced as a result of normal operation of Sizewell C and once appropriately treated will be discharged in combination with the cooling water (e.g. process effluents from some of the systems above and sanitary effluents).

The data for chemical discharges associated with cooling water effluents during the operational phase have been mainly provided as maximum loading rates over annual and 24-hour periods for most chemicals within the discharge (Appendix D). The derivation of the load calculations for some substances requires more detailed explanation and so this is provided e.g. for nitrogen and hydrazine which are included in the chemical discharges to the marine environment during operation and are discussed in the following sections.

6.2.3.1 Surface drainage and groundwater

The site will be managed to avoid contamination of surface drainage therefore the variable natural surface drainage from the site would not be assessed using the screening methodology. Groundwater discharges from the operational site would be made at a maximum rate of $15ls^{-1}$ (BEEMS Technical Report TR193). These discharges would be subject to discharge consent. The final discharge point for groundwater during operation is not confirmed, but if they pass the assessment for discharge via the CDO or have limited areas of exceedance then if routed via the cooling water discharge, they are unlikely to be of concern.

6.2.3.2 Demineralisation plant discharges

Various process operations in the nuclear plant require the use of demineralised water. Effluent from this process is generated from cleaning of membranes and ion exchange resins with acids and alkalis and will be characterised by high or low pH. The effluents will be treated by neutralisation using acids and alkalis before being discharged with the cooling water. Current estimations of discharge loadings from the demineralisation plant are largely based on extrapolation of information from the Flamanville 3 site (combined desalination and demineralisation plant) and local sea water quality. The proposal for Sizewell C is that demineralised water would be generated from a mains water supply rather than through use of desalination. There are no discharge loading data currently available for only demineralisation of the mains water supply. Therefore, the screening assessment uses the discharge loading values for a combined desalination and demineralisation plant. This is considered to provide bounding conditions of a worst-case discharge scenario for the assessment. The expected effluents from a combined desalination and demineralised plant are presented in TR193. For the Sizewell C demineralisation plant one of two sequestering agents will be used i.e. either an Amino tri-methylene phosphonic acid (ATMP) based sequestering agent or a sodium polymer-based compound (which comprises 10% alkyl phosphonic acid and 90% sodium polyacrylate).

Water treatment chemicals such as sodium hydroxide, hydrochloric acid and sulphuric acid contain traces of substances such as cadmium and mercury, which are priority substances listed by the Water Framework Directive. The potential impact of these trace contaminants is discussed below.

As part of the H1 assessment there are specific requirements for the minimisation of the annual loads of the priority hazardous substances cadmium and mercury. Based on operational experience and feedback (OEF) from EDF's French fleet of nuclear power stations. Annual and daily loadings for cadmium (0.37kg/y and 0.005kg/day) and mercury (0.099kg/y and 0.0011kg/day) are based on characteristics of reverse osmosis reject water. Both the annual load and scaled up daily loading figures meet the requirement to not exceed a significant annual load of 1kg (daily scaled to year cadmium 1.8kg/day and mercury 0.4kg/day) for mercury or 5kg for cadmium.

Accounting for these loadings in the operational assessment for large cooling water discharges, cadmium including local background, produces a maximum (24h) discharge concentration of $0.13\mu gl^{-1}$ and relative to its 95th percentile EQS a quotient of 0.13/1.5=0.09. Based on an assessment against the cadmium annual average EQS and the relevant annual average loadings predicted a quotient of 0.25 results. For mercury the assessment against the 95th percentile and annual average EQS results in quotient values of 0.29 and 0.28.

These values are all low and are largely contributed by site background values which are ca.,100 times higher than the maximum predicted daily discharge concentration and more than this for the annual values.

6.2.3.3 Hydrazine load derivation

The main operational waste streams that would potentially contribute to the discharge of hydrazine are shown in Table 16. Waste streams fed from the primary circuit include hydrazine loads that are not factored into daily and annual discharge calculations as they have no daily discharge and only apply during start up or shut down periods. The worst-case daily hydrazine discharge would be after wet lay-up of steam generators. The assumption is that this 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 (i.e. for Sizewell B this was ~15 years after first operation).

Waste stream hydrazine loads derived from the secondary circuit daily so these are used for the screening assessment as they are regularly subject to discharge. The daily value represents a daily worst case value that may occur on a given day dependent upon operational processes. The annual value is a total for the year and represents the generally lower daily values that more regularly occur during operation and that are summed to produce the annual figure.

Table 15: Operational phase chemical discharges of hydrazine from sum of waste streams for 2 EPR units (based on EDECME120678 PREL A, 2011).

	Waste stream discharge primary circuit	Waste stream discharge secondary circuit
Hydrazine (daily value) (kg)	1	3
Hydrazine (annual value) (kg)	3	24.3

6.2.3.4 Nitrogen load derivation

For the operational phase, for the screening assessment consideration is made of the contribution of all nitrogen sources in terms of the potential to affect the nutrient status of waterbodies receiving a discharge. In addition, all contributions to ammoniacal nitrogen are considered too as these can contribute to the un-ionised ammonia concentration for which due to its high toxicity, there is an established EQS.

A full assessment of the potential impact of ammoniacal nitrogen discharges requires an assessment of the relative contribution to the un-ionised ammonia concentration. A further calculation is required to derive the un-ionised ammonia contribution as it is influenced by the physicochemical character of the water and this and is explained in the following section.

Total ammonia concentrations from operational inputs (sanitary plus other inputs i.e. circuit conditioning) and the existing site background values are combined. Both an average annual loading and maximum 24 hour loading are considered. For the annual assessment the annual ammonia value for combined operational sources plus background for the site are used with average pH, salinity and temperature in the EA calculator to derive the annual un-ionised ammonia concentration. To derive the 24 hour maximum loading of un-ionised ammonia, extreme values for temperature, pH and salinity are used in the EA un-ionised ammonia calculator with the 24 hour loading of ammoniacal nitrogen and site background ammonia to derive the maximum un-ionised ammonia value.

The ammonia background concentration in the seawater is based on monitoring data from BEEMS Technical Report TR314. The physicochemical data for the site are derived from BEEMS report TR189. Comparable summary statistics for physicochemical parameters were derived for surveys from 2010/11 and 2014/15 but as the differences in the datasets were not large and modelling was developed around the earlier dataset and the scenarios provide a precautionary assessment it was not considered necessary to re run this modelling using slightly updated values from the 2014/15 survey although the more reliable data for ammonia background from the latter survey was used.

Sizewell C nitrogen discharges are derived from several sources and waste streams. The un-ionised ammonia figures in Table 17 were calculated using the Environment Agency calculator (Clegg and Whitfield, 1995) which requires input data for temperature, salinity, pH and total ammonia and takes account of typical (annual average) and worst-case (24 hour) temperature uplift (Table 18). All these source data were specific to the Sizewell site. The data recorded during the 2010 monitoring survey at Sizewell (BEEMS Technical Report TR189) and for the historic temperature record for the site (BEEMS TR131) were the reference source for the relevant physicochemical data used to derive un-ionised ammonia values for screening and the background ammonia concentration in the local seawater was derived from BEEM TR314.

For annual assessment a 98th percentile temperature value (19.4˚C), a 50th percentile pH (8.02) and 50th percentile salinity (33.3) were used to calculate un-ionised ammonia concentration. These values together with the typical uplift of 11.6˚C for the cooling water from Sizewell C (BEEMS Technical Report TR302) provided the input parameters for the Environment Agency calculator together with the total ammonia concentration to derive the maximum annual loading of un-ionised ammonia.

For the 24 hour assessment a combination of maximum likely daily loading of total ammonia and plausible extreme combination of physical conditions that will result in the maximum proportion of un-ionised ammonia is considered. For temperature the worst-case scenario is when 2 out of 4 pumps are under maintenance the flow of cooling water would be halved but the heat content of 2 full power reactors would remain approximately the same raising the excess temperature at the outfall from 11.6˚C to 23.2˚C (BEEMS Technical Report TR303 Edition 4). Hence a value of 23.2˚C together with the 98th percentile background temperature (19.4˚C) 95 percentile background pH (8.2) and 5 percentile background salinity (31.7) was used to derive the maximum 24h loading for un-ionised ammonia. This latter assessment is very precautionary as instead of taking “mean” values for the parameters influencing ammonia speciation, it has used extreme values which maximise the proportion of un-ionised ammonia. This approach was adopted as un-ionised ammonia concentrations are a particularly sensitive issue (e.g. as a potential barrier to fish migration).

Table 16: Operational phase chemical discharges of nitrogen from sum of waste streams for 2 EPR units (based on EDECME120678 PREL A, 2011 and adapted using input data from TR131 ED 2 and TR303 Edition 4).

Substance	Maximum annual loading (kg yr^{-1})	Maximum 24-hour loading (kg d^{-1})
Nitrogen (as N) (excluding hydrazine, morpholine and ethanolamine)	10130	332[1]
Nitrogen (in terms of ammonia ions NH_4 excluding hydrazine, morpholine and ethanolamine)	13009	77[1]
Nitrogen (in terms of Un-ionised ammonia NH_3	958[2]	27

1 For the annual figures total nitrogen is mostly contributed by the ammonia sources but for the maximum loadings nitrogen sources in addition to ammonia contribute to waste streams. 2 figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the NH_4 concentration that results from the combined sanitary and conditioning inputs and site background physicochemical data (see Table 18)

6.2.3.5 Sanitary waste discharges and calculation of un-ionised ammonia for combined inputs

Information on sanitary waste discharges during the operational phase are based on plans for HPC. For estimation of loadings from the treatment works into the cooling water for the screening assessment the following have been assumed:

- Maximum number of operational staff present during 24 hours (under outage conditions) – 1900 personnel (normal operation 700 staff + 200 contractors and outage 600-1000 extra);
- Waste water production per person – 100 litres/day; and
- Discharge concentrations – BOD 20mgl^{-1}, Total Ammonia 20mgl^{-1} and Total Suspended solids 30 mgl^{-1}. Based on these criteria the calculated discharge loadings are presented in Table 18. Further details relating to the calculation of these loadings are presented in EDF (2011).

The values for total ammonia and suspended solids have been combined with other respective sources for each for the screening assessment, to obtain a total discharge loading figure for the 2 EPRs during operation.

Table 17: Calculated discharge concentration of un-ionised ammonia (as N) for treated sanitary effluent and combined inputs.

Parameter	Derivation of value	24 hour value	Annual value
BOD	Sanitary loading	3.8kg d^{-1}	1,387kg yr^{-1}
Suspended solids	Sanitary loading	5.3kg d^{-1}	1,916kg yr^{-1}
Total Ammonia	Sanitary loading	3.8kg d^{-1}	1,387kg yr^{-1}
Total Ammonia (Circuit conditioning)	Circuit conditioning loading	77kg d^{-1}	13,009kg yr^{-1}
Maximum ammonia concentration in discharge NH4-N	Based on a 62.5[1] and 116[2] cumec flow	10.49µgl^{-1}	3.06µgl^{-1}
Temperature data used in calculator	Based on maximum site background 19.5°C + either thermal uplift of 23.2 or 11.6 ºC[1]	42.6°C	31.1°C
pH data used in calculator	Based on 95 percentile and 50th percentile	8.23	8.05
Salinity data used in calculator	Based on 5 percentile and 50th percentile	31.7	33.27
Site background ammonia NH4-N	Based on 95 percentile and mean	26.3µgl^{-1}	11.38µgl^{-1}
Total ammonia in discharge including background NH4-N	95 percentile and mean background added to respective mean and 95 percentile discharge	36.78µgl^{-1}	14.44µgl^{-1}
Un-ionised ammonia concentration NH_3-N	Calculated with EA un-ionised calculator using combined discharge concentration plus background ammonia	7.324µgl^{-1}	0.96µgl^{-1}

[1] see BEEMS Technical Report TR302 – worst-case scenario when 2 out of 4 pumps were under maintenance the flow of cooling water would be halved; [2] This provides a conservative assessment i.e. based on plant not at full capacity as at 132m^3s^{-1}there would be greater dilution

6.2.3.6 Sanitary waste discharges and microbiological parameters

Similar staff numbers on site during operation at Sizewell are anticipated as for the current assessment for Hinkley Point C and on this basis, estimates are made of maximum discharge concentrations of inputs into the sewage treatment plant. Secondary treatment implies a 100 factor (2 log) reduction in Coliforms and enterococci. If UV treatment is applied a 5.4 log reduction would occur. The dilution factor required to reduce the coliforms to levels that would comply with bathing water standards has been derived.

6.2.3.7 Chlorination and chlorination byproducts

Sizewell C would require an annual TRO discharge permit in order to allow year-round protection of critical plant- essential cooling water systems for the nuclear island and turbine hall (SEC, SEN respectively) and the condensers. It is assumed that chlorination would be applied at dose level to produce a TRO concentration of 0.2mgl^{-1} at the drum screens. The TRO discharge concentration from the CW systems at the outfall would be 0.15mgl^{-1} and this is the value included in the screening assessment Table 41 and Table 42.Chlorination of seawater at Sizewell is likely to lead to the production of chlorination byproducts which exert their own toxicity. The primary byproduct identified as likely to be produced at Sizewell is bromoform for which laboratory-based simulation studies indicate may be present at a concentration of 29µgl^{-1} (see section 7.2.4) so this is considered in the screening assessment.

6.2.3.8 Thermal elevation of cooling water discharge

The proposed Sizewell C power station would comprise a twin-unit European Pressurised Reactor (EPR), with a design cooling water outfall rate of 132m^3 s^{-1} and a mean excess temperature of 11.6°C. The cooling water will be extracted from the North Sea via two separate intake tunnels each with 2 intake heads and will be returned through one single outfall tunnel with 2 outfall heads. As Sizewell B will be operational until at least 2035 the in-combination effect of Sizewell B and Sizewell C needs to be considered. The thermal plume has been modelled taking account of mixing and dilution in a tidal regime and is described in section 7.

6.2.3.9 Dissolved oxygen saturation as influenced by the thermal plume

At a constant salinity, temperature has a direct effect on the concentration of dissolved oxygen. The dominant effect on oxygen concentration in the plume comes from the change in temperature and the likely saturation of the warm plume. The plume as it comes out of the power station will be warmer (approximately 11.6ºC) than the intake and will have less capacity to carry oxygen. If the original intake water was fully saturated, then the hotter water will be supersaturated greater than 100% saturation (as the O_2 has nowhere to go) and will escape to the atmosphere soon after discharge. In some water bodies, due to biological oxygen demand, the observed oxygen values are reduced below those of saturation; if such a body of water were to be heated then it would not reduce the oxygen available, if it stayed below 100% saturation.

In the specific case of Sizewell Bay there is no evidence of high biological oxygen demand. Several surveys designed to measure water quality at Sizewell were undertaken over a year; the results of which are presented in BEEMS Technical Report TR189. The results show that there are no apparent oxygen deficits in this water, the minimum oxygen saturation from 83 observations is 91% and the average is 101% saturation.

Calculations of the concentration of dissolved oxygen at saturation have been derived from the GETM model output using 50 percentile salinity values (33.27) from the annual data obtained during 2010, and the derived temperature fields from each run using the method of Benson and Krause (1984). As the field observations showed no biological demand, none has been applied to the results.

6.2.3.10 Un-ionised ammonia ratio as influenced by thermal plume

Criteria for defining the level of un-ionised ammonia that is acceptable have been defined by the UK Technical Advisory Group (UKTAG) (Johnson *et al.* 2007). Un-ionised ammonia concentrations have been calculated using the Environment Agency provided calculator (Clegg *et al.*1995) using the GETM output for temperatures and observed values for salinity, pH and background ammonia levels. The regulatory approach for ammonia considers an annual average with an EQS value of 21µgl^{-1}. The model runs replicate an annual cycle. Results have therefore been derived using an average temperature and average ammonia values and these are shown in Table 19. As various extremes of physicochemical parameters can affect the proportion of un-ionised ammonia some additional consideration of the potential worst case, results are also presented with 95 percentile temperatures and mean ammonia, pH and salinity, and also 95 percentile values of pH and ammonia and the 5 percentile value of salinity with mean temperature and it is these that are shown.

Table 18: Values used for calculation of un-ionised ammonia in thermal plume

	Salinity	pH
5th centile (yearly)	31.72	Not applicable
50th centile (yearly)	33.27	8.05
95th centile (yearly)	Not applicable	8.23

7 Assessment of the operational phase of the development on marine water and sediment quality

7.1 Thermal modelling assessment

BEEMS Technical Report TR301 summarises the setup, calibration and validation of the 2 hydrodynamic models of Sizewell that were setup in accordance with Environment Agency guidance on modelling of nuclear new build developments. That report describes why a GETM model was selected for thermal and chemical modelling of the station and the studies that were undertaken to select the locations of the cooling water intakes and outfalls. The thermal plume from both Sizewell B and Sizewell C was modelled using the validated Sizewell GETM in BEEMS Technical Report TR302. The modelling simulations of the thermal plume consider the preferred cooling water (CW) configuration (configuration 12) with offshore intakes at I3 and I4 and an offshore outfall at O9 determined from the TR301 study. The geotechnical data necessary to finalise the location of the outfall structure are not yet available. The location O9 was selected as the furthest west that a Sizewell C offshore discharge could be built. Modelling demonstrated that outfall locations further east would produce lower thermal effects and that O9 could be considered as bracketing the worst case option for environmental assessment purposes (BEEMS Technical Report TR302).

Sizewell B will be operational until at least 2035 and therefore the modelling undertaken in the study was of the in-combination effect of Sizewell B and Sizewell C. The modelled Sizewell C cooling water system represented a realistic CW configuration with a total of 4 intake heads and 2 outfall heads.

To take account of different power station combinations and operation levels three power station scenarios were considered:

a. ZeroReferenceV2: no power stations present

b. ReferenceV2: present day situation with only Sizewell B.

c. Conf12: Sizewell C with 4 intake heads and 2 outfalls, all offshore from the Sizewell-Dunwich bank, additionally to Sizewell B.

The GETM runs used in this report are listed in Table 20 and the location of the cooling water heads in Table 21.
The three basic configurations were run for one year with meteorological forcing from the ERA atmospheric model with assimilation of observations, and boundary forcing from a larger scale model domain, which includes wave energy (BEEMS Technical Report TR229). The effect of the power stations is evaluated by calculating the difference in temperature between the intended run and the Zero Reference run, which has no power station discharge. The difference is calculated for each hourly snapshot and the annual mean and the 98th percentile are calculated from this difference. The 98th percentile was chosen because it is a metric required under Habitat Regulations Assessment (HRA) and Water Framework Directive (WFD) assessment processes. In 2006 WQTAG 160," Guidance on assessing the impact of thermal discharges on European Marine Sites" cited in Turnpenny and Liney, 2006, recommended interim thermal standards for assessing SAC/SPA sites in estuarine and coastal sites under the Habitats Regulations based upon standards contained within the Freshwater Fish Directive. For a SPA these guidelines state that the annual mean water temperature uplift should not exceed 2°C at the edge of the mixing zone.

There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters (BEEMS Science Advisory Report SAR008). To be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis. As such, they act as triggers for further investigation of potential ecological effects. Thermal standards include criteria for absolute temperature and thermal uplifts to determine the potential for acute and chronic effects and behavioural responses. Recommended thermal standards exist for SACs, SPAs and Water Framework Directive (WFD) waterbodies. The receiving waters adjacent to the proposed development are within the southern North Sea SAC designated for harbour porpoise. Accordingly, SAC thermal standards are considered in the first instance.

SAC thermal recommendations include a maximum allowable 2°C thermal uplift (100th percentile) above ambient at the edge of the mixing zone. Furthermore, SACs designated for estuarine or embayment habitat and/or cold-water salmonid species, apply absolute temperature thresholds of 21.5°C as a 98th percentile (Wither *et al.* 2012). These criteria are not applicable to the southern North Sea SAC designated for harbour porpoise. Absolute temperature thresholds for marine mammal sensitivity assessments consider SPA thresholds (28°C as a 98th percentile). Thermal thresholds are provided in Figure 10.

For assessment against thermal standards unbiased estimates of absolute plume temperatures are also required. BEEMS Technical Report TR301 has demonstrated that the GETM absolute temperature estimates cannot reliably be used for this purpose as the model produces overestimates of absolute temperature (although these are also provided for reference). A more reliable prediction of 98th percentile absolute temperature can be derived at any location by adding the predicted mean temperature uplift due to the plume (i.e. the annual mean excess plume temperature) to the observed 98th percentile seawater background temperature. Further description and justification of this approach is provided in BEEMS Scientific Position Paper SPP098.

The actual seawater background temperature for Sizewell, outside the influence of the existing Sizewell B plume, was calculated from observations from the Cefas Coastal Temperature Network (BEEMS Technical Report TR131 Ed 2) and the 98th percentile of the surface temperature for the period 2009-2013 was 19.4°C. To calculate the plume area where temperatures are:

a) at or above 28°C as a 98th percentile then becomes calculating the area where the mean excess temperature is >8.6°C (i.e. 28°C -19.4°C).
b) at or above 23°C as a 98th percentile then becomes calculating the area where the mean excess temperature is >3.6°C (i.e. 23°C -19.4°C).

BEEMS Technical Report TR302 provides detailed thermal plume maps for each of the tests described above.

The Sizewell C and Sizewell B plumes are separate at high plume temperatures but at lower temperatures, the Sizewell C plume acts to increase the size and temperature of the Sizewell B plume at the surface and the seabed (BEEMS Technical Report TR301). This means that the thermal effects of Sizewell C also contribute to a magnified Sizewell B plume (the Sizewell C plume is smaller and largely outside the 1nm offshore limit). Figure 11 and Figure 12 illustrate the effect of the Sizewell C cooling water discharge on Sizewell B.

7.2 Thermal modelling assessment

BEEMS Technical Report TR301 summarises the setup, calibration and validation of the 2 hydrodynamic models of Sizewell that were setup in accordance with Environment Agency guidance on modelling of nuclear new build developments. That report describes why a GETM model was selected for thermal and chemical modelling

Table 19: GETM runs used (BEEMS Technical Report TR302).

Run ID	Description	Intake location	Discharge location	Discharge flow and Delta T (m^3s^{-1} @ °C)	Time period
ZeroReferenceV2-annual	Pristine condition	n.a.	n.a.	n.a.	1/1/2009 00:00 -1/1/2010 00:00
ReferenceV2-annual	Sizewell B	IB	OB	51.5 @ 11.0	1/1/2009 00:00 -1/1/2010 00:00
Conf12-annual	Sizewell B and Sizewell C	IB I3a,I3b I4a,I4b	OB O9a, O9b	51.5 @ 11.0 125 @ 11.6	1/1/2009 00:00 -1/1/2010 00:00
Conf12_maint-May	Maintenance at Sizewell C	IB I3a,I3b	OB O9a	51.5 @ 11.0 62.5 @ 23.2	1/5/2009 00:00 -1/6/2009 00:00

Table 20: Location of power station cooling water intake and outfall heads associated with the reference runs.

	Latitude WGS84 (degrees N)	Longitude WGS84 (degrees E)	Easting BNG (m)	Northing BNG (m)	Depth ODN (m)
Sizewell B					
IB	52.21472	1.63332	648297	263612	9.0
OB	52.21525	1.62658	647834	263647	5.1
Sizewell C					
I3a	52.21948	1. 66931	650726	264262	12.9
I3b	52.21945	1. 67077	650826	264264	13.6
I4a	52.21148	1. 66572	650526	263360	11.5
I4b	52.21126	1. 66714	650624	263341	13.5
O9a	52.21807	1.67435	651080	264125	16.9
O9b	52.21803	1.67544	651155	264125	16.8
WGS84: World Geodetic system 1984, BNG: British National Grid, ODN: Ordnance Datum Newlyn					

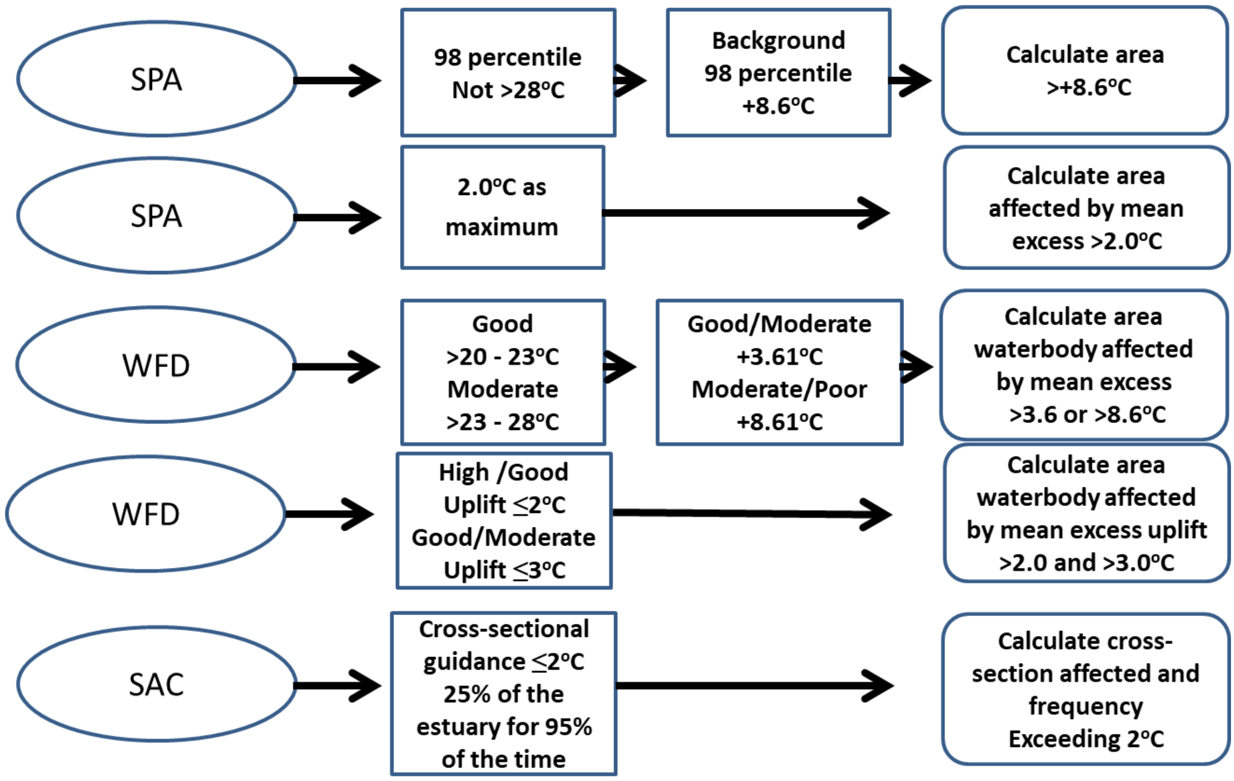

Figure 10: Summary of assessments made against relevant temperature standards using the GETM Sizewell model. Above values reference a 98% baseline temperature value of 19.39˚C for the Suffolk coastal waterbody derived from the product of monthly means for four sites: Lowestoft, Southwold, Sizewell, and Felixstowe Rotterdam (coastal) between 2009 – 2013, equivalent for Sizewell is 19.6˚C.

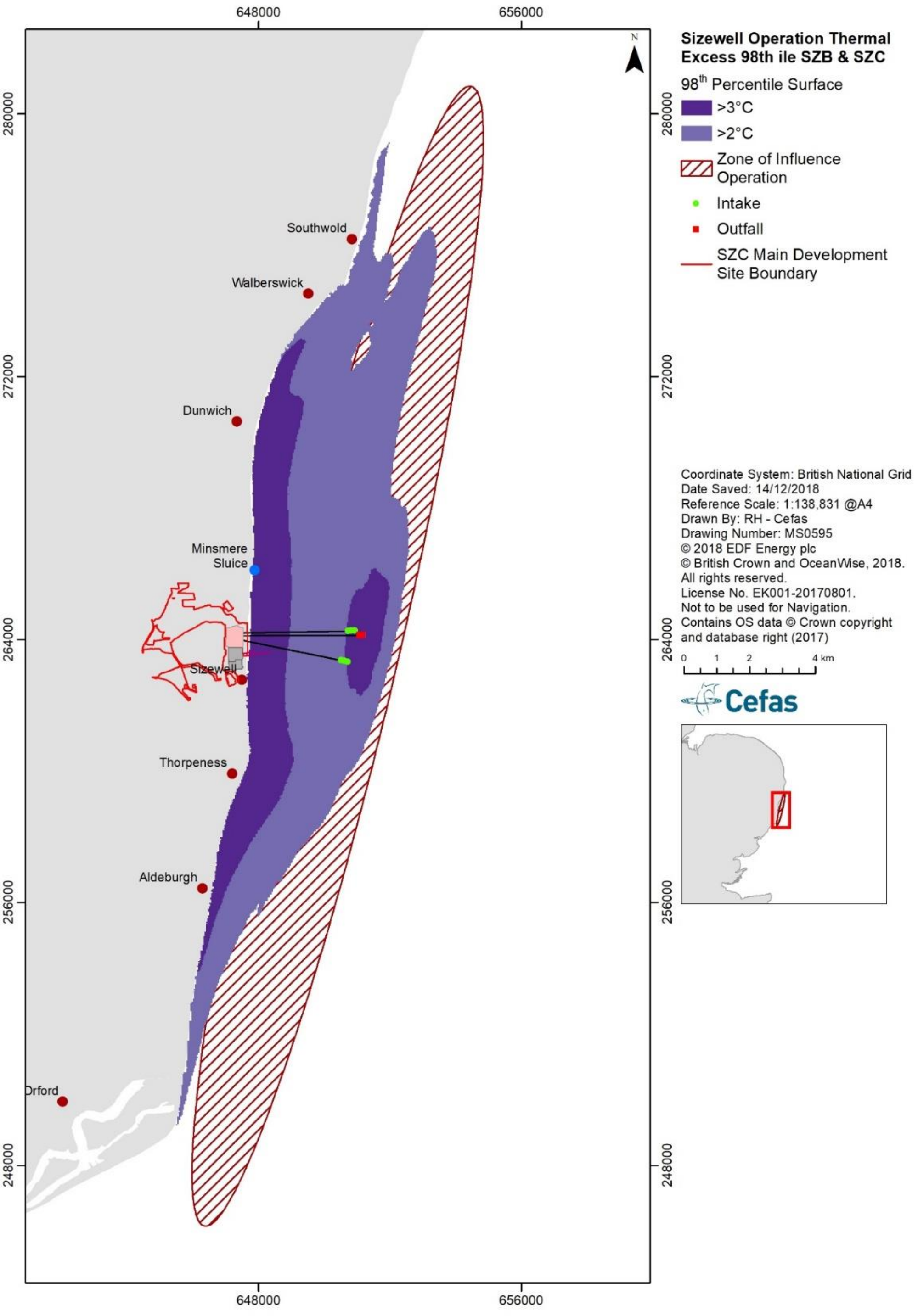

Figure 11: 98th percentile of excess surface water temperature showing >2 and >3°C for run with Sizewell B and Sizewell C operating (Conf12).

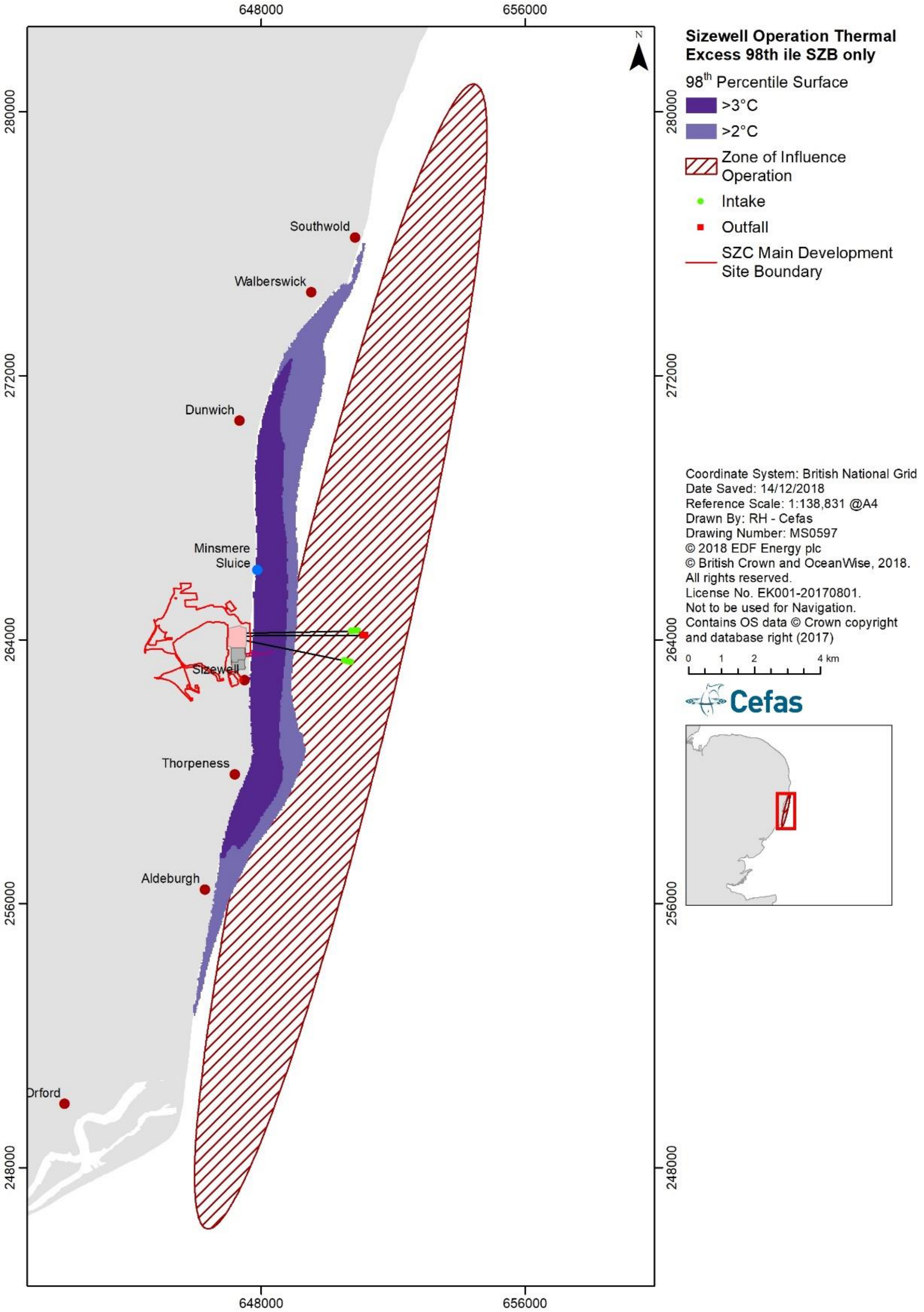

Figure 12: 98th percentile of surface excess water temperature showing >2 and >3°C contours for run with only Sizewell B operating (ReferenceV2).

Unlike chemical standards which normally have a clear evidence link to ecological effects, thermal standards are not always evidence based due to a lack of reliable data (BEEMS SAR008). To be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis and, as such, they act as trigger values for further investigation of potential ecological effects.

The extent and magnitude of the thermal plume from the existing Sizewell B and proposed Sizewell C is assessed against thermal standards relevant to the zone of influence for the site.

7.2.1 Application of Habitats thermal assessment to ZoI

As described in section 1.0 two threshold values are recommended as trigger assessments for SPAs:

3. Temperature uplift ≤ 2˚C as a Maximum Allowed Concentration (MAC) at the edge of the mixing zone
4. 98^{th} percentile of the absolute temperature ≤ 28˚C

The uplift threshold is specified as a 100 percentile. This metric is, therefore, very dependent on how the observations or model simulations are done and the time period considered. Using the GETM model the maximum taken from instantaneous temperature fields, saved every hour over a one-year simulation, provides data on the area that exceeds 2˚C excess temperature for at least 1 hour per year i.e. for 1h in 8760h per annum. At this temperature threshold, this metric is not considered to have any link to specific ecological effects, and it serves as a precautionary threshold to trigger further ecological investigation (The plume maps at a 2ºC uplift as a 100%ile threshold are shown in Appendix E)

The absolute temperature standard for SPAs of ≤ 28˚C as a 98%ile does have a better evidence link and is considered relevant to assess (BEEMS SAR008)

Absolute area of exceedance of thermal standards for habitats and scale relative to ZoI

The absolute areas of exceedance for each standard for the SPA thermal standards are shown in Table 21. The 2˚C uplift threshold is exceeded over a minimum of 5,219ha at the seabed for Sizewell B to 22,464ha at the surface for Sizewell B + Sizewell C. The corresponding maps are shown in Appendix E. According to WQTAG160 the exceedance of the threshold requires further evaluation of the potential environmental impact with respect to ecological receptors within that area.

The second criterion for SPAs concerns the 98^{th} percentile of the absolute temperature. The predicted absolute areas where the plume temperatures exceed 28˚C are shown in Table 22 column 5 and are all below 1ha. This contrasts greatly with the criteria for maximum uplift that is exceeded across Sizewell Bay even for the Sizewell B case. At the request of the Environment Agency the area of exceedance has also been calculated using GETM absolute temperatures outputs which produce inaccurate temperature predictions that are overestimates (Table 24 column 6). The plume maps of absolute temperatures are in BEEMS Technical Report TR303 Edition 3. Using either method, the absolute area exposed to risks of thermal lethality to marine species from temperatures > 28˚C is small.

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 98^{th} percentile statistics are not necessarily consecutive and could be days or months apart.

Table 21: Total area where the Habitat temperature standards are exceeded.

Model run	Position		Max excess temp. >2°C (100th percentile)	98th percentile >28°C. Calculated from mean excess temp. >8.6°C	98th percentile >28°C Calculated using GETM absolute temperatures (GETM absolute temperatures are over estimates)
ReferenceV2 annual Sizewell B	Surface	ha	9,375.03	0	0.78
	Seabed	ha	5,219.05	0	0
Conf12 annual Sizewell B+Sizewell C	Surface	ha	22,463.87	0.11	4.15
	Seabed	ha	16,451.21	0	1.57
Sizewell C only	Surface	ha	16,775	0	0
	Seabed	ha	12,244	0	0

Note: BEEMS Technical Report TR301 has demonstrated GETM absolute temperature predictions are overestimates (last column above).

7.2.2 Waterframework Directive thermal assessment

The WFD standards for water quality apply for both absolute water temperatures and temperature uplift:

1. 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

2. Annual 98th percentile uplift in water temperature

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

Table 22 and Table 23 show the results of applying these standards to the predictions from the Sizewell B+Sizewell C thermal plume modelling.

Applying a mean excess temperature of 3.6˚C to the baseline temperature value of 19.39˚C for the Suffolk coastal waterbody provides an assessment for exceedance of the >23˚C 'Good/Moderate' threshold. A maximum of 89.6ha at the surface exceeds this threshold for Sizewell C and Sizewell B in combination. There is less exceedance at the seabed with the lowest area of 8.75ha at the bed predicted for Sizewell B alone. Based on GETM absolute values the maximum exceedance at the surface is 4.15ha for Sizewell C and Sizewell B and at the bed the lowest area of exceedance is 0ha.

As absolute temperature exceedance only is considered here (i.e. no areas of intersect with specific designations) the evaluation of the 28˚C threshold for WFD is the same as that considered for the SPA assessment.

Exceedance of the 2˚C threshold for WFD results in a predicted area of maximum 7899ha at the surface for Sizewell B and Sizewell C (Table 24). A minimum area of 2433ha of exceedance is predicted at the surface for Sizewell B alone. For exceedance of the 3˚C threshold for WFD the predicted absolute areas of exceedance are lower with a maximum of 2200ha at the surface for Sizewell B and Sizewell C in combination and the lowest area affected at the bed for Sizewell B alone (667.67ha).

Table 22: Total areas where the Water Framework Directive absolute temperature standards are exceeded.

Model run	**Position**		**98th %ile >23°C. Calculated from mean excess temp.>3.6°C (Area at GOOD or below threshold)**	**98th %tile >28°C. Calculated from mean excess temp.>8.6°C (Area at MODERATE or below threshold)**
Reference V2 annual Sizewell B	Surface	ha	44.86	0
	Seabed	ha	8.75	0
Conf12 annual Sizewell B+Sizewell C	Surface	ha	89.60	0.11
	Seabed	ha	25.57	0
Sizewell C only	Surface	ha	0	0
	Seabed	ha	0	0

Table 23: Absolute areas where the Water Framework Directive uplift temperature standards are exceeded.

Model run	**Position**		**Excess temp. >2°C as a 98%ile Area at GOOD**	**Excess temp. >3°C as a 98%ile Area at MODERATE or below**
ReferenceV2 annual Sizewell B	Surface	ha	2,433.30	1262.57
	Seabed	ha	2126.71	667.67
Conf12 annual Sizewell B+Sizewell C	Surface	ha	7899.17	2200.05
	Seabed	ha	6240.64	1,552.56
Sizewell C only	Surface	ha	1551	305.7
	Seabed	ha	170.6	0

The exceedance of the relevant thresholds requires further evaluation of the potential environmental impact with regards to ecological receptors within that area.

7.2.3 Potential thermal barriers to fish migration

It is known from laboratory thermal preference experiments that fish species can choose to avoid areas of high temperature and there is, therefore, a possibility that thermal plumes could act as barriers to migration; principally in transitional waters.

Existing thermal standards for transitional waters specify that an estuary's cross section should not have an area larger than 25 % with a temperature uplift above 2˚C, for more than 5% of the time. There are no such standards for coastal waters, nevertheless an assessment is provided in BEEMS Technical Report TR483 on whether a coastal plume could act as barrier to migration for those species that migrate between coastal and transitional waters.

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, the exceedance area is a small percentage of the relevant designated areas. The resistance of marine water and sediment quality 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 judged to be low and overall impact minor but requiring further consideration of potential impacts for ecological receptors.

BEEMS Technical Report TR431 has summarised the available evidence to identify for each designated SAC/SPA species, that has the potential to be impacted by the Sizewell C development:

a. those species that have marine prey as an important component of their diet;

b. the foraging range of each species (where applicable); and

c. what their marine prey species are likely to be in the Sizewell area.

The marine prey species identified are as follows: sprat; herring; anchovy; swimming crab; waste from fishing vessels; whiting; bass; eels; bivalves; polychaetes; crustacea; gobies; dover sole and dab (BEEMS Technical Report TR431).

BEEMS Technical Report TR483 will consider the impacts of the Sizewell C development on the identified marine prey species for each designated SAC/SPA species.

7.2.4 Climate change influence on thermal discharges

The effects of future climate change and warming sea temperatures in relation to thermal discharges is considered further (with more details provided in Appendix F). This section considers the influence of climate change on future thermal parameters in relation to the operation of Sizewell C and Sizewell B. At the time of writing the recently updated UKCP18 marine climate predictions (November 2018) do not include sea temperature data. Future climate scenarios for Sizewell are based on UKCP09 data, which provides predictions of future climate for 2070-2100 relative to a baseline of 1961-1999 for the broad Sizewell area. These assessments focus on absolute temperatures as thermal uplifts are predicted to be largely independent of ambient water temperature and would remain the same.

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.

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. The thermal uplift due to the UKCP09 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. 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.

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. 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.

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. 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.

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.

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.

7.3 Chemical discharge modelling assessment

7.3.1 Screening results

The results of the screening tests for 24-hour and annual discharge assessment are shown in Appendix D. Initial screening (more detail is provided in BEEMS Technical Report TR193) Appendix D Table 46 shows chemical loadings. Table 47 shows the assessment for large cooling water discharges that are discharged to TraC waters for 24h operational discharges and Table 48 shows respective results for the annual operational discharges. Table 48 discharge concentrations are compared to the Water Framework Directive annual average environmental quality standards (WFD AA-EQS = Annual Average EQS), and in Table 47 the WFD EQS MAC = Maximum Acceptable Concentration EQS where these are available or AA values if not. In some cases, alternative or surrogate values have had to referenced i.e Pre-WFD EQS values have been adopted for assessment of boron; Coastal and Transitional Water WFD EQS for chromium is for chromium VI; and in some cases, toxicity data values are compared. Where no toxicity data are available background concentrations measured at the site are compared. For nitrogen reference is made to the winter dissolved inorganic nitrogen 99th percentile for TraC waters of intermediate turbidity (suspended solids levels of 10 to <100mgl^{-1}, Appendix B).

Reference to Table 47 shows that for the 24 hour discharge assessment, hydrazine, chlorine produced residual oxidants (TRO) and bromoform concentrations in the discharge during the operational phase will exceed the acute PNEC and so will be taken forward for more detailed modelling and are further discussed at the end of this section.

Discharge concentrations for copper and zinc also exceed EQS assessment criteria but, in each case, actual discharge concentrations are at least 30 times below the relevant AA EQS and are below their respective detection limits for analysis. It is the high derived 95th percentile background loadings that are responsible for this exceedance therefore no measurable exceedance resulting from the discharge itself would be detectable and so further assessment will not be conducted.

Lithium hydroxide, phosphate and aluminium do not have EQS or PNEC values but instead reference site mean backgrounds and so the 95th percentile load calculations which use site background 95th percentile values will invariably result in an exceedance. In the case of aluminium, the actual discharge contributes a sixtieth of the background and for lithium hydroxide the equivalent lithium input from the discharge is almost

300 times below the background in neither case are these inputs considered of significance. The phosphate input is over three times above the background and so as phosphate can contribute to nutrient status it will be given further consideration in section 7.2.9.

Concentrations of other substances for which the discharge 24-hour loading concentration are present in the operational discharge at >40% of their EQS or equivalent reference value are also considered here, and these are boron (boric acid), morpholine, un-ionised ammonia, DIN and acrylic acid.

The boron background concentration in Sizewell seawater as a 95th percentile (as used in the 24h discharge calculation) is around 4564µgl^{-1} and as the estimated discharge concentration of boron represents around one twentieth of this value it is the background concentration that has the most influence on the scale of the cooling water discharge concentration relative to the EQS. As the elevation of boron above the seawater background is relatively small and so any influence will be localised to the area around the immediate discharge. As an essential element for many marine algal species the low elevation of boron concentration expected in short term discharges is likely to have negligible effects.

Morpholine was 58% of its derived PNEC for 24-hour discharges but is a readily degradable chemical and has a low likelihood of bioconcentration (see Appendix D) this coupled with its low toxicity indicates it would have negligible effects on marine species under this discharge scenario.

Un-ionised ammonia was 35% of its derived PNEC. As temperature may influence the relative amount of un-ionised ammonia the operational discharge has been further assessed considering temperature elevation and this modelling is described in section 10.

The 24-hour discharge concentration of dissolved inorganic nitrogen was 49% of the site 99% winter standard for water bodies of intermediate turbidity. The discharge concentration is below the standard value but as the loading of DIN may influence algal growth this is further assessed in section 7.2.8.

The 24-hour discharge concentration of acrylic acid is 52% of the PNEC (0.34µgl^{-1}, see Table 5). The bioconcentration factor for acrylic acid is estimated at 1.0 and so is very low and it is readily degradable (Staples et al., 2000). Acrylic acid is therefore likely to have negligible effects at the predicted discharge concentration.

For annual loadings in the operational cooling water discharge hydrazine, chlorine and bromoform again exceed relevant PNEC or EQS values in the screening assessment and so more detailed modelling will also consider this discharge scenario. Discharges during the operational phase would also equal or exceed the annual average PNEC for lithium hydroxide, phosphates, aluminium, lead, zinc and acrylic acid (Appendix D, Table 48).

Lithium hydroxide, phosphate and aluminium do not have EQS or PNEC values but instead reference site mean backgrounds and so the mean load calculations which use site background mean values will invariably result in an exceedance. In the case of aluminium and lithium hydroxide, the actual discharge concentrations are below the method detection limit and are several orders of magnitude below the site background so the discharge contributions would have negligible effects. The phosphate discharge concentration is also below the method detection limit and although the discharge concentration is very low the input can contribute to nutrient status so it will be given further consideration in section 7.2.9.

Zinc fails the annual loading discharge assessment. However, it is the high background loading that is responsible for this exceedance and the actual discharge concentration would be below detection therefore this input is considered to have negligible effects.

The annual discharge concentration of acrylic acid is 13% over the chronic PNEC but as bioconcentration is low, estimated at 1.0 and it is readily degradable (Staples et al., 2000) it is likely to have negligible effects at the predicted discharge concentration.

In screening copper and chromium were 57 and 95% of their respective annual average EQS values but for both the predicted discharge concentrations are below method detection limits and are several orders of magnitude below their respective EQS (i.e. site backgrounds are not included) therefore negligible likely effects are predicted.

As was the case for the 24-hour screening assessment elevation of boron above the seawater background is relatively small and so any influence will be localised to the area around the immediate discharge. As an essential element for many marine algal species the low elevation of boron concentration is likely to have negligible effects and therefore this is screened out of further assessment.

For the annual discharge screening assessment as DIN at 37% of its background reference can contribute to nutrient status it is given further consideration in section 7.2.6. Un-ionised ammonia concentration was low at 0.05% of its EQS but un-ionised ammonia is also given further consideration in section 17.2.7 in relation to the influence of temperature elevation on the percentage of un-ionised ammonia.

For those substances that failed the screening assessment and for which significant discharge concentrations relative to their EQS are predicted further modelling is required. The chlorinated cooling water would fail initial screening at the point of discharge at a target value of 0.15mgl^{-1} total residual oxidants as compared to a maximum EQS of 0.01mgl^{-1}. The screening results also show that the residual hydrazine concentration would have the potential upon discharge and initial dilution to exceed relevant EQS or equivalent applied values. The most dominant chlorination byproduct bromoform was also subject to modelling using GETM.

The modelling has been undertaken using the validated GETM model of Sizewell used for thermal plume studies and previously described in BEEMS Technical Report TR302 and TR301 and which was chosen to support the chemical runs because it is better able to reproduce the natural variability due to meteorological and tidal conditions. The water quality parameters described below were fully coupled GETM runs with the hydrodynamical parameters.

The following chemical discharges or processes were investigated:

- Chlorination of the power station cooling water system to avoid bio-fouling. The total residual oxidants (TRO) resulting from the combination of chorine and organic material in the water are modelled using an empirical demand/decay formulation derived from experiments with Sizewell seawater and coupled into the GETM Sizewell model (BEEMS Technical Report TR143).

- Chlorination by-products (CBP's) as a result of complex chemical reactions in seawater. Many products are formed, the number and type being dependent on the composition and physical parameters of the seawater. The dominant CBP's are, in order of highest concentrations present, bromoform, dibromochloromethane (DBCM), bromodichloromethane (BDCM), monobromaceitic acid, dibromoaceitic acid (DBAA), dibromoacetonitrile (DBAN) and 2,4,6 tribromophenol. Laboratory studies carried out with chlorinated Sizewell seawater only detected bromoform (BEEMS Technical Report TR217). Bromoform is lost through volatilization to the atmosphere, with the loss rate a function of the thermal stratification and values obtained from the literature (see Mackay and Leinonen (1975)) and coupled into the GETM Sizewell model.

- The addition of hydrazine to control the oxygen concentration in the power station secondary circuit. Hydrazine is an oxygen scavenger that is used in power plants to inhibit corrosion in steam generation circuits. Hydrazine is used to condition the secondary circuit of PWR power stations and is also used in the primary circuit during start up. During normal operation most of the hydrazine injected daily into the secondary circuit is broken down by the high temperatures present, but trace amounts will be present in the power station effluent which is discharged via the cooling water system. Based on a conservative assessment of the residual hydrazine concentrations, the screening assessment indicates that following discharge and initial dilution the Predicted No Effect Concentration will be exceeded. Hydrazine is modelled by using an empirical decay formulation derived in the laboratory and coupled into the GETM Sizewell model (BEEMS Technical Report TR145).

  As the thermal input from the cooling water discharge can influence chemical and physical effects within the influence of the discharge the effects of the thermal input from Sizewell C were investigated for dissolved oxygen saturation:

- Reduction in dissolved oxygen (DO) in seawater due to the warming effect of the discharge plume. The Water Framework Directive (WFD) threshold is defined with respect to the 5 percentile, with High status being >5.7mgl^{-1} and Good status being >4mgl^{-1}.
- The potential increase in the ratio of un-ionised to ionised ammonia due to the elevated temperature of the discharged cooling water. The ammonia inputs and proportion of un-ionised ammonia are considered in more detail in terms of the influence of the thermal elevation on the proportion of un-ionised ammonia (Table 32). This assessment provides a worst-case evaluation of un-ionised ammonia inputs.

Phosphorus also passed the screening assessment but had one of the higher values in screening test 1 based on 24-hour loadings (352.5kg as PO_4). Converting this loading to PO_4-P gives a value of 115kg. The site background PO_4-P concentration is 33.5 µg l^{-1}. An area of 353x353m (12.5ha) at depth of ~16m (at the point of cooling water discharge) would contain an equivalent planned 24-hour load of a PO_4-P (66kg). A predicted PO_4-P daily exchange in summer between Sizewell Bay and outer tidal excursion and the wider area is 2440kg (BEEMS TR385) therefore the planned daily PO_4-P loading from Sizewell C would represent ~3% of this exchange value.

The microbiological assessment for operation of Sizewell C is based on that for Hinkley Point C. During operation the maximum number of staff on site is estimated at 1900 based on HPC and on numbers present during an outage. Mixing of the treated sewage effluent with the cooling water will achieve a dilution of ~2000. Assuming the same level of treatment is applied during operation as for the construction period then with UV treatment (assumed 5.4 log reduction) the discharge would comply with bathing water standards at the point of discharge.

7.3.2 Chlorine produced oxidant (TRO) assessment

Sizewell B has a permit to discharge cooling water with a maximum TRO concentration of 0.3mgl^{-1} all year round and this source term has been used for the modelling studies in this report.

For Sizewell C the TRO concentration at the outfall will depend on the chlorination strategy applied within the power station. BEEMS Technical Report TR316 presents an analysis of the possible chlorination options for Sizewell C and a recommendation for a preferred strategy that is based upon minimising environmental effects whilst maintaining the safe operation of the plant. TR316 recommends that a worst-case TRO concentration of 0.15mgl^{-1} at the outfalls should be used for plume modelling purposes based upon the preferred chlorination option in that report. This is the source term adopted for the modelling studies in this report. The GETM Sizewell model runs used in this report are listed in Table 24.

Table 24: GETM TRO modelling runs.

Run ID	Description	Intake location	Discharge location	TRO discharge at the outfall ($\mu g\ l^{-1}$)	Discharge flow and Delta T (m^3s^{-1} @ °C)	Time period
TRO_2outf-May	Conf12 with TRO discharge from Sizewell C and Sizewell B	IB I3a,I3b I4a,I4b	OB O9a, O9b	300 150,150	51.5 @ 11.0 132 @ 11.6	1/5/2009- 1/6/2009
TRO_2outf-MayTROB	Conf12 with TRO discharge from Sizewell B only	IB I3a,I3b I4a,I4b	OB O9a, O9b	300 0, 0	51.5 @ 11.0 132 @ 11.6	1/5/2009- 1/6/2009
ReferenceV2-annual	Sizewell B	IB	OB	n.a.	51.5 @ 11.0	1/1/2009 – 1/1/2010
Conf12-annual	Sizewell B and Sizewell C	IB I3a,I3b I4a,I4b	OB O9a, O9b	n.a.	51.5 @ 11.0 132 @ 11.6	1/1/2009 – 1/1/2010

The Maximum Allowable Concentration (MAC) for total residual oxidants in seawater is $10\mu gl^{-1}$ (UKTAG, 2013, Defra 2014). This forms the Environmental Quality Standard (EQS) for acute concentrations, which is taken as the 95th percentile of the concentration values. In the results both the average concentrations and the 95th percentile are presented. No EQS has been set for mean or chronic concentrations.

Two scenarios were considered:

- chlorination of Sizewell B plus Sizewell C operating in combination, and
- chlorination of Sizewell B only.

A discharge of $132m^3s^{-1}$ has been modelled for TRO for Sizewell C. For each model run a month-long simulation was analysed and the mean and 95th percentile of the TRO concentrations was extracted. The TRO plume areas at the EQS ($10\mu gl^{-1}$ as a 95%ile) have been calculated and are shown in Table 25. For Sizewell C only, there is a small area of 2.13ha exceeding the EQS at the seabed and 337.65ha at the sea surface. Figure 13 shows that the Sizewell C plume does not mix with the Sizewell B plume.

Table 26 presents the area of the plume that exceeds a concentration threshold., To show the depth profile for the plume not only the EQS value was included but also other values between 1 and $20\mu gl^{-1}$. Analysis of the TRO modelling runs shows that the EQS will only be exceeded in the mixing zone at the surface for Sizewell C and both at the surface and seabed for Sizewell B. An important observation from this modelling is the separation of the TRO plumes from Sizewell B and Sizewell C discharges with no interaction between them down to the level of $1\mu gl^{-1}$ of TRO (Figure 13). This is important because it implies that, within reason, the chlorination regimes of the two developments can be managed independently.

Table 25: Absolute areas exceeding the TRO EQS (These values are based on 132 m^3s^{-1} discharge from Sizewell C).

Model		TRO =10µgl^{-1} as a 95th percentile surface	seabed
Sizewell B+Sizewell C	ha	726.21	167.08
Sizewell B only	ha	388.56	164.95
Sizewell C only	ha	337.65	2.13

Table 26: Area of the plume at different levels of TRO concentration (from BEEMS Technical report TR303 Edition 4).

Model run	µg l-1	95th percentile surface (ha)	95th percentile seabed (ha)	mean surface (ha)	mean seabed (ha)
TRO_2outf_May - Chlorination of Sizewell B + Sizewell C	1	5450.62	3662.9	1704.96	579.31
	2	3302.04	1415.19	869.52	234.26
	4	1710.23	428.1	412.22	129.41
	6	1214.69	251.52	238.07	64.03
	8	928.17	200.28	157.89	27.13
	EQS 10	**726.21**	**167.08**	112.81	16.82
	15	436.55	101.93	64.82	8.63
	20	289.87	52.03	44.07	4.93
TRO_2outf_MayTROB - Chlorination of Sizewell B only	1	1652.14	1136.86	756.49	363.32
	2	1206.05	559.79	460.55	226.40
	4	821.86	332.71	257.02	126.72
	6	617.99	244.23	168.21	63.02
	8	483.09	197.14	122.90	27.03
	EQS 10	**388.56**	**164.96**	94.98	16.59
	15	264.98	101.26	60.11	8.41
	20	192.32	51.69	42.50	5.15
Sizewell C only	1	3798.48	2526.04	948.47	215.99
	2	2095.99	855.4	408.97	7.86
	4	888.37	95.39	155.2	2.69
	6	596.7	7.29	69.86	1.01
	8	445.08	3.14	34.99	0.1
	EQS 10	**337.65**	**2.13**-	17.83	0.23
	15	171.57	0.67	4.71	0.22
	20	97.55	0.34	1.57	-

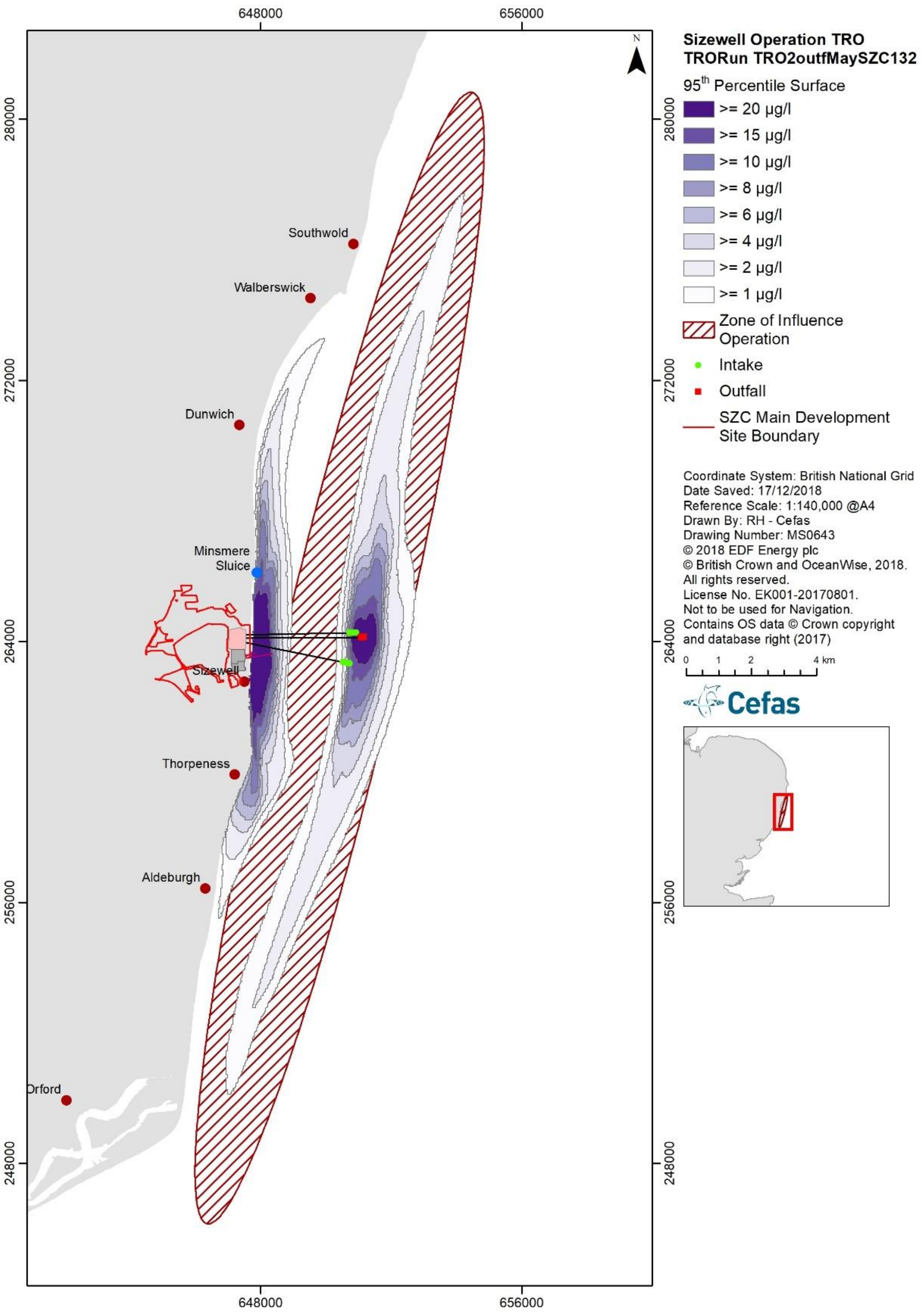

Figure 13: Sizewell B + Sizewell C modelling: 95th percentile of the TRO concentration at the surface (µgl^{-1}). The hatched area shows the outer tidal excursion.

7.3.3 Chlorination byproducts (bromoform) modelling assessment

Another consequence of the chlorination of the power station is the formation of chlorination by-products (CBP's) as a result of complex chemical reactions in seawater. Many products are formed, the number and type being dependent on the composition and physical parameters of the seawater. The dominant CBP's are, in order, bromoform, dibromochloromethane (DBCM), bromodichloromethane (BDCM), monobromaceitic acid, dibromoaceitic acid (DBAA), dibromoacetonitrile (DBAN) and 2,4,6 tribromophenol. Laboratory studies carried out with chlorinated Sizewell seawater only detected bromoform (BEEMS Technical Report TR217). Bromoform is lost through volatilization to the atmosphere, with the loss rate a function of the thermal stratification and values obtained from the literature (Mackay and Leinonen, 1975) and coupled into the GETM Sizewell model.

Since bromoform is a product of chlorination, the same scenarios as for TRO were considered: chlorination of Sizewell B plus Sizewell C operating in combination and chlorination of Sizewell B only. For each model run a month-long simulation was analysed and the 95th percentile of the bromoform concentrations was extracted. There is no published EQS for bromoform and so a calculated PNEC of 5µgl^{-1} as a 95%ile has been used (Taylor 2006). This value was predicted based on the results of a toxicological review and the application of Quantitative Structure Activity Relationships (the same figure was used In the HPC WDA permit application). Figure 14 shows the area of the plume that exceeds the relevant concentration threshold.

The amount of bromoform that is discharged mainly depends on the amount of chlorine that is added, but also on the amount of mixing. In laboratory experiments (BEEMS Technical Report TR217), different concentrations of bromoform are obtained from the same initial concentration when samples are stirred or not. Evident from these studies is that stirring, as might be expected in a turbulent discharge appears to reduce bromoform concentration. Unstirred replicate samples following addition of 0.5mgl^{-1} Cl_2 had 19µgl^{-1} of bromoform compared to the much higher value of 29µgl^{-1} that was reported for unstirred replicate samples.

Like the TRO plume, the bromoform plume is a long, narrow feature parallel to the coast. Also, the Sizewell B plume is always within the channel inshore of the Sizewell-Dunwich Bank and does not overlap with the Sizewell C plume that is outside the Bank (Figure 14). Both plumes are strongly stratified with larger areas at the surface than at the seabed. The Sizewell C plume is generally smaller and narrower than that due to Sizewell B; the exception is at the 1µgl^{-1} contour for the 95th percentile where the Sizewell C plume has a longer extent but at higher concentrations the Sizewell C plume is always smaller. This is due to the lower initial discharge concentration and greater water depth at the Sizewell C outfall location (16m vs. 5m for Sizewell B outfall).

The Bromoform plume areas that exceed the PNEC (5µgl^{-1} as a 95%ile) have been calculated and are shown in Table 27. For Sizewell C only, the area exceeding the applied EQS at the seabed is 0.67ha and 52.14ha at the sea surface.

Table 27: Absolute areas exceeding the Bromoform PNEC.

Model		PNEC = 5µgl^{-1} as a 95th percentile Surface ha	Seabed ha
Sizewell B+Sizewell C	ha	357.94	130.19
Sizewell B only	ha	305.80	129.52
Sizewell C only	ha	52.14	0.67

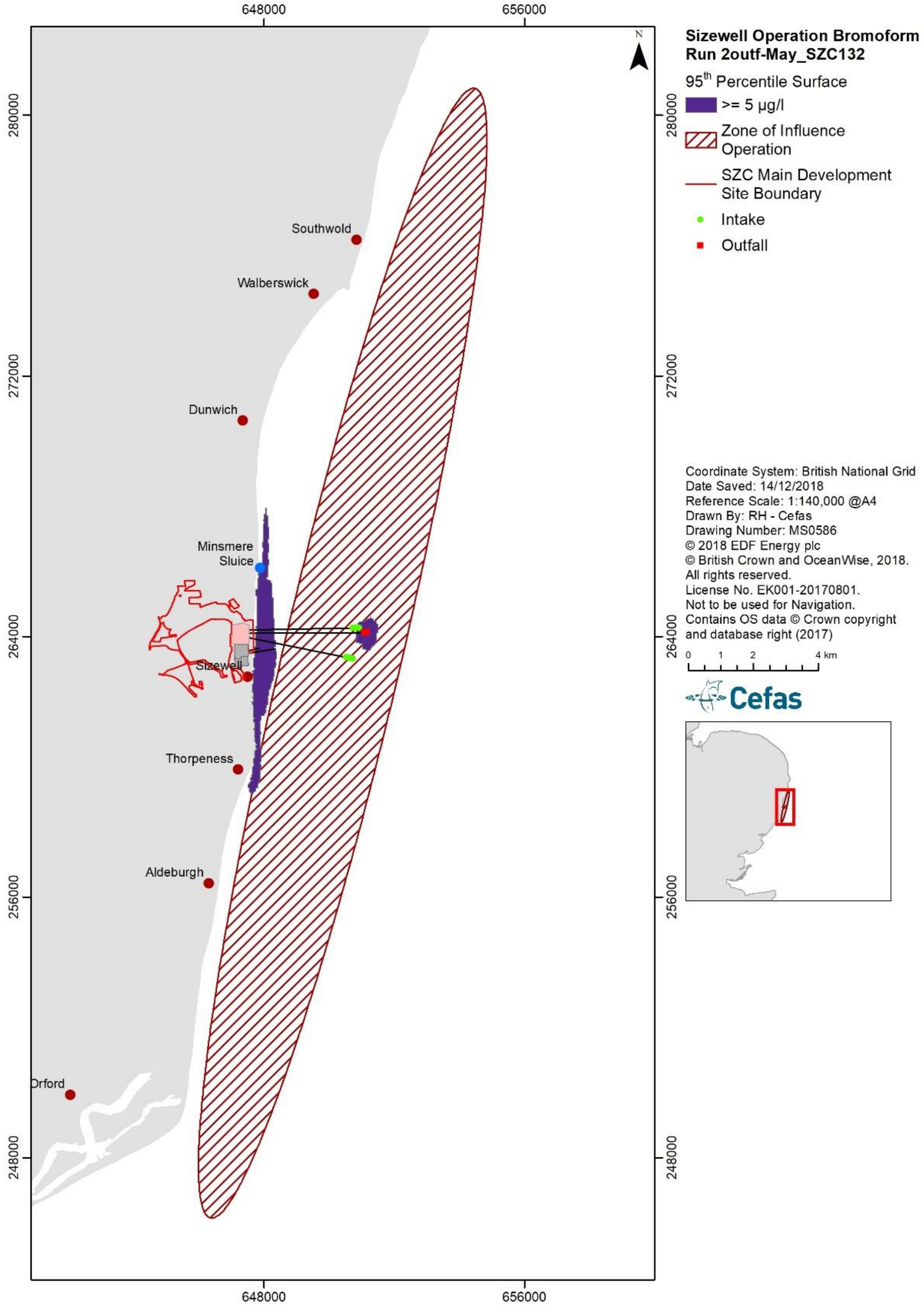

Figure 14: 95th percentile of the Bromoform concentration at the surface for chlorination from Sizewell B and Sizewell C (run Brom_2outf_May). The dark shaded area delineates the PNEC of 5µgl^{-1}. The hatched area shows the outer tidal excursion.

7.3.4 Hydrazine modelling assessment

There is evidence that hydrazine is harmful to aquatic organisms at low concentrations with the lowest acute six-day EC50 of 0.4µgl^{-1} for growth inhibition of a marine alga, *Dunaliella tertiolecta*. Hydrazine persistence in the marine environment is low to moderate dependent upon its concentration and the water quality. There is no established EQS for hydrazine and so a chronic PNEC (Predicted No-Effect Concentration) of 0.4ngl^{-1} has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4ngl^{-1} for short term discharges (represented by the 95th percentile).

In this report the daily discharges from the Sizewell C secondary circuit have been modelled corresponding to an annual hydrazine discharge of 24kg per annum into the cooling water flow of 125m^3s^{-1}. Sizewell B has no permitted hydrazine discharge so was not included in the scenario tested. To understand the impact of different discharge rates from the treatment tanks two discharge scenarios were studied for Sizewell C: the first one considering a hydrazine discharge of 69ngl^{-1} in daily pulses of 2.32h starting at 12pm, and the second one of 34.5ngl^{-1} of hydrazine discharged in daily pulses of 4.63h duration starting at 12pm. The amount of mass that is released in each of these scenarios is the same. Due to the pulse-like discharge, the interpretation of the short-term results (daily) is biased to the moment of the tidal cycle when hydrazine has been released. In order to minimize this aliasing with the tidal signal, the simulation period has been fixed to 28 days (from the 1st of May to the 29th of May), which corresponds to two complete tidal cycles.

Hydrazine is modelled by using an empirical decay formulation derived in the laboratory and coupled into the GETM Sizewell model (BEEMS Technical Report TR145). The derivation of this decay constant has proved problematic in the past because of limitations in the stability and sensitivity of analytical methods for the measurement of hydrazine in seawater. The experiments described in TR145 used an analytical method with a limit of detection of approximately 10µgl^{-1} and therefore had to perform decay experiments using initial hydrazine concentrations of 50 – 300µgl^{-1} which are considerably greater than the estimated concentration of the daily discharges from Sizewell C. These experiments produced an estimated hydrazine half-life of 12-35 hrs which in agreement with previous reported work and was used in the modelling reported in Technical Report TR303 Edition 4. Previous work by Cefas and others has obtained indications that the half-life of hydrazine in seawater is concentration dependent however it has previously not been possible to confirm that the half-life continues to fall at concentrations of less than 100ngl^{-1}. More recent work has been conducted using a proven method developed by Cefas that has a Limit of Detection of 5ngl^{-1}. A more extensive set of studies has now shown that for concentrations of hydrazine between 30-3000 ng l^{-1}, the decay rate of hydrazine in Sizewell sea water follows first-order kinetics and has a half-life of 38 minutes. This work is reported in TR352. However, the assessment made here is based on the earlier more conservative modelling derived from the data in TR145 (Half-life 32 hours).

In BEEMS Technical Report TR303 each hydrazine model run was for 28 days (two tidal cycles) and the mean and 95th percentile of the hydrazine concentrations was extracted. Table 28 presents the area of the plume that exceeds both concentration thresholds. To provide an indication of the hydrazine concentration profile with depth not only the chronic and acute PNEC values were included, but also other values between 0.1 and 0.5ngl^{-1} for the chronic concentrations and between 1 and 5ngl^{-1} for the acute concentrations.

Table 28: Area of the plume at different levels of Hydrazine concentration.

Model run		ngl^{-1}	95th percentile surface (ha)	95th percentile seabed (ha)	Mean surface (ha)	Mean seabed (ha)
Hydrazine_SZC_34ng_May – release of hydrazine in pulses of 4.63h a day starting at 12pm. SZC only	Chronic PNEC	0.1			3914.09	3364.50
		0.2			1269.19	795.85
		0.3			389.46	1.46
		0.4			**156.88**	**0.34**
		0.5			66.16	0.11
	Acute PNEC	1	446.42	15.14		
		2	132.54	0.78		
		3	54.72	0		
		4	**17.38**	**0.00**		
		5	1.23	0.00		
Hydrazine_SZC_69ng_May- release of hydrazine in pulses of 2.32h a day starting at 12pm. SZC only	Chronic PNEC	0.1			4399.32	3788.72
		0.2			1477.99	942.53
		0.3			441.04	2.24
		0.4			**158.12**	**0.56**
		0.5			60.55	0.11
	Acute PNEC	1	329.35	2.8		
		2	49.11	0.67		
		3	22.5	0.22		
		4	**13.79**	**0.22**		
		5	3.58	0.11		

The hydrazine plume areas at the chronic PNEC ($0.4ngl^{-1}$ as an average) and the acute PNEC ($4ngl^{-1}$ as the 95th percentile have been calculated and are shown in Table 29.

Table 29: Absolute areas exceeding the Hydrazine PNEC.

Model	**PNEC**		Absolute area of exceedance surface	seabed
Hydrazine_SZC_69ng_May mean	Chronic 0.4 ng l^{-1}	ha	158.11	0.56
Hydrazine_SZC_34ng_May mean	Chronic 0.4 ng l^{-1}	ha	156.88	0.336
Hydrazine_SZC_69ng_May 95th percentile	Acute 4 ng l^{-1}	ha	13.79	0.22
Hydrazine_SZC_34ng_May 95th percentile	Acute 4 ng l^{-1}	ha	17.38	0.00

The chronic PNEC is exceeded at the surface and at the seabed, although for the seabed, an area of less than 1ha is affected for both discharge scenarios. The acute PNEC is exceeded at the surface (less than 18ha) and at the seabed, but only in the case of the 69ngl^{-1} release for an area of 0.22ha.

BEEMS Technical report TR303 presents the predicted plume plots at the surface and the seabed from model runs of daily hydrazine discharges from Sizewell C. Figure 15 shows the predicted surface plume resulting from a daily hydrazine discharge from Sizewell C.

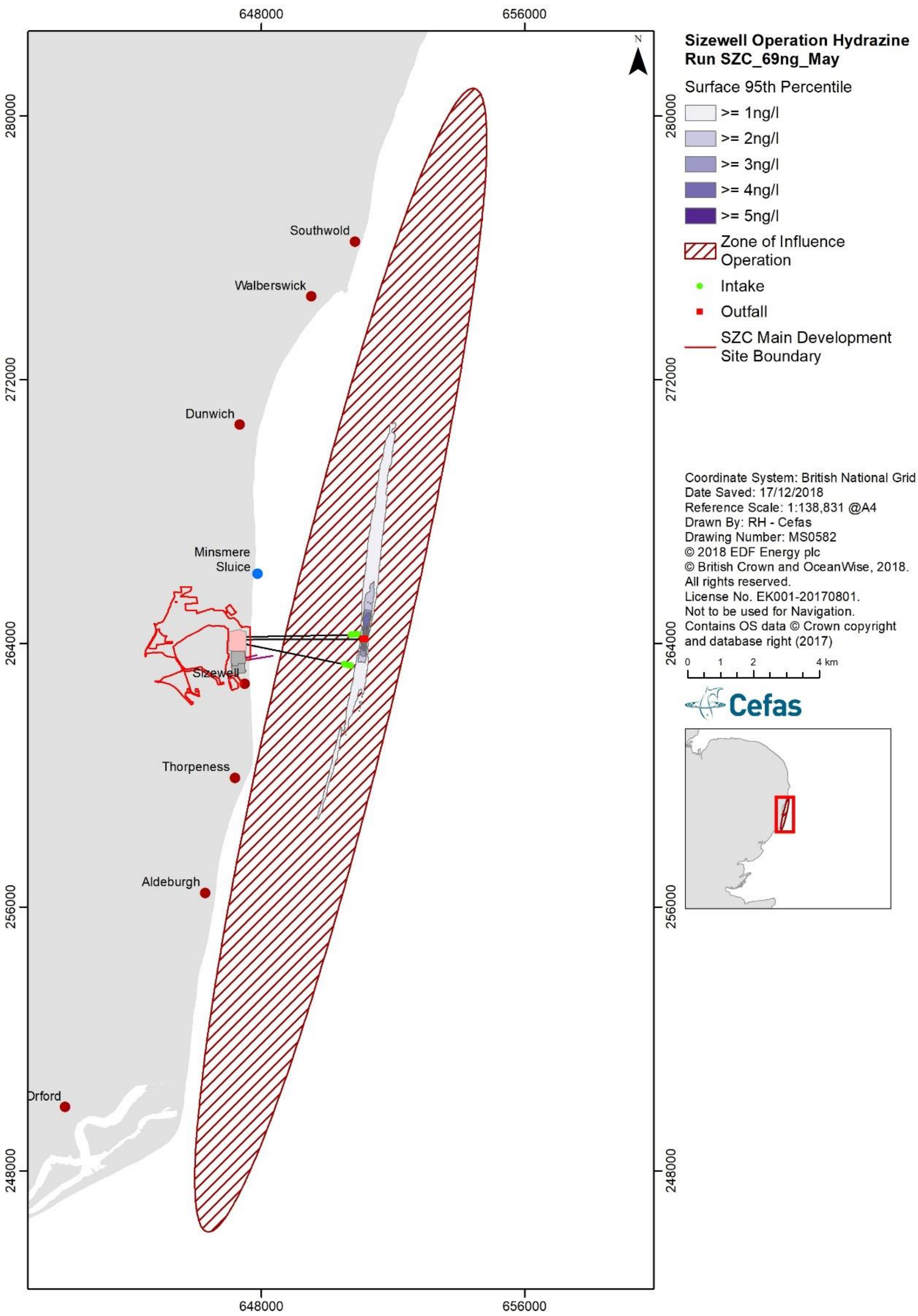

Figure 15: 95th percentile hydrazine concentration at the surface after release of 69ngl^{-1} in pulses of 2.32h from Sizewell C (run Hydrazine_SZC_69ng_May).

7.3.5 Dissolved oxygen modelling assessment

With dissolved oxygen the issue is to avoid low values, the WFD threshold for dissolved oxygen is the 5th percentile i.e. that concentration which will be exceeded 95 per cent of the time. In relation to the effect of the thermal plume, it is the temperature that directly determines the dissolved oxygen concentration in an inverse relationship, high temperatures lead to low dissolved oxygen concentration. The calculation method used in this report is therefore to use the 95th temperature fields derived from the model to generate the dissolved oxygen concentration that would be expected at 100% saturation, which gives the 5th percentile dissolved oxygen field across the whole domain.

The Water Framework Directive applies to 1 nm from the coast (approx. 1850m) and from 2016 the Marine Strategy Framework Directive applies to the UK boundary. Both standards use the same criteria for defining permissible dissolved oxygen (DO) concentrations, 4 – 5.7mgl^{-1} being good status and above 5.7mgl^{-1} is high status.

Table 30 shows the area calculated from the GETM runs that is beneath various DO concentrations for the entire model domain. The average DO concentration over the model domain for both scenarios is >7mgl^{-1} as a 5th percentile which is above the WFD threshold for High Status of 5.7mgl^{-1}. Therefore all areas are predicted to meet High status.

Table 30: Area in hectares below various waterbody quality status boundaries for dissolved oxygen for the entire model domain (Standards and Classification) Directions (England and Wales, 2015).

DO concentration as a 5th percentile (mg l^{-1}) Normalised to salinity 35	**Sizewell B + C (ha)**		**Sizewell B only (ha)**	
	Surface	Bed	Surface	Bed
4.47 (Boundary at Good status)	0	0	0	0
5.77 (1%)(Boundary of high status)	106	8	52	5
5.97 (5%)	631	279	234	104
6.19 (50%)	7,064	6,053	2,453	2,401
6.39 (95%)	108,437	108,045	102,068	105,808
6.43 (99%)	124,345	124,152	119,048	123,681

7.3.6 Relative proportion of un-ionised ammonia due to thermal elevation of cooling water and influence on wider environment

In the operational phase Sizewell C will discharge ammonia from plant conditioning chemicals and the on-site sewage treatment plant. The maximum annual discharge of nitrogen (as ammonia ions) from circuit conditioning for two EPRs is 13,009kg and the worst case sanitary loading during an outage is calculated to be 1,387kg giving a worst case ammonia discharge of 14,396kg (BEEMS Technical Report TR193) which gives a calculated mean ammonia discharge concentration of 3.9µgl^{-1} NH_4 (3.06 µgl^{-1} NH_4-N) at the outfall assuming a worst case cooling water discharge rate of 116m^{3}s^{-1}. (This is the lowest volume of water abstracted under normal operating conditions and represent a worst-case scenario in terms of dilution of contaminants in the CW stream). As a conservative assumption this value has been added to the regional background mean and 95th percentile values for relevant physicochemical parameters and used temperature fields generated by GETM and the relevant physicochemical data and total ammonia concentration for each scenario to derive the un-ionised ammonia calculation. A summary of the annual mean increases in un-ionised ammonia concentration predicted at the surface for Sizewell Bay is shown in Table 32. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of 21µgl^{-1} as an annual mean and the predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS of 21µgl^{-1}. Assessment of potential inputs of ammonia from breakdown of hydrazine, ethanolamine/morpholine indicate that this would be at a maximum an additional 4% increase to the annual loading. Relative to the assessment results Table 32 this is considered of negligible influence.

Table 31: Summary of un-ionised ammonia concentration (EQS is 21µgl^{-1} as an annual mean) at the surface

Un-ionised ammonia for mean temperature, mean ammonia, 50th percentile pH, salinity (The regulatory standard)		
	Sizewell B + C	Sizewell B
50th centile	**0.25**	**0.25**
95th centile	0.27	0.26
99th centile	0.29	0.27
Maximum	0.52	0.50
Un-ionised ammonia for 95th percentile temperature, mean ammonia, 50th percentile salinity, pH.		
	Sizewell B + C	Sizewell B
50th centile	0.8	0.46
95th centile	0.8	0.47
99th centile	0.9	0.52
Maximum	1.2	0.91
Un-ionised ammonia for mean temp, 95th percentile pH, ammonia , 5th percentile salinity		
50th centile	0.8	0.81
95th centile	0.8	0.83
99th centile	0.9	0.88
Maximum	1.61	1.55
50th centile	0.8	0.81

7.3.7 DIN in operational discharges

During operation, the maximum number of people on site occurs when there are refuelling outages, during this time nitrate and phosphate loads are increased above background concentrations. The refuelling outages typically last four to six weeks but can occur at any time of year. During the winter period light is limiting and there is no effect resulting from the additional supply of nutrients. It is only in summer that the discharge needs to be considered. During operation the maximum 24-hour loading of nitrogen from all sources is 332kg and the maximum annual loading 11725 kg per year (32.12kg d^{-1}). During the operational phase, maximum daily loading for nitrogen therefore reach approximately 2% of the daily exchange for Sizewell Bay, but the average daily value is low at 0.2% (again indistinguishable from background levels) (BEEMS TR385). The effect of Sizewell B and the proposed Sizewell C on phytoplankton that pass through the power station has been simulated using a phytoplankton box model. The observed cycle of plankton production has been simulated with emphasis on the spring bloom and summertime production. During operation the power stations discharge nutrients in the form of phosphate and nitrates resulting from the use of conditioning chemicals and the discharge of treated sewage. The influence of power station chlorination upon phytoplankton survival is also incorporated into the model. For much of the year light availability limits phytoplankton growth and the addition of relatively small quantities of nutrients has no effect. In the summer, nitrate is a limiting nutrient (when light is not limiting) and is consumed rapidly. However, the exchange with the wider environment is much greater than the maximum proposed discharges, during operation, so that no change in phytoplankton growth beyond natural variability would be observed. The phytoplankton growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. During operation the use of hydrazine, morpholine and/or ethanolamine have the potential to contribute to the nitrogen input to the marine environment. An assumption of maximum potential inputs not accounting for atmospheric nitrogen loss or incomplete breakdown, results in a small potential addition of 1.3kg/day. This addition is small relative to operational values of 32kg/day and would be insignificant relative to the daily exchange and would not be expected to influence phytoplankton growth above that predicted for other operational inputs of nitrogen.

7.3.8 Phosphate in operational discharges

Phosphorus also passed the screening assessment but had one of the higher values in screening test 1 based on 24-hour loadings (352.5kg as PO_4). Converting this loading to PO_4-P gives a value of 114.8kg. A predicted PO_4-P daily exchange in summer between Sizewell Bay and outer tidal excursion and the wider area is 2440kg (BEEMS TR385) therefore the planned maximum daily PO_4-P loading from Sizewell C would represent ~5% of this value. The maximum daily discharge concentration is 11.58µg$l^{-1}$$PO_4$-P and is below the site background value of 33.5µgl^{-1} (Table 21). However, the average daily operational discharge would be 0.7kg PO_4-P and this represents 0.03% of the daily exchange. There is no equivalent EQS value for phosphorus and it is not normally the limiting nutrient in marine waters, and the discharge concentration is also below background concentrations for offshore waters based on mean winter nutrient concentrations in Atlantic seawater (Foden *et al*., 2009). Incorporation of the operational phosphorus load together with that of the DIN was modelled in BEEMS TR385 as described in the 7.2.8 above and showed a negligible increase in carbon levels at 0.11%.

7.3.9 Biochemical oxygen demand (BOD) assessment for operational discharges

BOD loadings assessed during operation take account of maximum staff numbers on site during an outage based on Hinkley Point C this is estimated as 1900 staff. The waters off Sizewell are well mixed vertically. Draw down of oxygen will only occur if the rate of consumption due to BOD is greater than the oxygen transfer across the water surface. Typical values of oxygen flux are 100mmol $m^{-2}d^{-1}$ (Hull, 2016) or 3.2g$m^{-2}d^{-1}$. The maximum daily BOD loading based on 1900 staff on site is 3.8kg. This amount of oxygen would be transferred across just over 1000m^2 in a day. After mixing in the cooling water this loading is not expected to show measurable change in BOD background. Therefore, DO is likely to remain at high status. The discharge of BOD during operation is therefore considered to be of negligible significance for dissolved oxygen modification.

7.3.10 Coliforms and intestinal enterococci assessment for operational discharges

During operation the maximum number of staff on site is estimated at 1900 (with 100l^{-1} per head per day effluent production) based on HPC and on numbers present during an outage. Mixing of the treated sewage effluent with the cooling water flow from one EPR (66m^3 s^{-1}) will achieve a dilution of ~33000. Assuming the same level of treatment is achieved during operation as for the construction period then application of either secondary treatment only and with UV treatment will achieve compliance with the bathing water standards at the point of discharge.

7.3.11 Fish Recovery and Return assessment

A Fish Recovery and Return system (FRR) is planned to provide a safe return of the more robust organisms from the drum screens directly into the marine environment. An initial assessment of discharge of chlorinated seawater from this system was made in BEEMS TR333 and all the potential tunnel locations passed the assessment. However, intakes and tunnels will not be chlorinated. Chlorination first occurs after the drum and band screens but routing of the water sources that supply the FRR will mean that it is not chlorinated.

This section describes the impacts associated with the operation of the unmitigated FRR (alternative head designs are being evaluated and these would reduce impingement numbers, so the present assessment is very conservative). The FRR system is designed to minimise impacts on impinged fish and invertebrate populations. However, some species such as clupeids are highly sensitive to mechanical damage caused by impingement on the screens and incur high mortality rates. The return of dead and moribund biota retains biomass within the local food web but represents a source of organic carbon with the potential to enhance secondary production of carnivorous zooplankton and through the detrital pathways. In addition to organic loading, the potential for increases in nutrients, un-ionised ammonia concentration and reductions in dissolved oxygen are considered.

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 (BEEMS TR193). The biomass predictions are used to derive nitrogen and phosphorus contributions to the marine environment and to assess the affect upon dissolved oxygen and un-ionised ammonia levels due to decomposing tissues. Three biomass values are used in the assessment:

(i) During the period April to September increasing light and temperature mean that phytoplankton growth is increasing so this is a period when elevated nutrient levels can exert most impact.

(ii) Annual average biomass is derived to take account of the variability of species abundance throughout the year and is used to provide a more precautionary input for the phytoplankton modelling.

(iii) The maximum daily loading of biomass occurs during March and this is used to derive the most precautionary estimates of un-ionised ammonia and biochemical oxygen demand

Highest discharged biomass occur during the winter when it would have least influence on phytoplankton growth but to provide a more conservative assessment annual average biomass value was used to derive predicted nitrogen and phosphorus loadings which were 37.3kg per day N and 5.3kg per day P (Loadings for April to September were lower at ca., 14kg N and ca., 2kg P). These derived annual values for the FRR were combined with the predicted daily inputs during operation and used as source values in the Combined Phytoplankton and Macroalgae Model. A model run over an annual cycle predicts a less than 0.29% difference in annual gross production (BEEMS TR385) of carbon and this level of change would not be discriminated above natural background variation.

An assessment was also made for un-ionised ammonia. Studies on cod tissue were shown to contribute 125mg kg^{-1} NH_4 (Timm and Jorgensen, 2002) so this value was used together with Sizewell monitoring data for pH, temperature and salinity to derive an equivalent un-ionised ammonia concentration (BEEMS TR193). The average daily biomass loading from the Sizewell FRR over the April to September period and relevant pH, temperature and salinity during this period were used to derive an equivalent un-ionised ammonia loading. Based on a minimum depth at the FRR discharge point of 4m the volume of water (defined by surface area) that would be required to dilute the calculated load of un-ionised ammonia to the level of the EQS was derived. Considering extreme summer pH, temperature and salinity an area of 3.8ha would exceed the un-ionised ammonia EQS (21µg l^{-1} NH3-N, expressed as an annual average). For March when the predicted fish biomass loading discharged from the FRR is at a maximum (adjusting for appropriate seasonal temperature, pH, salinity) an area of 6.7ha would exceed the un-ionised ammonia EQS.

The effect of biomass decay on dissolved oxygen was also derived. The source biochemical oxygen demand values associated with a given unit biomass were calculated based on annual mean value (BEEMS TR193).

An oxygen deficit was calculated since 1.5mgl^{-1} deviation in BOD from background is expected to generate less than 0.5mgl^{-1} impact/reduction on dissolved oxygen (OSPAR Comprehensive studies report, 1997). The calculated annual mean daily biomass oxygen demand (447.5kg/day) represents 0.2% of the oxygen available in the volume of water exchange across the Greater Sizewell Bay (BEEMs TR385). Reaeration at the surface would also resupply oxygen with typical values of surface exchange for this area providing an equivalent loading to that consumed by the biomass discharge over an area of ca., 14ha. For the maximum predicted discharge of biomass during March oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha.

Each of the biomass impact assessments assumes direct breakdown of all tissue with no losses through scavenging and predation of the discharged fish. The high exchange rate for this area and the fact that the water is well mixed vertically indicate that the calculated impacts related to nutrient inputs, un-ionised ammonia and biochemical oxygen demand would affect a relatively small area and would not be significant. These assessments are made against the background contribution from Sizewell B.

7.4 Cooling water discharge and the influence Climate change

Under future climate change predictions various environmental changes would influence the behaviour, fate and effects of operational discharges from Sizewell C. The following sections consider the most likely effects that could occur and consider these in the context of the current impact assessment.

7.4.1 Thermal elevation influence on chlorination

Cooling water chlorination and hence 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.

Although the rate of TRO decay would increase at elevated temperatures, dosing would be adjusted to ensure that the target TRO of 0.2mg l^{-1} is achieved in critical sections of the CW plant. The relative temperature increase under future climate change would not necessitate significantly higher chlorination to achieve target TRO values therefore the associated chlorination by-product concentration would not be significantly elevated relative to the present conditions. The relative increase in temperature background in the wider environment is also unlikely to significantly increase TRO decay upon discharge and consequently a conservative assessment is that the discharge plume size and magnitude are likely to be comparable to those predicted under the current baseline.

7.4.2 Reduced pH levels influence on chlorination

Several Oceanic Global Circulation Models (OGCMs) have projected a pH reduction of 0.3 -0.4 units by the end of the century (Orr, 2011). Assuming atmospheric CO_2 increases by 500ppm by 2050 a decrease of ca., 0.1 pH unit is predicted over most of the North Sea area (Blackford and Gilbert, 2007). Other projections suggest a reduction 0.14 units below present values by 2050 and 0.3–0.4 below present units in 2100 (Nakicenovic, N, and Swart, R. 2000. Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios).

The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH (Jolley and Carpenter, 1981): 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 projected 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 for the present impact assessment.

The formation and types of other chlorination byproducts that occur during seawater chlorination is also influenced by aspects of seawater quality including pH. The most abundant CBP in discharges from coastal power stations, and the only one detected in recent CBP decay studies using Sizewell seawater is bromoform (BEEMS TR217).

TRO discharges would occur for the operational life of the proposed development and would be continuous when water temperatures exceed 10ºC. CBP 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 CBP 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 CBPs is unlikely to extend considerably

For bromoform, the dominant CBP 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 bromoform decay and consequently the discharge plume magnitude and extent are conservatively assessed to be like those predicted for the current baseline.

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 CBPs 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

7.4.3 Climate change influences on other operational discharges

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.

For hydrazine, the primary fate processes in water are oxygen dependent chemical breakdown and biological breakdown. The former is dependent on the presence in water of appropriate catalysts e.g. copper (MacNaughton et al., 1978) and other factors such as ionic strength, temperature and pH (Environment Canada, 2011). Biodegradation is also influenced by temperature. Hydrazine half-life (time for concentration to reduce 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. Reducing pH is also likely to reduce the degradation time for hydrazine but the degree of this change is expected to be small under future ocean acidification predictions. Hydrazine decay rate is only shown to significantly increase at values below pH 4 (Environment Canada, 2011) and future climate baseline predictions for regions such as the North Sea are ca., 7.8 - 7.6.

The proportion of un-ionised ammonia would change relative to the ionised form with increased temperatures increasing the proportion in the un-ionised form and decreasing pH, so reducing the un-ionised ammonia. However, 24-hour cooling water discharge assessments already take account of thermal extremes that occur within the cooling water system and even under these elevated temperatures the proportion of un-ionised ammonia when accounting for background, increases within the cooling water system to ca., one third of the EQS (Table 45 and BEEMS TR193). In the wider discharge plume temperature uplift would be more modest and even during peak predicted future summer temperatures (see Appendix F) based on the maximum ammonium input via the cooling water system the un-ionised ammonia would be low and equivalent to ca., 11% of the EQS.

7.5 Inter-relationship effects Operation

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 16** shows the extent and overlap at the seabed and surface of various operational discharges.

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

During the 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 CBPs depending on the water chemistry.

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

Seawater chlorination with ammonia present is likely to form different residual oxidants dependent on the ammonia to chlorine ratio. Dibromamine is one of the primary formation products and has a generally higher toxicity that uncombined oxidants of chlorine or bromine (Capuzzo, 1979, Fisher et al., 1999) although it is of very low persistence. However, total ammonia in the discharge is very low at around one third of the background ammonia, any increase in toxicity above that due to chlorination alone is expected to be insignificant.

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

In addition to the potential reaction of ammonia and chlorinated seawater the thermal uplift of the seawater has the potential to influence the sensitivity of exposed organisms to residual oxidants. The main potential for synergistic effects of temperature and toxicity of the chlorinated seawater is to species experiencing primary entrainment in the cooling water system and these are considered as part of the entrainment impact assessment. However, for organisms experiencing secondary entrainment in the thermal plume (beyond ca.,10 -20m) the residual oxidant exposure would be low at a few 10s of micrograms/litre and the thermal elevation would be a few degrees above background. Under these conditions the 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. The thermal uplift of the plume beyond the immediate discharge point in combination with the toxicological effects of chlorination is therefore not expected to change the assessment of the chlorinated seawater discharge or thermal plume considered separately.

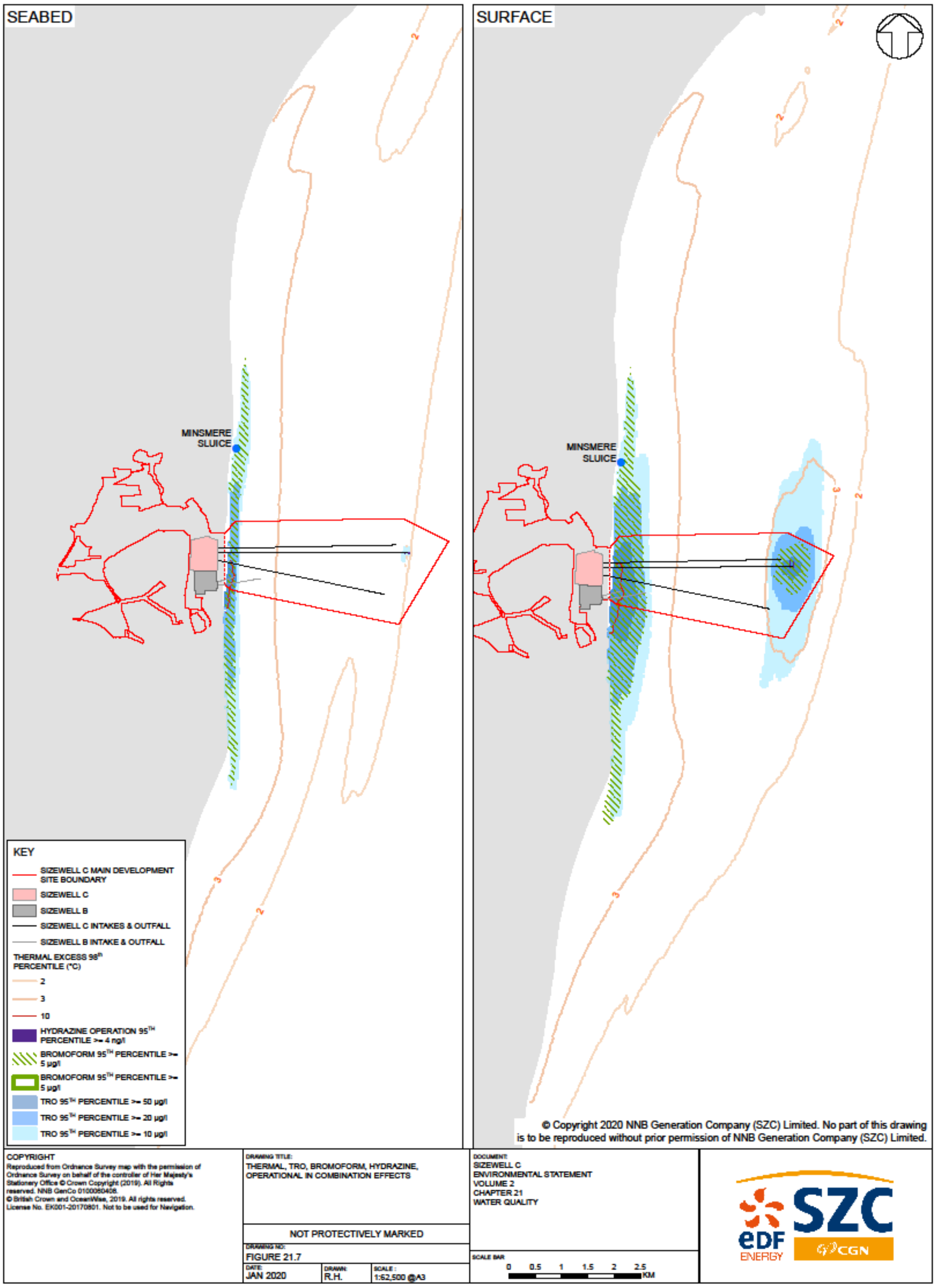

Figure 16: Overlap of thermal and chemical plumes during operation of Sizewell C and in combination with Sizewell B.

8 Summary assessment of main site activities

8.1 Background to assessment of main site activities

Table 32: Scale of construction activities in the marine environment with potential to influence sediment and water quality.

Structure	Activity	Influence of activity
Sediment	Disturbance	The sandy nature of the material and levels of contamination below Cefas Action Level 2 found in the marine sediment at Sizewell, there is a low risk of bioavailable contaminants. Sediments associated with dredging for the Planned Development are therefore considered to be uncontaminated and the effects of resuspension of contaminants on marine water quality and ecology receptors is not considered further.
Beach Landing Facility	Dredging	Capital dredging of the BLF would remove a total dredge volume of 4,600m^3. Modelling indicates sediment only settles on the bed over a relatively small area close inshore. Depth average location maximum SSC of more than 100mgl^{-1} above daily maximum background extend approximately 5 km north and south of the dredge site over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. Plume quickly disperses after dredge – low concentrations 20mgl^{-1} above background over three days. For maintenance dredging plumes of SSC of 100mg/l would affect an area of 108ha at the surface and 28ha at the bed but this elevation in SSC would relatively short-lived. Changes in SSC are not of sufficient duration and magnitude to alter the SSC status of the Suffolk Coastal Waterbody
Cooling water intake and outfall	Dredging	For intakes elongate area 13km north, 22km south ~2 km east-west affected by increases in SSC >100mgl^{-1}, depth averaged peak at >1,000mgl^{-1} above background. Elevated concentrations are short lived, with more typical SSC of 100mgl^{-1}. Following dredging, the plume quickly dissipates –ca., two days until at background. Dredging for outfall similar SSC elevation and time to return to background. Changes in SSC not significant for marine water quality.
	Drilling and shaft insertion	During the drilling of the bedrock at the intake structures, a very diffuse plume with SSC of around 5mgl^{-1} relative to background may occur– Changes in SSC not significant for marine water quality
	Installation head	Head is lowered into place, not cast in-situ so no predicted foreign material release effects to the water and sediment quality of the local area
FRR and CDO	Dredging	No areas are subjected to increased surface SSC of more than 50mg/l for more than 6 hours.
	Drilling	Tunnel approximately 0.8m diameter directionally drilled from onshore with drill cuttings returned to land no predicted sediment resuspension effects to the water. There are no details available for chemical selection and quantities required for tunnelling but conservative values for products assessed for use at HPC are evaluated for Sizewell. Changes in SSC not significant for marine water quality
	Installation of head	Head lowered into place, not being cast in-situ so negligible predicted foreign material release effects to the water and sediment

Table 33: Construction discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Metals load	Combined discharges for groundwater were assessed for contribution against the annual load limits for the priority hazardous substances cadmium and mercury of 5kg and 1kg cumulative loads. These values are not exceeded by the discharges during any phases of construction. Consideration also made of potential additional inputs from trace metal contamination of water treatment chemicals used for demineralisation of water and these additions did not result in exceedance of the annual load limits.
Metals thresholds	Several metals are present in groundwater. Chromium and zinc fail screening and were modelled. Chromium plume is below EQS at<25m and zinc is undetectable above background at<3m from the CDO outfall. Not significant.
Ammonia	Maximum ammoniacal nitrogen contributions from groundwater and sewage for the construction period were evaluated. Exceedance of the EQS for un-ionised ammonia (21µgl^{-1}) maximum only occurs within 6.3m of the point of discharge. Not significant
Nutrients DIN and phosphorus	Maximum dissolved inorganic nitrogen and phosphorus contributions from groundwater and sewage were combined with the nitrogen and phosphorus loading used during commissioning. These loadings provided source terms for input to a combined phytoplankton and macroalgae model. Run over an annual cycle the model showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.13% for maximum construction and commissioning inputs of DIN and phosphorus. Not Significant
BOD	Using 13.3ls^{-1} and BOD of 40mgl^{-1} and taking account of groundwater contributions a maximum daily BOD of 121kg was calculated. This represents an oxygen requirement of 40.6kg/day. This amount of oxygen would be transferred across 1.2ha in a day and reaeration at the sea surface would also contribute. There is therefore considered negligible impact on the well mixed and well oxygenated waters off Sizewell from this discharge. Not Significant
Microbiological	*E.coli* meets bathing water standards <1m of the outfall with UV treatment and intestinal enterococci are ≤200 cfu/100ml at discharge the nearest Bathing water is 10k North of the discharge. No impact.
Tunneling wastewater and chemicals	The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. Three chemicals used to facilitate tunnelling and that might be discharged at Sizewell were evaluated in terms of significance of discharge concentration. Conservative scenarios were modelled for a clay mineral (bentonite) that may be required at Sizewell and based on Hinkley Point information for two surfactant chemicals. The low toxicity of bentonite, the small areas affected (concentrations of 10µgl^{-1} restricted to sea surface areas of mean 1.35ha and a 95th percentile area of 10.8ha) and the low discharge concentrations are likely to have negligible effects on water quality. For both surfactants assessed no exceedance of the EQS occurred at the seabed and the maximum area of exceedance at the surface was small with highest mean exceedance of 3.14ha and 25ha as a 95th percentile. Not significant for marine water quality.

Table 34: Commissioning discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Commissioning discharges	For commissioning the predicted discharge concentrations of phosphate were already assessed in combination with construction discharges. The circuit conditioning chemical ethanolamine passed the H1 test 5 dilution screening test and hydrazine and un-ionised ammonia were evaluated using GETM discharge modelling via the CDO. Hydrazine would be treated to achieve a maximum discharge concentration of 15µgl^{-1}. This discharge was assessed in terms of areas of exceedance for the acute and chronic hydrazine PNEC and intersection with the Minsmere sluice, the Coralline Crag and the foraging area for three SPA breeding colonies of birds. Hydrazine only intersects the sluice on the ebbing tide when it is likely to be closed. Passage of species like Eel that move to and from the saltmarsh via the sluice are not expected to have a significant affect as the peak concentrations are 800,000-fold less than levels shown to cause sublethal effects in fish. Peak hydrazine concentrations over the coralline crag do not exceed the precautionary chronic PNEC. The hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. The hydrazine plume intersects foraging areas for the Minsmere Little Tern colony. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging range, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours a day. These changes are evaluated not significant for marine water quality, but further assessment is relevant for specific receptors. The un-ionised ammonia discharge during commissioning is rapidly reduced by the changing pH and salinity as well as by dilution as it mixes with seawater. Exceedance of the annual average EQS for un-ionised ammonia is predicted to only to occur in the direct vicinity of the discharge point and to be below the EQS 25m from the point of discharge. This change is not considered significant for marine water quality. As for the construction discharge assessment the total ammonium concentration at the point of mixing described above is at background for total ammonia and well below levels of concern.

Table 35: Inter-relationship effects during construction period

Determinand	Influence of discharge
Overview	This section provides a description of the identified inter-relationships that have the potential to affect marine water quality and sediment from construction and cold commissioning of the proposed development. Activities include potential for overlapping dredging for different infrastructure. Assessment of the construction discharges have already accounted for maximum potential inputs of the same substances from different phases of construction and cold commissioning. Here the interaction of the effects of the discharge from the CDO and the Sizewell B cooling water discharge plume are also considered.
Dredging activity	Simultaneous dredging activities may occur for some elements of the development. 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. 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. The plume is highly transient and the total duration of increases in SSC would be reduced due to the temporal overlap. Simultaneous overlap of BLF maintenance, CWS intake and FRR outfalls would represent an area equivalent to 5% of the Suffolk Coastal waterbody 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.
CDO chemical discharge and thermal elevation Sizewell B	CDO chemical discharges have a small area of exceedance at EQS levels <25m so the influence of thermal elevation at ca. 5°C above background would be very limited and insignificant.
Chlorinated discharge Sizewell B and ammonia input CDO	Chlorine and ammonia at similar molar concentrations and at low concentration can react in full strength seawater to form, predominantly, dibromamine which has higher toxicity than TRO alone. However, TRO typically at ca 20µg/l and ammonia NH4-N rapidly decreases to ca., 11µg/l at around 25 metres of the discharge meaning that the concentration of any combination products would be at very low concentrations and within a limited area around the CDO.

Table 36: Operation activities and discharges (cooling water thermal input) with potential to influence marine temperature and dissolved oxygen saturation.

Type of discharge	Influence of discharge
Cooling water – Thermal SPA	The absolute areas of exceedance for each thermal standard that applies to the SPA were assessed: For the 2˚C uplift threshold based on a maximum excess (100th percentile) the absolute areas of exceedance range between a minimum area of 5,219ha at the seabed for Sizewell B to 22,464ha at the surface for Sizewell B + Sizewell C. The second criteria for SPAs concern the 98th percentile of the absolute temperature. The predicted absolute areas where the plume temperatures exceed 28˚C are all below 1ha based on a calculated mean excess of >8.6˚C added to the 98%ile for Sizewell. In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Cooling Water Thermal WFD	The absolute areas of exceedance for each thermal standard that applies to the WFD waterbodies was assessed: For the 2˚C uplift threshold based on a 98%ile of >23˚C the absolute areas of exceedance range between a minimum area of 8.75ha at the seabed for Sizewell B to 89.6ha at the surface for Sizewell B + Sizewell C. For excess temperatures of 2˚C as a 98th percentile this was exceeded for a minimum of 2126.71ha at the seabed for Sizewell B and 7899.17ha at the surface for Sizewell B +Sizewell C In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Cooling water – Thermal effect on Oxygen WFD	The effect of the thermal discharge on the oxygen saturation of the surrounding area has been derived using modelling. GETM runs show the area calculated that is beneath various DO concentrations for the entire model domain. The derived average DO concentration for the model domain for both Sizewell B and Sizewell C and Sizewell B alone is>5.77mgl^{-1} as a 5th percentile which is at or above the WFD threshold for High Status of 5.7mgl^{-1}. The influence of this change on marine water quality is not evaluated as significant
Cooling water – Thermal effect on percentage un-ionised ammonia WFD	The calculated mean ammonia discharge concentration was added to either the mean or 95th percentile un-ionised ammonia regional background value derived using the temperature fields generated by GETM and the relevant physicochemical data and total ammonia concentration for each scenario to derive the un-ionised ammonia calculation. The predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS of 21μgl^{-1}. The influence of this change on marine water quality is not evaluated as significant

Table 37: Operation activities and discharges (cooling water chemical input) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Cooling water - TRO	For the Sizewell C discharge plume there is a small area of 2.13ha that exceeds the TRO EQS 95th percentile of 10µgl^{-1} for Sizewell C at the seabed and over ca., 337ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. (The absolute values for Sizewell B and Sizewell C in combination exceed the TRO EQS 95%ile of 10µgl^{-1} over 726ha at the surface and 167ha at the seabed. In some cases, large areas are influenced by TRO concentrations above the EQS but as TRO is not persistent the effects are not evaluated as significant for marine water quality but this is further considered in the Marine Ecology Environmental Statement Chapter.
FRR - TRO	An initial assessment of discharge of chlorinated seawater from this system was made in BEEMS TR333 and all the potential tunnel locations passed the assessment. However, intakes and tunnels will not be chlorinated.
Cooling water – CBP's	The Bromoform discharge was modelled for 132m^{3}s^{-1}. The Bromoform plume area that exceeds the applied EQS (PNEC 5µgl^{-1} as a 95th percentile) for Sizewell C only at the seabed is ca.,0.15ha and ca.,52ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. The combined plumes for Sizewell B and Sizewell C result in an area of ca.,357ha at the surface and ca.,130ha at the seabed. In some cases, large areas are influenced by bromoform concentrations above the EQS but based on toxicity and persistence the effects are not evaluated as significant for marine water quality but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Cooling water - Hydrazine	Hydrazine discharges exceed the acute and chronic quality standard (PNEC) values for discharge concentrations derived from both 24-hour and annual loadings. The chronic PNEC 0.4ngl^{-1} is exceeded at the surface and at the seabed, although in the latter case, an area of less than 1ha is affected for both discharge scenarios. The acute PNEC 4ngl^{-1} is exceeded at the surface (for less than 18ha) and at the seabed, but only in the case of the 69ngl^{-1} release for an area of 0.13ha. Relatively small areas are influenced by hydrazine concentrations above the acute or chronic EQS. These values are precautionary and so the effects are evaluated as not significant for marine water quality but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Various substances screened out	Various substances (copper, zinc, chromium) exceeded the 24 hour or annual discharge assessment but this resulted from high background concentrations and predicted discharge concentration for these substances would be below detection limits, so they were screened out. Other substances that have no PNEC and reference site background cannot be effectively assessed but again most are below detection limits so again are screened out of further assessment

Table 38: Operation activities and discharges (Un-ionised ammonia, dissolved inorganic nitrogen, phosphorus and microbiological parameters) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Un-ionised ammonia	During operation the concentration of ammonia predicted in the discharge has been added to the site background and predictions of un-ionised ammonia concentrations derived for the discharge to Sizewell Bay. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of 21µgl^{-1} NH_3-N as an annual mean. Evaluated as not significant for marine water quality.
DIN	The predicted DIN loading during operation 332kg represents ca., 2% of the exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with PO_4-P a phytoplankton and macroalgal growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluations are considered in the Marine Ecology Environmental Statement Chapter 21.
Phosphorus	The predicted phosphorus loading during operation PO_4-P gives a value of 114.8kg. This loading represents ~5% of the PO_4-P exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with DIN a phytoplankton growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21..
Microbiological parameters	During operation the maximum number of staff on site is estimated at 1900 based on HPC. If UV treatment is applied to the predicted sewage effluent volume discharge and assuming a 5.4 log reduction in specific microorganisms compliance would be achieved at the point of discharge. Evaluated as not significant for marine water quality.

Table 39: Discharges of moribund fish from the FRR with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
FRR moribund fish influence on nutrient status	Nitrogen and phosphorus concentrations from decaying fish biomass predicted to be discharged from the FRR and based on annual average fish loadings were assessed in a model run in combination with operational inputs using a Combined Phytoplankton and Macroalgae Model. A model run over an annual cycle predicts a less than 0.29% difference in annual gross production of carbon and this level of change would not be discriminated above natural background variation. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on un-ionised ammonia	The un-ionised ammonia input from decaying biomass from the FRR was derived for the maximum annual biomass loading. Relevant seasonal pH and temperature which influence the proportion of un-ionised ammonia were also accounted for an equivalent area of 6.7ha would potentially exceed the un-ionised ammonia annual average EQS. This area of exceedance is considered to be low relative to the potential for mixing and exchange of water across the GSB. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on dissolved oxygen	The effect of biomass decay on dissolved oxygen was also derived. The calculated annual mean daily biomass oxygen demand represents 0.2% of the oxygen available in the volume of water exchange across the Greater Sizewell Bay. Reaeration at the surface would also resupply oxygen with typical values of surface exchange for this area providing an equivalent loading to that consumed by the biomass discharge over an area of ca., 14ha. For the maximum predicted discharge of biomass during March oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21.

Table 40: Influence of climate change on Operational discharges.

Type of discharge	Influence of discharge
Cooling water – Thermal	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. 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. 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.
Cooling water - TRO	TRO decay will increase at elevated temperatures, but dosing is adjusted to ensure that the target TRO of 0.2mgl^{-1} is achieved in critical sections of the CW plant. The residual oxidant level at the point of discharge is therefore unlikely to be reduced under climate change. The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH. Lowering pH could in theory reduce toxicity but the pH change and influence on ratio of hypobromous and hypochlorous acid is not considered significant so the assessment remains the same as for current conditions.
Cooling water – CBP's	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 CBPs 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
Cooling water - Hydrazine	Hydrazine half-life 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.

Table 41: Inter relationship effects Operation

Type of discharge	Influence of discharge
Synergistic effects chlorinated discharge and treated sewage effluent	Seasonal chlorination and un-ionised ammonia from treated sewage discharge have the potential to interact in the cooling water discharge. 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. The synergistic effects of chlorination and ammonia discharges may result in the formation of additional combined products. However, the low level of ammonia available to interact with chlorinated seawater would limit the byproduct formation to below levels of significance in terms of change to toxicological influence of the chlorinated seawater alone.
Synergistic effects of temperature and toxicity of chlorinated seawater	Beyond the immediate point of discharge ca 10-20m the residual oxidant exposure would be low at a few 10s of micrograms/litre and the thermal elevation would be a few degrees above background. Beyond this point the low level of thermal elevation and its influence on the toxicity of residual oxidants would be insignificant. The area affected with potential for synergistic effects of temperature on chlorinated seawater toxicity would therefore be very limited.

9 Potential in-combination and cumulative effects from Sizewell C development

The Sizewell C Environmental Statement will assess the potential in-combination (activities associated with the Sizewell C project) and cumulative effects (activities associated with Sizewell C plus activities from other relevant developments). Zones of Influence (ZoI) will be established for these assessments and the Planning Inspectorate guidance will be adhered to.

The activities and associated pressures relevant to water and sediment quality that will be included in these assessments are as follows:

- Increases in suspended sediment concentration from dredging activities (in-combination and cumulatively);
- Increases in temperature from the thermal discharge (in-combination and cumulatively). Interaction of the Sizewell C and Sizewell B discharge have been considered in this report; and;
- Contamination from the chemical and microbiological discharge (in-combination and cumulatively)

10 References

Alabaster, J. S. & Lloyd, R. 1980. *Water Quality Criteria for Freshwater Fish*.– 297 pp. London-Boston: Butterworth 1980. ISBN 0 408 10673 5.

Atkins, 2016. data (sampling conducted from October 2014-2016)

Bamber, R. N. 1990. Environmental Impact Assessment: the Example of Marine Biology and the UK Power Industry. Mar. Pollut. Bull. **21**: 270–274. doi:10.1007/978-3-540-88256-5_17

BEEMS Scientific Advisory Report SAR008.v2. BEEMS Expert Panel. 2019. *Thermal standards for cooling water from new build nuclear power stations*. Cefas, Lowestoft.

BEEMS Scientific Position Paper SPP098. Derivation of the Thermal 98th Percentile from GETM 3D hydrodynamic models. Cefas, Lowestoft.

BEEMS Technical Report TR131 Ed. 2. Sizewell Water Quality Literature Report Edition 2. Cefas, Lowestoft.

BEEMS Technical Report TR142. Sizewell Power Station: The decay of Total Residual Oxidant (TRO) measured in sea water samples. Cefas, Lowestoft.

BEEMS Technical Report TR143 Ed. 2. Calibration of a Model of Total Residual Oxidant (TRO) Using Laboratory Data on Seawater Samples Collected in the Vicinity of Sizewell Nuclear Power Station. Cefas, Lowestoft.

BEEMS Technical Report TR145. Sizewell: Laboratory studies of the decay of Hydrazine measured in sea water samples. Cefas, Lowestoft.

BEEMS Technical Report TR189 Sizewell Marine Water Quality Monitoring Final Summary Report. Cefas Lowestoft.

BEEMS Technical Report TR193 Sizewell C H1 Assessment Edition 5 – Supporting Data Report. Cefas

BEEMS Technical Report TR217 Experimental studies to identify key chlorination by-products (CBPs) in cooling water discharge from Sizewell C. Cefas, Lowestoft.

BEEMS Technical Report TR230. Sizewell Thermal plume modelling: GETM Stage 2 Results of Initial Configurations Report. Cefas, Lowestoft.

BEEMS. Technical Report TR231. Thermal Plume Modelling; Estimates of the Temperature Regime at the Intakes at SZB & SZC. Cefas, Lowestoft

BEEMS Technical Report TR233. Sizewell – Tidal Modelling with TELEMAC2D – Validation Edition 2. Cefas, Lowestoft.

BEEMS Technical Report TR301. Sizewell Thermal Plume Modelling: Stage 2a review. Selection of preferred SZC cooling water configuration. Cefas, Lowestoft.

BEEMS Technical Report TR302. Sizewell Thermal Plume Modelling: GETM Stage 3 results with the preferred SZC cooling water configuration. Edition 3. Cefas, Lowestoft.

BEEMS Technical Report TR303. Sizewell Chemical Plume Modelling: TRO, CBP's, Hydrazine, DO and Ammonia. Edition 4. Lowestoft

BEEMS Technical Report TR305. Sizewell Marine Sediment Quality. Cefas, Lowestoft

BEEMS Technical Report TR311 Ed. 4. Sizewell Coastal Geomorphology and Hydrodynamics Synthesis. Cefas, Lowestoft

BEEMS Technical Report TR310 Ed 2. Sizewell C Assessment of scour at the marine structures. Cefas, Lowestoft.

BEEMS Technical Report TR314. Sizewell supplementary water quality monitoring data 2014/2015. Cefas, Lowestoft.

BEEMS Technical Report TR316. Evaluation of chlorination dosing options for Sizewell C (balancing biofouling efficacy and non-target species effects). Cefas, Lowestoft.

BEEMS Technical Report TR333. Modelling the optimal position for a fish recovery and return outfall for Sizewell C. Cefas, Lowestoft.

BEEMS Technical Report TR352. Laboratory studies on the decay of hydrazine in Sizewell Seawater and derivation of modelling terms for Sizewell C Cefas, Lowestoft

BEEMS Technical Report TR354. Sizewell Plankton:2016-2017. Cefas, Lowestoft

BEEMS Technical Report TR385. Modelling the effects of SZC on phytoplankton in Sizewell Bay. Cefas, Lowestoft

BEEMS Technical Report TR431. Sizewell SPA/SAC features and associated marine prey species. Cefas, Lowestoft.

BEEMS Technical Report TR480 Ed 2. Modelling of Sediment Dispersion of Dredge Material from SZC Construction and Operation. Cefas, Lowestoft.

BEEMS Technical Report TR483. Synthesis of evidence for SZC WFD and HRA marine assessments. Cefas, Lowestoft.

BEEMS Technical Report TR494. Hydrazine construction discharge plume modelling. Cefas, Lowestoft.

Benson, B.B. and Krause, D Jr. 1984. The concentration and isotopic fractionation of oxygen dissolved in freshwater and seawater in equilibrium with the atmosphere. Limnol. Oceanogr., 29(3) 620-632.Cefas 2004. UK National Marine Monitoring Programme – Second Report (1999-2001). Marine Environment Monitoring Group.

Blackford, J.C. and Gilbert, F.J. (2007) pH Variability and CO2 Induced Acidification in the North Sea. *Journal of Marine Systems* 64 (1–4), 229–241.

Buchmann, M.F., 2008. NOAA Screening Quick Reference Tables. NOAA OR & R Rep.(08–1).

Capuzzo, J., Lawrence, S.A. Davidson, J.A. 1976. "The combined toxicity of free chlorine, chloramine and temperature to stage I larvae of American Lobster Homarus americanus." Water Research 10: 1093-1099.

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

Cefas 2006. Dose assessments in relation to disposal at sea under the London Convention 1972: judging de minimis radioactivity. Murray, L., McCubbin, D., and Vivian, C. Project AA005. https://www.cefas.co.uk/publications/environment/rl0506.pdf

CCME. (2001). Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment.Cefas. (2004). UK National Marine Monitoring Programme – Second Report (1999-2001). Marine Environmental Monitoring Group.

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

CIS TECHNICAL GUIDELINES FOR THE IDENTIFICATION OF MIXING ZONES, 2010. pursuant to Art. 4(4) of the Directive 2008/105/EC

Clegg S. L. and M. Whitfield (1995) 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. Acta 59, 2403-2421.

Defforey, D., Patan, A. Phosphorus cycling in marine sediments: Advances and challenges. 2018. Chemical Geology 477 1-11.

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

Defra and Environment Agency Surface water pollution risk assessment for your environmental permit. Last updated 3 of April 2018. https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit

Dolphin, T.J., Silva, T.A.M., Rees, J.M., 2011. Natural Variability of Turbidity in the Regional Environmental Assessment (REA) Areas. MEPF-MALSF Project 09-P114. Cefas, Lowestoft, 41 p.

Dunn, R.J.K., Waltham, N.J., Teasdale, P.R., Robertson, D., and Welsh, D.T. Short-Term Nitrogen and Phosphorus Release during the Disturbance of Surface Sediments: A Case Study in an Urbanised Estuarine System (Gold Coast Broadwater, Australia). 2017. J.Mar.Sci. Eng, 5, 16.

Eddy, F.B. 2005. Review Paper Ammonia in estuaries and effects on fish. Journal of Fish Biology, 67, 1495-1513.

EDECME120678, 2011. UK EPR - A review of Radionuclides and Chemicals maximum discharges and limits during operation. HPC-EDECME-XX-TEU-RET-000038

EDECME-AU-000-RET-000063, 2017. UK EPR- An estimation of the volume and composition of effluents for the commissioning phase at Hinkley Point C.EDF-CIDEN, 2011. Hinkley Point C: update to non-radiological discharges for H1 Assessment. ELIER1100060.

SZC Co, 2014a. Sizewell C EIA Scoping Report. Doc reference: SZC-NNBPEA-XX-000-TEM-000001

Environment Agency, Food Standards Agency, Food Standards Scotland, Natural Resources Wales, Northern Ireland Environment Agency, and Scottish Environment Protection Agency. (2015) Radioactivity in Food and the Environment, 2014. RIFE – 20, October 2015

Environment Agency Catchment Data Explorer accessed 2019.01.23 https://environment.data.gov.uk/catchment-planning/WaterBody/GB650503520002

Environment Canada (2011). Screening Assessment for the Challenge. Hydrazine. Chemical Abstracts Service Registry Number 302-01-2. Environment Canada/Health Canada, January 2011, pp. 1-96.: http://www.ec.gc.ca/ese-ees/17647095-B851-46F4-A4BB-79F887D84666/batch10_302-01-2_en.pdf Accessed 28th October 2011

Fisher, J., Harrah, C. B. and Berry, W. O. Hydrazine. (1980): Acute Toxicity to Bluegills and Sublethal Effects on Dorsal Light Response and Aggression. Transactions of The American Fisheries Society, 109 , pp. 304–309.

Foden, J. Devlin, M.J., Mills, D, Malcolm, S.J. (2010) Searching for undesirable disturbance: an application of the OSPAR eutrophication assessment method to marine waters of England and Wales. Biogeochemistry, 157-175.

Fugro. (2015). Sizewell C Offshore Services NNB Generation Company (SZC) Ltd, WE8 Integrated Report. Fugro Document No: J35034-IDR02(02).

Garcia, H. E. and Gordon, L. I. 1992. Oxygen solubility in seawater: better fitting equations, Limnol. Oceanogr., 37, 1307–1312.

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

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

Hull, T., Greenwood, N., Kaiser, J., and M. Johnson 2016 Uncertainty and sensitivity in optode-based shelf-sea net community production estimates Biogeosciences, 13, 943–959.

Hydrogen Peroxide Products 1-6 Report, 2015. Regulation (EU) No 528/2012 concerning the making available on the market and use of biocidal products. Finland.

Inman, G.W. and Johnson, J.D. 1977. The effect of ammonia concentration on the chemistry of chlorinated seawater. In Jolley, R. L., Gorchev, H., Hamilton, D.H., (eds) (1977). Water Chlorination: Environmental Impact and Health Effects. Vol 2. Lewis Publishers.

IPCC 2000, Intergovernmental Panel on Climate Change - Summary for Policymakers Emissions Scenario ISBN: 92-9169-113

Jacobs , 2010. Hinkley C – Networks Conceptual Design Basis of Design –Drainage Systems. B1454107/702.06a/0001, revision 2 16/08/2010.

Johnson I, Sorokin N, Atkinson C, Rule K and Hope S-J. 2007. Proposed EQS for Water Framework Directive Annex VIII substances: ammonia (un-ionised) Science Report: SC040038/SR2 SNIFFER Report: WFD52(ii).

Jolley, R.L. and Carpenter, J.H. 1981. A review of the chemistry and environmental fate of reactive oxidant species in chlorinated water. In Water Chlorination Environmental Impact and Health Effects Volume 4, Book 1 Chemistry and Water Treatment Edited by Robert L. Jolley et. al.

Kelly, C.A., Law, R.J., Baker, K., Waldock, R. & Pendle, M. (2002). Polycyclic aromatic hydrocarbons in dredged material from ports and navigation channels in England and Wales. Poster, CEFAS Lowestoft, ISEAC 32 Conference, Plymouth, 17 – 21 June 2002.

Kemp, W. M., Testa, J. M., Conley, D. J., Gilbert, D. and Hagy, J. D. 2009. Temporal responses of coastal hypoxia to nutrient loading and physical controls. Biogeosciences, 6, 2985-3008

London Convention. 1972. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. International Maritime Organisation.

Mackay, D. and Leinonen P.J., 1975. Rate of evaporation of low-solubility contaminants from water bodies to atmosphere. Environ. Sci. Technol. 9:1178-1180.

MacNaughton, M. G., Urda, G. A., Bowden, S. E., (1978) Oxidation of hydrazine in aqueous solutions, CEEDO (Civil and Environmental Engineering Development Office) Technical report 78-11, Tyndall AFB, Florida, ADA058239

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

Marine and Coastal Access Act 2009 https://www.legislation.gov.uk/ukpga/2009/23/contents

MMO. (2015a). Details of sediment and sample analysis for marine licence applications. Planning and development – guidance. Marine Licensing: sediment analysis and sample plans. Available: https://www.gov.uk/guidance/marine-licensing-sediment-analysis-and-sample-plans (accessed on 10/12/2015).

MMO (2015b). High Level Review of Current UK Action Level Guidance. A report produced for the Marine Management Organisation, pp 73. MMO Project No: 1053. ISBN: 978-1-909452-35-0.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/485575/High_level_review_of_current_UK_action_level_summary___1053_.pdf

Nakicenovic, N, and Swart, R. Emissions scenarios - special report of the Intergovernmental Panel on Climate Change.United Kingdom: N. p., 2000. Web.

Natural England Commissioned Report NECR221. 2016. Phosphorus in Package Treatment Plant Effluents.

Orr, J. C.: 2011. Recent and future changes in ocean carbonate chemistry, in: Ocean Acidification, edited by: Gattuso, J. P. and Hansson, L., Oxford University Press, Oxford, 41–66.

OSPAR Commission, 2008:Overview of Contracting Parties' National Action Levels for Dredged Material

OSPAR. (2010). Quality Status Report. OSPAR Commission London. ISBN 978-1-907390-38-8. Publication number 497/2010

Osprey, 2017a. Sizewell C BLF Concept Design. NNB GenCo Document Number: SZC-3RDSPY-XX-000-REP-100000.

Osprey, 2017b. Sizewell C BLF Operational Capability Statement. NNB GenCo Document Number: SZC-3RDSPY-XX-000-REP-100001.

Offshore chemicals (Amendment) Regulations 2011 http://www.legislation.gov.uk/uksi/2011/982/pdfs/uksi_20110982_en.pdf

Richardson, A. J. 2008. In hot water : zooplankton and climate change. 279–295.

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

Stuart, A. W. & Lapworth, D.J. 2016. Macronutrient status of UK groundwater: Nitrogen, phosphorus and organic carbon. Science of the Total Environment 572 (2016) 1543–1560

Turnpenny, A. W. H & Liney, K.E. 2006. Review and development of temperature standards for marine and freshwater environments. Jacobs Engineering Consultancy Report No. 21960.

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

Tyler-Walters, H., H.M., Tillin, E. A.S., d'Avack, Perry, F., Stamp, T. 2017. Marine Evidence -based Sensitivity Assessment (MARESA) -A Guide. Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth, pp. 91. Available from https://www.marlin.ac.uk/publications

UK National Report. 2017. Painting, S., Garcia, L. and Collingridge K. Common Procedure for Identifying the Eutrophication Status of the UK Maritime Areas.

(UKTAG) UK Technical Advisory Group on The Water Framework Directive. UK Environmental standards and conditions Phase 2 (SRI-2007), Final March 2008.

UK TAG. 2007.Proposals for environmental quality standards for Annex VIII substances.. UK Technical Advisory Group on the Water Framework Directive.

UKTAG, 2007. UK Technical Advisory Group on The Water Framework Directive. Recommendations on Surface Water Classification Schemes for the purpose of the Water Framework Directive. December 2007, alien species list updated Oct 2008 and Nov 2008.

UK TAG. 2008a. UK Environmental Standards and Conditions Phase 1. UK Technical Advisory Group on the Water Framework Directive.

UK TAG. 2008b. UK Environmental Standards and Conditions Phase 2. UK Technical Advisory Group on the Water Framework Directive.

UKTAG, 2013. UK Technical Advisory Group (UKTAG) on The Water Framework Directive. Updated Recommendations on Environmental Standards. River Basin Management (2015-21), November 2013 (minor amendments January 2014).

Underwood, G. J. C., and J. Kromkamp. 1999. Primary Production by Phytoplankton and Microphytobenthos in Estuaries. Adv. Ecol. Res. **29**: 93–139.

Water Framework Directive (WFD), European Commission. 2003. 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. http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/guidance_documents&vm=detailed&sb=Title

Water Framework Directive Standards and Classification Directions, 2015 http://www.legislation.gov.uk/uksi/2015/1623/pdfs/uksiod_20151623_en_003.pdf

Wither, A.W., Bamber, R., Colclough, S.R., Dyer, D., Elliott, M., Holmes, P., Jenner H.A., Taylor, C.J.L., Turnpenny, A.W.H. 2012. Setting new thermal standards for transitional and coastal (TraC) waters. Marine Pollution Bulletin 64: 1564–1579.

World Health Organisation (WHO). 2005. Bentonite, kaolin and selected clay minerals. Environmental Health Criteria 231. World Health Organization Geneva.

WQTAG086 Ammonia standards in estuaries Habitats Directive Technical Advisory Group on Water Quality Revised 20th April 2005.

WQTAG160 Guidance on assessing the impact of thermal discharges on European Marine Sites WQTAG sub-group, presented October 2005. doi:10.1016/j.marpolbul.2012.05.019

11 Appendix A Zone of Influence

To determine the effects of entrainment on phytoplankton populations, from Sizewell B and C, BEEMS Technical Report TR385, determined the approximate volume of water within the influence of the power station during a tidal cycle. Based upon a current meter (S2) deployed near the proposed Sizewell C intake locations, a progressive vector diagram (PVD) method indicated that the north – south excursion is approximately 15.9 km in each direction, and 1.4km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 31.8 km long and approximately 2.8km wide. The average depth was calculated at 12.5m giving a total volume of 1209.7 x 106 (Table 43) and (Figure 17).

Table 42: The volume of water associated with the Greater Sizewell Bay and the tidal excursion originally reported in BEEMS Technical Report TR385.

Body of water defined in TR385	Surface area (ha)	Average depth (m)	Volume (x10^6 m^3)
GSB	4120	8.8	363.8
GSB + tidal excursion beyond the Sizewell-Dunwich Bank	9670	12.5	1209.7

The tidal excursion is dependent on the stage within the spring-neap cycle but provides an estimate for the zone of influence. The method applied to determine the tidal excursion has a bearing on the calculation of the estimated area and volume. The following section details several methods applied to estimate the body of water potentially influenced by the power station.

For comparison, a harmonic analysis was conducted on the same current meter (BEEMS Technical Report TR233) and provided similar results to the PVD method. The tidal ellipse indicates that the north – south excursion is approximately 17.2km, and 1.8km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 34.4 km long and approximately 3.6km wide.

Further analysis was undertaken to support the estimate of the tidal water volumes reported in BEEMS Technical Report TR385. To determine the Outer Tidal Excursion, a particle tracking study was considered but the trajectories exceeded the hydrodynamic model domain. Instead, without running a new model set-up, two alternative methods have been considered: a PVD and a harmonic analysis. The PVD method estimates the potential transport based upon measured velocity time-series (at a fixed location). The distance travelled between each time step of the record, is determined from using the U and V velocity components, and its trajectory plotted from the original starting point (i.e. the outfalls). The tidal excursion is then determined from an area encompassing the total trajectory path. For the harmonic analysis method, an idealised tidal curve was reconstructed, using the M2, S2 and N2 tidal constituents, to determine the major and minor axis of the tidal ellipse. This provides a maximum theoretical tidal excursion, excluding any meteorological forcing. The area and volume based upon the average depth, of the associated ZoIs are shown in Table 44.

To determine the volume of water that may be influenced by the CDO and FRR discharges, within the Sizewell-Dunwich Bank particle tracking associated with the FRR was completed (BEEMS Technical Report TR333). Particles were released from FRR Position 5 over a spring-flood tide and a neap-flood tide for May 2009. This is representative of the mean conditions for the area of Sizewell. The tidal excursion within the Sizewell-Dunwich Bank was then determined by defining an area encompassing every particle position at each time step of both runs combined. This indicates that the total tidal excursion is approximately 20.8km North-South and approximately 3.5km east-west.

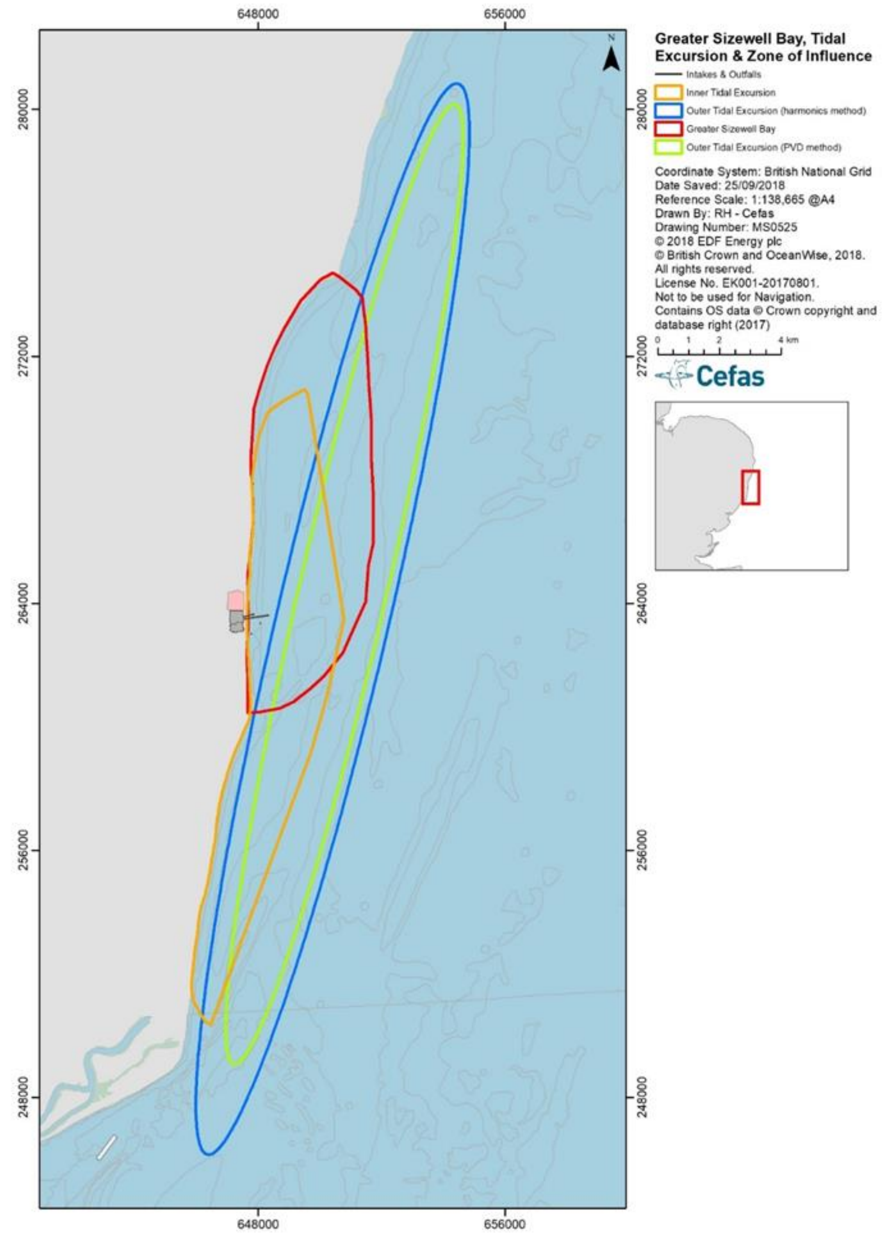

Figure 17: The area of the tidal excursion from the Sizewell C CDO/FRR and outfall during spring tides, the outer tidal ellipse and the Greater Sizewell Bay body of water.

Table 43: Approximate surface area and volume of the Zones of Influence based on the areas delineated in Figure 14.

Body of water	Surface area (ha)	Average depth (m)	Volume (x10^6 m^3)
GSB (geomorphic extent)	4577.5	8.73	399.7
Inner Tidal Excursion	4323.2	8.49	367.0
Outer Tidal Excursion			
PVD method	7081.4	13.91	985.0
Harmonics method	10129.1	13.84	1401.9
***GSB + tidal excursion**	9906.7	12.14	1202.9

12 Appendix B Extract from Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

Table 16

Dissolved inorganic nitrogen standards for coastal water (salinity 32), or part of such water, (coastal waters categorised by type in accordance with paragraph 3 of Schedule 2)				
Mean dissolved inorganic nitrogen concentration (micromoles per litre) during the period 1st November to 28th February				
	Dissolved inorganic nitrogen concentration (micromoles per litre)			
Type	*High*	*Good*	*Moderate*	*Poor*
	Mean for the period 1st Nov to 28th Feb			
Clear	12[i]	18[i]	27 [i]	40.5[i]
		99 percentile standard for the period 1st Nov – 28th Feb		
Intermediate turbidity	12	70	105	157.5
Turbid	12	180	270	405
Very turbid	12	270	405	607.5

[i] The standard refers to the concentration of dissolved inorganic nitrogen at a mean salinity of 32 for the period of 1st November to 28th February.

Table 6

Criteria for identifying types of transitional and coastal water to which the dissolved inorganic nitrogen standards for transitional and coastal water apply	
Type	*Annual mean concentration of suspended particulate matter (mg/1)*
Very turbid	> 300
Turbid	100 - 300
Intermediate turbidity	10 < 100
Clear	< 10

Table 17

Dissolved inorganic nitrogen standards for transitional water (salinity 25), or part of such water, (transitional waters categorised by type in accordance with paragraph 3 of Schedule 2)				
Mean dissolved inorganic nitrogen concentration (micromoles per litre) during the period 1st November to 28th February				
	Dissolved inorganic nitrogen concentration (micromoles per litre)			
Type	*High*	*Good*	*Moderate*	*Poor*
		Mean for the period 1st Nov to 28th Feb		
Clear	20(i)	30(i)	45(i)	67.5(i)
		99 percentile standard for the period 1st Nov to 28th Feb		
Intermediate turbidity	20	70	105	157.5
Turbid	20	180	270	405
Very turbid	20	270	405	607.5

(i) The standard refers to the concentration of dissolved inorganic nitrogen at a mean salinity of 25 for the period of 1st November 28th February.

13 Appendix C Microbiological assessment of sewage discharges

For the construction discharge following either sewage treatment at a secondary or tertiary (UV) level the distance from the discharge point, at which enough dilution occurs to be below relevant microbiological standard levels, has been estimated using CORMIX for Case D (30ls^{-1}) sewage discharge and Case D1 (72ls^{-1}). Results are shown below in Table 45.

Table 44 Estimate of minimum distance from point of discharge at which microbiological standards for bathing waters are met following different levels of sewage treatment for the construction discharge from SZC

Species	Standard cells/ 100ml	Discharge concentration cells / 100ml	2^{ndry} treatment 2 log reduction	Dilution required to meet bathing water standard	Maximum potential distance from the discharge at which meets bathing water standard 30 l s^{-1}	72 l s^{-1}	UV treatment reduction 5.4 log reduction	Dilution factor required for discharge to meet bathing water standard	Maximum distance from the discharge at which it meets bathing water standard
E.coli	500	240,000,000 [1]	2400000	4800	~1.7 km	~3.1 km	955.5	1.9	<1 m pass immediately on discharge, for both cases.
Entero -cocci	200	13,600,000	136000	680	~66 m	~460 m	54.1	0.3	<1 m pass immediately on discharge, for both cases.

[1]Cell numbers/100ml are based on data in support of the Hinkley Point C development (pers. Comm. EDF);

14 Appendix D Screening of Operational discharges

Operational phase chemical discharges for 2 EPR units based on EDF, 2011 and subsequent modifications incorporated in EDECME120678). For the Operational discharge assessment, it has been assumed that all metals within the effluent are present 100% in the dissolved state and therefore biologically available. This provides a worst-case scenario in terms of the modelling assessment. In the following sections Table 46 shows the loading of different chemicals used during operation as 24-hour and annual load.

Thereafter two tables Table 47 and 48 show the screening test results for maximum 24-hour and average annual loadings respectively during operation:

Table 47 shows Screening Test for large cooling water discharges to TraC waterbodies for the maximum 24 hour loadings predicted for operational phase chemical discharges (this includes sanitary waste for 1900 staff and demineralised water additives for two UK EPR units) for SZC – bold underlined values indicate failure of the relevant test. Table 48 shows Screening Tests for large cooling water discharges to TraC waterbodies for the average annual loadings predicted for operational phase discharges for 2 EPR units at SZC – bold underlined values also indicate failure of the relevant test.

Table 45: Loading of different chemicals used during operation as 24-hour and annual loading for 2 EPR units based on EDF, 2011 2014 and subsequent modifications incorporated in HPC-EDECME-XX-000-RET-000061120678)

Substance	Circuit conditioning (kg yr^{-1})	Sanitary waste discharge (kg yr^{-1})	Producing demineralised water (kg yr^{-1})	Maximum annual loading (kg yr^{-1})	Maximum 24-hour loading (kg d^{-1})
Boric acid (H_3BO_3)[1]	14000	-	-	14000	5625
Boron	2448	-	-	2448	984
Lithium hydroxide	8.8	-	-	8.	4.4
Hydrazine	24.3			24.3	3
Morpholine	1680	-	-	1674	92.25
Ethanolamine	920	-	-	919	24.75
Nitrogen as N	10130	1595	-	11725	332
Un-ionised Ammonia (NH_3)	-	-	-	958	27
Phosphates	800	-	-	790	352.5
Detergents	-	-	624	624	-
Suspended solids	2800	2080	88000	92879	870
BOD	-	1278	-	1387	3.8
COD	5050	-	-	5050	330
Aluminium	5.26	-	-	5.26	1.1
Cadmium[2]	-	-	0.37	0.37	0.005
Copper	0.42	-	-	0.42	0.08
Chromium	8.37	-	-	8.37	1.7
Iron	34.97		46000	46035	257
Manganese	3.33			3.33	0.67
Mercury[2]			0.099	0.099	0.0011
Nickel	0.44			0.44	0.09
Lead	0.3			0.3	0.07
Zinc	5.6			6.0	1.2
Chloride			87100	87100	450
Sulphates			98400	98400	2000
Sodium			52400	52400	855
ATMP			9100	9100	45
HEDP			890	890	4.5
Acetic Acid			14	14	0.1
Phosphoric acid			12	12	0.1
Sodium polyacrylate			8030	8030	40

Acrylic acid			165	165	1

1 Dissociation boric acid in seawater so equivalent boron concentration in discharge is presented and assessed 2 Cadmium and mercury loadings are derived from estimates based on trace contamination of raw material chemical use in water treatment systems based on Hinkley Point C data

Table 46: Screening Test for large cooling water discharges to TraC waterbodies for the maximum 24 hour loadings Operation.

Substance	EQS/surrogate value µg l^{-1}	Derivation of surrogate	Discharge concentration + background (µg l^{-1})	Annual Discharge/EQS <1
Boron[1]	7000	Pre WFD EQS	4656	0.67
Lithium hydroxide	65[2]	Mean background	90.2[2]	**1.39**[3]
Hydrazine	0.0004	Chronic PNEC	0.53[4 5]	**131.5**
Morpholine	17	Chronic PNEC	16.2	0.58
Ethanolamine	160	Acute PNEC	4.34 [5]	0.03
Nitrogen as N	980[6]	WFD 99th percentile	484.3[7]	0.49
Un-ionised Ammonia (NH_3-N)	21	WFD AA-EQS	7.34[8]	0.35
Phosphates(PO_4-P)	33	Mean background	127	**3.79**
Suspended solids	74000[3]	Mean background	154[5]	0.002
BOD	2000	Mean background	0.67[5,9]	0.0003
COD	239000	Mean background	57.87 [5]	0.00024
Aluminium	12	Mean background	20.19	**1.68**
Cadmium	1.5	WFD MAC-EQS	0.13	0.09
Copper	3.76	WFD AA-EQS	4.76	**1.27**
Chromium	0.6	WFD AA-EQS	2.48	0.08
Iron	1000	WFD AA-EQS	302	0.3
Manganese	2	Mean background	-	-
Mercury	0.07	WFD MAC-EQS	0.02[10]	0.29
Nickel	34	WFD AA-EQS	1.17	0.03
Lead	1.3	WFD AA-EQS	3.94	0.28
Zinc	6.8	WFD AA-EQS	46	**6.77**
Chloride	14128000	Mean background	78.9 [5]	0.00
Sulphates	2778000	Mean background	350.7 [5]	0.00
Sodium	10400000	Mean background	150 [5]	0.00
ATMP	74	NOEC 96h fw[11] algae	7.89 [5]	0.11
HEDP	13	EC_{50} 96h algae	0.79 [5]	0.06
Acetic Acid	301	LC_{50} 48h fw crust	0.02 [5]	0.00006
Phosphoric acid	200	LC_{50} 72h algae	0.02 [5]	0.0001
Sodium polyacrylate	180	LC_{50} 96h fw fish	7.01 [5]	0.04
Acrylic acid	1.7	LC_{50} 96h fw fish	0.18 [5]	**0.1**
Chlorine (TRO) bromoform	(10) 5	MAC-EQS	(150), 190	**(15)38**

1 Variable dissociation products of Boric acid and other boron compounds in seawater so assessment focuses on equivalent boron concentration. 2 Expressed as lithium. 3. Figures in bold exceed the EQS or reference value. 4 This loading does not include hydrazine from stream B+C because this would not be discharged except during start up and shutdown when hydrazine from stream D would not be discharged. 5 Discharge only does not include background or no background either measured or detected 6 It should be noted that a more specific methodology for deriving 99th percentile values based on a relationship between SPM and DIN is recommended in draft Environment Agency guidance and for an annual average SPM of 55.2mgl-1 would give a slightly lower value of 952µgl-1 as a 99th percentile but the screening here would only slightly change. 7 This figure includes a calculated 4.4kg day from sanitary effluent derived by calculation from permitted 23mg/l N from STW discharge – stream G. 8 These figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the NH4 concentration that results from the combined sanitary and conditioning inputs [69] 9 The BOD value is derived from stream G based on a BOD5-atu concentration of 20 mg/l and the derived concentration due to the discharge (0.67µgl-1) is negligible relative to the site background (2mgl-1) and not significant in terms of impact on dissolved oxygen when oxygen flux for vertically well mixed water column at site is considered.10 The mean is used in place of the 95th percentile as values below detection result in lower 95th percentile value 11 fw represents freshwater species toxicity test data which determines PNEC

Table 47: Screening Test for large cooling water discharge to TraC waterbodies for the average annual loadings during Operation.

Substance	EQS/surrogate value µg l^{-1}	Derivation of surrogate	Discharge concentration including background (µg l^{-1})	Annual Discharge/EQS <1
Boron[1]	7000	Pre WFD EQS	4145.67	0.59
Lithium hydroxide	65[2]	Mean background	65[2]	**1.00**[3]
Hydrazine	0.0004	Chronic PNEC	0.01[4]	<u>**16.6**</u>
Morpholine	17	Chronic PNEC	0.46[5]	0.03
Ethanolamine	160	Acute PNEC	0.25[5]	0.001
Nitrogen as N	980[6]	WFD 99%	360.12[7]	0.37
Un-ionised Ammonia (NH_3-N)	21	WFD AA-EQS	0.96[8]	0.05
Phosphates	33	Mean background	33.57	**1.00**
Detergents	-	-	0.17[5]	0.2
Suspended solids	74000[3]	Mean background	25.4[5]	0.0003
BOD	2000	Mean background	0.38[5,9]	0.0002
COD	239000	Mean background	1.38[5]	0.00001
Aluminium	12	Mean background	12	**1.00**
Cadmium	0.2	WFD AA-EQS	0.05	0.25
Copper	3.76	WFD AA-EQS	2.15	0.57
Chromium	0.6	WFD AA-EQS	0.57	0.95
Iron	1000	WFD AA-EQS	132.58	0.13
Manganese	2	Mean background	-	-
Mercury	0.07	WFD MAC-EQS	0.02	0.29
Nickel	8.6	WFD AA-EQS	0.79	0.09
Lead	1.3	WFD AA-EQS	1.0	**0.76**
Zinc	6.8	WFD AA-EQS	14.7	**2.16**
Chloride	14128000	Mean background	23.81[5]	-
Sulphates	2778000	Mean background	26.90[5]	-
Sodium	10400000	Mean background	14.32[5]	-
ATMP	74	NOEC 96h fw[10] algae	2.49	0.03
HEDP	13	NOEC 96h algae	0.24	0.02
Acetic Acid	62.8	NOEC 21d fw crust	0.004	0.0001
Phosphoric acid	20	LC_{50} 72h algae	0.003	0.0002
Sodium polyacrylate	11.2	NOEC 72h fw crust	2.20	0.20
Acrylic acid	0.34	NOEC 72 h fw algae	0.05	**0.13**

1 Variable dissociation products of Boric acid and other boron compounds in seawater so assessment focuses on equivalent boron concentration. 2 Expressed as lithium. 3. Figures in bold exceed the EQS or reference value. 4 This loading does not include hydrazine from stream B+C because this would not be discharged except during start up and shutdown when hydrazine from stream D would not be discharged. 5 Discharge only does not include background or no background either measured or detected. 6 It should be noted that a more specific methodology for deriving 99th percentile values based on a relationship between SPM and DIN is recommended in draft Environment Agency guidance and for an annual average SPM of 55.2mgl-1 would give a slightly lower value of 952µgl-1 as a 99th percentile but the screening here would only slightly change.7 This figure includes a calculated 1595kg/y from sanitary effluent derived by calculation from permitted 23mg/l N from STW discharge – stream G. 8 These figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the NH4 concentration that results from the combined sanitary and conditioning inputs 9 The BOD value is derived from stream G based on a BOD5-atu concentration of 20 mg/l and the derived concentration due to the discharge (0.38µgl-1) is negligible relative to the site background (2mgl-1) and not significant in terms of impact on dissolved oxygen when oxygen flux for vertically well mixed water column at site is considered 10 fw represents freshwater species toxicity test data which determines PNEC

15 Appendix E Thermal modelling extremes(100 percentiles)

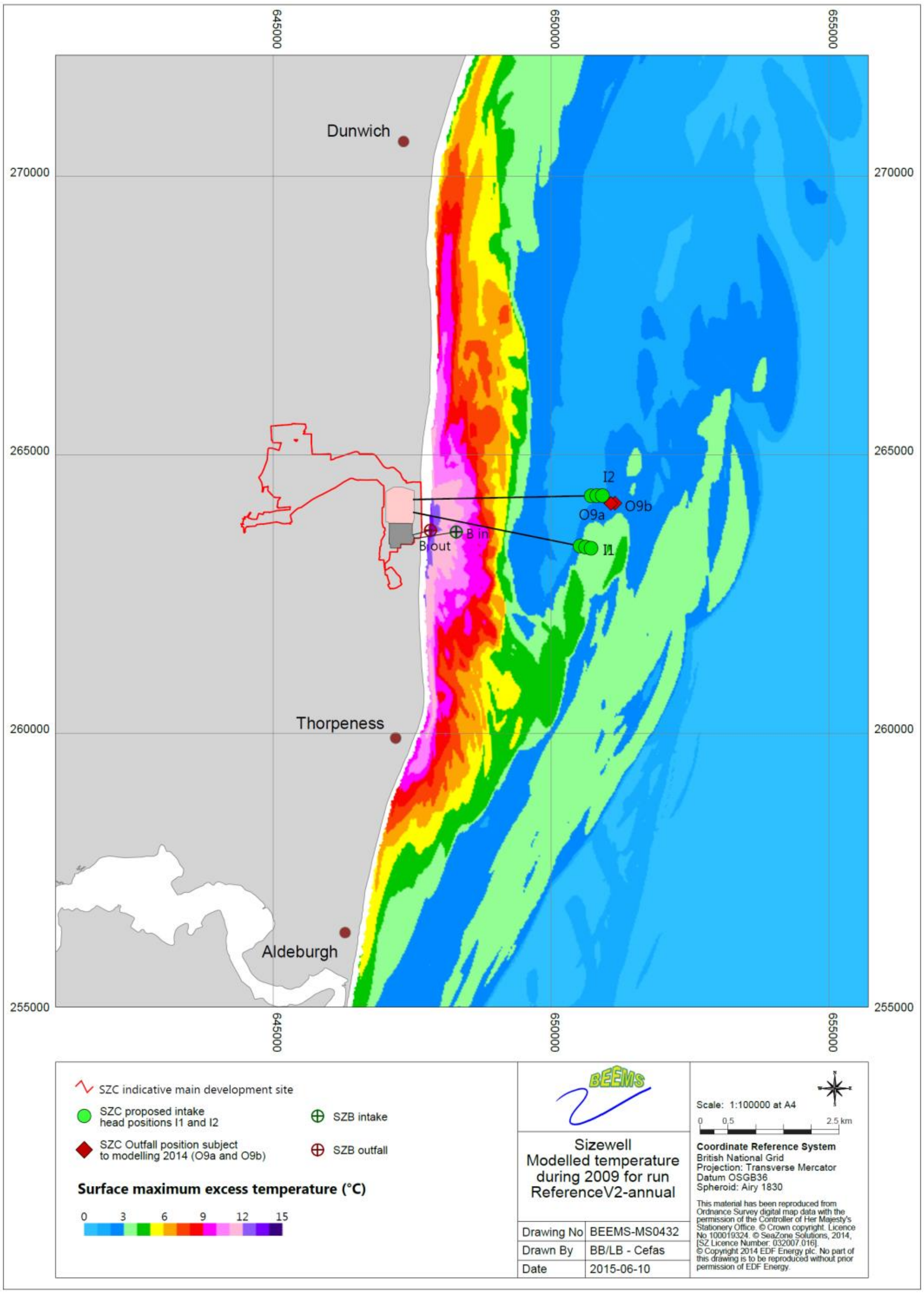

Figure 18: Surface annual maximum excess temperature for SZB only (100%iles).

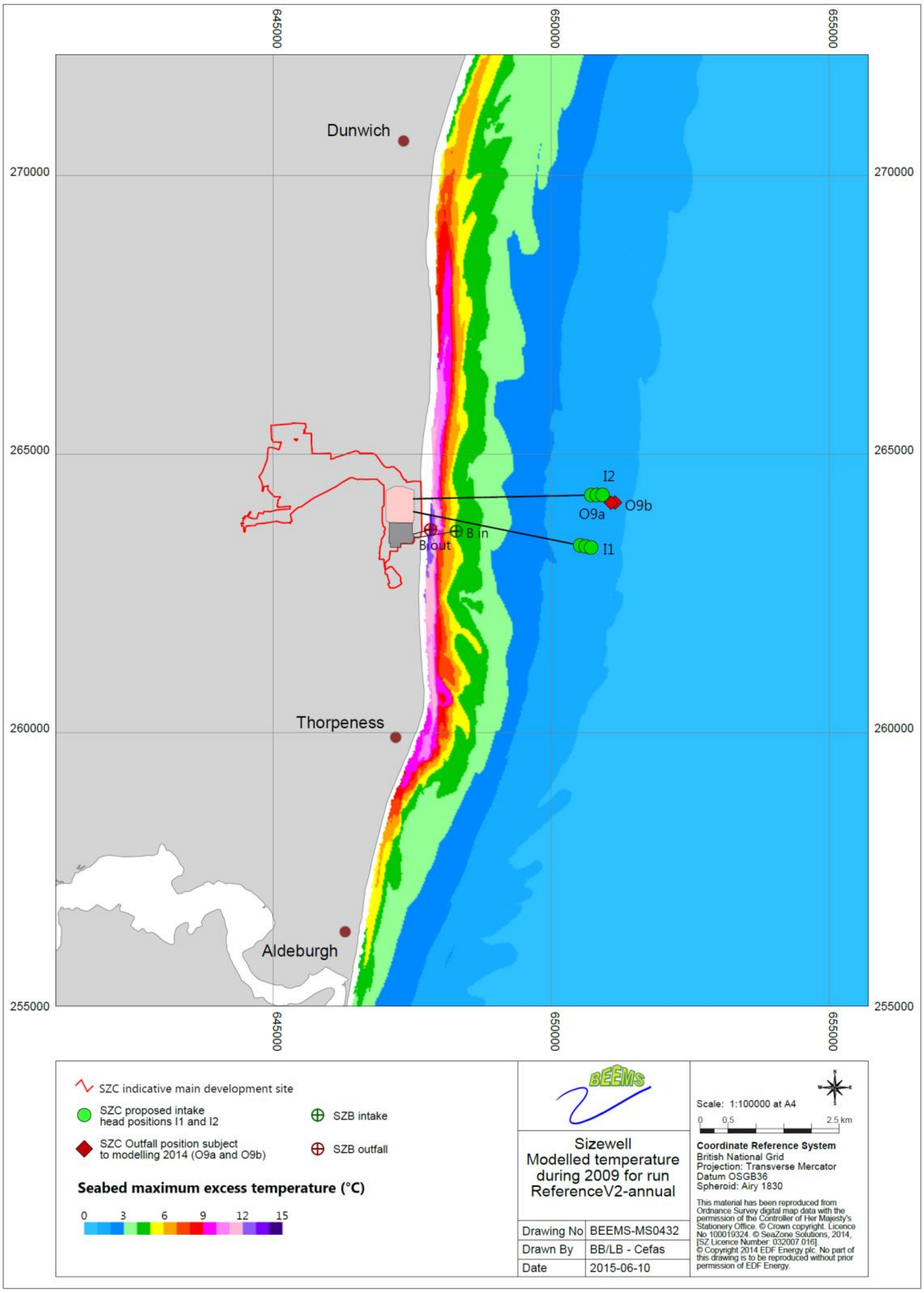

Figure 19: Seabed annual maximum excess temperature for SZB only (100%iles).

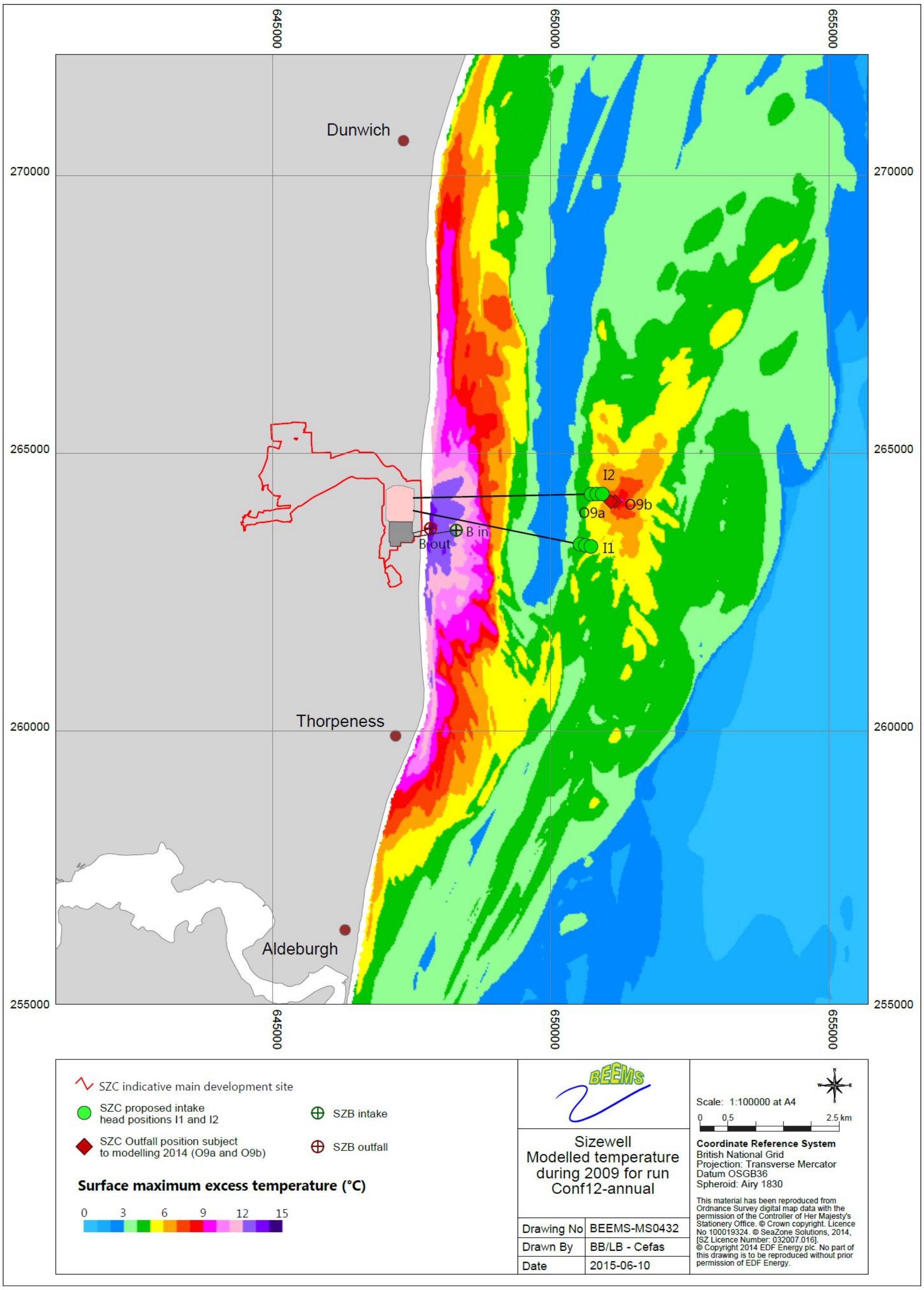

Figure 20: Surface annual maximum excess temperature for SZB + SZC.

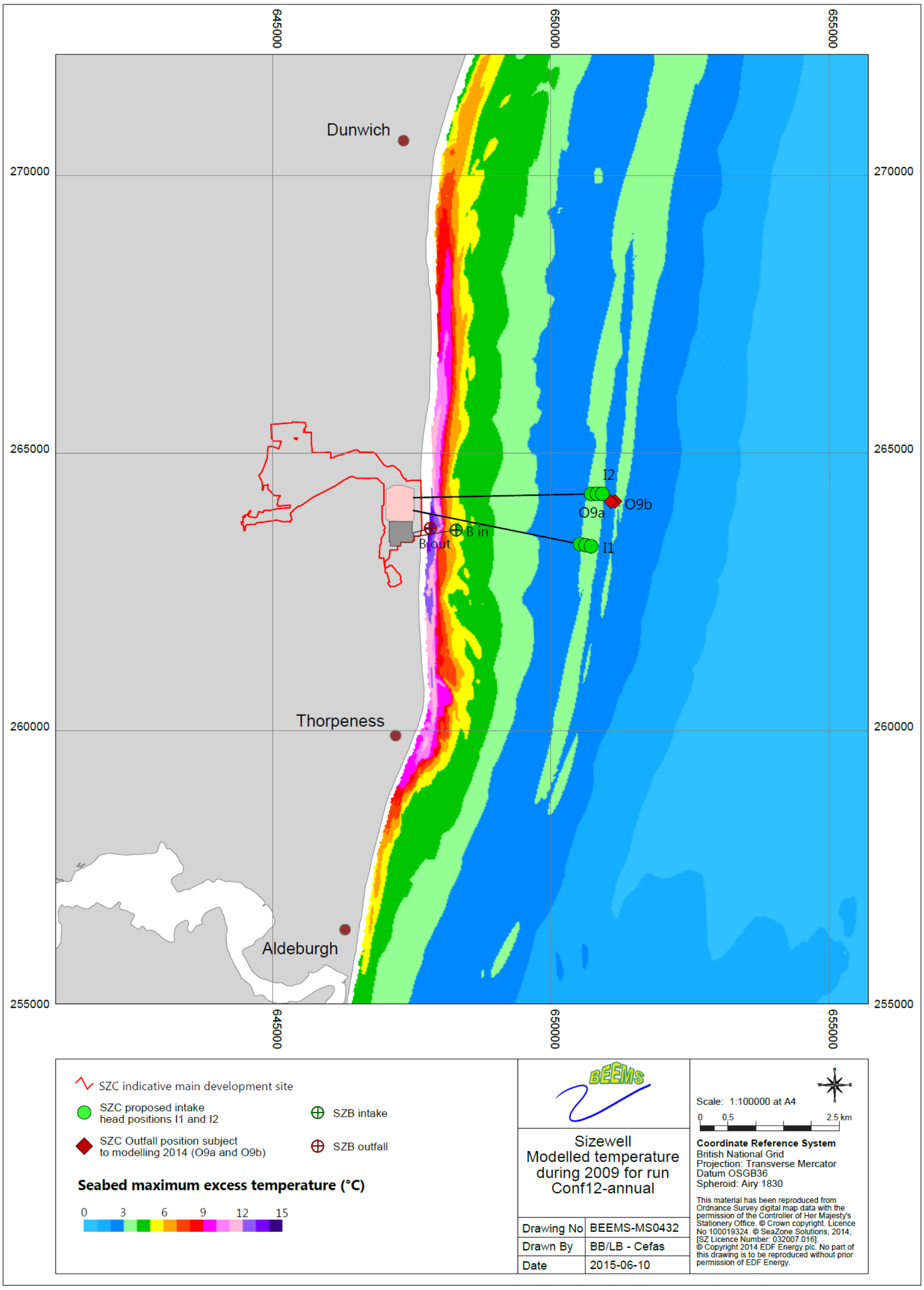

Figure 21: Seabed annual maximum excess temperature for SZB + SZC

16 Appendix E Future Climate and Thermal Considerations

This section considers the influence of climate change on future thermal parameters in relation to the operation of Sizewell C and Sizewell B. At the time of writing the recently updated UKCP18[3] marine climate predictions (November 2018) do not include sea temperature data. Future climate scenarios for Sizewell are based on UKCP09 data, which provides predictions of future climate for 2070-2100 relative to a baseline of 1961-1999 for the broad Sizewell area.

Whilst the UKCP09 air temperature predictions provided three emissions scenarios: High, Medium and Low, sea temperature is only provided for the medium emissions scenario (SRES A1B). In addition to the medium emissions, the UKCP09 provides data on daily variability including predictions of the maximum daily mean temperatures within a month. This data can be used to represent extreme maximum values (99.9%tiles) for each month based on 30 years of data (BEEMS Technical Report TR231).

Future temperature estimates are used to consider the following parameters:

- Intake temperatures at Sizewell B and Sizewell C for the full operational life-cycle of the power stations accounting for recirculation and climate change;
- Entrainment temperatures at Sizewell B and Sizewell C accounting for recirculation and climate change;
- The influence of future climate change on (contemporary) thermal standards.

Temperature records from Sizewell A and Sizewell B, collected between 1967 and 2017, were used to estimate monthly mean intake temperatures (with an associated standard deviation).). In addition, recently hourly temperature data from SZ B has become available from 1994 – 2018 with monthly values shown in Table 44. These temperatures were centred on the year 2006 to provide a basis for future intake temperature and entrainment predictions. This higher frequency record has been used in subsequent analysis

The average monthly UK baseline (1961-1999) were subtracted from the UKCP09 projected temperatures for 2070-2100. The differential was applied to calculate future thermal baselines at Sizewell using linear interpolation. Predications for Sizewell were centred on 2006. Therefore, climate predictions assume a linear increase in temperature which will be subject to increased uncertainty further into the future.

To account for the effects of the power stations operating on intake temperatures, recirculation of thermal discharges at the point of the Sizewell B and Sizewell C intakes was incorporated into the predictions based on outputs from GETM thermal plume modelling (BEEMS Technical Report TR302).

To incorporate a range of future intake temperatures the following scenarios were investigated:

1. **2030:** The earliest potential date for Sizewell C to be operational. The scenario includes both stations running simultaneously.
2. **2055:** The hypothetical last likely date for Sizewell B to be operational. The scenario includes both stations running simultaneously and SZC running in isolation.
3. **2085:** Towards the end of the operational life of Sizewell C.

[3] https://www.metoffice.gov.uk/research/collaboration/ukcp (last accessed 03/03/2019)

4. **2110:** A hypothetical extreme date for Sizewell C to remain operational prior to decommissioning.

By assuming the last likely date of station operation, these scenarios are precautionary in terms of the effects of long-term climate change. However, it should be noted that extreme scenarios are subject to increased uncertainty.

Future intake temperatures

Mean monthly temperatures at the Sizewell B and Sizewell C intakes are provided in Table 48 and illustrated in (Figure 22. Predicted mean monthly temperatures at the location of the Sizewell B intakes (± s.d.) for 2030 and 2055, with both Sizewell B and Sizewell C operating.Figure 22 and Figure 233). Predicted mean monthly temperatures at the location of the Sizewell B intakes (± s.d.) for 2030 and 2055, with both Sizewell B and Sizewell C operating (Figure 22 and 23). Intake temperatures peak in August at 20.4ºC at Sizewell B in 2030 with slightly lower temperature of 19.4ºC predicted at the more offshore Sizewell C intakes. By 2055, the last likely operational date for Sizewell B, mean August temperatures are predicted to be 21.9ºC at Sizewell B and 20.2ºC at Sizewell C. By the year 2110, August temperatures at Sizewell C are predicted to be 21.7ºC, corresponding to a 2.3ºC increase from 2030.

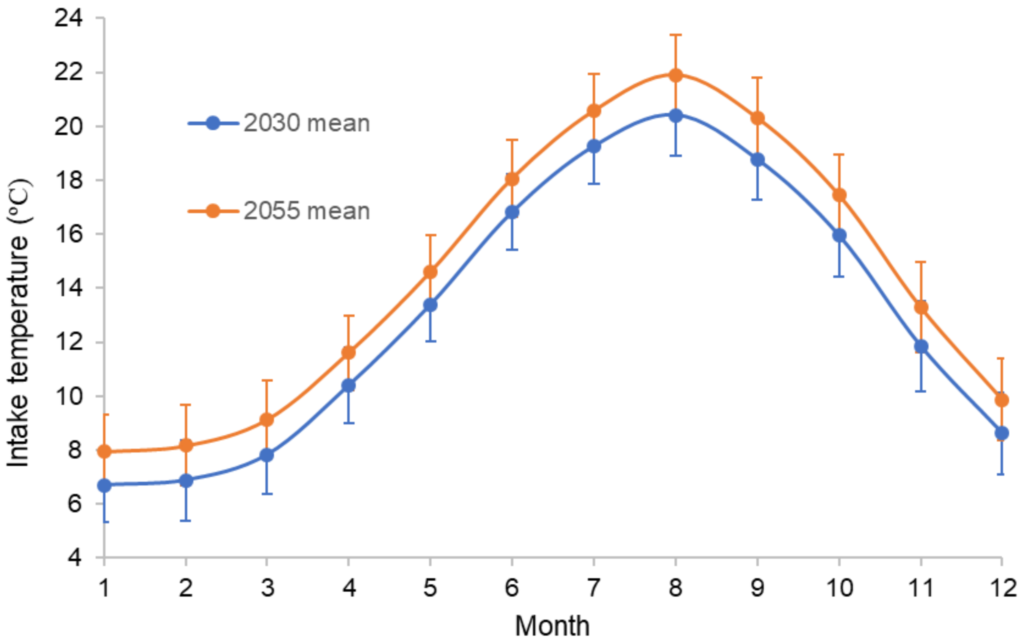

Figure 22. Predicted mean monthly temperatures at the location of the Sizewell B intakes (± s.d.) for 2030 and 2055, with both Sizewell B and Sizewell C operating.

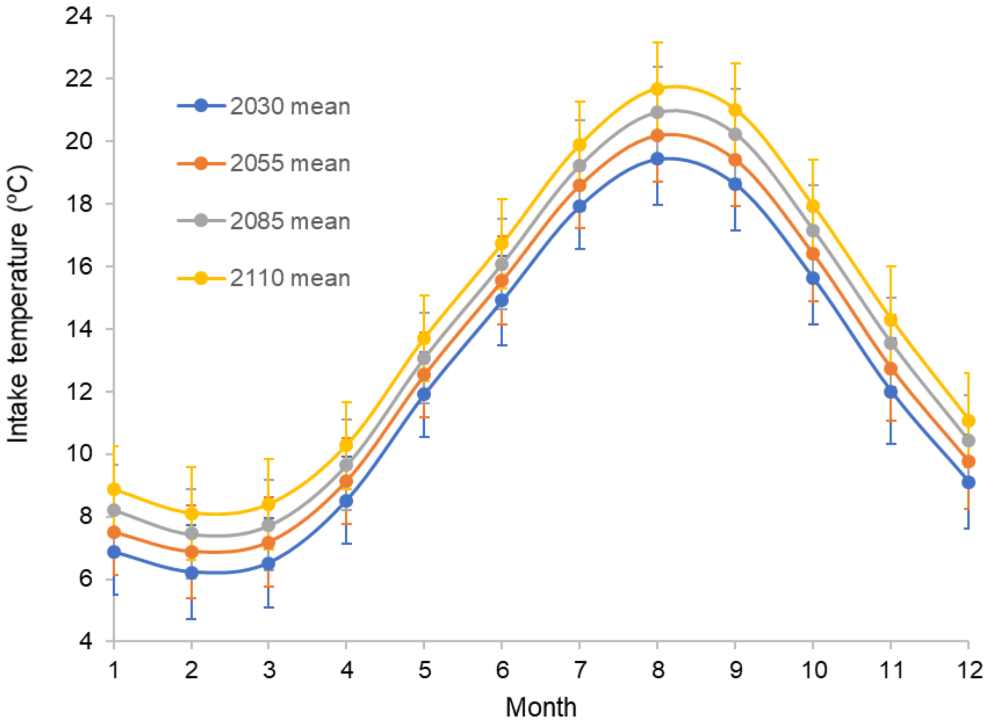

Figure 23 Predicted mean monthly temperatures at the location of the Sizewell C intakes (± s.d.) for 2030 and 2055, 2085 and 2110.

To account for the worst-case temperature predictions for each month, the maximum of daily temperatures for a given month was applied to the data. Table 49 details the future maximum daily temperature at the Sizewell B and Sizewell C intakes for each month. Maximum intake temperatures at the inshore Sizewell B site are predicted to occur in July and peak at 24.7ºC in 2030 and 25.5 ºC in 2055. At the offshore Sizewell C intakes maximum temperatures are predicted later in the year in September peaking at 23.4 ºC in 2030 and 26.2 ºC by 2110 (Table 49).

Table 48 Predicted monthly mean temperatures (°C) at the location of the Sizewell B and Sizewell C intakes. Assessments are based on mean daily temperatures from the UKCP09 medium emissions scenario (SRES A1B).

Month	UKCP09 (Baseline)	UKCP09 Projected	UKCP09 Increase in mean temp (°C)	1967-2017 SZA_SZB	Hourly data 1994 - 2018	Recirculation component		Daily mean SZB		Daily mean SZC				Standard deviation between years of monthly values
	1961-1999	2070-2100			Centre 2006	Estimated temp. at SZC intakes, if SZC were operating	Estimated temp. at SZB intakes if SZC were operating	2030	2055	2030	2055	2085	2110	
January	4.6	7.3	2.7	6.0	5.9	6.3	6.1	6.7	7.9	6.9	7.5	8.2	8.9	1.4
February	4	6.8	2.8	5.4	5.4	5.6	6.3	6.9	8.2	6.2	6.9	7.4	8.1	1.5
March	4.5	7.4	2.8	6.2	6.4	5.9	7.2	7.8	9.1	6.5	7.2	7.7	8.4	1.4
April	6.7	9.3	2.6	8.6	8.9	7.9	9.8	10.4	11.6	8.5	9.1	9.7	10.3	1.4
May	9.8	12.5	2.6	11.7	12.2	11.3	12.8	13.4	14.6	11.9	12.5	13.1	13.7	1.4
June	13.5	16.2	2.7	15.2	15.6	14.3	16.2	16.8	18.1	14.9	15.5	16.1	16.7	1.4
July	16.5	19.4	2.8	18.1	18.1	17.3	18.6	19.3	20.6	17.9	18.6	19.2	19.9	1.4
August	17.9	21.1	3.2	19.1	19.1	18.7	19.7	20.4	21.9	19.4	20.2	20.9	21.7	1.5
September	16.3	19.6	3.3	17.8	17.6	17.9	18.0	18.8	20.3	18.6	19.4	20.2	21.0	1.5
October	13.3	16.5	3.2	14.8	14.5	14.9	15.2	15.9	17.4	15.6	16.4	17.2	17.9	1.5
November	9.6	12.7	3.1	11.4	10.9	11.3	11.1	11.8	13.3	12.0	12.7	13.6	14.3	1.7
December	6.5	9.2	2.7	7.9	7.6	8.5	8.0	8.6	9.9	9.1	9.7	10.4	11.1	1.5
Average	10.3	13.2	2.9	11.8	11.8	11.7	12.4	13.1	14.4	12.3	13.0	13.6	14.3	

Table 49 Predicted maximum daily temperatures (°C) for each month at the location of the Sizewell B and Sizewell C intakes. Assessments are based on UKCP09 medium emissions scenario (SRES A1B).

Month	Max Daily Mean Sea Temperature 1961-1999_(UKCP09)	Max Daily Mean Sea Temperature 2070-2100_(UKCP09)	Increase	Maximums at hourly interval (1994 – 2018)	Maximum daily average at SZB (1994 – 2018)	Estimated daily max temp at SZC intakes, if SZC were operating	Estimated daily max temp at SZB if SZC were operating	Maximum daily value SZB		Maximum daily value SZC			
								2030	2055	2030	2055	2085	2110
January	8.3	9.8	1.5	**9.6**	9.3	10.0	9.5	9.9	10.2	10.4	10.7	11.2	11.5
February	6.8	10.1	3.3	**9.2**	8.1	7.6	8.8	9.6	10.4	8.3	9.1	10.1	10.9
March	7.7	10.9	3.2	**15.7**	12.9	11.5	13.5	14.2	15.0	12.3	13.0	13.9	14.7
April	9.7	12.4	2.7	**17.5**	16.4	14.3	17.2	17.8	18.5	14.9	15.5	16.3	17.0
May	12.8	15.9	3.1	**18.9**	18.2	16.3	18.7	19.4	20.2	17.0	17.7	18.6	19.4
June	17.2	19.4	2.2	**19.8**	18.6	16.7	19.2	19.7	20.3	17.2	17.8	18.4	18.9
July	19.2	22.5	3.3	**24.4**	23.4	21.5	24.0	24.7	25.5	22.3	23.1	24.0	24.8
August	20.3	23.2	2.9	**23.2**	22.1	21.1	22.7	23.3	24.0	21.7	22.4	23.2	23.9
September	19.1	22.8	3.7	**23.2**	22.5	22.5	22.8	23.6	24.5	23.4	24.3	25.3	26.2
October	17.2	20.3	3.1	**20.8**	20.1	19.7	20.8	21.6	22.3	20.4	21.2	22.1	22.8
November	13.5	17.2	3.7	**17.2**	16.8	16.5	17.5	18.4	19.3	17.4	18.3	19.4	20.3
December	10.5	13.7	3.2	**11.7**	10.8	10.6	10.8	11.6	12.3	11.4	12.1	13.1	13.8

Entrainment temperatures

Following passage of cooling water through the condensers at the Sizewell B power station thermal inputs result in temperature increases of approximately 11°C above ambient. At the Sizewell C entrainment temperatures are predicted to be approximately 11.6°C above ambient intake temperatures. Mean monthly entrainment temperatures under future climate conditions are provided in Table 50.

Elevated temperatures can cause lethal effects to a range of invertebrates, fish eggs and larvae entrained in the cooling water flow. Experimental work indicates that mortality due to temperature shock for the egg and larval life stages of many fish and zooplankton species increases rapidly once maximum temperatures exceed 30°C (see BEEMS Technical Report TR081). The thermal death point or upper incipient lethal temperature (UILT) has not commonly been calculated for invertebrates or primary producers, however, UILT of 30 to 33°C (regardless of latitude) are typical (Bamber 1990). Welch and Lindell (1980) found that the statistical mode for the lethal temperatures for many invertebrate species, lay between 35°C and 40°C (see BEEMS Scientific Advisory Report SAR008 for further information of UILT). The monthly distribution of mean entrainment temperatures are shown for Sizewell B (Figure 24) and Sizewell C (Figure 25).

Mean daily entrainment temperatures are predicted to exceed 30ºC for 57 days in July-September by 2030, temperatures peak in early August reaching 31.3 ºC. By 2055, entrainment temperatures exceed 30 ºC for 100 days in much of July, August and September and continue into October. Entrainment temperatures exceed 33 ºC for 13 days in August and September (Table 51). Following the end of the operational life of Sizewell B (after 2055 at the latest), entrainment temperatures exceeding 30 ºC occur for fewer days; 92 in 2085 and maximum temperatures remain below 33 ºC. By, 2110 the extreme of the operational life-cycle of Sizewell C, entrainment temperatures are predicted to exceed 30 ºC for 105 days per annum between the beginning of July and mid-October. Temperatures above 33 ºC are predicted to occur throughout much of August and into September (41 days) reaching a maximum of 33.6 ºC.

Whilst it is likely that high mortality rates will be observed for longer periods of time during the summer months with future climate change, thermal lethality is species specific and adaptation to future climate conditions and potential species distribution shifts may influence the ability to tolerate thermal stress and determine survival following entrainment (BEEMS Scientific Advisory Report SAR008). Furthermore, the peak in abundance of ichthyoplankton occurs prior to the hottest periods of the year, between May and July, with May being the peak for invertebrate zooplankton (BEEMS Technical Report TR315). The most abundant component of the ichthyoplankton off Sizewell was anchovies, which are becoming increasingly abundant in the southern North Sea. Anchovy eggs and larvae peak in June and July. The timings of the commercially important finfish species with high egg and larvae abundance at Sizewell are as follows:

- Dover sole; eggs and larvae peak in May.
- Seabass; eggs peak in May, larvae peak in June.
- Plaice; eggs peak in May, larvae peak in June.
- Herring; eggs and larvae peak in May

Table 50 Predicted monthly mean entrainment temperatures (°C) for Sizewell B (ambient + 11°C) and Sizewell C (ambient + 11.6°C). Assessments are based on mean daily temperatures from the UKCP09 medium emissions scenario (SRES A1B). Month with mean temperatures above 30°C are shaded pink.

Month	Sizewell B		Sizewell C			
	2030 Entrainment	2055 Entrainment	2030 Entrainment	2055 Entrainment	2085 Entrainment	2110 Entrainment
January	17.7	18.9	18.5	19.1	19.8	20.5
February	17.9	19.2	17.8	18.5	19.0	19.7
March	18.8	20.1	18.1	18.8	19.3	20.0
April	21.4	22.6	20.1	20.7	21.3	21.9
May	24.4	25.6	23.5	24.1	24.7	25.3
June	27.8	29.1	26.5	27.1	27.7	28.3
July	30.3	31.6	29.5	30.2	30.8	31.5
August	31.4	32.9	31.0	31.8	32.5	33.3
September	29.8	31.3	30.2	31.0	31.8	32.6
October	26.9	28.4	27.2	28.0	28.8	29.5
November	22.8	24.3	23.6	24.3	25.2	25.9
December	19.6	20.9	20.7	21.3	22.0	22.7

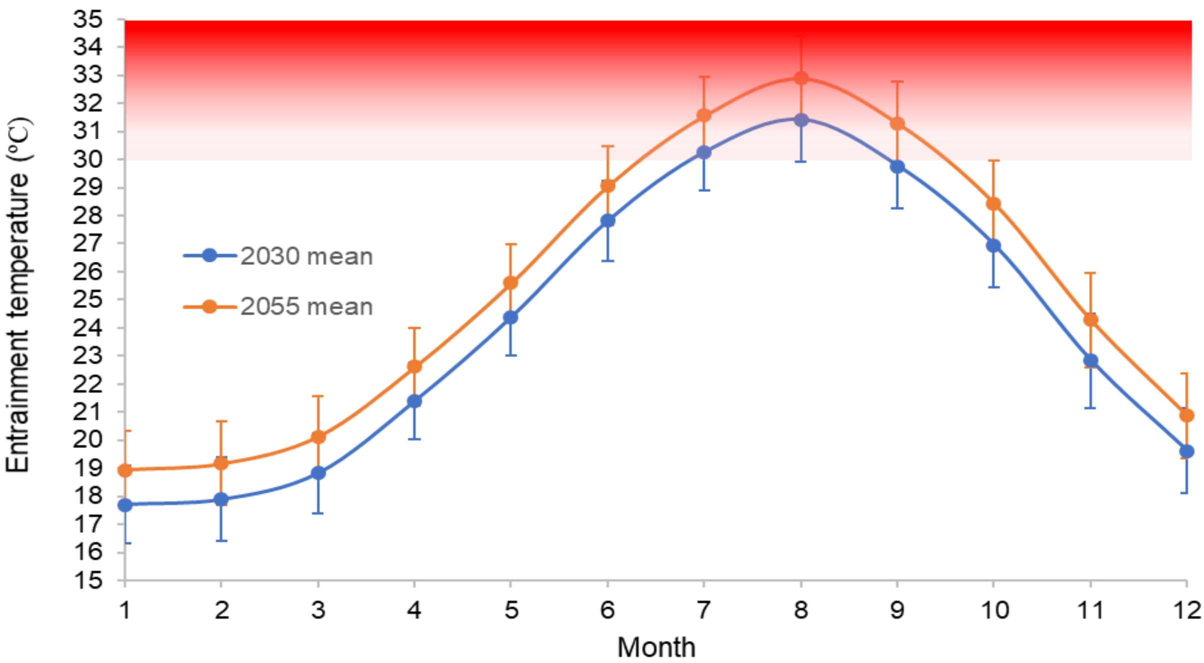

Figure 24. Mean monthly entrainment temperatures (± s.d.) under future climate predictions for Sizewell B. Shaded areas depict periods where typical UILT may be exceeded.

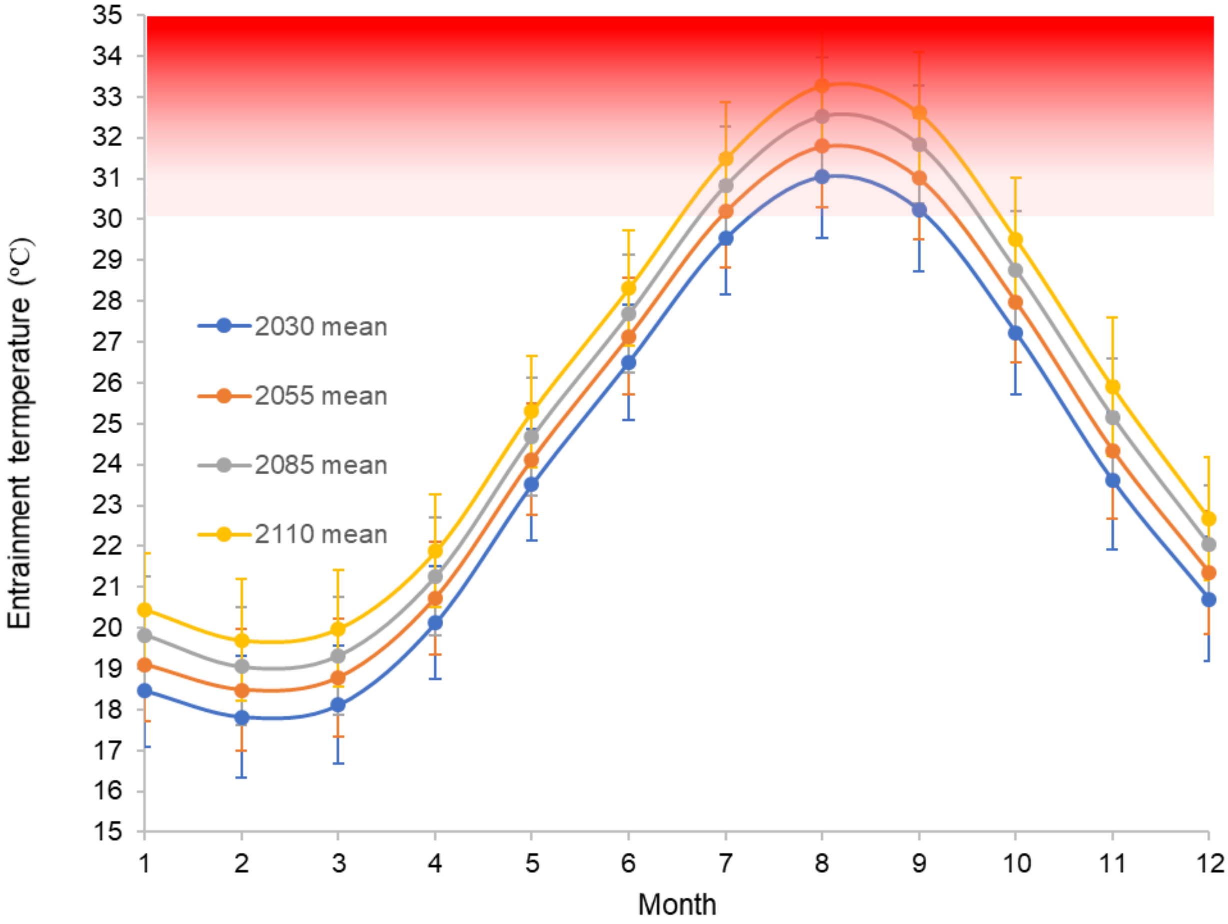

Figure 25 Mean monthly entrainment temperatures (± s.d.) under future climate predictions for Sizewell C. Shaded areas depict periods where typical UILT may be exceeded.

Table 51 Number of days the mean month entrainment temperatures are predicted to exceeds given levels with future climate change at Sizewell C. Predictions account for the recirculation of Sizewell B thermal discharges up until and including 2055 (hence the reduction in 2085).

Month	2030			2055			2085			2110		
	28ºC	**30 ºC**	**33 ºC**	**28 ºC**	**30 ºC**	**33 ºC**	**28 ºC**	**30 ºC**	**33 ºC**	**28 ºC**	**30 ºC**	**33 ºC**
January	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	17	0	0	12	0	0	17	0	0
July	31	9	0	31	29	0	31	27	0	31	31	0
August	31	31	0	31	31	11	31	31	0	31	31	28
September	30	17	0	30	30	2	30	30	0	30	30	13
October	10	0	0	25	10	0	21	4	0	30	13	0
November	0	0	0	0	0	0	0	0	0	1	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0
Total	**102**	**57**	**0**	**134**	**100**	**13**	**125**	**92**	**0**	**140**	**105**	**41**

Implications of climate on chlorination strategy

Chlorine would be applied seasonally 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. Chlorination would be applied at a dose level to produce a total residual oxidant (TRO) concentration of 0.2mgl^{-1} after the drum screens. The TRO discharge concentration from the CW systems at the outfall would be 0.15mgl^{-1}.

The seasonal chlorination strategy for the proposed development involves chlorination during the period of the year when water temperatures exceed 10ºC. At the earliest time of operation of the proposed development (2030), predicted water temperatures at the Sizewell C intakes would exceed 10ºC for 219 days per annum from the beginning of May until the start of December (Table 52). By the year 2085, climate change is predicted to result in temperatures exceeding 10ºC from late April until late December for a total of 244 days per annum.

Shifts in plankton phenology have been observed in the North Sea. Since the 1960s, peaks in dinoflagellates have occurred 23 days earlier, diatoms 22 days earlier, copepods 10 days earlier, and other holozooplankton groups 10 days earlier (Richardson 2008). Whilst the duration of the growing season is likely to extend in the future, temperature driven changes in phenology would be moderated by day length and solar elevation thus restricting the total growth period. When photosynthesis is light limited, increases in temperature are not predicted to enhance productivity (Underwood and Kromkamp 1999). 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.

Table 52. Duration of the year intake temperatures at SZC are predicted to exceed 10ºC, accounting for recirculation and future climate change.

Month	Days per month average daily temperature exceeds 10ºC at SZC intakes				
	1994-2018 average at SZB	2030	2055	2085	2110
January	0	0	0	0	0
February	0	0	0	0	0
March	0	0	0	0	0
April	0	0	6	10	17
May	26	31	31	31	31
June	30	30	30	30	30
July	31	31	31	31	31
August	31	31	31	31	31
September	30	30	30	30	30
October	31	31	31	31	31
November	24	30	30	30	30
December	0	5	13	20	28
Total	203	219	233	244	259

Thermal Standards

Thermal standards for TraC waterbodies are detailed in Section 1.2.2. Thermal standards relate to maximum absolute temperature thresholds and thermal uplifts above ambient. Determining the influence of future climate change on contemporary regulatory standards is flawed as baseline conditions are inherently predicted to change and standards would be expected to respond to such changes in the baseline. Therefore, the following sections should be considered as indicative.

Thermal uplifts above ambient

Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature (BEEMS Technical Report TR302). Therefore, thermal uplift areas predicted for in section 7.1 would remain largely unchanged under future climate scenarios. The results for the different model scenarios are summarised in Table 53 below.

Table 53. Absolute areas of thermal uplifts in exceedance of HRA and WFD criteria. The scenario of SZB and SZC operating in-combination (bold) represents the worst-case scenario and is considered as the primary assessment scenario.

Model run	Position	unit	Max Excess temp. >2°C (100%ile) HRA threshold	Excess temp. >2°C (98%ile) WFD assessment (area above 'good' status)	Excess temp. >3°C (98%ile) WFD assessment (area above 'moderate' status)
ReferenceV2 annual SZB	Surface	ha	9,375	2,433	1,263
	Seabed	ha	5,219	2,127	667.7
Conf12 annual SZB+SZC	**Surface**	**ha**	**22,464**	**7,899**	**2,200**
	Seabed	**ha**	**16,451**	**6,241**	**1,553**
SZC only	*Surface*	*ha*	*16,777*	*1,550.5*	*305.7*
	Seabed	*ha*	*12,244*	*170.6*	*0.0*

Maximum absolute temperatures

There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters (BEEMS Science Advisory Report SAR008). To be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis. As such, they act as triggers for further investigation of potential ecological effects. Recommended absolute thermal standards exist for SACs, SPAs and Water Framework Directive (WFD) waterbodies. The receiving waters adjacent to the proposed development are within the Southern North Sea SAC and the Outer Thames SPA. SAC absolute thermal criteria are more conservative and therefore considered in the first instance.

SACs designated for estuarine or embayment habitat and/or cold-water salmonid species, apply absolute temperature thresholds of 21.5°C as a 98th percentile (Wither et al. 2012). These criteria are not applicable to the Southern North Sea SAC is designated for harbour porpoise. Therefore, absolute temperature assessments consider SPA thresholds (28°C as a 98th percentile).

In addition, to SPA thresholds the EIA will consider WFD standards which have thresholds of <23°C as a 98th percentile for 'good' status and <28°C as a 98th percentile for 'moderate' status.

Absolute exceedances for relevant standards are detailed in Section 7.1. Here the influence of climate change is added to the thermal uplifts to ascertain absolute temperatures in the future. The method considered SZB and SZC operating in 2030 and 2055 as a worst-case. Sizewell C operating alone is also considered in 2055, 2085 and 2110 to represent an extreme hypothetical scenario.

The 98th percentile temperature for the five year period from 2009-2013 is 19.4°C and forms the basis for absolute temperature calculations. Exceedance of the relevant WFD and SPA thresholds is calculated as follows:

a) at or above 28˚C as a 98th percentile is calculated as the area where the mean excess temperature (+ the influence of climatic warming) is >8.6˚C (i.e. 28˚C -19.4˚C).
b) at or above 23˚C as a 98th percentile is calculated as the area where the mean excess temperature (+ the influence of climatic warming) is >3.6˚C (i.e. 23˚C -19.4˚C).

To calculate the uplift due to climate change, the UKCP09 monthly increase in mean temperature, as shown in Table 49, were applied to the daily mean temperatures of SZC intake temperatures. The SZC daily mean intake temperatures over a full year were derived from the observed hourly SZB intake temperatures from 1994 – 2018 and adjusted to the offshore location using the GETM model results, as described in BEEMS Technical Report TR302. The thermal uplift due to the UKCP09 monthly increase in mean temperature, centred on 2006, was applied to this contemporary annual baseline projecting forward to 2030, 2055, 2085 and 2110. The average and 98th percentile uplift over the year, for each projected scenario, was calculated and presented in Table 55.

Table 54. Annual thermal uplift due to climate change

	Annual thermal uplift due to climate change (°C)			
	2030	2055	2085	2110
Annual average	+0.660	+1.347	+2.014	+2.701
Annual 98th percentile	+0.737	+1.508	+2.263	+3.045

The annual 98th percentile thermal uplift for climate change was applied in calculation of future absolute temperature scenarios as the largest annual uplifts coincided with the same month of the year (August) as the observed 98th percentile background temperatures.

This climate uplift (98th percentile) and the 98th percentile ambient temperature 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 (BEEMS Technical Report TR302). Whilst the thermal uplift was calculated using the SZC intake temperatures, the thermal uplift due to climate change is independent of the location and is applied uniformly to the GETM model results to calculate areas of exceedance above the thresholds.

The results in Table 55 indicate:

i. that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28˚C, which remain under 1 ha for all scenarios tested.

ii. Following the decommissioning of SZB, 28˚C as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of operations in 2110.

iii. During the operation of both stations, absolute temperatures of 23˚C increase from 198.2 ha at the surface in 2030 to 506.2 ha at the surface in 2055. At the seabed absolute temperatures of 23˚C are 92.3 ha and 264.4 ha in 2030 and 2055, respectively.

In the event SZB is decommissioned prior to 2055, leaving SZC operating alone, the exceedance of the absolute 23˚C threshold is predicted to be just 5.38 ha at the surface and 0 ha at the seabed (Figure 28). Warming effects result in larger areas exceeding 23°C as a 98th percentile (7,080 ha at the surface, and 6,540 ha at the seabed) in the extreme operational scenario of 2110 (Figure 29).

However, the influence by 2110 the 98th percentile uplift due to climate change is estimated to be +3.045 across the model domain, hence a station uplift of just 0.56°C is sufficient to exceed contemporary thermal standards.

In 2085, towards the end of the likely operational life-cycle, seabed areas in exceedance of 23˚C are predicted to occur over just 0.22 ha, whereas surface exceedance occurs over an area of 69.1 ha. The total area of the thermal plume above 23˚C in 2085 is therefore smaller and further offshore than the contemporary predictions for the two power stations. Furthermore, the offshore location of the outfalls would mean no intersection of the Sizewell C plume with the WFD water body (extending to 1nm) under the current standards (Figure 28 and Figure 29).

Table 55. Total areas where absolute temperatures are exceeded accounting for climate change. Contemporary results are provided for comparison. It should be noted that applying contemporary standards to future climate scenarios ignores responses to climate change in regulations and should be considered as comparative only.

Model run	Year	Position	Units	>23°C (98th %ile) Calculated from mean excess temperature (+climatic warming) >3.6°C (WFD 'good' status)	>28°C 98th %ile) Calculated from mean excess temperature (+climatic warming) >8.6°C (WFD 'moderate' status and SPA threshold)
ReferenceV2 annual SZB	**Contem-porary**	**Surface**	**ha**	**44.9**	**0**
		Seabed	**ha**	**8.75**	**0**
Conf12 annual SZB+SZC	**Contem-porary**	**Surface**	**ha**	**89.60**	**0.11**
		Seabed	**ha**	**25.6**	**0**
SZC only	**Contem-porary**	**Surface**	**ha**	**0***	**0**
		Seabed	**ha**	**0**	**0**
Conf12 annual SZB+SZC	*2030*	*Surface*	*ha*	*198.2*	*0.11*
		Seabed	*ha*	*92.3*	*0*
Conf12 annual SZB+SZC	*2055*	*Surface*	*ha*	*506.2*	*0.90*
		Seabed	*ha*	*264.4*	*0*
SZC only	*2055*	*Surface*	*ha*	*5.38*	*0*
		Seabed	*ha*	*0*	*0*
SZC only	*2085*	*Surface*	*ha*	*69.1*	*0*
		Seabed	*ha*	*0.22*	*0*
SZC only	*2110*	*Surface*	*ha*	*7,080*	*0*
		Seabed	*ha*	*6,540*	*0*

* Mean exceedance temperatures were 3.52˚C marginally below the 3.6˚C threshold

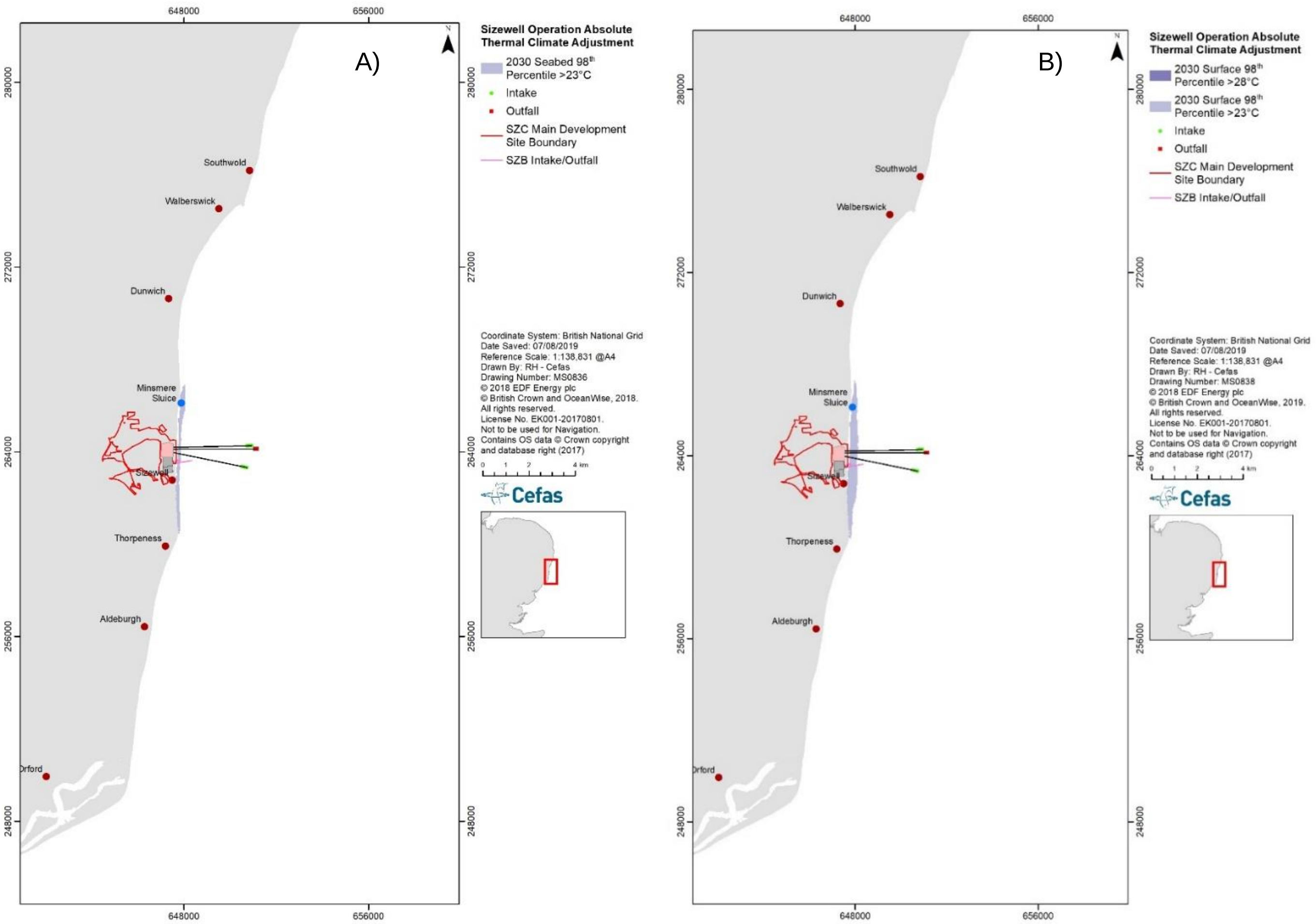

Figure 26. Predicted areas where absolute temperature thresholds are exceeded at A) the seabed, and B) the surface as a 98th percentile due to the combined Sizewell B and Sizewell C thermal plumes and accounting for climate change in the year 2030.

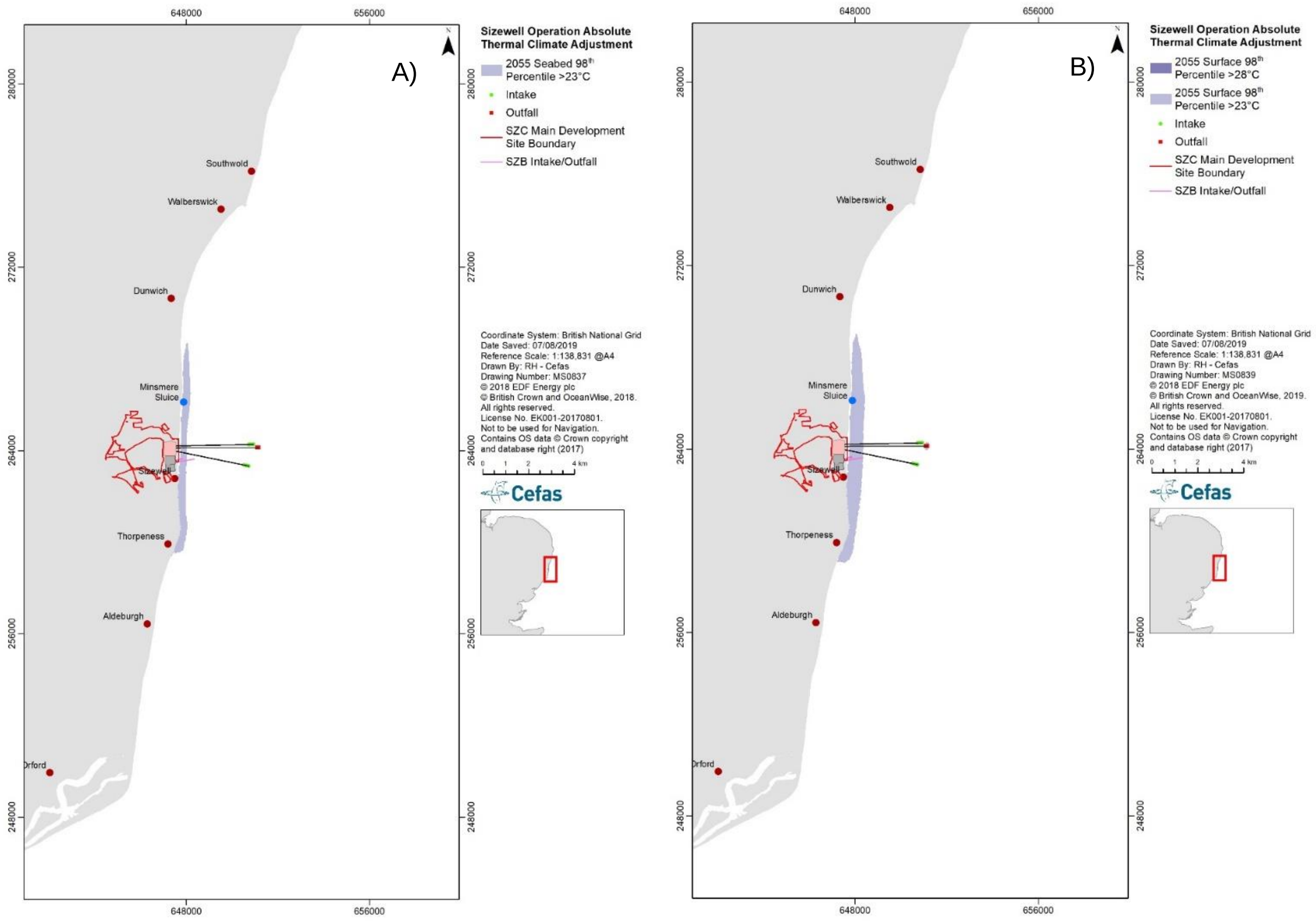

Figure 27. Predicted areas where absolute temperature thresholds are exceeded at A) the seabed, and B) the surface as a 98th percentile due to the combined Sizewell B and Sizewell C thermal plumes and accounting for climate change in the year 2055.

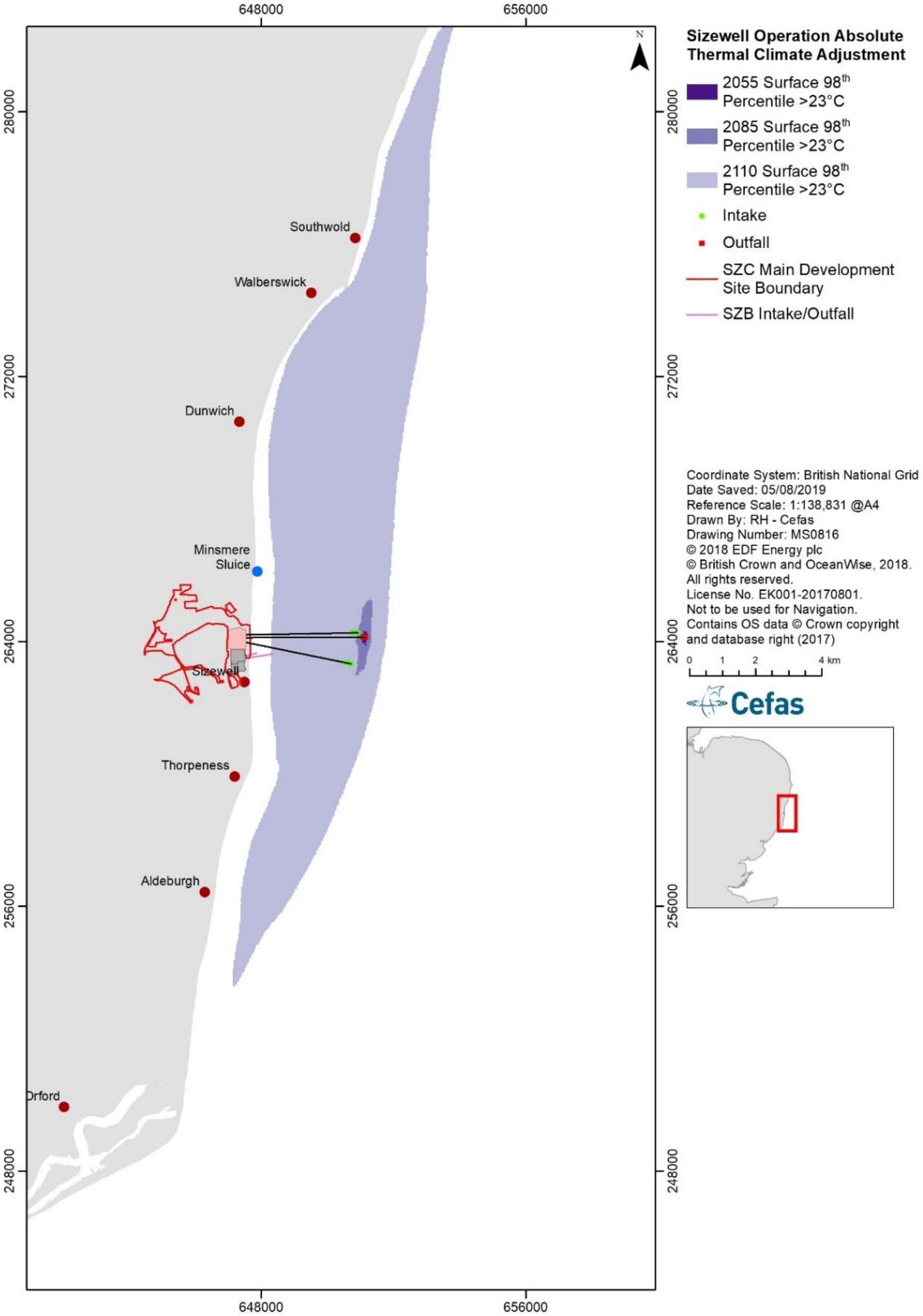

Figure 28. Predicted areas where the absolute temperature of 23°C is exceeded at the surface as a 98th percentile due to the Sizewell C thermal plume and accounting for climate change in 2055, 2085 and 2110.

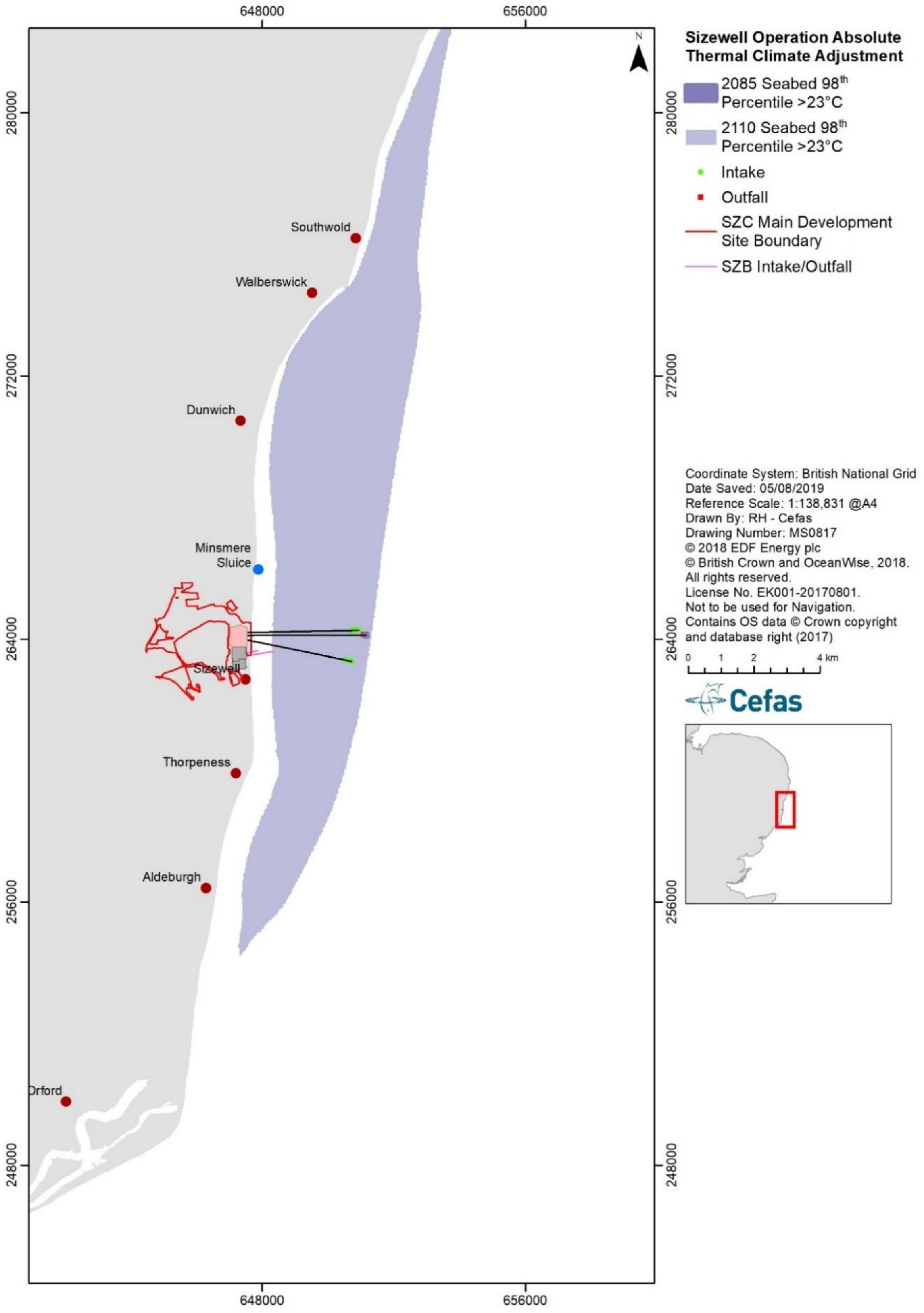

Figure 29. Predicted areas where the absolute temperature of 23ºC is exceeded at the seabed as a 98th percentile due to the Sizewell C thermal plume and accounting for climate change in 2055 (no exceedance), 2085 and 2110.