Sizewell C Water discharge activity permit application

Environment Agency review of the Water Framework Directive compliance assessment

March 2023

Version 2

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Note for readers
This version of the report differs from Version 1. It includes minor changes to better reflect the language used in the permit determination documents. The changes are in the Executive summary, the Conclusions and to a sentence in section 4.3.11.1.

Figures

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Executive summary

This Environment Agency report reviews the Water Framework Directive (WFD) compliance of the applicant's submissions for the Sizewell C nuclear power station operational water discharge application (op WDA) and hot functional testing (HFT) commissioning discharge. In doing this, it references important information the applicant submitted, including its WFD compliance assessment and any other information that we may obtain or produce that is not part of the applicant's submission.

As part of its operation to provide cooling to the operational reactor, direct-through water cooling, using large water intakes placed offshore is proposed. The heated water, containing some additional chemicals is planned as a discharge. A fish recovery and return (FRR) system to reduce fish mortality associated with the cooling water system will also discharge biota. The commissioning and operational discharges are to the marine environment only, so the applicant's assessment largely focuses on transitional and coastal (TraC) waterbodies. A separate habitats regulation assessment is completed which is not considered in this report or the applicant's WFD assessment.

The applicant's overall assessment considers that the discharges will not cause deterioration, nor result in any waterbodies being unable to meet their objectives under the Water Framework Directive. While we can agree with much of the data and many of the conclusions drawn in the assessment, there are several points of concerns that we felt needed further consideration in this report.

These are:

- the thermal impacts

While we agree with the modelled temperature information, we have further considered the impact on migratory fish in the Blyth and the Alde and Ore estuaries due to the occlusion of the estuary mouth (specifically for the Blyth) and the contribution of thermal impacts to fish behaviour along the coast

- the biota estimates in the FRR system discharge

The applicant's assessment was based on the fish loss predictions presented in TR406 v7 (EDF, 2020e), which we have challenged, as we considered that the conclusions underestimated the impacts. We have produced our own analysis using revised figures

- as a result of the revised biota estimates, the conclusions over the impacts on receptors needed to be revisited

- the in-combination assessment was considered incomplete and there were concerns over the robustness of this assessment

From this additional work, the thermal impacts on smelt remain of concern as it is still uncertain if they could potentially be negatively impacted by the SZC thermal plume.

Evidence provided to date does not demonstrate that smelt will not avoid the area of the thermal plume at the 2°C or 3°C uplift, or what effect absolute temperatures will have on this species. A breeding population is known to exist in the Alde and Ore waterbody. Smelt have also been recorded in the Blyth waterbody. Avoidance of or delays due to the presence of a thermal plume while undertaking a spawning migration could potentially affect the species reproductive success. This impact also needed to be considered along with impingement losses via the cooling water abstraction.

No in-combination assessment that considers the abstraction impacts has been provided in this assessment as that is being led through the WFD assessment for the Development Consent Order (DCO).

Following our evaluation we have no additional information to change the findings based on the data presented. There does remain some uncertainty in the use of the temperature avoidance data for smelt in this assessment, but it is considered that significant avoidance as a result of the thermal plume remains low. So no deterioration of fish status in both the Alde and Ore and Blyth transitional waterbodies is expected.

We acknowledge that with the agreement on suitable mitigation measures being secured through the SZC DCO (via its Deed of Obligation and Deed of Covenant) and a robust monitoring programme in place, this would trigger additional compensation for fish if required. So we feel that risks to the transitional fish populations due to the uncertainties in the data could be managed.

The revised biota figures demonstrate an increase in the modelled area of impact, but do not give rise to any additional impacts that could compromise WFD objectives for water quality, habitats or fish.

We have general agreement that our own in-combination assessment has demonstrated that there will be no compromise to WFD objectives when considered alongside the other activities associated with the construction or operation of the site**. However, since the applicant has not formally provided all information on the construction permits, our conclusions on these are informative/indicative only and will be subject to a formal assessment at the time these are considered in the construction permit application process.**

So, subject to those points in bold, we consider that the water discharge application (op WDA) and hot functional testing (HFT) commissioning discharge will not cause waterbody deterioration or prevent the WFD objectives from being met.

1. Introduction

1.1. Background

Sizewell C (SZC) is a new nuclear power station proposed on the Suffolk coast next to the existing Sizewell B (SZB) power station.

As part of its operation to provide cooling to the operational reactor, direct-through water cooling using large water intakes placed offshore are proposed. The heated water, containing some additional chemicals is returned as a discharge to the coastal water and a fish recovery and return (FRR) system to reduce fish mortality associated with the cooling water system will also discharge biota. Dead biota can be considered polluting matter and so needs to be considered in any impact assessment related to the discharge.

Some commissioning related discharge is also required, which is also considered here.

The commissioning and operational discharges are to the marine environment only, so the applicant's assessment largely focuses on transitional and coastal (TraC) waterbodies. Where adjoining freshwater waterbodies could potentially be affected, the applicant has considered this.

1.2. Aim of this report

This report reviews the Water Framework Directive (WFD) compliance of the applicant's submissions for the Sizewell C operational water discharge application (op WDA) and hot functional testing (HFT) commissioning discharge. In doing this, it references important information the applicant submitted, including its WFD compliance assessment and any other information that we may obtain or produce that is not part of the applicant's submission. This report does not include other construction related discharge permits, although the applicant has provided information on this activity in its submission for this permit that allows for some broad assessment of combined impact.

1.3. Water Framework Directive (WFD)

The Water Framework Directive (WFD) was a European directive (2000/60/EC) which was passed into UK law in 2003. This is now revoked and its requirements are now encompassed within the Water Environment Regulations (WER)[1]. The WER imposes legal requirements to protect and improve the water environment. The WER requirements must be considered at all stages of flood and coastal planning and development. Reference is made to the WFD in documents used in this assessment, since they were created prior to enacting the WER.

Under the WER, all waterbodies are classified based on quality elements which encompass a range of physical, biological, and chemical parameters. Waterbody elements may be classed as being at high, good, moderate, poor or bad status, with the lowest scoring element defining the overall status of the waterbody (under the 'one out, all out' principle). The target is for all waterbodies to achieve a minimum of good status (or good potential for heavily modified waterbodies). It is the applicant's responsibility to show that activities will not lead to a deterioration in waterbody status or prevent waterbody objectives being achieved. Following the European Court of Justice 'Weser ruling'[2], deterioration is considered when a WFD quality element falls by one class, even if that fall does not result in a drop in the overall classification of a waterbody.

We have published the 'Clearing the Waters for All (CtW)' guidance[3] on how to carry out a WFD compliant assessment in estuarine (transitional) and coastal waters. It consists of 3 stages – screening, scoping and appropriate assessment.

1.4. Waterbodies in the vicinity of Sizewell C (SZC)

Waterbodies in the vicinity of SZC include those surface waters categorised as coastal, transitional (Fig 1), freshwater rivers and lakes (Fig 2), and groundwater waterbodies.

The site is within the Waveney and East Suffolk Chalk and Crag (GB40501G400600) ground waterbody.

The SZC water discharges considered in this WFD assessment discharge to the Suffolk coast. The Suffolk Coast waterbody encompasses the east coast from Lowestoft in the north to Felixstowe in the south and out to one nautical mile

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[1] Water Environment (Water Framework Directive) (England and Wales) Regulations 2017, UK statutory instrument 407.

[2] European Court of Justice, 1 July 2015, Case C-461/13 – the 'Weser ruling'

[3] https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters

offshore. The SZC development would sit approximately midway between the two. The Suffolk Coast waterbody covers an area of 14,653 hectares.

Figure 1. Transitional and coastal waterbodies in the vicinity of the SZC development site.

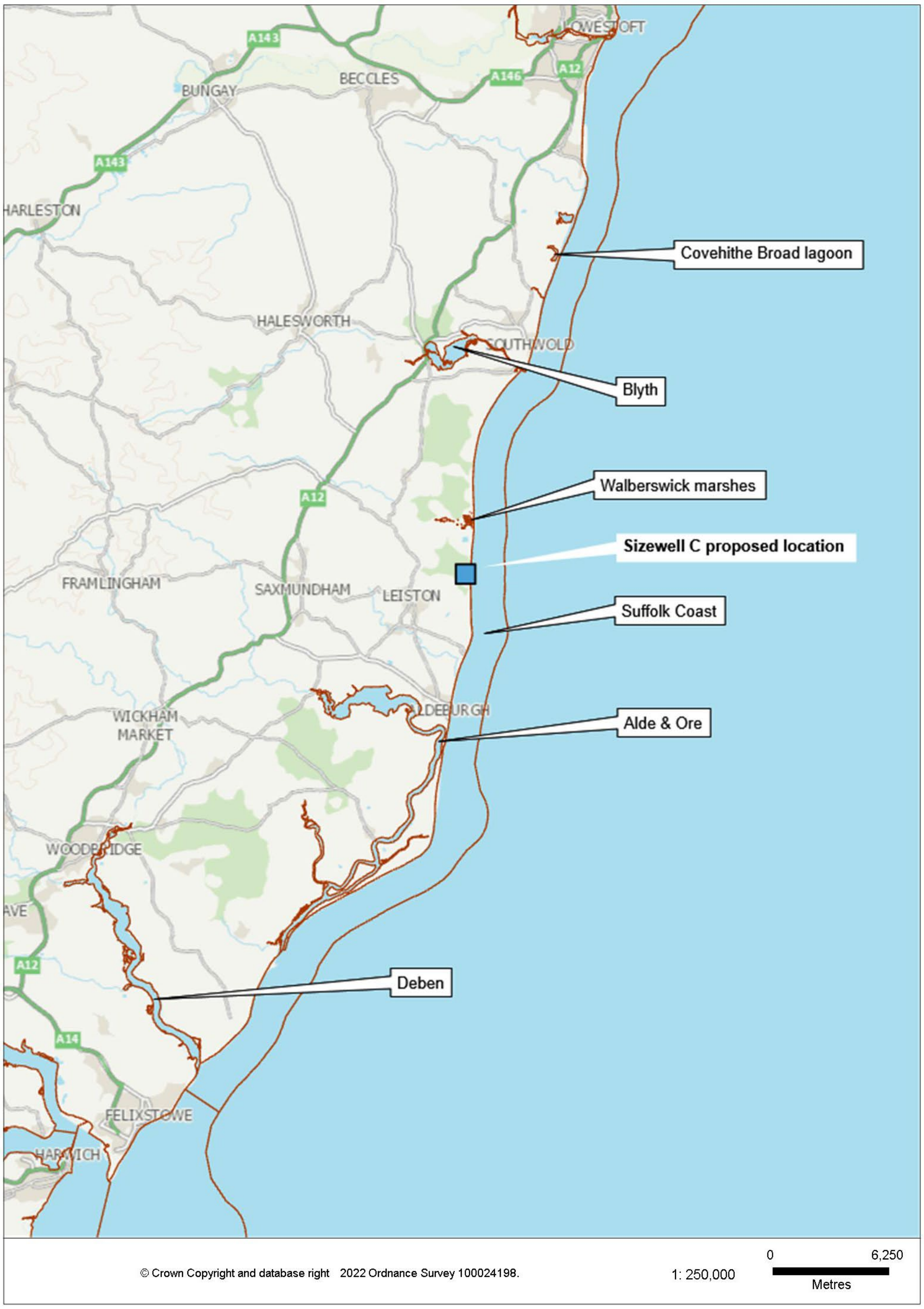
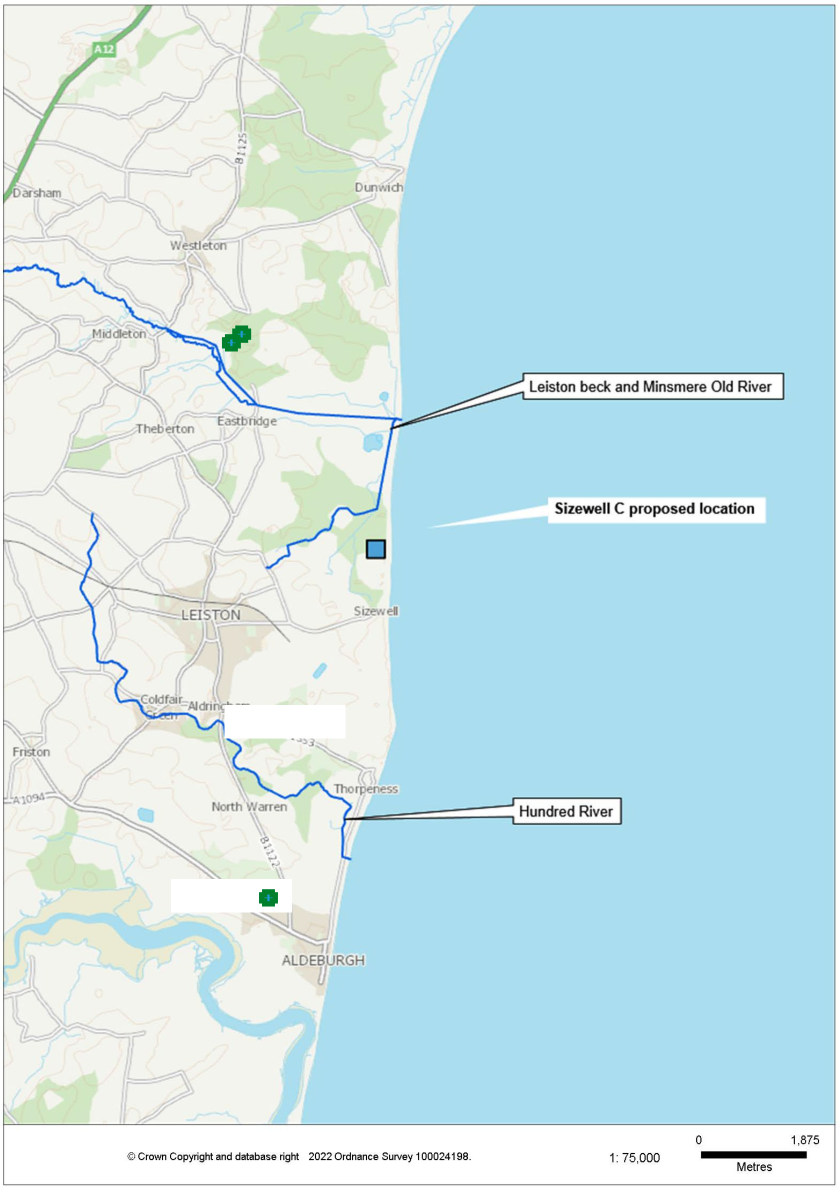


Figure 2. River waterbodies in the vicinity of the SZC development site.



2. Main documents

A number of documents were used to assess compliance of the SZC project with the WFD. These include permit application and supporting technical reports referred to by the applicant as part of the application process. The main reports considered in this assessment are in Table 1.

Table 1. Summary of main documents considered as part of this WER assessment.

Document title (version)	Reference	Notes
Water Discharge Activity Permit Application – Appendix D - WFD Compliance Assessment (States Doc. ref. 100232392, Revision 1). Received in Word form by the Environment Agency on 20 May 2021 and recorded as Environment Agency version 3 in response to changes in TR520 v3	EDF 2021a	This report is provided in support of SZC's WDA permit application to the Environment Agency for the operational phase of the power station, from hot functional testing (HFT) onwards. It assesses whether the proposed commissioning (HFT only) and operational water discharge activities are compliant with the Water Environment (Water Framework Directive) Regulation 2017. Given that the commissioning and operational discharges are to the marine environment only, this assessment only focuses on transitional and coastal waterbodies (TraC). Where there is the potential for effects on adjoining fresh waterbodies, consideration is given within section (5.5.74 onwards) to the further assessment.
WFD Compliance Assessment Part 1, Appendix 1A	EDF 2015	Doc Ref 8.14 – Royal HaskoningDHV. Marine Strategy for Sizewell C Water Framework Directive Assessment. 2015a. Sets out proposed approach to developing and providing information for WFD assessment.
Technical Report TR520 SZC Water quality effects of the fish recovery and return system	EDF 2021b	Cefas report for EDF. Considers the Influence of the fish recovery and return system on water quality and ecological receptors, from decomposing dead fish discharged.

(Ref 100813986, Rev 3: dated 2 Apr 21)		
Synthesis of evidence for Sizewell C Water Framework Directive (WFD) and Habitats Regulations Assessment (HRA) marine assessments. Technical Report TR483 v 6.	EDF 2020g	Contains a summary of specific evidence to inform the HRA and this WFD compliance assessment.
Sizewell C Discharges H1 Assessment – supporting data report, Technical Report TR193	EDF 2021d	Required Environment Agency overall (H1) assessment for environmental water discharge permits. Considers discharge streams and what to take forward into further discharge assessment.
Water Discharge Activity Permit Application Submission– Appendix A. Revision 3	EDF 2021c	EDF Main SZC WDA submission document.

The main document referred to in much of this review is EDF 2021a.

3. WFD compliance assessment by the applicant

3.1. Background

Appendix D of the 2021 WDA permit application (EDF, 2021a) considered whether activities which are relevant to the commissioning and operational SZC WDA permit application would affect compliance of the project with WFD. Potential impacts of SZC were considered for the Suffolk coastal waterbody. Adjoining coastal and transitional waterbodies were considered if an effect is predicted on Suffolk coastal water and if there is a hydrological link with the seawater of the Suffolk coast.

The other waterbodies scoped in were Leiston Beck and Minsmere Old River, Walberswick Marshes and Blyth (S) and Alde and Ore estuaries.

The applicant's assessment followed the Environment Agency's 'Clearing the Waters (CtW) for All' guidance for the completion of WFD assessments in transitional and coastal waters. The combined discharge from the cooling water outfall, and the fish recovery and return system discharge were identified as having the potential to affect ecological, physical and/or chemical aspects of these waterbodies[4]. Associated potential impacts on protected sites were also highlighted.

The Environment Agency H1 screening approach for discharges was used to determine the physical and chemical attributes of the discharge to take forward into modelling. This was provided in the applicant's report TR193 (EDF, 2021d).

3.2. Focus of document and conclusions

The WDA activities that were scoped in for further consideration were identified as the:

- cooling water discharge (CWD), which included:
  - seawater at elevated temperature (waste stream A – thermal properties only)
  - process chemicals during commissioning/operation (trade effluents) (waste streams A to F – chemical parameters only)
  - sewage effluent during operation (waste stream G)
- fish recovery and return (FRR) system discharge, which included:

[4] Decommissioning impacts were considered likely to be similar to, or less than, those identified in the construction and operational phases. As such, decommissioning activities were not considered explicitly.

- polluting matter from the FRR system (waste stream H)

3.2.1. Cooling water discharge (Commissioning and operational phase)

During operation, waste streams A to G would be discharged out of the cooling water outfall. The cooling water intake mean flow is $132m^3\ s^{-1}$ at mid tide level. Stream A contains the cooling water return – characterised by thermal content and seasonally dosed chlorine. It discharges warmed seawater with a mean excess temperature of 11.6^oC above ambient background. Streams B to G include trade chemical and some treated sewage.

Exceptions to the regular discharge regime are noted:

- Periodic desiltation of the forebay may be needed. The plan is to discharge this sediment through the cooling water system.
- Maintenance testing is a theoretical condition when excess temperature at the outfall could rise to 23.2 °C. This is unlikely to occur but represents a worst case in terms of cooling water flow and is used to characterise short-term (24 hour) discharges.

During commissioning, cold flush testing (CFT) involves cleansing and flushing the various plant systems with demineralised water to remove surface deposits and residual debris from the installation. The CFT effluent is to be discharged to the Sizewell Bay via the combined discharge outfall. The discharges resulting from CFT will be subject to a separate, later water discharge activity permit application, so are not considered in the applicant's WFD assessment.

HFT tests the system under high temperature and pressure. The chemical substances discharged during the hot functional testing would be the same as those discharged during the normal operation of Sizewell C (EDF, 2021a). HFT begins following completion of CFT and when all the required systems are available. It takes place only once the cooling water infrastructure is in place and operational. HFT is considered in the applicant's assessment.

EDF 2021a considered that HFT would have the same effects as running the systems under normal operating conditions and, therefore, the assessment for operational discharges also applies to HFT discharges. As a result, HFT is not specifically referred to in this assessment, but the outputs include consideration of HFT.

Quality elements scoped in by the applicant were:

- biology – habitats and fish (indirect effects on fish of transitional waterbodies only)[5]
- water quality – physico-chemistry and chemicals (includes phytoplankton)

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[5] Fish are not a biological element considered in the WFD and, therefore the WER, for coastal waterbodies.

- invasive non-native species (INNS)
- Protected Areas – European Designated Sites, Nitrate Sensitive Areas and Bathing Waters

3.2.1.1. Cooling water discharge: Thermal impacts

When one of the pump systems is under maintenance, the flow of cooling water would be halved but the heat content would remain approximately the same, raising the temperature at the outfall from 11.6°C to 23.2°C. However, the warmer plume loses heat faster to the atmosphere, which reduces the size of the excess temperature plume compared to that arising during normal operation. As a result, the maintenance scenario is not considered further as the thermal plume effects of any maintenance would be within the extent of the effects experienced during normal operation.

EDF Technical Report, TR302 Sizewell C Thermal Plume Modelling GETM Stage 3. Edition 5 (EDF, 2020a) describes the approach to modelling and the standards applied. The thermal thresholds for marine waterbodies under WFD are presented in EDF 2020a in section 4.2.2 as:

WFD	High	Good	Moderate
Annual 98th percentile of absolute temperature	< 20ºC	20ºC < T ≤ 23ºC	23 ºC < T ≤ 28ºC
Annual maximum uplift as a 98%ile	≤ 2ºC	2ºC < Uplift ≤ 3ºC	Uplift > 3ºC

TR302 states, “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, Wither and others, 2012). 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.”

During normal operation, these thermal standards are not predicted to be exceeded when the discharge from SZC alone is modelled, but uplift thermal standards are predicted to be exceeded while SZB and SZC are both operating: the modelled mixing zone is 26% of the Suffolk coastal waterbody at the seabed (Fig. 3) and 28% of the Suffolk coastal waterbody at the surface. (Fig. 4).

Figure 3. Seabed 98th percentile of excess water temperature for run with SZB and SZC operating (from EDF 2021a).

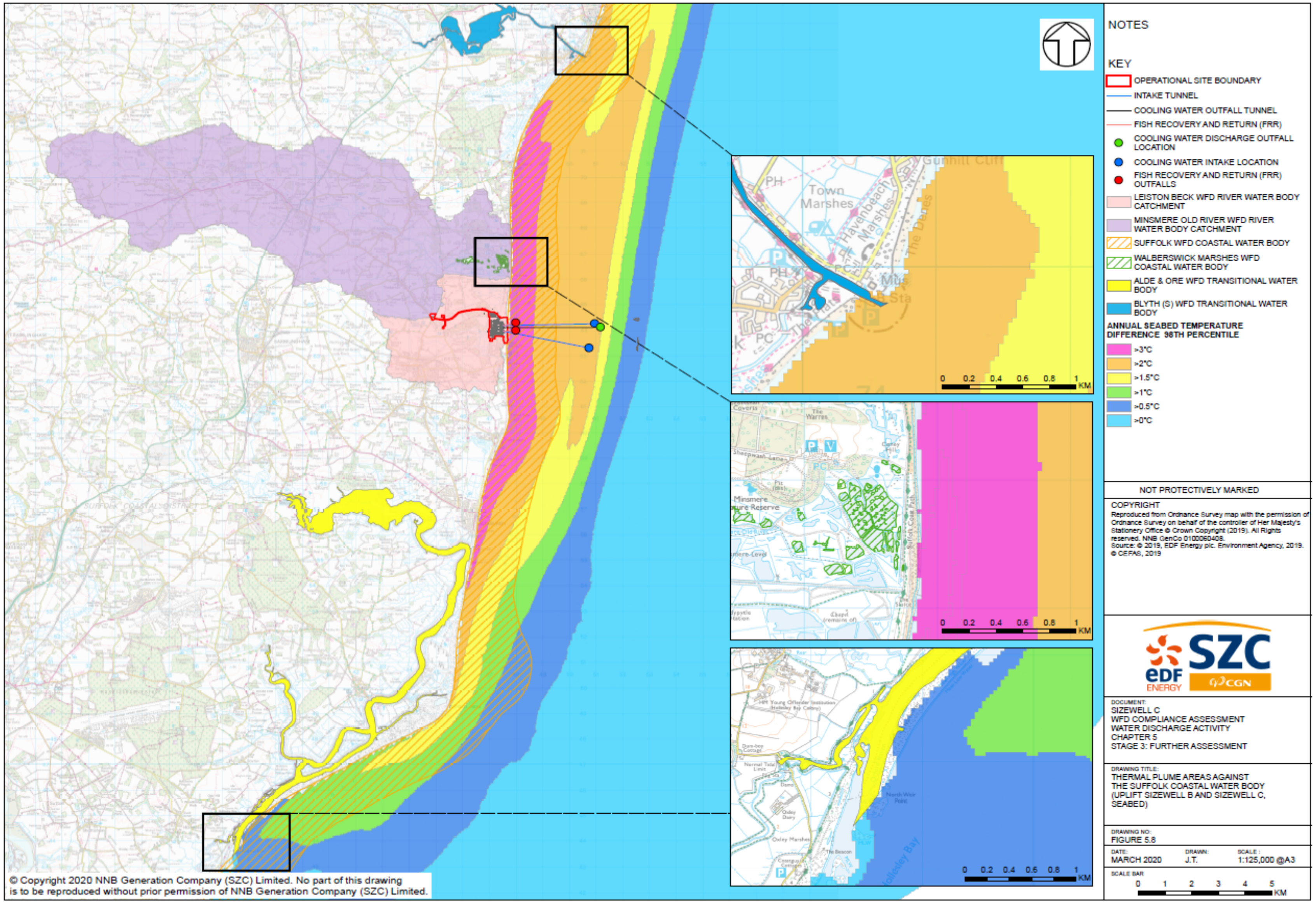


Figure 4. 98th percentile of excess surface water temperature run SZB & SZC operating (From EDF 2021a).

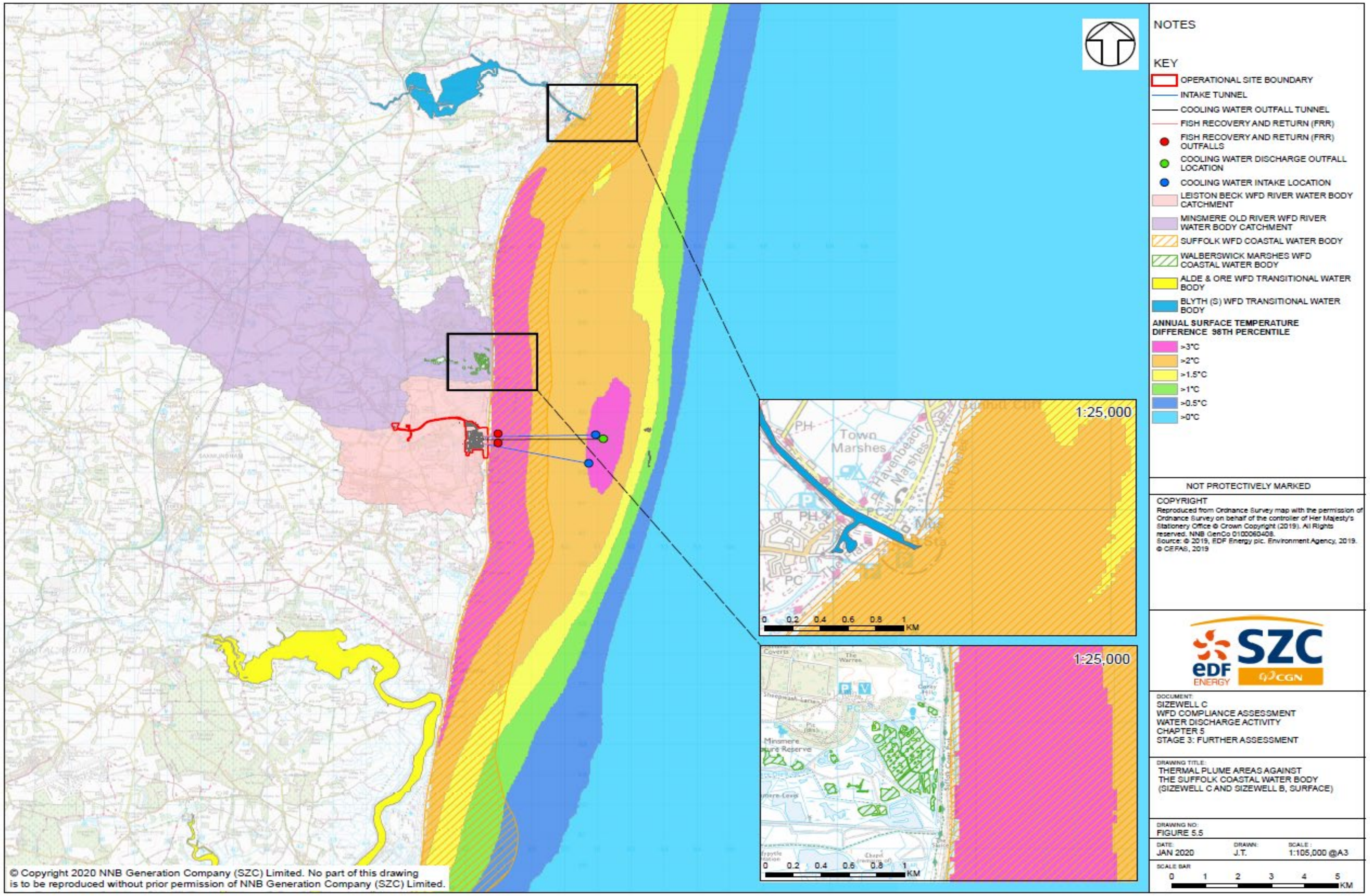
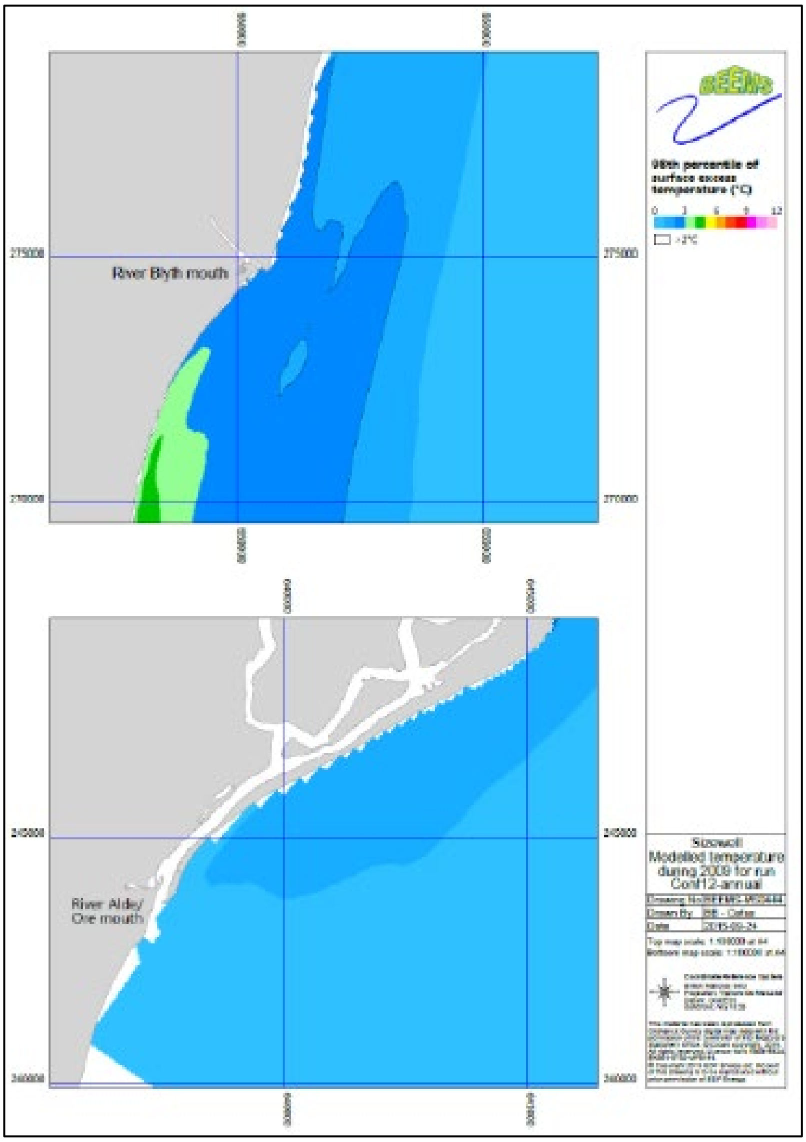


Figure 5. SZB+SZC Thermal plume maps as 98%ile at the Blyth and Alde-Ore estuaries (from Fig 15 in EDF 2021a).



The sensitivity of benthic vertebrates – those living in or on the seabed- found within the WFD waterbody to thermal discharges ranged from 'not sensitive' to 'low sensitivity'. It is concluded that differences in species' responses to the thermal plume may lead to minor changes in community composition, but such changes are unlikely to alter the overall structure or functioning of benthic communities within the habitats present within the WFD waterbody. Consequently, a deterioration within class or between classes for benthic invertebrates is not predicted for either the higher or lower sensitivity habitats.

With respect to fish populations, there is no intersection of above 2ºC predicted for the Alde and Ore. The thermal plume intersects the Blyth Estuary and the estuary cross section standard is predicted to be exceeded for 3.5% of the year. The cross-section standard is not predicted to be exceeded in the Alde and Ore (Figure 5).

The applicant has focused on the period of migration of important species – lamprey, eel and smelt and related this to the period when the cross-sectional area across the estuary mouth may exceed 25%.

The applicant has also applied this ‘cross-sectional’ approach to the coastal waters to consider the impact on migratory routes for important fish species. We acknowledge this is not an established standard, but this assessment recognises the potential impact that thermal uplift can have on the health or behaviour of fish as they move towards any nearby estuaries and how this may impact the status of fish in those estuaries.

The applicant considers there is no reason to consider WFD objectives will not be met in the Blyth or Alde and Ore estuaries as a result of the SZC thermal discharge on fish.

The thermal plume may enhance growth rates of phytoplankton but the hydrodynamics of the open coastal site are predicted to reduce the potential for the formation of phytoplankton blooms. To assess the risk to migratory fish, lab thermal preference experiment results were compared against modelling outputs.

The assessment concluded that WER deterioration with regards to water temperature or temperature-driven impacts on water quality, invertebrate or fish assemblages, were unlikely.

Predictions of effects based on current thermal baselines are considered. The date for decommissioning of SZB is not fixed, but is hypothetically given as 2055, with SZC expected to be operational in 2034 until between 2085 and no further than 2110 (EDF, 2021c). Scenarios were considered with SZC operating with and without SZB, across these hypothetical dates.

The results indicate that:

- future climate change is not predicted to significantly increase the absolute areas in exceedance of 28°C, which remain under one ha for all scenarios
- following the decommissioning of SZB, 28°C as an absolute temperature is not predicted to be exceeded as a 98th percentile. Concluding acute thermal effects in the receiving waters are predicted to be minimal
- If SZB is not operational in 2055, there are no exceedances of the absolute 23°C threshold within the WFD waterbody, either at the surface or at the seabed. The same applies to 2085 towards the end of the likely operational life cycle of SZC
- In 2110, large areas of the WFD waterbody could exceed the absolute 23°C threshold both at the surface and at the seabed. The influence due to climate change is estimated to be +3.045ºC across the model domain, therefore a station uplift of just 0.56°C is sufficient to exceed contemporary thermal standards

Assumptions are made that fish will adapt to rises in sea temperature. The reduction in overall spatial area impacted (with the decommissioning of SZB) and the potential for the impacted area to be further offshore from coastal fish migration routes, means additional effects over and above those already assessed within the WFD waterbody are not predicted.

3.2.1.2. Cooling water discharge: Dissolved oxygen and unionised ammonia

The plume as it comes out of the power station would be warmer than the intake and would, therefore, have less capacity to carry oxygen. The spatially average dissolved oxygen concentration for the operation of both Sizewell B and Sizewell C and Sizewell B alone is >7mgl^{-1} as a 5th percentile, which is considerably above the WFD threshold for achieving ‘high status’ of 5.7mgl^{-1}. As a result, a deterioration in class status is not predicted.

Although unionised ammonia (UIA) was 35% of its environmental quality standards (EQS), increases in temperature could influence the relative amount of unionised ammonia. As a result, modelling has been carried out to assess this effect. The interaction of temperature and UIA was considered. No areas in the model domain (and, therefore, the Suffolk coast WFD waterbody) exceed the EQS of 21µgl^{-1} as an annual mean. No effect due to interaction of UIA with temperature was expected, that would change the assessment of the discharge or thermal plume alone.

3.2.1.3. Cooling water discharge: Chemical parameters

Some localised elevations of total residual oxidants (TRO), bromoform, hydrazine and phosphate concentrations were predicted after initial dilution in the vicinity of the discharge. To assess the significance of specific chemical discharges, the required H1 methodology uses, as its reference, existing EQSs. Where no EQS is available for a given substance, available toxicity test data were 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, the marine background concentration for a substance from monitoring conducted adjacent to the Sizewell site was used as a point of reference. EQSs are not available for bromoform and hydrazine, so the applicant has put forward PNECs. Table 2 refers to the size of the areas of the mixing zone (that is, where these different chemical thresholds are exceeded).

These water quality impacts are covered with additional detail in the ‘Marine water quality and sediment synthesis report’ (EDF 2020c).

The outfall is outside the WER seaward boundary (approximately 1.6 nautical miles (nm) offshore compared to the one nm for the waterbody boundary), and chemical plumes are not predicted to reach as far as the Suffolk Coast waterbody.

Table 2. Absolute areas exceeding the EQS/PNEC values at the surface and seabed from TRO, bromoform and hydrazine modelled discharges (EDF, 2021d).

Discharge	Surface (ha)	Seabed (ha)
Total residual oxidant (TRO) – 132m^3s^{-1} discharge scenario as a result of chlorination when sea temp above 10°C. **EQS = 10µgl^{-1}MAC as a 95%ile**	336.65	2.13
Bromoform – PNEC of 5µgl^{-1}MAC as a 95%ile	52.14	0.67
Hydrazine - 69ng discharge scenario (worst-case of daily pulses of 2.32hr) **PNEC = 4ngl^{-1} (acute, as 95%ile)**	13.79	0.22
Hydrazine - 34ng discharge scenario (of daily pulses of 2.32hr) **PNEC = 4ngl^{-1} (acute, as 95%ile)**	17.38	0.00

Nutrient loadings from the discharge are predicted to increase phytoplankton production within the greater Sizewell Bay by 0.14%.

Free chlorine and chloramine are known to increase in toxicity as a result of increasing temperature: a 5°C increase in temperature more than halved the effect concentration for various marine species. However, the acute effects of this exposure would be expected to diminish rapidly upon discharge with rapid loss of temperature and reduction in oxidant concentration as the plume mixes and reaches the sea surface. The thermal uplift in combination with the toxicological effects of chlorination is therefore not expected to change the assessment of the chlorination discharge or thermal plume alone.

The synergistic effects of chlorination and ammonia discharges were considered as these may result in the formation of additional combined products, primarily the more toxic dibromamine. As total ammonia is only around one-third of the background ammonia, any increase in toxicity is expected to be very small. As a result, additional water quality effects are not predicted.

3.2.1.4. Cooling water discharge: Invasive non-native species (INNS)

Only one INNS species, the American jacknife, Ensis leei, was found in one grab sample. This species is also recorded north of this waterbody, so the ability for this species to spread due to increasing temperature is already in motion. No additional INNS effects as a result of the thermal discharge are predicted.

3.2.1.5. Cooling water discharge: Protected Areas

Impacts on Bathing Waters and Nitrate Sensitive areas are not predicted. The applicant points us to its shadow HRA for impacts to marine protected areas.

3.2.1.6. Cooling water intake

This was not scoped in because this assessment purely focuses on the impacts from the water discharge activities.

3.2.2. FRR system discharge

Waste stream H is discharged through this outfall. Quality elements scoped in were:

- biology – habitats and fish (indirect effects on transitional waterbodies only)
- water quality – physico-chemistry (includes phytoplankton)
- Protected Areas – European Designated Sites, Nitrate Sensitive areas and Bathing Waters

Impacts of the FRR system discharge were considered for several water quality parameters. In addition, impacts of the organic enrichment of benthic sediments due to smothering and subsequent habitat loss were considered.

Calculations were based on conservative estimates and considered to represent 'worst-case' assumptions, since:

- highest biomass discharge is predicted from January to March, with lowest values during the spring-summer period. Nutrients derived from the biomass during the winter period would not directly contribute to phytoplankton growth due to light limitation and lower temperatures. However, values were conservatively based on the annual average biomass
- a worst-case scenario is applied which assumes that the fish are not removed from the system through being consumed by other species
- calculations also assume that dead fish would sink immediately. As such, there would be no effective dilution of any pollutants as a result of distribution by local currents
- it assumed instant release of pollutants which would in fact be a slower process

Based on this modelling, impacts at a waterbody scale for nearby estuaries, and on their fish populations, are not predicted.

EDF 2021a concluded negligible impacts on dissolved organic nitrogen, phosphate, oxygen conditions and un-ionised ammonia, based on the following summary of effects:

- Nutrients: 3,442kg/day wet weight biomass predicted to be mean daily discharge during March. 1,066 kg/day is predicted to be the annual daily average. This is predicted to equate to an average daily load of nitrogen of 32kg (stated in paragraph 5.6.7) or 37kg (stated in Table 5.15) increasing daily exchange by 0.3%.
- The spatially average dissolved oxygen concentration for the operation of both Sizewell B and Sizewell C and Sizewell B alone is >7mgl^{-1} as a 5th percentile, which is considerably above the WFD threshold for achieving high status of 5.7mgl^{-1}.
- For March as a worst case, the oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha.

Therefore, as waters off Sizewell are well mixed vertically facilitating reaeration at the surface and there is good water exchange in Greater Sizewell Bay (GSB), the Biological Oxygen Demand (BOD) from biomass discharged is predicted to have a negligible effect on dissolved oxygen concentration.

- Unionised ammonia: Under worst-case predictions (March) an area of 6.7ha would exceed unionised ammonia EQS within Suffolk coastal waterbody due to the FRR system outfall.

These water quality impacts are covered with additional detail in the 'Marine water quality and sediment synthesis report' (EDF 2020c).

Following on from this, impacts of nutrient inputs on phytoplankton were also concluded to be insignificant. This was linked to light being the principal limiting factor to phytoplankton growth in Sizewell Bay until the summer, at which point nutrients start to become limiting. Initially, phosphate is the primary limiting factor from mid-May. However, this is very short-term and the system enters a period of nitrate limitation until August. Phytoplankton production within Greater Sizewell Bay may be increased by 0.3%. Habitat effects on a waterbody scale are not predicted.

In addition to considering water quality impacts, impacts of the organic enrichment of benthic sediments due to smothering and subsequent habitat loss/change were considered. Habitats stated as potentially at risk are the WFD lower sensitivity habitat 'subtidal soft sediments' and higher sensitivity habitat, 'polychaete reef'. Subtidal soft sediment makes up the greatest proportion of the Suffolk Coast waterbody. The invertebrates most abundant in in the seabed (infauna) in the Greater Sizewell Bay have a high reproduction rate, suggesting that these infaunal populations are resilient in what is considered a dynamic environment. Benthic invertebrate community changes at a waterbody scale are not predicted.

3.2.3. Cumulative impact assessments

The applicant considered the combined effects from within-project proposed operational discharges: cooling water, STW and FRR system waste streams. The applicant does not predict that these discharges would, together, affect water quality parameters or fish and marine ecology at a waterbody scale.

The applicant followed a staged approach to assess the potential for cumulative impacts with other projects. The first stage was to establish a zone of influence to define the search area to compile a long list of non-SZC projects. The long list was screened with specific regard to relevant quality elements to identify a shortlist of projects, which included decommissioning of Sizewell B and offshore energy schemes. The applicant then collated information, where available, (stage 3) to inform an assessment as to whether the project should be screened in for further consideration (stage 4). The applicant concluded that no non-SZC projects should be screened in for further consideration.

3.2.4. Overall conclusion

The applicant's WFD assessment concluded that the proposal will not cause deterioration in waterbody status or inhibit the potential for waterbodies to achieve their WFD objectives in future, either alone or with other projects.

4. Common ground and disagreement

Here, we look at the areas where we agree and disagree with the applicant's assessment and any of our additional work carried out to examine those differences further.

4.1. Screening and scoping stages

The 'Clearing the Waters (CtW) for All' guidance approach has been followed for both discharges. Based on the applicant's own information, we agree with the receptors scoped in. We have some issues over what should go forward in in-combination, which we have considered further in section 5.9.

We would point to the outcome of the HRA for impacts on Special Areas of Conservation (SAC), Special Protection Areas (SPA) and Ramsar sites. So, those protected sites are not considered further in this review.

There are expected to be other discharge permits associated with CFT and potentially for construction, but these have not been applied for, although some detailed information on these has been provided in the applicant's submission.

4.2. Further assessment stage

The CtW guidance approach has been followed, although the CtW guidance itself does not provide details on how to carry out an appropriate assessment or cumulative/in-combination assessment. For more on the appropriate assessment review, see sections 4.3 onwards, where we have areas for further consideration, under the following headings:

- cooling water discharge: thermal impacts (section 4.3)
- cooling water discharge: chemical impacts (section 4.4)
- FRR system discharge: chemical and physical impacts (section 4.5)

4.3. Cooling water thermal impacts

4.3.1. The thermal model applied

In the SZC Marine Technical Forum – Environment Agency BEEMS Review (Period 1) our comments of 18 September 2014 note that we consider both the Delft 3D and GETM models fit for purpose for their intended use.

While there was continued discussion on several topics, our basic understanding and acceptance of the model results, including their use for calculating the thermal and chemical plumes, has not changed.

4.3.2. The basis of the thermal standards applied and their application

In TR193 (EDF, 2021d), the applicant refers simply to 'the WFD temperature standards', but also states the need to 'apply these as a trigger value' where further investigation may be needed.

It should be noted, there are no formal standards for assessing thermal occlusion in coastal waters. Draft WFD standards were published by the UK Technical Advisory Group for WFD in March 2008 (UKTAG 2008), which formed the basis for the WFD standards for rivers quoted in Table 3.

Table 3. Proposed boundaries for temperature (for rivers).

	Temperature (ºC) (Annual 98-percentiles)			
	High	**Good**	**Moderate**	**Poor**
Cold water	20	23	28	30
Warm water	25	28	30	32

The types for rivers and lakes were grouped and condensed according to 2 temperature preferences of fish species: cool-water (formerly 'salmonid') and warm-water (formerly 'cyprinid'). This typology for rivers and lakes was then compared with fish species for transitional waters and coastal waters. It was identified that all fall into the 'cool water' group.

Concerning the maximum temperature values defined in Table 3 for rivers, UKTAG 2008 stated that:

"it is proposed that the values are not used for the classification of lakes, estuaries and coastal waters, but are to be used for these waters to calculate the action needed to achieve a target class, or for day-to-day operational control of discharges and abstractions. **In the regulation of thermal discharges more specific locally derived background reference conditions may be required if the thresholds (above) are not appropriate**."

An additional requirement of the draft standards was that, outside the mixing zone, a temperature uplift relative to background (ΔT) of +3ºC is allowable, except for waters of high ecological status, where a 2°C uplift limit is proposed. In the UKTAG report, it was also proposed that these uplift standards are the 98th percentile, or in other words, should not be exceeded for more than 2% of the time.

In addition to these proposed targets under the WFD, there are existing temperature thresholds for assessing the impact of thermal discharges on European marine sites designated under the Habitats Directive and provided in Table 4.

Table 4. Temperature thresholds for assessing the impact of thermal discharges on European marine sites designated under the Habitats Directive.

Designation	Deviation from ambient	Maximum temperature
SPA	2°C as a maximum allowable concentration (MAC) at the edge of the mixing zone.	28°C as a 98 percentile at the edge of the mixing zone.
SAC (any designated for estuary or embayment habitat and/or salmonid species)	2°C as a MAC at the edge of the mixing zone.	21.5°C as a 98 percentile at the edge of the mixing zone.

Therefore, the impact of an individual thermal discharge on the ecology of a waterbody needs to ensure that the objectives of environmental regulations are met. The temperature thresholds being applied to coastal waters are considered to be indicative screening thresholds or triggers rather than a pass or fail assessment and provide a useful indication of the extent of a mixing zone.

The assessment should include details of impacts for specific areas of a waterbody if they are used as migration routes and for specific periods of migration rather than an annual mean. This is due to the uncertainty that exists over when negative impacts to a given species could occur.

The applicant in its assessment refers to the BEEMS Expert Panel, Thermal standards for cooling water from new build nuclear power stations SAR008 (BEEMS 2011a). SAR008 'critically reviews the available scientific information from published and grey literature over the past 50 years'. The general conclusions from this report were:

- "Existing standards (even where they have statutory basis) are not considered to be a realistic guide for the protection of the marine environment; freshwater limits have been uncritically transferred to marine waters, and there appears to have been a reliance on intuition; for example, in many cases there is an assumption that a cooling-water discharge forms a thermal barrier to migratory fish, yet this is supported by little experimental evidence. Current standards are almost entirely based on known responses of fish and take no account of other marine biota or putative climate change effects.
- Whereas previous thermal standards developed in the UK, primarily for application to freshwaters, have distinguished between salmonid and cyprinid waters, this distinction is inappropriate for TraC waters, which support a greater diversity of fish species. In marine waters, it is of greater relevance to consider thermal responses of species based on zoogeography, considering, for example, Arctic–Boreal and Lusitanian domains (cold- and warm-water species, respectively).
- In general, fish and other swimming organisms can detect and actively avoid warmed waters if they perceive them to be harmful, making it unlikely that they will

suffer significant impact from the shorter-term temperature elevation. Equally, planktonic organisms in the receiving water will only be at risk as the effluent mixes and dilutes. It is therefore predominantly benthic organisms that are at risk of being affected by thermal effluents, but this risk is moderated by the buoyancy of the plume. Hence the importance of a good knowledge of the hydrodynamics of the receiving waters.

- While there is little evidence to suggest that existing thermal discharges have created barriers to cold-water migratory fish species such as salmon, sea trout, eel and smelt (which are also of stated conservation importance), future responses must be considered against a background of longer term water temperature rise associated with climate change, which is gradually reducing the metabolic headroom for cold-water species. The much larger flows of cooling water planned for NNB stations could also be expected to have a greater potential for this type of effect, although planned temperature rises (ΔTs) will remain similar to those for existing thermal stations.
- Combining fish zoogeographic data with sea-surface temperature data indicates the preferred temperature ranges of fish. Seasonal movements of fish away from fringe areas, and the ability of some fish to exploit cooler, deeper layers in some areas, may prevent them from experiencing the full ranges of temperatures inferred, as has been demonstrated, for example, in cod. Hence the zoogeographic information provides a useful indication of temperature preferences of species for which there are no laboratory studies or other measurements.
- Although the UK Technical Advisory Group on the WFD has been unable to accept recommendations for draft temperature standards for TraC waters due to insufficient data, the more extensive information reviewed in the present report, now including invertebrate data as well as an expanded fish database, allows the reconsideration of the temperature boundaries and allowable changes (Table 5)."

Table 5. Proposed temperature boundary values for all TraC waters outside the mixing zone, reproduced from SAR008 (BEEMS, 2011a).

Typology	Normative definition boundary positions (as annual 98%-ile)			
	High/Good	Good/Moderate	Moderate/Poor	Poor/Bad
Maximum Allowable Temperature*	23°C	23°C	28°C	30°C
Maximum Allowable Temperature Uplift	+2°C	+3°C	+3°C	+3°C

Additionally, in line with international good practice as outlined in the BEEMS SAR008 (BEEMS 2011a), it is also recommended that the mixing zone should not occupy more than 25% of the cross-sectional area of an estuarine channel as an annual 95%ile. We also apply this standard.

It should be noted, an earlier report produced by the BEEMS group in 2011 (BEEMS 2011a) originally stated this was a 98%ile, but the applicant has approached the authors of this report who have confirmed this was likely to be an error. That would seem to be the case as an earlier 2007 report (Turnpenny and Liney, 2007a), including those by one of the authors of this BEEMS report, which was commissioned by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) working with the UK WFD technical advisory group, stated this as a 95%ile. The 95%ile was also stated in a 2007 report to the Environment Agency (Turnpenny and others, 2007b). We agree this should be used.

The intention of this mixing zone boundary was to maintain an open corridor for fish migration.

So, in summary:

- we use the freshwater UKTAG (WFD) standards for ‘Good’ status for non-cyprinids to define the extent of the mixing zones for thermal discharges in TraC waters in relation to WFD requirements. There are separate mixing zones for the absolute temperature (23^{o}C max) and the temperature uplift (3^{o}C)
- 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
- consideration of important species may need to use different standards more relevant for protecting those species or maintaining the ecological quality of the waterbody

The applicant has considered these 3 points in its assessment.

The applicant has determined that there is no intersection of above 2^{o}C predicted for the Alde and Ore (Fig 5). With the distance of over 9,000 metres from the estuary mouth at which elevated levels (>2^{o}C) were reached, over the period of a year, we would support that general thermal modelling conclusion.

While we agree with the modelled information, we consider further the evidence used and interpretation of the impact of the thermal plume on fish in the Blyth and the Alde and Ore estuaries in sections 4.3.3 to 4.3.11.

4.3.3. applicant’s conclusions on thermal discharge impacts from the operation of SZC, EDF 2020a

4.3.3.1. Thermal occlusion of the Blyth waterbody

Given some important fish species migrate into the estuary at particular periods of the year (not across the whole year), the impact of any barrier is more ecologically relevant to the protection of those species when applied during those important periods.

The applicant has provided an annual assessment, but this does not include the more constrained potential smelt migration periods in the Blyth waterbody. We recorded smelt in this waterbody in 2016 with very limited sampling and, there is, therefore, the potential for a breeding population to be present within this waterbody. Applicant’s TR302 (EDF2020a) states, “The SZB+SZC thermal plume intersects the Blyth estuary at temperatures in the

2°C to 3°C range as 98 %iles” (Figure 5) “and there is, therefore, a potential to exceed the estuarine thermal standard and to create an impact on the movement of migratory fish. The temperatures in the cross section across the estuary mouth were extracted from the GETM SZB+SZC model outputs and the time series of exceedance of the thermal standard is shown” (Figure 6). ”Over the annual cycle the condition was violated in 307 hourly episodes or 3.50% of the time. This is below the 5% threshold in the standard and therefore no barriers to fish migration in the estuary are expected.”

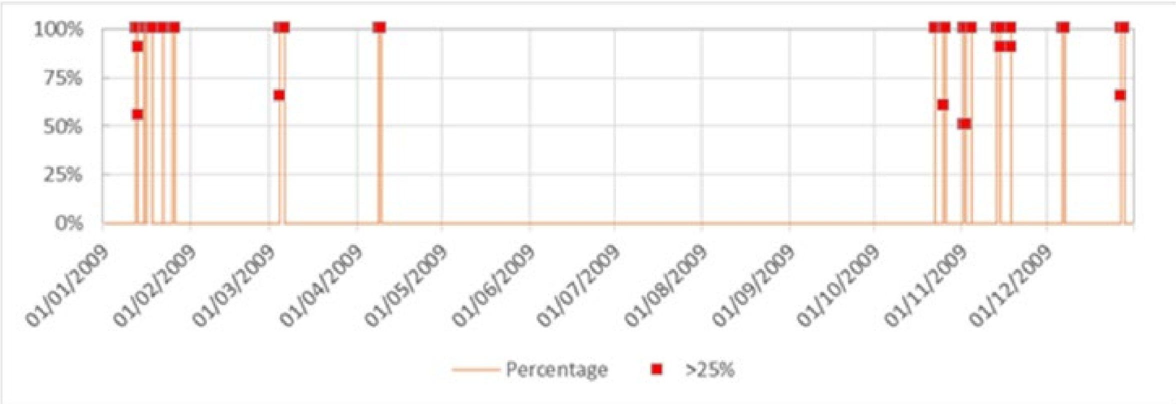


Figure 6. Relative area of the cross section of the River Blyth mouth that exceeds the 2°C thermal uplift threshold under the SZB+SZC scenario (EDF 2020a).

It would appear from this graph that 25% of the cross section of the River Blyth mouth that exceeds the 2°C thermal uplift threshold under the SZB+SZC scenario for a potential smelt migration period between November and May could exceed 5% during that crucial period.

4.3.3.2. Possibility of a thermal barrier to fish migration off Sizewell

Figure 7 shows the predicted thermal occlusion along a transect drawn from the coast to the SZC outfalls reproduced from TR302. Applying the standard estuarine thermal barrier test to this transect leads to a prediction that the 25% occlusion threshold would be exceeded for 18.7% of the year, thereby triggering further ecological investigation.

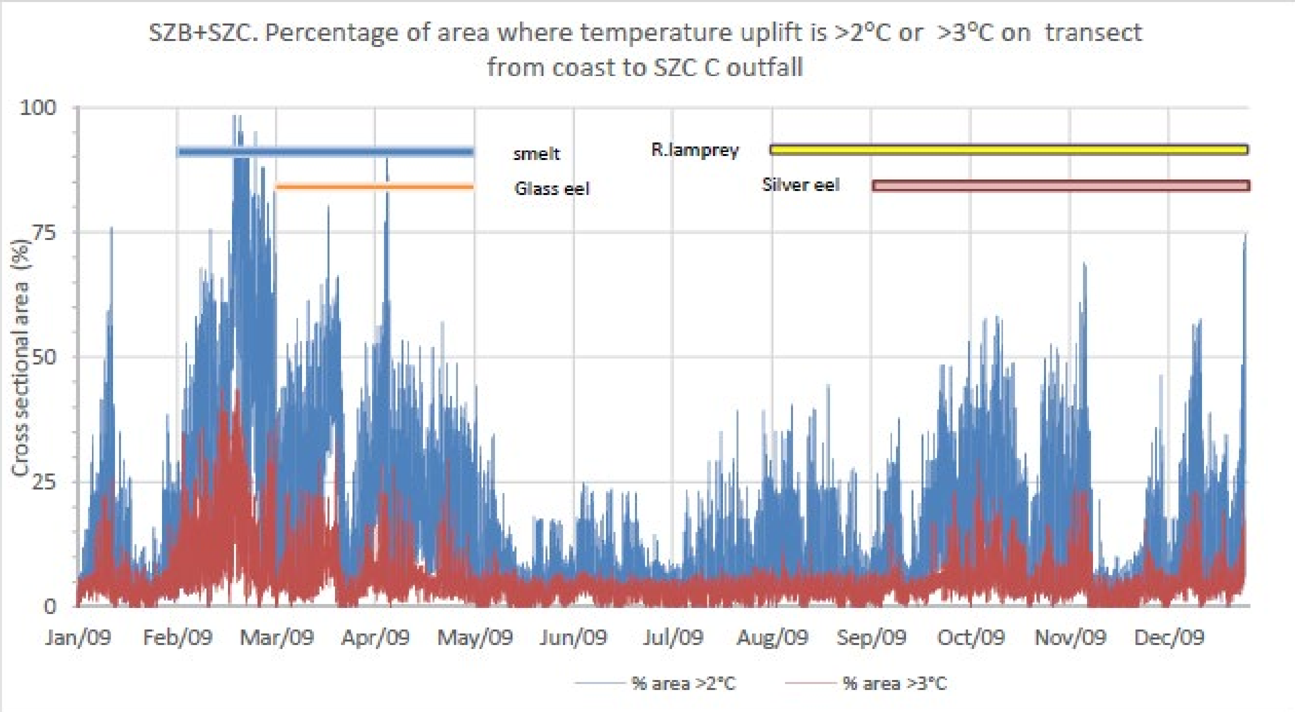


Figure 7. Percentage of Sizewell transect with >2°C uplift shown against fish migration periods from TR302 (EDF, 2020a).

Using a transect from the coast to the SZC outfalls, the percentage of the cross section that would exceed 3°C uplift varies depending on whether the more restricted ecologically-relevant migratory period is applied, or the full year. Using a migratory period for smelt of February to April would give a mean percentage of exceedance of 4.6%, at times the 3°C uplift exceedance occupies 40% of this 3km long transect (EDF, 2020a). Using a migratory period of February to March would give a mean percentage of exceedance of 7% (EDF, 2020a), which would trigger further ecological investigation. The timing of the coastal smelt migration in the Sizewell area is not known. Smelt have been observed forming pre-spawning shoals in the outer Cree Estuary in November, with spawning taking place in the upper estuary in February to March (Hutchinson, 1983). The applicant has stated in EDF 2020a that “in practice the potential for thermal occlusion for smelt would be negligible given their avoidance thresholds of >+4°C.”

4.3.3.3. Review of the ‘Experimental study on the preference and avoidance of thermal increments by estuarine/freshwater juvenile fish’, Jacobs (2008)

The applicant has referenced avoidance uplift thresholds for some fish species in TR302. These have been taken from the ‘Experimental study on the preference and avoidance of thermal increments by estuarine/freshwater juvenile fish’, Jacobs (2008).

- Background: “The laboratory tests are ‘designed to answer the question ‘can fish detect and avoid a temperature change (ΔT) of a given magnitude?’ The question of whether they will do so in the wild must be dealt with by other means, such as telemetry studies.” The extent to which these laboratory tests can be applied to fish in the wild is limited, and this is acknowledged in the paper (acknowledgement of this limitation is not in the SZC supporting documents).
- The study focuses on a “selection of species commonly found in transitional waters” – dace, common goby, (glass) eel, smelt, flounder. It is not possible to extrapolate results to species that haven’t been tested.
- Sources of fish: source smelt had a mean fork length of 129mm (range 96 to161mm) ‘smelt were held and tested in 11‰ of saline water”. Results may not be applicable to conditions smelt will experience in the Greater Sizewell Bay which are fully saline at over 30‰. Experiment replicated estuarine environment which corresponds with the size range of smelt used in the experiment.
- Experimental protocol: Fish were acclimated to a trial control temperature of 12°C. Temperature changes are relative to the 12°C temperature. We do not know whether avoidance behaviour is due to ΔT or absolute temperature. For example, if smelt would respond differently to a ΔT of 2°C & 4°C if start temperature was 5°C (North Sea winter) or 17°C (North Sea summer).
- Fish positions were recorded every 30 seconds for 5 minutes. Continuous observation could have recorded a different response. Five minutes is a relatively short period of time to determine avoidance. Some species or individuals which did not exhibit avoidance at a given temperature threshold may have exhibited avoidance of the same temperature over a longer period of time.
- Smelt: 2°C shows decline in proportion on test side during 5-minute acclimation period (Figure 8).

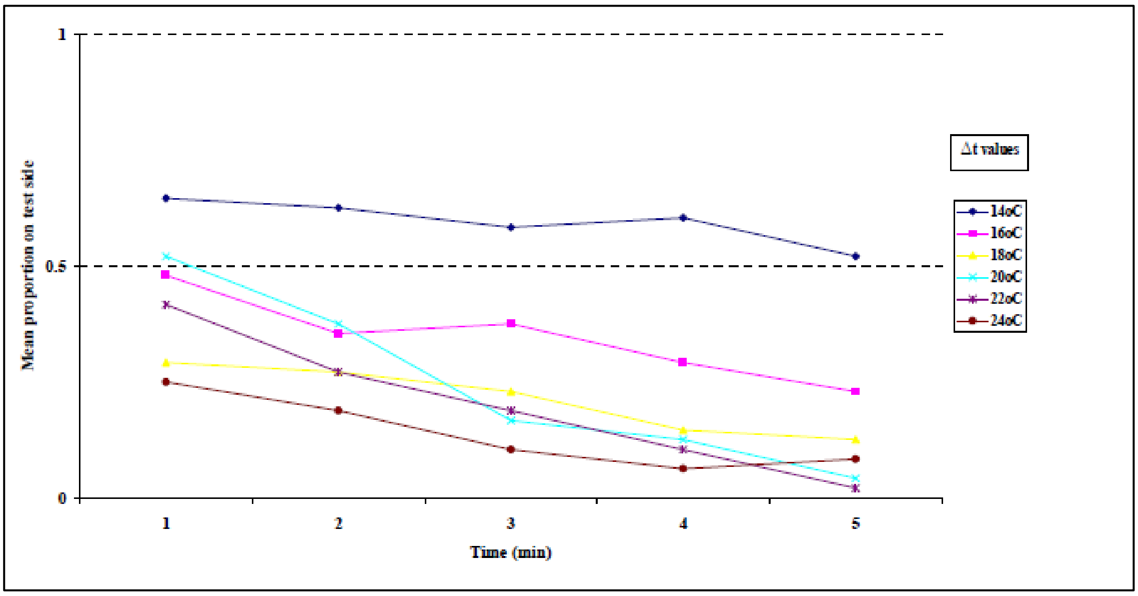


Figure 8. Mean smelt positions in the test arena during the 5-minute flushing period prior to the observation period for each temperature trialled.

Would stronger avoidance behaviour have been seen if the trial had been longer than 5 minutes? Figure 9 shows where there is bias below the 0.5 proportion line this indicates an avoidance of the treatment temperature. 3 out of 5 trials showed >50% in the control side.

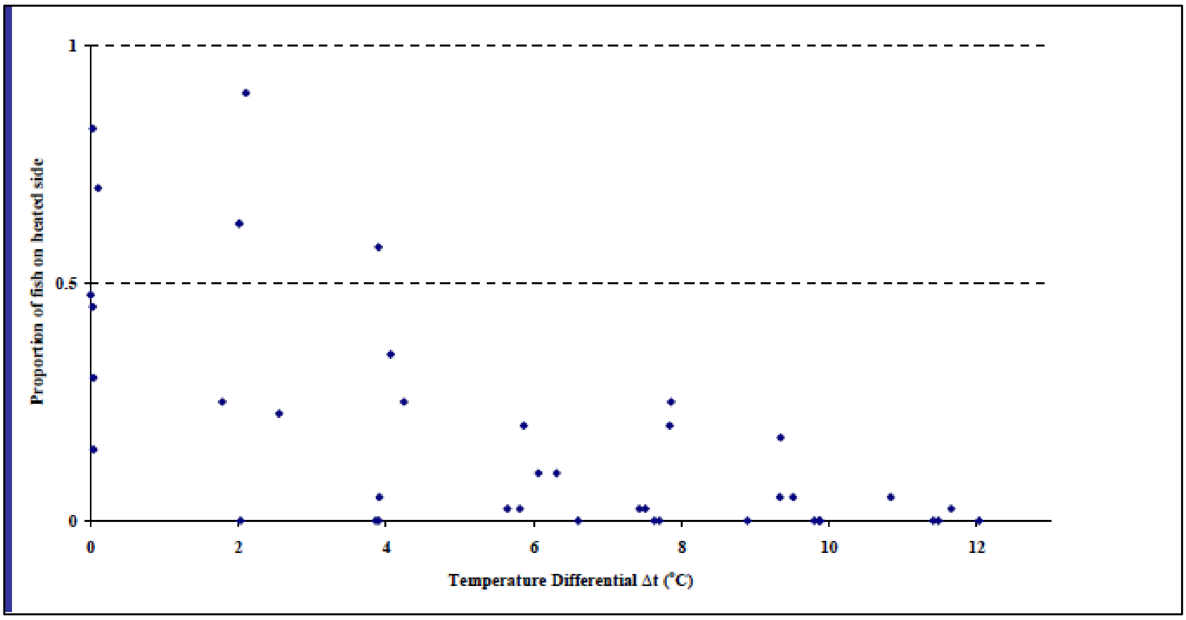


Figure 9. Summary of the 5-minute observation periods for all 6 smelt trials, control temperature 12.29oC (±0.28).

Based on the sample size, and trial length (5 minutes), we are unable to conclude there is no avoidance behaviour at 2°C. In addition, the experiment is conducted at a 12°C start point. Avoidance may be more obvious using different start temperatures and observing behaviour for a longer period.

If one more point were below the line for Δ2°C, it would indicate avoidance. The highest point at 2°C uplift could be an outlier. In addition, it is difficult to conclude when avoidance happens due to the small sample size, the 2°C increment rise in temperatures, and only using a single start temperature.

- Results summary: States strong avoidance observed at 16°C (Δ4°C) for smelt. But no test was carried out for Δ3°C. Even with the limited sample size and experiment methods, Δ2°C could also indicate a weak level of avoidance. It is not possible to conclude on the basis of this paper that there is no avoidance behaviour shown at 2°C or 3°C for smelt or for other species that have not been tested.
- Discussion: Different species have different thermal avoidance behaviour (sea trout smolts +6°C, salmon smolts +4°C). The differences in response between the salmonid species and the other species investigated in this study might be expected as a result of differences in biological and ecological requirements. Salmonids and smelts are generally considered to be cold water fish which exhibit anadromous migration. These species may be greatly affected by Δt, as seasonal

migrators travel during distinct periods of the year and might thus have a narrower thermal tolerance than those of transitional species.'

Actual temperature may have a greater impact on estuarine or saline species.

Daily water temperature ranges in the shallow margins can therefore be substantial, in the order of 15°C in a single day (Turnpenny and others, 2006). In comparison, in adjacent deeper water, Spencer (1970) reported surface temperatures to vary typically by <0.5°C in winter and <1.5°C in summer. It's difficult to conclude if avoidance responses are due to absolute temperature or due to temperature differential.

It is unclear whether the observed response is due to the temperature difference or an overriding requirement of an individual to remain with the shoal, as directed by the dominant individual. This could result in a variation in behaviour between individuals of this species and a shoal, resulting in individuals remaining in unfavourable conditions that can potentially have an impact on their fitness and survival.

The conditions used in the laboratory trials were selected to be representative of a range of conditions in which the species have been observed to move along estuary margins. Not necessarily representative of conditions in the coastal area of Sizewell Bay.

Further studies using other temperature/temperature-rise combinations may be helpful in some circumstances, and there remains a role for the study of fish responses in the field using methods such as telemetry.

Looking at the data and the discussion presented in this report, it is not possible to conclude that smelt do not exhibit avoidance at ∆2°C or ∆3°C for the conditions tested, or how using different environmental conditions such as different start temperatures or salinities could affect the results. It is also not possible to conclude what impact absolute temperature has on smelt.

Table 6. Latitudinal distribution and corresponding surface sea temperatures of selected fish species, (Withers 2012, Fishbase 2021). MA = marine, MJ = marine juvenile, CA = diadromous.

Temperature guild	Species	Ecological guild	Latitude range	Surface sea temperatures (-20°W)			
				September (°C) range		February (°C) range	
				Min	Max	Min	Max
Cold-water, boreal species	(Clupea harengus) Herring	MJ	80°N–33°N	-0.9	24.7	Ice	17.8

	(Lampetra fluviatilis) River lamprey	CA	69°N–38°N	3.2	23.5	-0.9	15.5
	(Osmerus eperlanus) Smelt	CA	70°N–43°N	1.9	20.4	-1	12.6
Warm-water, lusitanian species	(Anguilla anguilla) Eel	CA	75°N–8°N	0.2	27.8	Ice	27.7
	(Dicentrarchus labrax) Sea bass	MA	72°N–11°N	1.7	27.8	Ice	25.5
	(Petromyzon marinus) Sea lamprey	CA	72°N–25°N	1.7	24.7	Ice	22
	(Sprattus sprattus) Sprat	MJ	66°N–30°N	8.4	24.7	3.6	19.6

4.3.4. Environment Agency consideration by species – Smelt (Osmerus eperlanus)

Smelt are an anadromous boreal species and a member of the salmonid family (Table 6). Wither (2012) states that the future situation for this species must be considered against a background of longer-term water temperature rise associated with climate change, which is gradually reducing the metabolic headroom for cold-water species. Keskinen (2012) describes significant declines in smelt density in a land-locked population of smelt in a boreal lake when water temperatures exceed 21ºC.

A breeding population of smelt is present in the Alde and Ore waterbody which is located to the south of the proposed SZC site. References to this population are made in Maitland, 2003a and in Colclough, 2013. Both papers mention that it is probable that the Alde and Ore population is common to a population belonging to the Deben, Orwell and Stour. The Environment Agency WFD TraC surveillance monitoring programme has recorded 278 smelt ranging in length from 49mm to 247mm in the Alde and Ore between 2003 and 2018 (no fish monitoring was carried out in this waterbody between 2007 and 2012). We also captured 128 smelt in an electrofishing survey in the freshwater Alde at a site upstream of Langham Bridge in the spring of 2003. The smelt ranged from 160 to 210mm in length. It was presumed that this was a spawning migration.

Smelt are impinged at SZB which indicates that smelt migrating along the coast, and to and from the Alde and Ore waterbody, use this area. Evidence indicates that smelt will avoid thermal elevation and absolute temperatures at a certain threshold. For this reason, smelt are a species of concern from the operation of the SZC cooling water system. We do not agree that the ∆4°C threshold taken from the Jacobs 2008 paper is sufficiently precautionary for the reasons discussed. The use of this uplift threshold without further supporting evidence is against current regulatory guidance.

We requested further evidence to support the use of the thermal avoidance threshold applied to smelt, including a detailed assessment of the abundance and length of impinged smelt for each month monitored against the range of tidal conditions and thermal plume from the operating Sizewell B station. The applicant produced SPP101 'Implications of tidal elevation and temperature on smelt, *Osmerus eperlanus*, impingement at Sizewell' (EDF, 2020i).

4.3.4.1. Environment Agency review of SPP101 'Effects of tidal elevation and temperature on smelt impingement at Sizewell' (EDF, 2020i).

- Executive summary: Most fish impinged throughout the year were in the one-year and 2-year age class, with some older fish between 3 and 6 years old present in very low numbers during the period February to April. This could indicate that different age classes respond differently to the same environmental conditions, or that older smelt have been excluded from the assessment, potentially as a result of disregarding the Comprehensive Impingement Monitoring programme (CIMP) bulk overflow samples which sampled at night. Smelt undertaking a spawning migration in an estuary migrate on a flood tide at night.

- Detailed thermal modelling to investigate the influence of modelled temperature regimes on impingement rates of smelt for the year 2009 showed that significantly more fish were impinged in warmer temperatures, corresponding with the species summer feeding pattern. Between 13 and 28.4% (range depending on offset scenarios) of smelt were impinged when absolute water temperatures at the seabed exceeded 21.5˚C. This occurs less than 3% of the time during the year at the position of the intakes, with maximum annual temperature predicted to be 22.6°C. This demonstrates that smelt did not avoid the area of the intakes when water temperatures reached their maximum. This demonstrates that some one-year and 2-year smelt were impinged during the maximum temperature period. Without knowing what the level of impingement would be in the absence of the thermal plume, it is not possible to know if the level of impingement decreased with the presence of the plume (no control sample). It is also not possible to confirm if older smelt avoided the area of the plume during the maximum temperature period for the same reason, but we can say that older smelt were not impinged in this period.

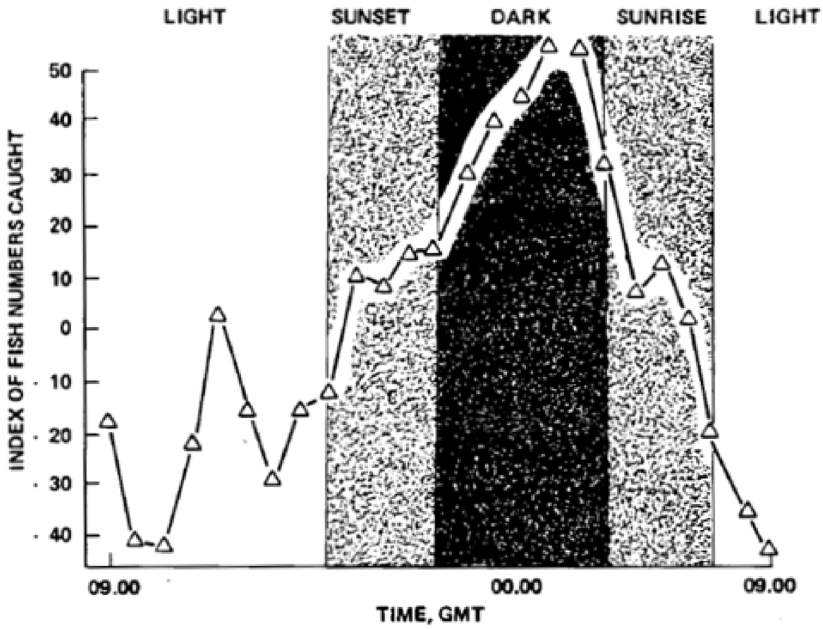
- Analysis of smelt length distribution shows that significantly smaller fish were impinged at warmer background and absolute temperatures - this is considered to be a seasonal effect of smaller fish utilising the offshore waters as summer feeding grounds. This could also be the result of larger fish avoiding the thermal plume when warmer background and absolute temperatures exist.

- No effect of excess temperature, tidal elevation or tidal state on the length distribution of impinged fish was observed. Analysis of the length-frequency distribution of smelt impinged annually and each month showed no evidence that large fish are more likely to avoid the area of the intakes with increasing excess seabed temperatures up to 2.5°C. But older, larger smelt are only impinged in very low numbers during the period February to April. No avoidance of the 2.5°C excess seabed temperature by some one-year and 2-year smelt does not justify the use of the 4°C threshold applied by the applicant.

- The nearest estuary to the north of Sizewell is the Blyth, approximately 12km to the north of the existing power station. Smelt migrate up estuary in the period from February to April. Surveying using fyke nets and kick sampling methods was carried out in the tidal and estuarine areas of the Blyth in April and May 2016 when spawning migrations would have been expected if the fish were spawning in the river. No smelt were found in the area, the absence being attributed to an absence of suitable spawning substrate and a barrier to migration (EDF Technical Report, TR382). It is therefore considered highly unlikely that there is a spawning population in the Blyth. The nearest estuary with a known spawning smelt population is the Alde-Ore, 25km to the south of Sizewell (BEEMS Technical Report TR382). We caught smelt in the Blyth in 2016 and provided this information to the applicant, but this has not been acknowledged. Please note our comment on TR406 (SZC-SZ0200-XX-000-REP-1000XX, Revision 01), dated 19 July 2019: "The River Blyth has had a very small amount of fish sampling undertaken on it to come to the conclusion that a smelt population does not exist. The Environment Agency undertook 2 x 1.5m beam trawls, 200m in length on the Blyth estuary in May 2016 and recorded smelt. The details of this were provided to Cefas along with photographic evidence. It would appear this has been incorrectly recorded in BEEMS Technical Report TR382 and this should be amended."

- Methodology: CIMP samples are gathered over a 24-hour period, which is split into 6-hourly samples during the day and an 18-hour bulk overnight sample. For the purposes of this study, bulk samples were discarded as it is not possible to determine the state of the tide or thermal uplifts at the point smelt were impinged. Therefore, all samples used in this analysis were collected during daylight hours. The potential implications of discarding over 75% of the sample is not discussed. The bulk CIMP samples contained the sampling which was carried out at night.

Figure 10. Diurnal pattern of fish catch at Sizewell A power station. Averaged over 41 sampling days. From Turnpenny (1988).



Legend:

Lightly stippled areas show range of times of dusk and dawn from mid-winter to mid-summer.

Dark stippling shows hours of darkness common to all dates.

- The role of visual cues in avoidance of water intakes by fish is indicated by the diurnal patterns of screen catch. Figure 10 shows the averaged hourly index of catch measured on 41 dates at Sizewell A power station and indicates that peak catches occurred at night.

  Fish are better at avoiding intakes during the day when they can see them. In addition, some species are more mobile at night. This is an observed behaviour for smelt undertaking spawning migrations in estuaries. The analysis may not be representative if only considering daytime impingement.

- Statistical methods: Impacts of fish length and environmental variables on impingement were explored using generalised linear models and assuming that impingement follows a negative binomial distribution. It is unclear if this is this still a valid approach as the negative binomial model is no longer being used to predict annual impingement.

  Seasonal impingement rates at SZB: “Impingement rates of smelt varies throughout the year, with more smelt impinged in the warmer summer months - only 5.4% of all fish impinged were caught during the smelt migratory period, February to April.” It isn’t clear if this is for all smelt impingement data or just for the 6-hourly samples. Does the statement hold true if examining all smelt impingement, rather than those caught during daylight?

- Only 5.4% of all fish impinged were caught during the smelt migratory period, February to April. The February to April period is when the spawning migration takes place in estuaries. Smelt are described as forming pre-spawning shoals in outer estuaries from

October to November in some waterbodies. This would indicate that a coastal pre-spawning migration could take place prior to this (possibly November to January).

- A seasonal component to the length distribution of fish impinged was evident. During the winter when fewer fish were impinged the length distribution was statistically larger, whilst in the summer more smaller fish were impinged. This could be as a result of larger smelt having a lower tolerance to absolute temperature as a result of the thermal plume. It is unclear if this is the case when the bulk overnight sample (18hr) data is included.

- In 2009 between 13 and 28.4% (range depending on offset) of smelt were impinged when absolute water temperatures at the seabed exceeded 21.5˚C, which occurs less than 3% of the time during the year at the position of the intakes with maximum annual temperature predicted to be 22.6°C. This demonstrates that smelt did not avoid the area of the intakes when water temperatures reached their maximum. The result shows smelt of a certain age and size do not completely avoid the area at >21.5°C, but we cannot conclusively say that there isn't any avoidance. We can say that older, larger smelt are not impinged during this period. We do not know how many smelt would have been impinged had temperatures been lower as no control sample is available.

- Excluding the CIMP bulk overflow samples (the only samples that are taken at night) significantly reduces the validity of the data. Smelt are known to move at night when migrating in estuaries and could exhibit similar behaviour in the coastal environment, particularly when starting a migration. Looking at the data and discussion presented in SPP101, it is not possible to conclude that smelt do not exhibit avoidance at Δ2°C or Δ3°C or how background or absolute temperatures may affect smelt. Larger smelt may avoid the area with increasing background or absolute temperatures. It is not possible to know if more smelt would have been impinged in the absence of the plume during any period as no control samples are available for comparison.

The use of a Δ4°C avoidance threshold for smelt is not considered precautionary and the effect absolute temperature has on the species requires further consideration.

4.3.5. Environment Agency consideration by species – Bass (Dicentrarchus labrax)

Bass are a demersal lusitanian species which are acclimated to warmer temperatures (Table 6). Several papers document juvenile bass being attracted to areas of elevated temperature as a result of a thermal discharge. This led to some areas, which are influenced by thermal elevation as a result of a power station discharge, being designated as Bass Nursery Areas (BNAs). BNAs were set up in the 1990s to protect juvenile bass and prohibited the fishing for that species in those specified areas. In 2015, Defra assessed the need for changes to existing BNAs and whether new designations were needed. In the 2015 assessment, the area in front of Sizewell was nominated as a new BNA in the Cefas report: 'Presence of European sea bass (Dicentrarchus labrax) and other species in proposed bass nursery areas' (2018). The paper stated: "The area around power station outflows is known to attract small sea bass and a number were included in the original BNA designation. Sizewell Power Station has four intakes with screens that young fish are impinged on. At Sizewell, impingement sampling was done between 2009 and 2012 over 24 hours on 97 occasions. Analysis of the power station screen samples showed that juvenile sea bass were found in 78 (80%) of samples collected during 2009-2012. The mean number of sea bass in the catch was 1,304 fish per sample, and samples contained juveniles and adults. Sea bass were found all year round. Conclusion: There is good evidence that the area in the immediate vicinity of the power station has sufficient aggregation of juvenile sea bass to give a high probability of them being impinged by the cooling water intakes, although individuals of other species above Minimum Conservation Reference Size (MCRS) are present. Hence, there is evidence to support further consideration of the proposed Sizewell BNA."

In TR406 (EDF, 2020e) the applicant applied a reduction of 90% to the predicted impingement figures derived for bass. In section 6.5.1 the applicant stated: "The density of bass was 20 times greater inshore of the Sizewell- Dunwich Bank in the vicinity of the SZB thermal plume than offshore of the Bank. When SZC begins operation, it will generate a thermal plume but in the deeper water at the SZC outfalls there will be negligible warming at the seabed and the greatest thermal plume effects will be limited to the top 1 m of the sea surface. The SZC plume will have the effect of further warming the inshore waters inshore of the Bank. Bass is a demersal species, but it is known to feed at the surface at night and so could be attracted to the SZC surface plume at night. However, at the surface bass would be invulnerable to the impact of SZC abstraction by the seabed mounted intakes. At depth, the water inshore of the Bank would be appreciably warmer than at the SZC intakes and there is no reason to consider that the distribution of bass would materially change from what it is now. Making a precautionary assessment that 90% of bass would remain inshore of the Bank (rather than the measured 95%) the expected bass impingement for SZC is 0.032% SSB and not the 0.32% SSB described in Section 6.4."

This statement makes a number of assumptions which are not evidenced. It implies that bass will only feed at night on the surface in the vicinity of the SZC intakes. It implies that no difference will exist between the attractant levels of juvenile or adult bass to areas of elevated temperature. It also implies that attraction to areas of elevated temperature is consistent at any time of the year, including warmer summer months. Evidence indicates that it is predominately juvenile bass that are attracted to areas of elevated temperature and that this happens to a much higher degree in colder months of the year. We do not think the use of a 90% reduction factor applied in TR406 (EDF, 2020e) by the applicant is acceptable or precautionary.

In addition to the concerns over the application of this 90% reduction factor for the period when SZB and SZC are operational, the applicant has not provided an assessment of impacts to bass for the period when SZB has ceased operation and a thermal plume is only being discharged by SZC. It would be expected that without a thermal discharge inshore of the Sizewell Bank bass would no longer be attracted to this area and would be attracted, at certain times of the year, to the location of the SZC plume.

4.3.6. Environment Agency consideration by species – Herring (Clupea harengus)

Herring are the second most abundant species impinged at SZB and an important food source for piscivorous fish. They are a pelagic boreal species (Table 6) and are potentially sensitive to thermal increases. Limited experimental studies have been carried out on herring to determine the impact thermal elevation has on this species or when avoidance behaviour may occur.

4.3.6.1. Temperature tolerance of unacclimated herring, (Clupea harengus), Brawn (1960)

Brawn (1960) carried out upper lethal temperature experiments on unacclimated herring, most of which were captured immediately prior to being tested. Using recently caught herring had the advantage that the fish were tested in their natural condition of fatness and had been fed only on natural food. Brawn stated that this latter point is of importance as it has been shown that the temperature tolerance of some fish can be altered by changes in the nature of the oils fed to them in captivity (Hoar and Dorchester, 1949). In this investigation, the upper lethal temperature was defined as the temperature that would cause 50% mortality in 48 hours. Brawn concluded that at a start temperature of 8 to 11°C herring commonly were found to show a lethal temperature of about 19.5°C as the point at which 50% of the group would die after 48 hours' exposure.

Brawn also noted that mortality occurred at a lower upper lethal temperature for herring with a greater mean length when tested under the same conditions.

4.3.6.2. The effect of extremes of temperature on herring larvae. Blaxter (1960)

Blaxter carried out experiments on the upper and lower lethal temperatures for herring larvae to:

- find out the range of temperature the larvae could withstand in rearing experiments at different acclimatisation temperatures
- look for possible differences in temperature tolerance between spring and autumn spawned herring
- obtain some idea of what danger larvae might experience if subjected to rises in temperature in the sea caused by effluents or hot weather

The lethal temperature for Blaxter's experiment was defined as the temperature at which 50% of the larvae died or became moribund after a 24-hour period of exposure. Blaxter concluded that for herring larvae 6 to 8mm long acclimated to temperatures of 7.5°C, 11°C and 15.5°C, the upper lethal temperatures recorded were 22°C, 23°C and 24°C for spring spawned herring. The range of temperature tolerance was slightly less for autumn spawned herring acclimated at temperatures of 11°C and 15.5°C, which recorded upper lethal temperatures of 22°C and 23°C, although this was not statistically significant. Upper lethal temperatures were rounded to the nearest °C.

Having reviewed the available publications for this species and given the relatively short duration that herring would be exposed to the thermal plume from SZC, it is unlikely that this species, at a population level, would be impacted by the thermal discharge. This species may move away from the plume if required without it negatively affecting the success of a reproductive migration. However, avoiding areas of elevated temperature could result in reduced numbers of this species in the affected area. This, in turn, could lower availability of the species for prey, and could reduce the number of this species entering estuaries affected by, or in close proximity to, the plume. This could also act to reduce the number of this species present in the Blyth and the Alde and Ore waterbodies.

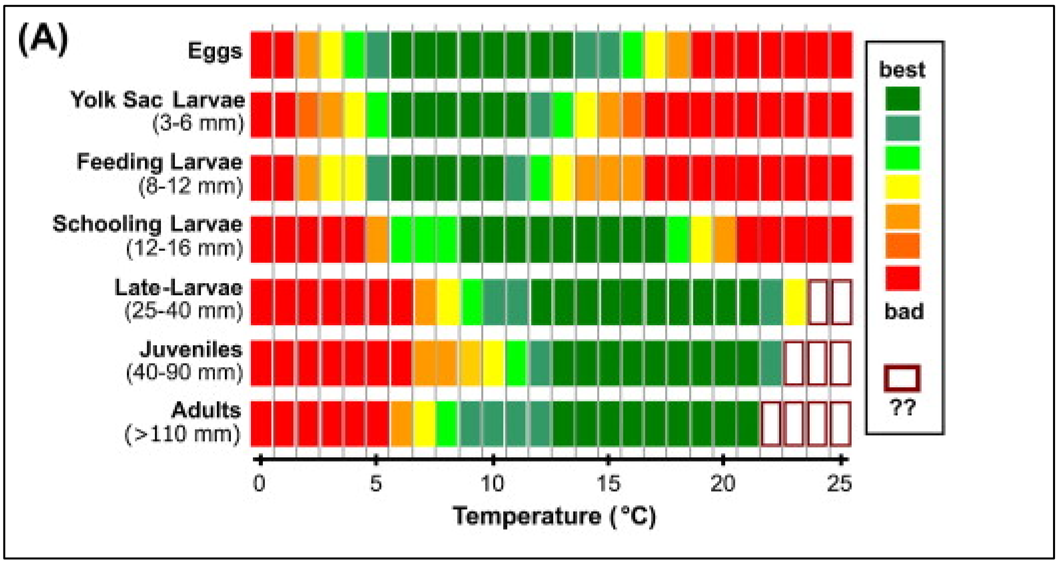
4.3.7. Environment Agency consideration by species – Sprat (Sprattus sprattus)

Sprat are a pelagic lusitanian species (Table 6). Sprat are the most abundant species impinged at SZB and are an important food source for the designated bird features in the area and for piscivorous fish. Limited information has been found on the thermal avoidance thresholds or upper lethal temperature thresholds for this species and most research focuses on larval sprat in the Baltic Sea.

4.3.7.1. The ecophysiology of Sprattus sprattus in the Baltic and North Seas, Peck (2012)

This review summarises literature on the ecophysiology of sprat, with an emphasis on describing how environmental factors influence the life-history strategy of this small pelagic fish. Ontogenetic changes in feeding and growth, and the impacts of abiotic and biotic factors on vital rates are discussed, with particular emphasis on the role of temperature as a constraint to life history scheduling of this species in the Baltic Sea (Fig. 11). A combination of field and laboratory data suggests that optimal thermal windows for growth and survival change during early life are wider for eggs (5 to 17°C) than in young (8 to 12mm) early feeding larvae (5 to 12°C). As larvae become able to successfully capture larger prey, thermal windows expand to include warmer waters. For example, 12 to 16mm larvae can grow well at 16°C and larger, transitional-larvae and early juveniles display the highest rates of feeding and growth at 18 to 22°C.

Figure 11. Temperature-specific growth potential and life history scheduling of sprat (Sprattus sprattus) in the Baltic Sea. Reproduced from Peck 2012.



4.3.7.2. Recent studies on the spawning sprat (Sprattus sprattus) in the English Channel, Milligan (1986)

During 1981, the Ministry of Agriculture, Fisheries and Food (MAFF) carried out a series of ichthyoplankton surveys in the English Channel. During these surveys, they captured sprat eggs and reared them over a range of temperatures in order to record their development and survival. Sprat eggs were incubated through to hatching from 4.3°C to 20°C. Mortalities were high at the extremes of the temperature range used in the experiment, but recorded consistent survival for a temperature range between 6°C and 18.5°C. From 18.5°C to 19°C, the percentage survival of eggs to hatching reduced from 40% to 13%, and from 19°C to 20°C, the survival to hatching further reduced to only 3.75%.

Having reviewed the available publications for this species and given the relatively short duration that sprat would be exposed to the thermal plume from SZC, it is unlikely that this species, at a population level, would be impacted by the thermal discharge. This species may move away from the plume if required without it negatively affecting the success of a reproductive migration. However, avoiding areas of elevated temperature could result in reduced numbers in the affected area. This, in turn, could reduce the number of this species entering estuaries affected by, or in close proximity to, the plume. This could act to reduce the number of this species present in the Blyth and the Alde and Ore waterbodies.

4.3.8. Environment Agency consideration by species – Sea lamprey (Petromyzon marinus)

Sea lampreys are an anadromous lusitanian species (Table 6), spawning in freshwater, with a larval freshwater stage, followed by a marine parasitic phase, following which adults return to freshwater to spawn.

Adult sea lampreys enter the estuaries of many North Atlantic rivers from April onwards, spawning in late May or June in British rivers, when the water temperature reaches at least 15°C (Maitland, 2003b). Sea lampreys are semelparous, reproducing only once before dying (Maitland, 2003b). The species does not 'home' to reproduce in the river system in which they were born, instead being attracted into rivers on the basis of pheromone cues from individuals of their own species (Waldman and others, 2008).

Sea lamprey larvae (ammocoetes) remain in the silty deposits of a river for an average of 5 years (Maitland, 2003b). They grow slowly, filter feeding on algae, diatoms and other organic detritus until they reach 150 to 200mm when they metamorphose into 'transformers' (Bird, 2008) and begin a downstream migration to the sea (Baer and others, 2018). Juvenile sea lamprey begin parasitic feeding when they reach the estuary, although some may begin feeding in the river. Once arriving in the estuary, they may remain there for a period of months, feeding on estuarine fish. In their marine phase, sea lamprey are generalists and parasitise a wide variety of species, including European eel, Atlantic salmon, sea trout, Atlantic herring, Atlantic cod, haddock, sturgeon and basking shark (Maitland, 2003b, Bird, 2008).

Data on the at-sea distribution of sea lampreys are limited, but sea lamprey are believed to occur in shallow, coastal, and deep offshore waters (Maitland, 1980). This is backed by UK and international trawl survey data, from which the mean depth of capture is 88m and mean distance from shore is 14km (Environment Agency National Fish Population Database, Beam Trawl Survey, Celtic Sea Irish Quarter 4 Otter Trawl Groundfish Survey, Irish Ground Fish Survey, Northern Ireland Ground Fish Survey, Scottish West Coast Bottom Trawl Survey (up to 2010), Scottish West Coast Groundfish Survey (from 2011) – as reported to the Environment Agency by Natural Resources Wales, during consultation over EDF's application to vary its water discharge activity variation to remove the acoustic fish deterrent (AFD) at the Hinkley Point C site).

Sea lampreys may be able to breed freely, with individuals distributed within the same oceanographic region (regional panmixia). However, they are likely to have limited potential for breeding, with adults restricted to neighbouring, or distant, oceanographic regions. Seabed topography, for example, is thought to provide some geographic structuring to sea lamprey populations (Lança and others, 2014).

Sea lamprey are impinged in very small numbers at SZB and the predicted impingement for SZC is 5 individuals a year, from which it can be inferred that the species is not especially numerous in Greater Sizewell Bay. Sea lamprey breeding populations have been recorded in several East Anglian rivers and therefore it is possible that some fish may be transiting off the Sizewell coast. In addition to local rivers, SPP103 (EDF, 2020f) states that:

"UK SACs where sea lamprey is a primary reason for site selection are predominantly on the western and southern coasts. The nearest UK SAC to Sizewell where sea lamprey is a qualifying feature, but not a primary reason for site selection, is the Humber Estuary and the associated spawning site of the River Derwent. Sea lamprey SACs are found all along the European coast from the Netherlands to Denmark with specific concentrations in the Scheldt, Hollands Diep, Waddenzee, Ems, Weser, Elbe and Eider and any sea lamprey caught at Sizewell could have originated from any of these systems. In terms of geography the Dutch coast is nearer to Sizewell than the Humber but due to their parasitic feeding lifestyle the distances travelled by the species depend largely upon the dynamics of their prey. As sea lamprey do not home to natal rivers, mortality at Sizewell could not be attributed to any specific site of origin."

Due to its wide-ranging distribution, lack of natal homing, and lack of evidence of genetic differentiation, sea lamprey in the southern North Sea appear unlikely to belong to individual river populations. Similarly, due to their lack of natal homing and the size of the thermal plumes compared to marine ranges, any avoidance behaviour exhibited by sea lamprey or their prey as a result of the thermal plume emitted from SZC would not have a detrimental impact on the species, either generally or with regard to rivers designated as Natura 2000 or national network sites.

4.3.9. Environment Agency consideration by species – River lamprey (Lampetra fluviatilis)

River lampreys are an anadromous boreal species (Table 6), spawning in freshwater, with a larval freshwater stage, followed by a marine parasitic phase, following which adults return to freshwater to spawn.

Adult river lampreys usually migrate into fresh water from October through to January and February (Maitland, 2003b, Bird, 2008, Masters and others, 2006). Spawning occurs in March and April in British rivers, when the water temperature reaches at least 10 to 11°C (Maitland, 2003b). River lampreys are semelparous, reproducing only once before dying (Maitland, 2003b). The species is not thought to 'home' to reproduce in the river system in which they were born, instead being attracted into rivers on the basis of pheromone cues from individuals of their own species (Gaudron and Lucas, 2006).

River lamprey larvae (ammocoetes) remain in the silty deposits of a river for 3 to 5 years, feeding on fine particulate matter (Maitland, 2003b). They reach a length and weight of around 100 to 120mm and 1.5g after just over 4 years in rivers before metamorphosing into downstream migrant 'transformers' and can occur in estuaries 'in some numbers' (Maitland, 2003b). In their marine phase, river lamprey feed parasitically upon a wide variety of species, including Atlantic herring, European sprat, allis shad, twaite shad, flounder, sea trout, whiting and Atlantic cod (Maitland, 2003b, Bird, 2008).

Bird (2008) suggests that adult lampreys do not move far from the coast during their marine feeding phase, due to attacks being recorded on migratory or brackish water fish, such as sea trout and shad. From UK and international trawl survey data, the mean depth of capture for river lampreys was 26m, and the mean distance from shore 3.9ekm (Environment Agency National Fish Population Database, Beam Trawl Survey, Celtic Sea Irish Quarter 4 Otter Trawl Groundfish Survey, Irish Ground Fish Survey, Northern Ireland Ground Fish Survey, Scottish West Coast Bottom Trawl Survey (up to 2010), Scottish West Coast Groundfish Survey (from 2011) – as reported to the Environment Agency by Natural Resources Wales, during consultation over EDF's application to vary its water discharge activity to remove the AFD at the Hinkley Point C NNB site).

Further evidence for limited at-sea distribution of river lampreys comes from stable isotope analysis of river lamprey, captured on their spawning migration in the Yorkshire Ouse. Here, the high similarity in the lamprey and estuarine food web stable isotope ratios could suggest that the Humber catchment's river lamprey forage mainly in the estuary, although further work was recommended to explicitly test this possibility (Nunn and others, 2021).

River Lamprey are impinged at Sizewell throughout the year, with peaks in June (juveniles) and December. The predicted impingement at SZC with no mitigation is 2,929 a year (EDF, 2020e). Thermal avoidance thresholds or upper lethal temperature thresholds for this species could not be found. The applicant has applied a thermal avoidance threshold of 2°C and described the percentage of migration period that the 25% occlusion threshold is exceeded in the Sizewell coastal area as 13.2% for a migration period of between August to December.

River Lamprey have not been recorded in the Alde and Ore or Blyth waterbodies. No evidence of breeding populations is present in other waterbodies along the Suffolk coast. It is therefore considered unlikely that river lamprey, avoiding the thermal plume from SZC while migrating along the Suffolk coast, would be prevented from entering a suitable river. It is unlikely that any extra energy required to avoid the plume, if avoidance occurred, would reduce reproductive potential for river lamprey.

Due to its lack of natal homing, potentially restricted marine range (as compared to sea lamprey) and the size of the thermal plumes compared to marine ranges, any avoidance behaviour exhibited by river lamprey or their prey as a result of the thermal plume emitted from SZC would not have a detrimental impact on the species.

4.3.10. Environment Agency consideration by species – Eel (Anguilla anguilla)

Eel are a catadromous lusitanian species (Table 6). The migratory life stages of the eel have been considered to assess if they have the potential to be impacted by the SZC thermal plume. Glass eel are considered to have a relatively high tolerance to thermal uplift (>10°C) and absolute temperatures and are therefore not considered to be at risk from the plume. Silver eel exiting freshwater and estuarine systems, which have a lower tolerance to thermal uplift, are undertaking a significant migration back to the Sargasso Sea. Expending more energy to avoid the area of thermal plume around Sizewell on this migration is unlikely to have a detrimental effect on migration success. Therefore, this species is unlikely to be impacted by the proposed thermal plume.

4.3.11. Overall species conclusions

4.3.11.1. Smelt

Smelt are of concern as this species has the potential to be negatively impacted by the SZC thermal plume. Evidence provided to date does not demonstrate that smelt will not avoid the area of the thermal plume at the 2°C or 3°C uplift, or what effect absolute temperatures will have on this species. This species is thought to perform natal homing to its birth river. A breeding population is known to exist in the Alde and Ore waterbody. Our WFD fish programme in the Suffolk coastal area indicates that the Alde and Ore has the smallest amount of sampling effort, and significantly more smelt have been recorded in this waterbody as can be seen in Table 7.

Smelt have also been recorded in the Blyth waterbody, but insufficient sampling has been carried out to determine if a breeding population is present.

Table 7. Smelt records with catch per unit effort (CPUE) from the Environment Agency's WFD surveillance monitoring programme in estuaries in Suffolk.

Waterbody	No. of smelt caught	Size range mm	Years of sampling	CPUE (Estuary only)
Alde and Ore	278 (406 inc. freshwater)	49-247	10	1.66
Stour	11	28-216	12	0.03
Orwell	9	62-222	15	0.03

As a consequence, avoiding a thermal plume while undertaking a spawning migration could potentially affect reproductive success if avoiding the plume leads to the fish being unable to detect its spawning river, or if the delay in detecting its spawning river prevents the migration from occurring. Smelt may also expend more energy avoiding the plume and relocating its spawning river; for smaller individuals this could reduce reproductive success.

While there remains some uncertainty in this assessment, it is considered that the risk of deterioration due to significant avoidance as a result of the thermal plume remains low. So no deterioration is expected. Although this assessment also needs to be considered in light of other fish species reduction scenarios (see section 4.3.11.7).

This impact also needs to be considered in-combination with impingement losses for the population identified, led through the environmental assessment process for the DCO.

4.3.11.2. Bass

Bass is a species that has been observed to benefit from thermal plumes, with juvenile bass showing increased growth and survival, with reduced overwinter mortality due to inadequate nutritional reserves and low temperatures. Bass will be attracted to the thermal plumes, particularly juveniles during the colder months. The 90% reduction factor applied by the applicant for the period when SZB and SZC operates makes a number of assumptions which are not adequately evidenced.

Those fish could be attracted to SZC further offshore once the nearer shore SZB thermal discharge ceases. This could have the potential to reduce the number of bass entering the waterbodies in close proximity to the Sizewell area. However, this would be expected to occur mainly in the colder periods of the year, and it could be that the increase in temperature that any plume may have could be beneficial to fish survival/health generally. It should also be noted that the assessments for WFD are based on spring and autumn data from the estuaries.

Therefore, the impact of SZC on bass populations is not expected to have a detrimental impact on the quality of the fish element in WFD waterbodies.

4.3.11.3. Sprat and herring

It is unlikely that this species, at a population level, would be impacted by the thermal discharge. This species may move away from the plume if required without it negatively affecting the success of a reproductive migration. However, avoiding areas of elevated temperature could reduce the number of this species entering estuaries affected by, or in close proximity to, the plume.

While the plume from SZC could act to reduce the number of these species present in the Blyth and the Alde and Ore waterbodies, it is not expected to be significant enough alone to cause a deterioration of the quality of the fish element in those WFD waterbodies, although this assessment would be uncertain and it needs to be considered in light of other fish species reduction scenarios (see section 4.3.11.7).

4.3.11.4. Sea lamprey

Due to its wide-ranging distribution, lack of natal homing, and lack of evidence of genetic differentiation, sea lamprey in the southern North Sea appear unlikely to belong to individual river populations. Similarly, due to their lack of natal homing and the size of the thermal plumes compared to marine ranges, any avoidance behaviour exhibited by sea lamprey or their prey as a result of the thermal plume emitted from SZC would not have a detrimental impact on the species, either generally or with regard to WFD classification status.

4.3.11.5. River lamprey

Due to its lack of natal homing, potentially restricted marine range (as compared to sea lamprey) and the size of the thermal plumes compared to marine ranges, any avoidance behaviour exhibited by river lamprey or their prey as a result of the thermal plume emitted from SZC would not have a detrimental impact on the species, either generally or with regard to WFD classification status.

4.3.11.6. Eel

Due to the relatively high temperature tolerance of glass eels migrating into the Sizewell area, and considering the significant migration this species undertakes while undertaking a spawning migration back to the Sargasso Sea in the silver eel life stage, any additional energy required to avoid the area of thermal plume around Sizewell in the silver eel life stage are unlikely to have a detrimental effect on migration success. This species is unlikely to be impacted by the proposed thermal plume.

Any avoidance behaviour exhibited by these species or the lamprey’s prey as a result of the thermal plume emitted from SZC would not be expected to have a detrimental impact on the species or cause deterioration of the quality of the fish element in those WFD waterbodies.

4.3.11.7. Multispecies reductions in estuaries

The conclusions for thermal impacts on estuarine fish status for WFD is based on the wider estuarine fish community in the relevant waterbody. So, reductions in multi species and not just one species alone in the Alde and Ore needs to be considered.

Based on those main fish species contributing to the WFD classification (which looks at diversity and abundance) and those that are at greater risk with temperature changes, we considered one hypothetical scenario focusing on reductions in:

- herring, since these contribute most to the abundance measure
- smelt, as these are a key indicator species

Table 8. Alde and Ore fish reductions transitional fish classification index scenarios.

Scenario	EQR	EQR sd	Assessment	<0.58	>0.58		< Good	> Good
2019 classification[6]	0.69	0.04	Good	8%	92%		None	Quite
No smelt 25% reduction in herring[6]	0.62	0.04	Good	35%	65%		None	Uncertain

This multispecies reduction scenario provides an indication of how this could impact a status classification. It is not intended to illustrate a known calculated reduction. The scenario applied illustrated a notable reduction of herring and complete loss of smelt over time through potential avoidance and health impacts resulting from the operational cooling water and FRR system discharges at SZC. This resulted in a lowering of the calculated class, but not a deterioration between classes, although the result of 'good' status was now uncertain.

4.3.11.8. Consideration of losses in freshwater river waterbodies

While the focus of the impact of the thermal discharge has been on the fish entering the Blyth and Alde and Ore estuaries, this review has highlighted a potential risk to fish status in the upstream river waterbodies for those migratory fish entering freshwater reaches via those estuaries. While this was not taken forward as a risk in the applicant's assessment, we have considered it here.

Fish in fresh waters are classified for WFD using the Fisheries Classification Scheme 2 (FCS2) tool. FCS2 compares observations of the presence and abundance of the 23 most prevalent fish species in England and Wales with the expected abundance of these species under reference conditions. To establish a risk of WFD deterioration with regards to freshwater fish, losses in terms of fish abundances must therefore be considered.

Of the 23 fish species considered by FCS2, 6 have relevance to TraC waters: Atlantic salmon (Salmo salar), sea trout (Salmo trutta), European eel (Anguilla anguilla), river lamprey (Lampetra fluviatilis), sea lamprey (Petromyzon marinus), and 3-spined stickleback (Gasterosteus aculeatus).

Three-spined stickleback are rarely recorded in fully marine conditions and have numerous non-anadromous populations in brackish and purely freshwater habitats[7]. Given

[6] Without fyke net data for all scenarios

[7] https://www.fishbase.se/summary/Gasterosteus-aculeatus.html

that these freshwater populations are not considered to be at significant risk from impacts occurring at SZC, this species is not considered further.

Of the other species, those considered to be impacted by the thermal plume (sea lamprey, river lamprey and eel) were addressed in sections 4.3.11.4 to 4.3.11.6. In all 3 cases, any avoidance behaviour exhibited by those species (or their prey) because of the thermal plume emitted from SZC would not have a detrimental impact on the species, either generally or with regard to WFD classification status.

4.4. Cooling water discharge: chemical impacts

We agree with the chemical screening approach and the EQS applied. Where there is no EQS, PNECs have been applied. We do not agree with 4 of the PNECS applied, which are for ethanolamine, acetic acid, phosphoric acid and acrylic acid, and we propose different values.

However, using these revised PNECs, these 4 substances all still screen out from requiring further WQ/chemical plume modelling, following the process specified in TR193 section 10.1 to 10.4 (EDF, 2021d).

The chemicals that do screen in and we agree required further assessment are hydrazine, the total residual oxidant (TRO) and bromoform. The extent of those plumes at the surface and seabed as provided by the applicant are in Table 2.

These water quality impacts are covered in additional detail in the applicant's 'Marine water quality and sediment synthesis report' (EDF 2020c).

We agree with the applicant's assessment of these 3 screened in discharges. Our evaluation of these PNECs and a summary of the plume extents they provide are covered in section 4.4.1 to 4.4.3.

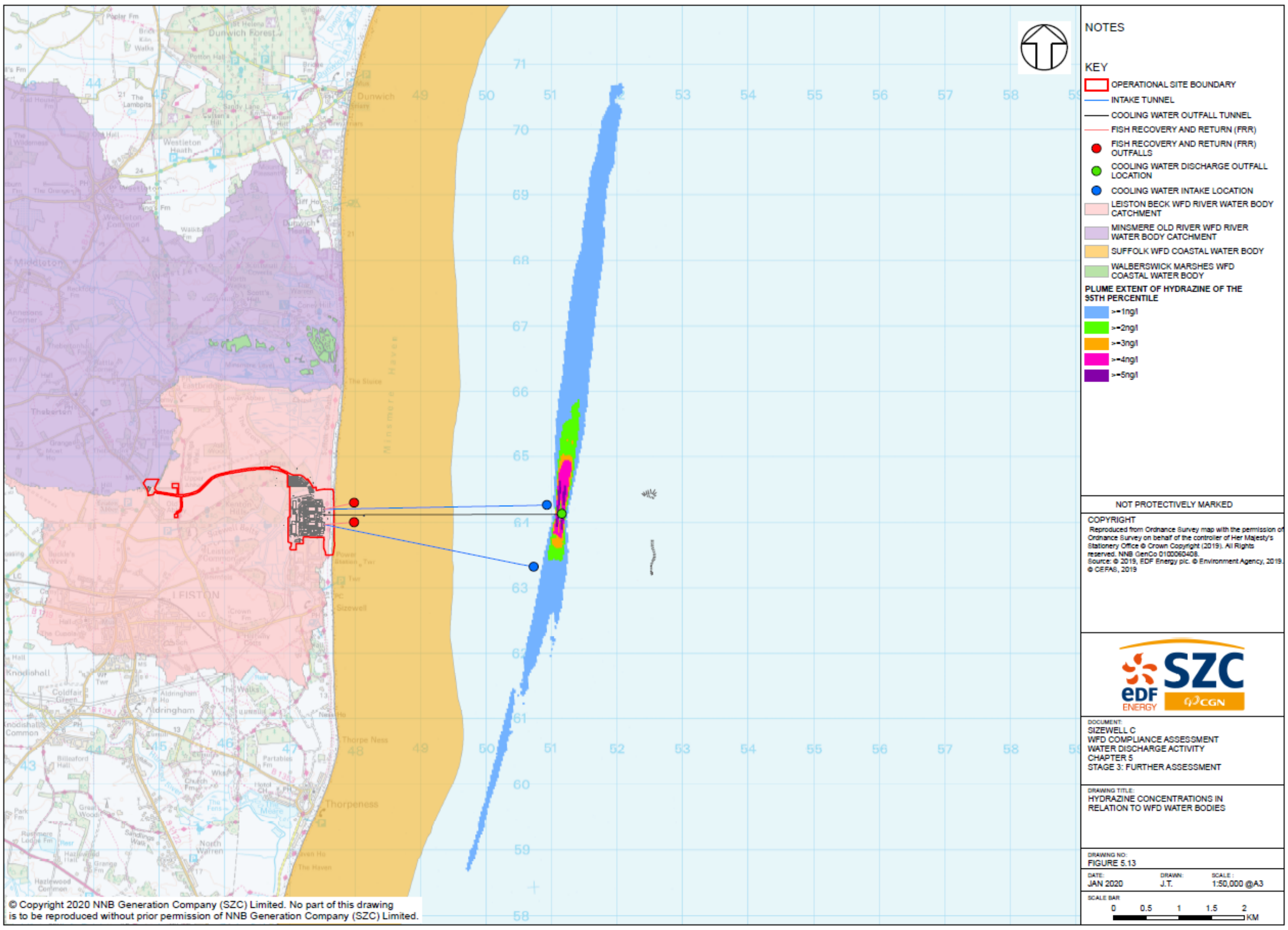
4.4.1. Hydrazine

Hydrazine is a reducing agent which is used in very low concentrations to prevent corrosion in the boiler water. Consequently, a liquid effluent containing residual hydrazine may be released. The assessment factors (AF) used to derive the PNEC are broadly in line with the assessment factors noted in the EU guidance for deriving EQS values under the Water Framework Directive (EU 2018). The exception is that an additional AF of 10 is generally applied to a PNEC used in freshwater when it is applied in the marine environment, but this has not been applied here. Additional AFs are proposed in deriving EQSs for saltwater where there is limited data for saltwater species. These are used to recognise greater species diversity in the marine environment.

This PNEC is still considered acceptable since it is based on the most sensitive toxicity saltwater endpoint available, that is:

- it is based on a toxicity study on the saltwater algal species Dunaliella tertiolecta for which an EC50 of 0.4µgl^{-1} was reported (EDF, 2020h)
- algae/macrophytes appear to be more sensitive to hydrazine than invertebrate and fish

Figure 12. Surface 95th percentile hydrazine concentrations in relation to WFD waterbodies after SZC release of 69ngl-1 in pulses of 2.32h. Reproduced from Figure 5.13 in EDF 2021a.



The results of the modelling show that there is a narrow, elongated plume running up the coast with no interaction between the hydrazine plume and the Suffolk coastal waterbody in this 69ngl^{-1} scenario. The second hydrazine scenario of 34ngl^{-1} will impact a larger area by an additional 3.58ha (Table 2). Given the spread of the plume it is unlikely that this additional area of cover would interact with the Suffolk Coast waterbody (waterbody area – 14,653.3 ha) to any measurable extent. So, we agree that there will be no deterioration in water quality in the Suffolk Coast waterbody as a result of the hydrazine plume for either scenario.

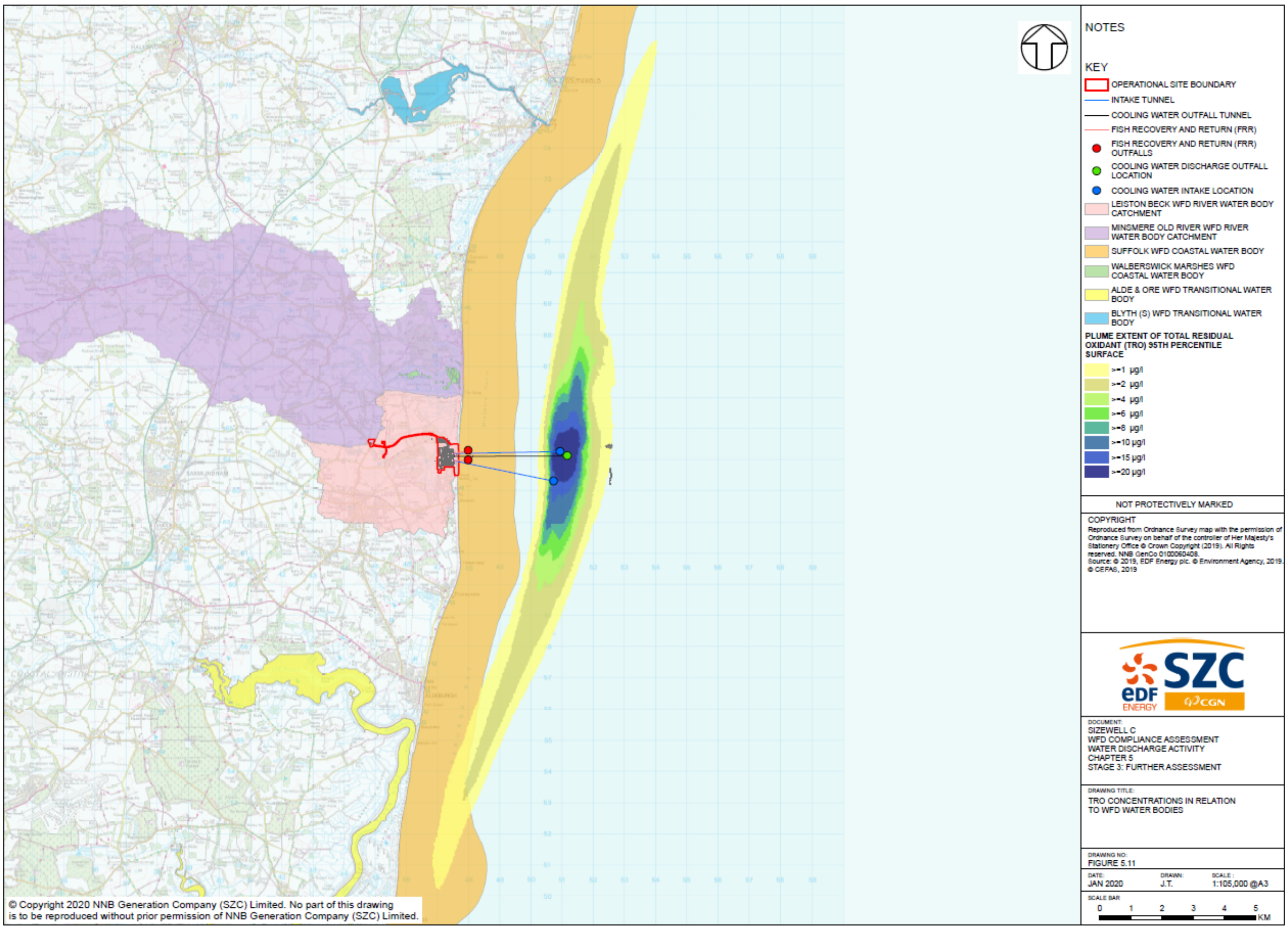
Any adverse hydrazine impacts that result in increased avoidance or toxic effects by fish migrating into the nearby estuaries need to be considered – see section 5.8.

4.4.2. Total residual oxidant (TRO)

TRO and bromoform are the by-products of the chlorination process which required further assessment.

TRO is the sum of all oxidants, including non-chlorine species. In water containing bromine, such as seawater, there is displacement of chlorine by bromine resulting in hypobromous acid, hypobromite ions and bromamines. The accepted EQS has been applied here. The 1994 EQS was based on an assessment factor of ~2 applied to acute (lethal concentration) LC50s of 28µg l^{-1} for the marine fish plaice (Pleuronectes platessa) and sole (Solea solea) for TRO (Sorokin and others, 2007). This resulted in an EQS of 10µg l^{-1}.

Figure 13. TRO concentrations in relation to WFD waterbodies. Reproduced from Figure 5.11 in EDF 2021a.



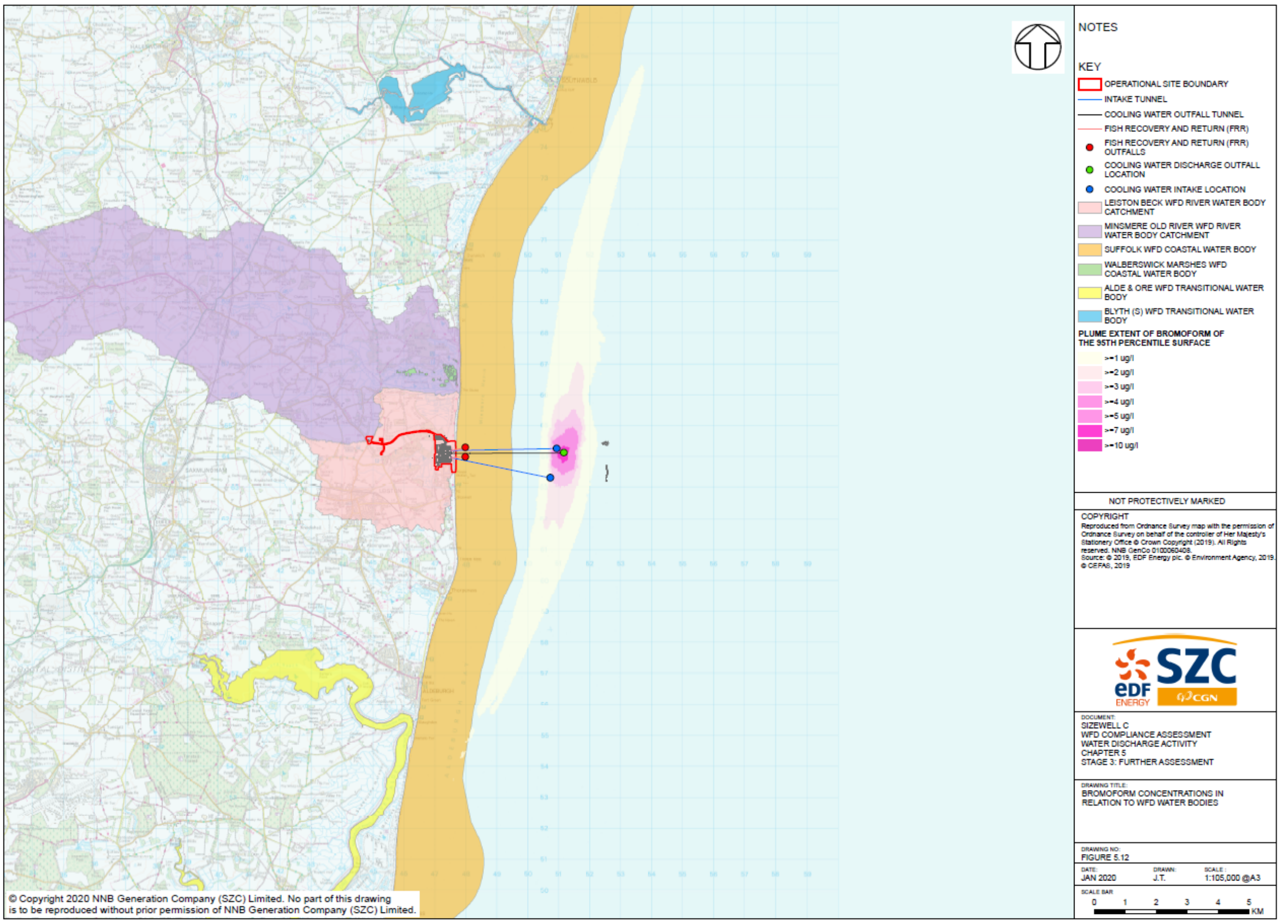
The results of the modelling show that there is no interaction between the TRO plume and the Suffolk coastal waterbody at levels exceeding the EQS. We agree that there will be no deterioration in water quality in the Suffolk Coast waterbody resulting from the TRO plume.

Any adverse TRO impacts that result from avoidance or toxic effects on fish migrating into the nearby estuaries need to be considered – see section 5.8.

4.4.3. Bromoform

There is no published saltwater 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. Bromoform is considered unlikely to represent a major issue in terms of food chain effects as, although it has the potential to bio concentrate, the exposure period to the highest bromoform concentrations is brief and depuration is rapid, with a half-life in the tissues of organisms of 3 to 5 hours reported for species such as Japanese flounder (Libuchi and others, 2011).

Figure 14. Bromoform concentrations in relation to WFD waterbodies. Reproduced from Figure 5.12 in EDF 2021a.



The results of the modelling show that there would be no interaction between the bromoform plume and the Suffolk coastal waterbody. So, we agree that there will be no deterioration of water quality in the Suffolk Coast waterbody as a result of the bromoform plume.

Therefore, the cooling water discharge is unlikely to cause deterioration to the chemical water quality of the Suffolk Coast waterbody.

Any adverse in-combination impacts with bromoform that result in avoidance or toxic effects on fish migrating into the nearby estuaries need to be considered – see section 5.8.

4.5. Fish Return and Recovery (FRR) system outfall – chemical and physical impacts

Impacts of the FRR system discharge were considered for several water quality parameters, including the interaction of water quality changes with the biology. In addition, impacts of the organic enrichment of benthic sediments due to smothering and subsequent habitat loss were considered.

We disagree on the starting point of the mean daily biomass figures, for a number of reasons. These are explained in section 5.2 and adjusted for in our own biomass assessment in section 5.3. However, there is agreement on the approach to calculating the water quality impacts of the discharged biota. We also consider the prolonged period impact on the benthic community.

4.5.1. Basis of assumptions in estimating water quality effects

The water quality effects of the FRR system discharge provided by the applicant, are as analysed in EDF (2021b). In TR520 **(**EDF, 2021b), the conservative assumption was made that all of the dead fish discharged from the FRR system would sink immediately and there was no consumption by detritivores or predation by fish (EDF, 2021f). No attempt was made to account for dispersion/resuspension (such as using the results of the particle tracking of dead sprat reported in TR511 (EDF, 2021f). The bulk of the TR520 analysis uses neither a spatial nor temporal scale in determining the potential impact of the decay of dead fish on the water quality to the WFD waterbody in the vicinity of the FRR system discharge – the Suffolk Coast waterbody. The approach also considers that both FRR systems are discharging from a single location, rather than operating at 2 separate locations.

The applicant's calculations were based on conservative estimates and considered to represent 'worst-case' assumptions on the behaviour of the discharge. We agree this is the case for the most part, although:

- the applicant reported it was worst case as it also assumed instant release of pollutants which would in fact be a slower process. In reality, once the continuous discharge is well underway pollutants would be released constantly, irrespective of whether this was instantaneous or not
- the applicant's assessment of biota did not include all contributing biota, only those that contributed most to the overall abundance. These were some of the species that would be considered to suffer 100% mortality through the FRR system, the biomass of all other species was ignored, irrespective of their individual size or that they would be expected to suffer some mortality. This would underestimate the overall impact
- the applicant hasn't considered differences between day and night samples when scaling up the overflowing bulk samples. We consider that there may be more fish impinged at night and have included this in our assessment
- it should also be noted that the water chemistry impacts were based on the low velocity side entry (LVSE) "intake being in place" (EDF 2021a, 5.6.10, 5.6.14, 5.6.21). It is not clear, but indicated from these statements, that the applicant has assumed that the LVSE is providing an additional reduction to fish intake. However, it has been agreed that the LVSE will be considered to have no impact. Our own assessment will review the biota discharge on this basis.

Except for the starting point of the mean daily biomass figures, on which we disagree, we consider this analysis is largely conservative and an acceptable approach for running our amended biomass figures through the TR520 models.

4.5.2. Interpretation of benthic community impacts

The applicant stated the benthic invertebrate fauna were resilient to disturbance and, given the mobile sandy nature of the environment, that the impacts of elevated organic matter discharged into these habitats would be negligible. We would challenge this, as resilience to long-term change for constant long-term organic enrichment from the discharge of biota could result in reduction in abundance of some functional groups.

The applicant's conclusions consider the short-term impacts from the biomass, but there's no consideration as to whether there would be a longer term effect of sediment enrichment over the lifetime of the project.

To address these points, the calculations in TR406 (EDF, 2020e) were re-run with updated values and the data and our interpretation of the impacts using this revised data are provided in section 5.5.

4.5.3. Cumulative effects assessment

We and the applicant disagree on the biomass calculations from the FRR system, which could be important for the cumulative assessment as well as when assessing the impact of the FRR system operating alone.

We also disagree with the applicant that the within-project part of the cumulative assessment should be restricted to operational water discharge activities. Our view is that other project activities could affect water quality and so should be considered together with operational discharges: dredging, combustion activities and construction discharges are relevant to consider (See section 5.9).

We are satisfied with the applicant's approach and conclusions for screening non-SZC projects to include in a cumulative assessment.

5. Final assessment

5.1. Outstanding issues

Issue	Impact	Receptors	Action
Impinged biota estimated to change	Potential increase in biota from FRR system discharge	Potential increased impacts on water column, subtidal benthic habitats and estuarine fish	Environment Agency to provide a new assessment of scale of biota from the discharge and spatial area of worse case impact (section 5.2-5.3)
Alone and in-combination assessment altered in lieu of changes to biota discharged from FRR system	Potential increase in biota from FRR system discharge	Potential increased impacts on water column, subtidal benthic habitats and estuarine fish require review of in-combination assessment	Environment Agency to provide a new assessment on revised scale of biota from the discharge and spatial area of worse case impact (section 5.4- 5.8)
In-combination assessment incomplete	Other discharges mentioned in H1 in some detail but not part of in-combination assessment	Potential increased impacts on water column, subtidal benthic habitats and estuarine fish require review of in-combination assessment	Environment Agency to review in-combination and include other construction related discharges (section 5.9)

Table 9. Outstanding compliance issues to be address by the final assessment.

5.2. Reconsideration of the impacts of impingement losses on fish and invertebrate assemblages

The uncertainty analysis of the biomass estimates is based on the work reviewing the LVSE factor and a vertical audit of the applicant's data. The pertinent findings from this work are provided in section 5.2.1 to 5.2.5.

5.2.1. LVSE factor uncertainty

Uncertainty remains as to the correct LVSE factor to apply in going from SZB to SZC impingement estimates. On this basis, we consider adopting an LVSE factor of less than one is overly optimistic. We therefore adopted an LVSE factor of one for the uncertainty analysis. This is line with the factor used by the applicant for the application.

5.2.2. Overflowing bulk sample uncertainty

The applicant's document TR339 (EDF, 2021g) highlights the presence of a relatively large number of overflowing bulk (18 hour) samples in the CIMP data set. The presence of the overflowing samples in the data set, and the manner in which they are treated, may significantly affect the estimate of the SZB impingement derived, and thereby the SZC impingement predicted from these data. Consequently, uncertainty is introduced into the true level of impingement measured at SZB and predicted for SZC.

While we do not know the true level of impingement at times of overflowing bulk samples, we do know it is greater than the level measured. We also know that overflowing bulk samples at times of high impingement of finfish species were predominantly collected in night-time hours.

Evidence from literature and Environment Agency surveys suggests the night-time impingement rate may be greater than daylight rate. In its analysis, the applicant has assumed that night-time and daylight rates are the same.

We have to address this uncertainty by applying a precautionary factor to the measured level. To help inform this work we have reviewed available literature on evidence for what the night to day-time impingement rate ratio might be.

From the literature reviewed, it appears the ratio of night-time to day light rates is not greater than 5. We have therefore applied a diurnal adjustment factor of 5 to the hourly daytime average to get an hourly night-time average. By doing so, we are not stating that the night-time impingement rate is 5 times greater than measured daytime data, but, because we do not know what the true night-time impingement rate is, we have applied what we consider to be a reasonable worst-case adjustment factor to account for the uncertainty introduced. We have selected this factor of 5 on a precautionary basis. We have arrived at an estimate of SZC impingement that we consider the true value is unlikely to exceed, therefore we have termed it a 'reasonable worst case'. Where the bulk sample has not overflowed, we used the survey data at face value.

As part of our role in the consultation for the SZC Development Consent Order, we requested sensitivity analysis accounting for overflowing bulk samples among a number of other factors. The applicant's response to the request is set out in SPP116 'Quantifying uncertainty in entrapment predictions for SZC'. In SPP116 (Cefas, 2021), the applicant states that diurnal bias was investigated in TR339: Appendix F (EDF, 2021g). This concluded that there was no significant misrepresentation of impingement results as a result of any sampling bias, but has not considered diurnal bias further in SPP116. Only we have carried out this type of calculation, and there is no part of the application to which a direct comparison can be made, therefore comparison is made to the baseline scenario.

5.2.3. Different intake location uncertainty

Potential sources of uncertainty in the impingement estimate for SZC that we have not included in this uncertainty analysis include the different spatial locations of SZB and SZC abstraction intake. Fishing surveys found no significant spatial differences in the fish community nor the fish length distributions for species other than sea bass between the locations of the SZC and SZB intakes (EDF, 2020e). For sea bass, the applicant's SZC impingement prediction was reduced by 90% based on these findings (EDF, 2020e). We have not applied a similar adjustment in our analysis.

5.2.4. Vertical audit of impingement data

This audit comprises our checks of the data processing performed by the applicant in TR339 (EDF, 2021g), correction of any errors identified in this processing, and derivation where appropriate of amended predictions of SZB impingement. Significant issues with implications for the accuracy of the SZB impingement predictions were highlighted.

Through quality assurance on the raw data, we identified several issues with the data analysis performed by the applicant. We raised these issues with the applicant who subsequently re-submitted part of the Comprehensive Impingement Monitoring Programme raw data files correcting these errors. The re-submission arrived in June 2021. As we had already identified and corrected the errors, we continued to work from the initial data provided in October/November 2020. We have not worked from the June 2021 files other than to carry out spot checks to ensure that the required corrections had been made.

The applicant corrected errors in its calculations relating to overflowing samples in SPP111 version 2 which was provided in March 2021[8]. In addition, in this report they amended the

[8] In June 2021, the applicant provided TR339 version 5 No. 2 part 8. TR339 version 5 included the results of the corrected calculations as per SPP111 version 2, and therefore TR339 was brought in line with SPP111.

factor applied to scale from impingement on the day surveyed to impingement for the plant at full capacity. This adjustment accounts for auxiliary cooling water (ACW) and essential cooling water (ECW). SPP111 also provides impingement estimates for SZC and is used as the basis for the assessment of water quality effects of the FRR system discharges in TR520.

Our calculations also adopted a raising factor to full capacity that accounts for ACW and ECW.

5.2.5. Mortality rates

Following the adjustments to the impingement data, in order to calculate biomass discharged from the FRR system, we reviewed the mortality rates. The applicant had only used mortality rates for the species contributing most to the biomass discharged, but this excluded many other species and would therefore underestimate the value of biomass. It was considered necessary to apply mortality rates, alongside the review of mortalities that the applicant had applied. Our values used were based on:

- our method used to assess mortalities for Hinkley Point C (HPC) development (Environment Agency, 2020), but takes account of any additional mortality that the applicant has given to account for the particular design and location of the FRR system (Environment Agency, 2020)
- where no information is provided as defined in Environment Agency (2020), the applicant's value is reviewed against the mortality rates in the Environment Agency's best practice guide (BPG) (Turnpenny and O'Keeffe, 2005) and the more conservative value used, where appropriate
- Where no data is provided by either the approach in Environment Agency (2020) or the applicant, the BPG is applied. The BPG applies a simple habit (demersal, pelagic or benthic) group as the basis of mortality. This is not always similarly defined in literature and so some further expert judgement may be required on the habit and if this is related to a physiology which could make it more or less prone to damage. Fishbase is taken as the basis for any habit description and includes benthopelagic fish which describes fish that live and feed near the bottom as well as in midwaters or near the surface.

The full set of FRR system mortality rates was used with the Environment Agency reanalysis of SZC impingement to assess the potential water quality impacts of the moribund biomass discharged.

The revised figures alter the estimated scale of water quality impacts and impacted area compared to those the applicant provided in TR520. These are summarised in Table 10.

5.3. Potential water quality effects of FRR system discharge

5.3.1. Waterbodies at potential risk

The basis of the calculated area follows that produced by the applicant, which, in turn, is modelled on local hydrographic conditions.

Minsmere Old River waterbody (Waterbody ref GB105035046270 and Walberswick Marshes waterbody (Waterbody ref GB GB610050076000) are hydrologically linked to the Suffolk Coast waterbody. The applicant states that for Walberswick Marshes, this is generally through slow percolation through dune and is therefore unlikely to result in additional WQ pressures impacting on the quality of ponds within the marsh (EDF, 2021a).

The Scott's Hall Drain has a fish pass mechanism built into it, with the main flap valve having a smaller flap working in the opposite way to allow fish migration at high tides. The applicant acknowledges that for "Minsmere Old River waterbody GB105035046270 - seawater can enter many of the ponds within the Minsmere RSPB reserve if the penstock at the downstream end of Scott's Hall Drain (part of the Minsmere Sluice structure) is opened as part of the management of the reserve." The impact of this on Walberswick Marshes is not recognised, but the location of the Walberswick Marshes to the north of Scott's Hall Drain would suggest that saline ingress could be another means of water exchange to this waterbody, in addition to percolation through the dunes. There is therefore another potential mechanism for the thermal or chemical plumes or the potential area of nutrient enrichment to reach these 2 waterbodies.

The applicant's modelling of the thermal plume from SZC alone shows that there is the potential for the thermal plume to interact with the coastline at the location of the Minsmere Sluice, but that this is below the threshold of concern, with the annual surface temperature difference at the coast predicted to be less than 1.5^{o}C (98th percentile) (Fig 5.3 and 5.6 in EDF 2021a). There will be no adverse effect from the thermal regime in the vicinity of the sluice.

The modelling of the chemical plumes shows the areas of exceedances are also well offshore and there is therefore no mechanism for chemicals from the operational discharges of SZC to reach the site (Figures 12, 13 and 14).

Nutrients/organic enrichment from the sewage treatment works (STW) and FRR systems could reach the intake. However, the increase in nutrient/organic enrichment is not at a level to cause a deterioration in water quality, therefore there will be no adverse impact on Water Framework objectives for the Walberswick Marshes or Minsmere Old River waterbodies.

5.3.2. Environment Agency revised FRR system discharge predictions

Table 10 presents a summary of our predicted water quality effects of SZC's FRR system discharge. This table compares the results provided in the applicant's TR520 to the revised Environment Agency figures. The process in which these figures were calculated is identical to the analysis in TR520. However, the loadings of dead biota discharged from the FRR system have been revised (See section 5.2) and several scenarios were considered.

There are a number of uncertainties in all of these calculations. The factors used to calculate the breakdown products are specific to one or a limited number of species or studies; they do not strictly apply to all fish/invertebrate species. In the absence of more or better data, it was considered acceptable to apply the factors universally.

The approach also does not take account of dispersal, accumulation or consumption by detritivores. Our figures are thought to provide a worst-case acute impact. Given the location of SZC, dispersal could be relatively significant.

Table 10. Summary of FRR system discharge loading estimates and related to scale of impact on Suffolk Coast waterbody (as %WB).

		From applicant's report TR520	Environment Agency calculations					
		Without effects of LVSE (as upper 95% confidence limit)	**Baseline fish only as upper 95**	**Baseline fish and Inverte-brates as upper 95**	**Worst case fish only**	**Worst case fish and Inverte-brates**	**Worst case fish only as upper 95% confidence limits**	**Worst case fish and Inverte-brates as upper 95% confidence limits**
Daily loading of impinged fish - Annual mean		1,498	1,661	1,773	2,257	2,505	3,835	4,083
Daily loading of impinged fish - Q1 mean		3,326	3,700	3,812	5,917	6,063	7,900	8,046
Nutrient input	Max daily P content (kg)	7.5	8.3	8.9	11.3	12.5	19.2	20.4
	Max daily N content (kg)	52.4	58.1	62.1	79.0	87.7	134.2	142.9

Un-ionised ammonia	Total NH_4 (mg)	415,780	462,478	476,515	739,685	757,842	987,531	1,005,688
	Unionised ammonia from calculator (mg)	11,797	13,122	13,520	20,998	21,502	28,018	28,534
	Volume required to dilute to the EQS (l)	608,073	676,368	696,898	1,082,379	1,108,335	1,444,251	1,470,806
	Area required (m^2 area)	**152.02**	**169.09**	**174.22**	**270.59**	**277.08**	**361.06**	**367.70**
	Unionised ammonia from calculator with temperature uplift (mg)	13,741	15,284	15,748	24,459	25,046	32,637	33,237
	Volume litres required to dilute to the EQS with temperature uplift (l)	708,303	787,855	811,768	1,260,790	1,291,023	1,682,309	1,713,242
	Area required with temperature uplift (m^2 area)	**177.1**	**197.0**	**202.9**	**315.2**	**322.8**	**420.6**	**428.3**
Influence on dissolved oxygen	kg of biological oxygen demand (BOD)	4,191	4,662	4,803	7,456	7,639	9,954	10,137
	kg/day O_2 reduction	1,397	1,554	1,601	2,485	2,546	3,318	3,379

	Area needed to meet oxygen demand through reaeration (m^2 area)	436,569	485,602	500,341	776,669	795,735	1,036,907	1,055,973
	Area needed to meet oxygen demand through reaeration (km^2 area)	**0.437**	**0.486**	**0.500**	**0.777**	**0.796**	**1.037**	**1.056**
Organic enrich-ment	kg of carbon/day	3,326	3,700	3,812	5,917	6,063	7,900	8,046
	Area affected (m^2 area)	3,787,922	4,213,358	4,341,246	6,738,825	6,904,248	8,996,802	9,162,224
	Area affected (km^2 area)	**3.79**	**4.21**	**4.34**	**6.74**	**6.90**	**9.00**	**9.16**
	Area affected (% WB)	**3**	**3**	**3**	**5**	**5**	**6**	**6**
	Ellipse length (m)	**5,334**	**5,626**	**5,710**	**7,115**	**7,201**	**8,220**	**8,296**
	Ellipse width (m)	**904**	**953**	**968**	**1,206**	**1,221**	**1,393**	**1,406**

The inputs of additional nutrients (N and P), un-ionised ammonia or the potential decrease in dissolved oxygen have been assessed in terms of the surface area required to dilute the input to the EQS, with the input from the FRR systems being based on the upper 95% confidence level of the mean of our ‘reasonable worst case with invertebrates’ scenario.

The surface area required to dilute to the EQS is then related to the size of the tidal excursion within Greater Sizewell Bay, this being the horizontal area over which a particle would be transported through the ebb and flow of a tidal cycle. This gives an indication of how the discharge from the FRR system will be dispersed and mixed as it leaves the outlet, given the diffuse nature of the inputs from discharged biota.

5.4. Impact of materials discharged from FRR system on water quality

Our calculations of the predicted FRR system discharge of moribund biota resulted in changes to nutrient, BOD and unionised ammonia entering the Suffolk Coast waterbody, compared to that predicted by the applicant in EDF 2021a (Table 10). The applicant summarises its assessment of these water quality impacts in EDF 2020c. The reasonable worse-case scenarios were considered for assessing the discharge impact. These were conservative values based on similar principles as provided by the applicant in section 4.5.1 but with changes on the base data we used as summarised in section 5.2.

5.4.1. Influence of nutrient increase

Nutrient increases as a result of the discharge from the FRR system have the potential to negatively impact water quality. There are also discharges from the STW that will add to nutrients for the period of the site operation. The nutrients from the sewage treatment and the FRR system are considered in combination (Table 11) for this assessment, by both the applicant in its original assessment, and subsequently by us in our revised figures.

We are satisfied with the applicant's loading estimates for the STW effluent, based on the information provided on the expected population equivalent and level of treatment. However, we estimate that nutrient loadings from the FRR system would be greater than the applicant has estimated (this is based on our higher biomass estimate of dead and moribund biota from the FRR system).

From Table 10, our revised reasonable worst-case scenario nutrient input from the FRR system is estimated to be as a maximum daily input of 12.5kg P and 87.7kg N. With 20.4kg P and 142.9kg N as an upper 95% confidence limit of these values.

The combined nutrient loading estimates for the FRR system and STW are given in Table 11. Our values are based on annual average impinged daily biomass and not the upper 95%ile confidence limit on this average because nutrients act over a relatively prolonged period, and over this period it is reasonable to expect variation in the daily mean to average out.

Table 11. Daily loading during operation as kg (FRR system and STW), and as a % of daily exchange with the wider environment outside Sizewell Bay.

Substance	applicant TR385 (EDF 2020b) Table 5	TR385 as % of daily exchange	Environment Agency	Environment Agency as % of daily exchange
Nitrogen as N	69.3	0.4%*	136.7	0.81%
Phosphate as P	6.04	0.25%	15.7	0.64%

The revised Environment Agency FRR system and STW nutrient load is estimated to be less than 1% of the normal daily exchange of nutrients with the wider environment (Table 11). Given this, and the fact that the approach excludes any removal of fish (and therefore nutrients) through consumption by predators, it is considered that this revised assessment of nutrients discharged from the FRR system will not result in a failure to meet WFD water quality objectives in the wider Suffolk Coast waterbody.

5.4.2. Influence on dissolved oxygen

A lowering of dissolved oxygen has the potential to impact ecological quality for benthic communities and fish. From Table 10, the influence of the additional biological oxygen demand is likely to result in a worse case (as an upper 95%ile of the average) area of 1.056km^2 needed to meet oxygen demand through reaeration. This is an increase from the 0.437km^2 (as an upper 95% confidence limit) provided in TR520.

Waters off Sizewell are well mixed vertically, which enabled reaeration at the surface, the Suffolk Coast waterbody has a relatively high exchange with the wider marine environment and the background dissolved oxygen levels are high. In addition, this is predicted to be an acute estimate of impact which excludes any estimate of removal of discharged fish by predation. The impacted area is likely to be within the larger estimated benthic footprint of the organic material (for that organic matter assessment on benthic invertebrates see section 5.5).

Even with this increase from that predicted by the applicant, it is considered that this revised assessment of dissolved oxygen resulting from the discharge from the FRR system will not result in a waterbody deterioration or a failure to meet WFD water quality objectives in the Suffolk Coast waterbody.

5.4.3. Unionised ammonia

Unionised ammonia (UIA) increases with a rise in temperature. So, this assessment takes into account the temperature uplift from SZC which overlaps with the FRR system discharge.

From Table 10, the worse-case area as an upper 95%ile is 428m^2 where there is the potential to exceed the EQS. This takes into account the effect of any temperature uplift. Note: The temperature uplift will extend over a smaller area at depth. This is an increase from the 177m^2 (as an upper 95% confidence limit) provided in TR520, but still does not include any reduction of ammonia through removal of fish by predation. The revised value is insignificant in comparison to the wider waterbody.

It is considered that this revised assessment of UIA discharged from the FRR system will not result in a failure to meet WFD water quality objectives in the Suffolk Coast waterbody. This conclusion also takes into account the impact of temperature on UIA.

5.5. Impacts of materials discharged from the FRR system on benthic habitats

5.5.1. Habitat sensitivity overview

The WFD screening criteria requires applicants to consider certain high sensitivity and low sensitivity WFD habitats present that may be impacted by their activity. If there is a likelihood these could be impacted, then 'habitats' are taken forward into further assessment. The presence of these habitats is provided via interrogation of the MAGIC mapping database, but the applicant has sought more recent unpublished data to improve those maps.

The baseline habitat mapping the applicant has completed in the Sizewell Bay area provides a good, detailed baseline to a lower level of European Nature Information System (EUNIS) classification, and is the best source of data to apply for a detailed site characterisation (Figure 5.2 in EDF 2021a). The Suffolk Coast waterbody is dominated by subtidal soft sediments (Table 5.3 in EDF 2021a).

While the WFD benthic community assessment is based on a tool that uses soft sediment invertebrates, the intention of the original directive is to consider benthic communities as a whole. However, harder substrates do not feature in the current WFD classification, which uses an infaunal classification index (IQI), based on animals that live in the seabed. These soft substrates such as sands and mud extend over the majority of the Suffolk Coast waterbody, so generally speaking the IQI represents a tool that works effectively for the majority of the Suffolk Coast waterbody. The applicant has assessed these softer substrates and individual sites are currently indicated as good or moderate status using the WFD IQI tool.

The applicant refers to the “resilience” (EDF, 2021a) of the benthic community in what is considered a dynamic environment. While we can accept that the community can be quick to respond to changing seasonal pressures and influences, the ability of the benthic community to retain its original diversity and abundance to a pressure lasting many years is less likely. The community is likely to undergo some non-temporary change, and potential deterioration, at a local scale in response to a consistent and long-term settlement of dead biota on the seabed. So, this assessment needs to consider the scale of the impacted area and if this change is significant to influence the quality of the benthic invertebrate community as a whole.

Additional work was done to assess and report on the Coralline Crag feature to the south of Sizewell, near Thorpeness (EDF, 2019). The Coralline Crag is an erosion resistant outcrop. This bedrock provides an unusual area of approximately 4km^2 hard substrate in an area where the coastal seabed is dominated by soft mobile sands. Surveys were carried out around the Coralline Crag to assess whether Sabellaria spinulosa reef was present in this area. Reefs are recognised generally as a ‘high sensitivity’ habitat to pressure for WFD, but do not feature in the IQI assessment. It is necessary to note the term ‘WFD sensitive’ has been adopted to illustrate the relevance to WFD and the need for closer assessment of impact. It's not a term defined in the directive or regulations.

Biogenic and bedrock reefs differ in sensitivity to external pressures such as chemical contamination or thermal variation. The exposed area of Coralline Crag qualifies as a bedrock reef and the balance of evidence, and based on the temporal persistence of the S. spinulosa structures, it is likely also that biogenic reef habitats exist. Examples of this reef habitat are likely to be present, particularly within the north, central, west and south west regions of the Coralline Crag (EDF, 2019).

The Coralline Crag community to the north has the potential to be within the footprint of the organic enrichment plume, but preferences with this community for areas of high water movement suggest that organic matter would not accumulate on reefs, limiting exposure to this pressure. S. spinulosa and the associated species assemblage, which typically includes attached filter feeders from a number of phyla, are likely to be able to consume extra organic matter. This conclusion is supported by the enhanced growth rates that have been recorded on the vicinity of sewage disposal areas (Walker and Rees, 1980).

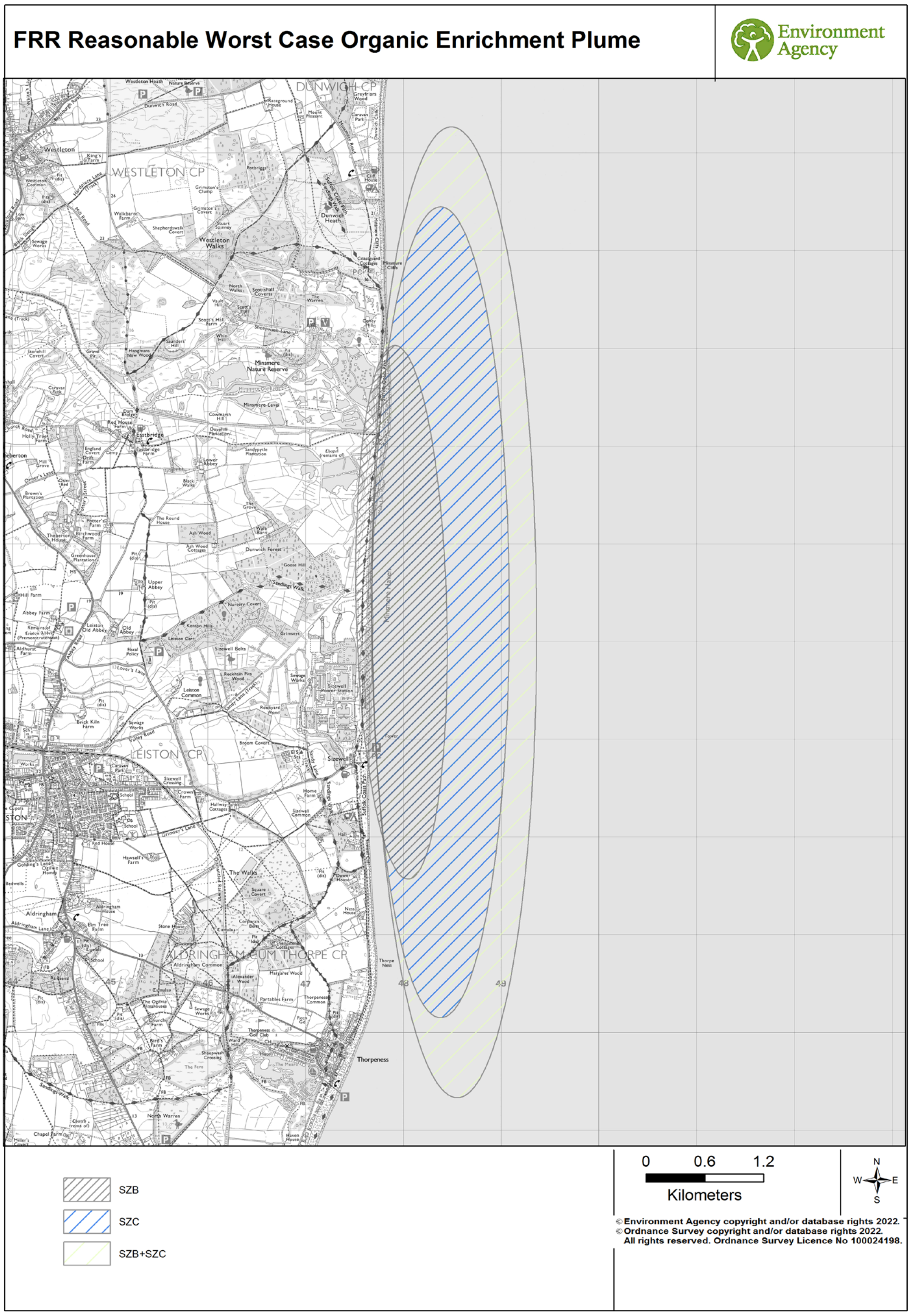
The applicant’s reference to resistance is assessed as ‘high’ to this pressure and recovery is assessed as ‘high’ (no impact to recover from). So, all S. spinulosa reef biotopes are considered to be ‘not sensitive’ at the pressure benchmark (Gibb and others, 2014). It should be noted however that this is based on short-term effects, with the benchmark pressure for siltation being “up to 30cm of fine material added to the seabed in a single event.” The sensitivity assessment methodology takes account of both resistance and resilience (recovery). Recovery pre-supposes that the pressure has been alleviated, but the sensitivity assessments do not take account of spatial or temporal scales. We therefore consider the Coralline Crag community to be potentially sensitive to the discharge of organic enrichment at the temporal scale planned. As a result, we must consider that all communities within the footprint of the discharge have some sensitivity to this pressure.

5.5.2. Extent of benthic invertebrate change from organic enrichment

We have determined the load of organic material discharged from the FRR (Table 10). In our assessment of the area of sea-bed impacted by this discharge we have assumed the material to be spread over the bed to achieve an even thickness that will release carbon at the proxy EQS rate over the whole area. This gives the maximum area at the proxy EQS. In arriving at the shape taken by the layer of organic material, we have used tidal parameters taken from assessment of the thermal plume that shows the plume to describe an ellipse about the discharge point. We have therefore described the area of organic enrichment as an ellipse.

From Table 10, the organic enrichment is estimated to cover an elliptic area of seabed length 8,220m and maximum width 1,393m as a worst-case scenario and 8,296m by 1,406m as the upper 95%ile (Table 10, Figure 15).

Figure 15. The maximum potential area of organic exceedance for SZC alone, SZB alone, and SZC+SZB in combination, based upon the upper 95% confidence limit of the mean of the EA's precautionary 'worst-case with invertebrates' scenario.



This area represents 6% as the upper 95%ile of the Suffolk Coast waterbody (Table 10). This is an increase from 3% provided in EDF 2021a.

This has the potential to alter the functional groups of the existing benthic invertebrate community within the footprint, particularly given the significant number of years the discharge will be operating. It also has the ability to reduce the benthic community in this area by smothering.

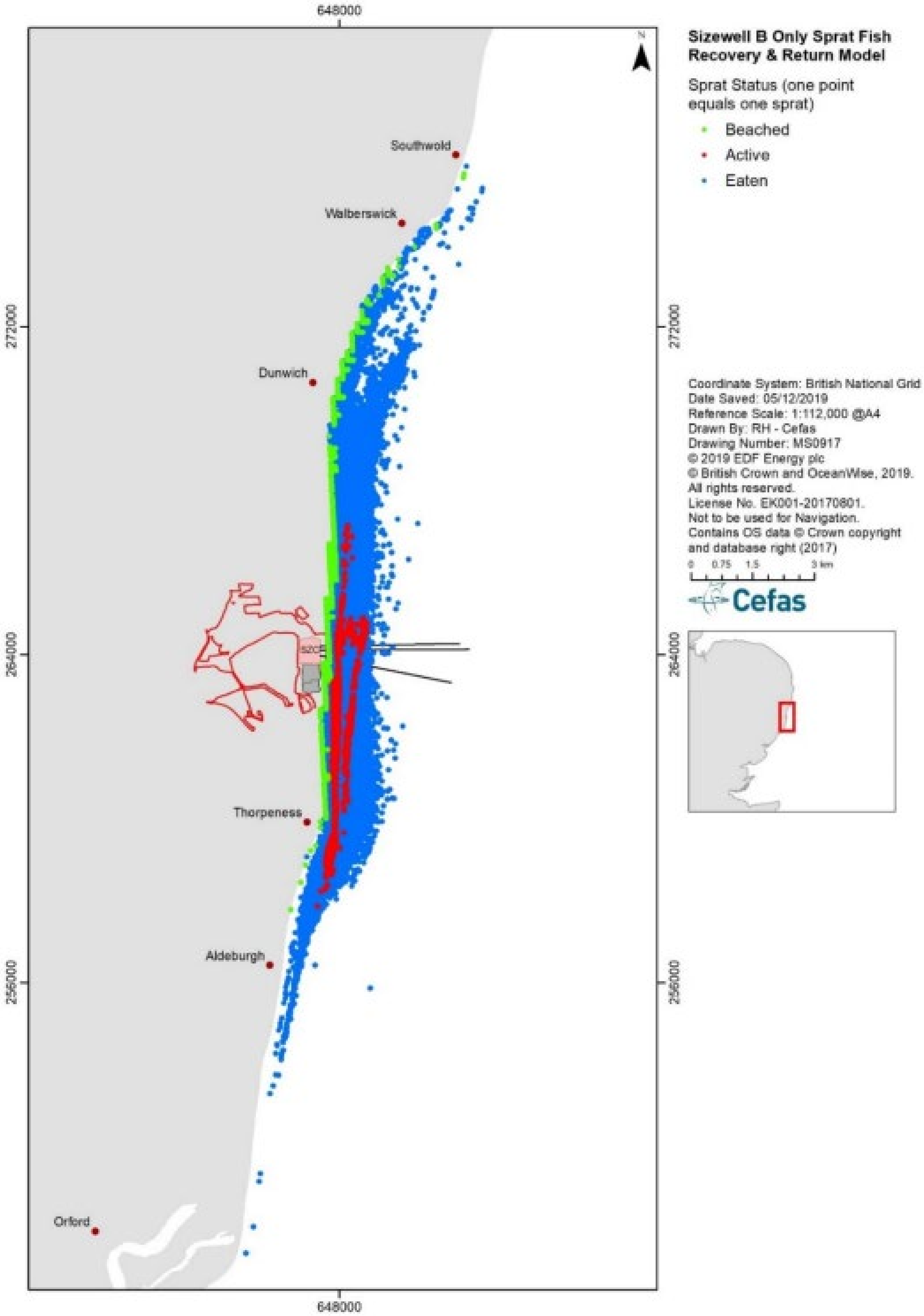
Some of the conservative elements of the modelling used by both the applicant and replicated by us in our own assessment, include:

- 100% of the biomass discharged will sink immediately and not be re-suspended or advected over a larger area. This is contrary to the particle tracking study in TR511 (Cefas, 2021), which predicted 12% of dead sprat would be transported away from the discharge point by tidal currents (Fig 16). TR511 is also conservative as it makes the assumption that once a fish has sunk to the bottom it is not transported further

- the open location of SZC, where dispersal could be significant, reducing a more localised acute impact

- there is no account of consumption by detritivores or benthic fish

Figure 16. The results from the particle tracking model used to determine the fate of dead sprat leaving the FRR system outfall. Reproduced from Figure 7 from TR511 (EDF, 2021f).



Consequently, the figures are thought to provide a worst-case acute impact, and impacts are likely to be less than those we modelled.

While we can consider the benthic community to show some sensitivity to organic enrichment and the effects of smothering, it has also been shown that the Coralline Crag filter feeding community may also show improved growth from the additional food supply (Walker and Rees, 1980).

It is predicted that there will be no overall WFD deterioration in benthic invertebrate community class of the Suffolk Coast waterbody due to organic enrichment of the seabed.

5.5.3. Impact on benthic community as a result of changes to water quality

Ellipses have not been mapped for other water quality criteria as they have for organic enrichment in Figure 15. While the areas are predicted to be greater than those modelled by the applicant, it is still considered that for dissolved oxygen, UIA and nutrient input that the combined spatial scale of the EQS failures for the water quality parameters assessed remain small. They would also be expected to be within the larger footprint of the organic enrichment.

Only a small fraction of the benthic population in the Suffolk Coast waterbody may be exposed to lower dissolved oxygen levels or any chemical concentrations above EQS. And there is no impact within the estuary of the nearby Alde and Ore or the Blyth Estuaries waterbodies. As a result, effects on the benthic communities at a waterbody scale are not predicted as a result of these water quality pressures alone or in combination.

5.6. Impact of materials discharged from the FRR system and STW on phytoplankton

The applicant has modelled (EDF, 2020b) the effects of Sizewell C nutrient inputs, the thermal plumes and entrainment on phytoplankton biomass of Sizewell Bay, using Cefas' Combined Phytoplankton and Macroalgae (CPM) model and the applicant's nutrient loading estimates.

It states in EDF 2021a, "the CPM model was used to predict the effects of nutrients on the annual gross primary production within the tidal excursion accounting for entrainment from Sizewell B and Sizewell C during the operational phase. The model predicted annual nutrients loadings would increase production within the GSB area by 0.14%. Such changes are orders of magnitude below the natural variation in chlorophyll a biomass."

The applicant concluded that the effect of discharged nutrients would be more than offset by entrainment mortality. There would be greater daily exchange of water between Sizewell Bay and the southern North Sea than daily extraction of water for the power stations. Due to this exchange, the apparent concentration of phytoplankton is not expected to reduce in Sizewell Bay when considered against the high natural variability, and the predicted effect of the proposed SZC would not be observable in any monitoring programme.

We do not know all the CPM model input values to repeat this modelling and model the effect of varying the nutrient loads from the FRR system to our own higher estimates. However, we can make a qualitative assessment.

There are a number of uncertainties in evaluating the impact this could have on phytoplankton communities. In general terms, N is the more important as a limiting nutrient (for growth) in the marine environment. Initially, P is the primary limiting factor from mid-May. However, this is very short-term, and the system enters a period of nitrate limitation until August, so the 2 nutrients do not have equally weighted or additive impacts on phytoplankton growth.

Increasing the nutrient loadings from the FRR system to the levels we estimated would offset the reduction in primary production in the summer months estimated by the applicant. We are unable to be certain if this offset would be sufficient to make the net effect of SZC increase phytoplankton productivity locally.

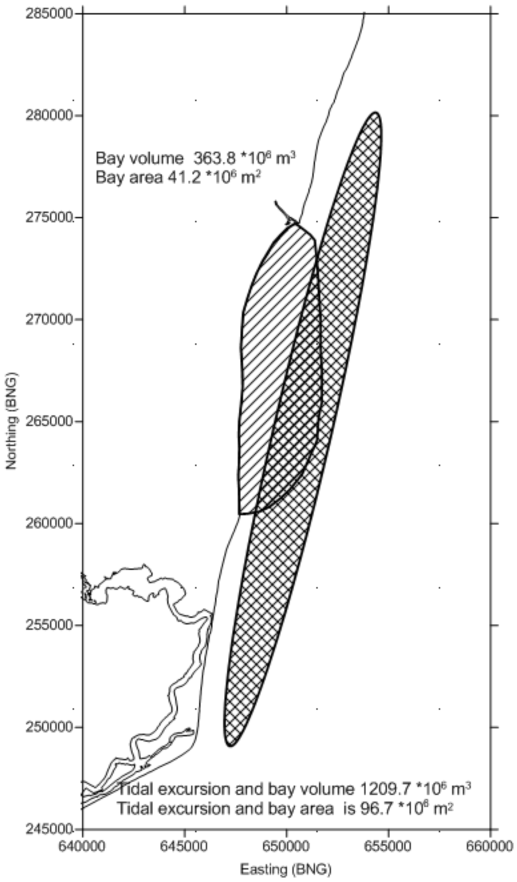
Both the applicant's and our revised estimates have used other precautionary assumptions about the FRR system discharges in their modelling work:

- It uses daily average nutrient loads, even though the FRR system load would be seasonal and expected to peak in winter when phytoplankton growth is light limited.
- It assumed all the FRR system biomass would be available as nitrogen and phosphorus sources, even though some biota will be dispersed and a proportion consumed by scavengers, reducing the mass that could break down and affect local water quality.

While our revised average nutrient load is about double for nitrogen and more than double for phosphorus (Table 10), it is still estimated to be less than 1% of the normal daily exchange of nutrients with the wider environment. It should also be noted that those values are attributed to the area defined as Sizewell Bay applied in the model (see Figure 17), which represents only part of the full Suffolk Coast waterbody. Given this and the conservative nature of this assessment, we would consider that the combined discharges (FRR system and STW) would not be likely to alter the trophic status of the Suffolk coastal water.

It is predicted that there will be no WFD deterioration in phytoplankton community class of the Suffolk Coast waterbody due to nutrient enrichment from the FRR system and STW discharges in combination.

Figure 17. Areas from which the Sizewell B and Sizewell C intakes extract cooling water (used to calculate volumes for use in the simple box model). Single hash marks encapsulate the Sizewell Bay region and the double hash marks the volume used in association with the Sizewell C intakes. Reproduced from EDF 2020b Figure 2



5.7. Impacts of materials discharged from the FRR system on fish that use nearby estuaries

5.7.1. FRR system impact on fish - General

This section considers the FRR operational water discharges to the marine environment and, where applicable, considers the effects of one FRR system discharge parameter on the other (for example, the effects of the thermal plume on physico-chemical parameters such as dissolved oxygen).

Our calculations extended the size of the FRR system plume compared to that predicted in EDF 2021a. For fish, the relevant parameters are UIA and oxygen concentrations in the water column and their impact on more mobile pelagic fish species using the area as they move into the nearby estuaries. There is no requirement to consider the impact on fish communities within the Suffolk Coast waterbody, as fish are not a biological element considered in coastal waterbodies for WFD.

As stated in section 5.4.2 and 5.4.3, the spatial extent of these parameters on water quality is predicted to be small in comparison to the wider Suffolk Coast waterbody, but the impact is considered significant as it interferes with the movement or health of fish using this part of the coastline. This, in turn, could impact the populations of the Blyth or Alde and Ore Estuaries. The main issues are whether the discharge would:

- cause fish avoidance and increase energetics involved in migration affecting population health
- act as an obstacle to migration
- cause a direct health issue to the fish

All of which could impact the fish community in the estuaries in question over the period of operation.

The main fish species of interest are those also considered in the assessment of thermal impacts on WFD status for fish (section 4.3.11.7) and would be those pelagic species actively moving along the coast and into the estuaries. Examples of these species include herring, which contribute most to the WFD abundance measure, and smelt, which are an important WFD indicator species.

5.7.2. FRR system – Un-ionised ammonia (UIA) impacts on fish

This is predicted to be minor, even when accounting for the increase in toxicity due to interaction with the thermal plume (see section 5.4.3). This is due to the size of the UIA' footprint' (428m^2) (Table 10), and ability of the mobile nature of the fish that move in and out of estuaries to avoid this area. While this, in theory, may have some impact on energetics, the overall distance required to avoid any elevated levels is likely to be insignificant. Toxic levels are unlikely to have a direct impact on fish that would tend to show avoidance and are not expected to remain in the area for long.

No deterioration of the fish element of estuaries is predicted as a result of the UIA discharge from SZC, including the combined interaction with the thermal discharge. This impact is considered negligible to pelagic fish, so is not considered further in the in-combination assessment.

5.7.3. FRR system - Dissolved oxygen impacts on fish

Biological oxygen demand impacts from biota breakdown are considered as this can contribute to a lowering of dissolved oxygen.

The surface area required to meet the daily oxygen demand of the discharge from the FRR system of SZC alone was calculated as being 1.056km^2 (Table 10). As with un-ionised ammonia, this does not mean that pelagic fish species will encounter a de-oxygenated area of this size. The actual areas over which effects on oxygen levels occur will be smaller due to the continuous discharge of biota from 2 separate outlets, the dispersal of that biota away from the outlets, the consumption of a proportion by scavengers and the tidal movement of water past the outlets. The surface area of water required to meet the daily oxygen demand of the discharge from the FRR system of SZC alone (1.056km²) is just 2.4% of the tidal excursion (EDF, 2020c). So, dissolved oxygen levels are highly unlikely to reduce to a sufficient level to cause pelagic fish mortalities or cause avoidance from the area, with a resulting higher use of energy. In addition, there is no dissolved oxygen reduction predicted at the mouth of the Alde and Ore or Blyth Estuaries, which could create an obstacle to fish movement.

No deterioration of the fish element of estuaries is predicted as a result of change to dissolved oxygen from the SZC FRR system discharge.

Since this impact is considered negligible, dissolved oxygen will not feature further in the in-combination assessment.

5.8. Cooling Water Discharge (CWD) hydrazine, bromoform and total residual oxidant (TRO) impacts on fish using nearby estuaries

This section considers the CWD operational water discharges to the marine environment and, where applicable, considers the effects of one CWD discharge parameter on the other (for example, the effects of the thermal plume on chemical toxicity).

5.8.1. Hydrazine

The plume area exceeding the PNEC values at the surface covers an area of 13.79 to 17.38ha at the surface and a much smaller spatial area of 0 to 0.22ha at the seabed. (Table 2).

Sublethal concentrations based on altered behaviour (Fisher and others, 1980) are approximately 1,400 times higher than the potential hydrazine concentration at the initial discharge point.

Hydrazine is considered not to directly add to or act as a barrier to fish passage due to its limited spatial scale, the modelled plume location running elongated and narrow up the coast; and that it does not extend as far as the mouths of the Alde and Ore and Blyth Estuaries (Fig. 12).

Therefore, pelagic fish can readily avoid any area of toxicity and are not obstructed or would not use additional energy to progress along the coast while still avoiding the plume.

No deterioration of the fish element of the Alde and Ore and Blyth Estuaries is predicted as a result of the hydrazine discharge from SZC CWD.

Since this impact is considered negligible, hydrazine will not feature further in the in- combination assessment.

5.8.2. TRO

The TRO plume is a long, narrow plume running north to south from a relatively central point of original at the CWD discharge offshore (Fig 13). The plume area exceeding the EQS/PNEC values at the surface covers an area of 52.14ha at the surface and 0.67ha at the seabed. (Table 2). While it does extend north beyond the Blyth Estuary, this plume is still some distance offshore so does not obstruct the entrance to the Blyth Estuary itself and the offshore values nearest to this location are less than 4ug l^{-1}. While effects thresholds have been found to be greater, at around 20µg l^{-1} in the most sensitive species (Cooke and Shreer, 2001), these are only predicted in the immediate area of the discharge (Fig. 13).

Therefore, pelagic fish can readily avoid any limited area of toxicity and are not expected to demonstrate measurable avoidance to the plume.

As stated by applicant in EDF 2021a section 5.5.70, on the interaction with TRO and thermal plume, “TRO toxicity may increase with the near field of the thermal plume. However, limited acute (lethal) effects are predicted to be localised and mobile species and life history stages would demonstrate avoidance behaviours reducing exposure.”

Temperature elevation has been shown to increase toxicity of chlorine TRO in fish (Cooke and Schreer, 2001), with an approximate halving of the median lethal concentration (LC50) of TRO being observed with an increase of temperature between 10°C and 20°C. However, the studies reviewed report temperature effects on toxicity in acute studies with durations of hours to a few days and with exposure concentrations in the hundreds of micrograms - significantly greater than the predicted exposure concentrations at SZC. In the same review, in some cases, fish were reported to actively avoid much lower TRO concentrations than would be lethal over several days’ continuous exposure.

At the immediate point of discharge, the maximum predicted temperatures at the surface are between 7.5°C and 8°C above ambient. As a 98th percentile, the 5°C above ambient temperature contour is 30.6ha (0.306km²) in a relatively symmetrical position around the outlets. Overlapping this area, TRO concentrations above 50µg l^{-1} and 20µg l^{-1} occur over sea surface areas of approximately 9ha (0.09km²) and 98ha (0.98km²), respectively as a 95th percentile.

Absolute temperature uplifts of 28°C (98th percentile) occur over a very small area (0.11ha, 0.0011 km²) at the sea surface. Absolute thermal uplifts of >23°C occur over an area of 89.6ha (0.896km²) at the surface, and 25.6ha (0.256km²) at the seabed) as a 98th percentile.

The most sensitive species in the individual assessments showed effect thresholds at around 20µg l^{-1}. It is therefore unlikely that the synergistic effects of TROs and modest temperature uplifts or absolute temperature would cause adverse effects to extend beyond the TRO EQS contour (10µg l^{-1}). In the very small areas of the thermal plume with temperatures of 5°C above background and in which TRO concentrations are >20µg l^{-1}, increased TRO toxicity may occur.

While there is the potential for synergistic effects, such effects would be restricted to a very localised area, with pelagic fish species exposed over a very limited time only due to their high mobility.

It is highly unlikely that the inter-relationship between thermal and chlorinated discharges would increase beyond the significance of the effects predicted for the pressures individually.

No deterioration of the fish element of the Alde and Ore and Blyth Estuaries is predicted as a result of the TRO discharge from SZC CWD.

5.8.3. Bromoform

The bromoform plume area exceeding the PNEC values at the surface covers an area of 52.14ha at the surface and a much-reduced spatial area of 0.67ha at the seabed. (Table 2).

Like the TRO plume, the bromoform plume would be a long, narrow feature parallel to the coast, although it potentially creates a wider plume (Fig. 14), which spatially could be said to create an area that fish may avoid when moving along the coast. It does not extend as far south to the mouth of the Alde and Ore Estuary, but does extend north beyond the Blyth Estuary.

EDF 2021a refers to BEEMS 2011b which discusses toxic impacts of chlorination by-products (CBPs), of which bromoform is one. In this report, "it can be concluded that for sea bass, and probably for most fish species, survival rates of all fish live stages are comparable in chlorinated and non-chlorinated water. Long-term exposure to CBPs produced by low-level chlorination (1 to 2mg l^{-1} TRO) did not impose ecotoxicological stress. Also, it is reported that fish can detect low levels of chlorine and may actively avoid areas with higher chlorine concentrations (Gammon, 1971). Such behaviour would help limit the exposure of fish to CBPs."

Long-term studies of the sea bass Dicentrarchus labrax in a fish farm receiving power station cooling water indicated that levels of mortality were comparable with other fish farms over a 3-year study (Taylor, 2006). Bromoform was present in fish tissues at concentrations up to 1.7mg kg-1 in the fatty tissues of exposed fish, but this decreased rapidly when chlorination ceased. There was no indication of elevated detoxification enzymes, or abnormal pathology or tumour development in the tissues of exposed fish.

Fish can detect and actively avoid areas with elevated chlorine concentrations (Gammon, 1971; Cherry and others, 1979; Stober and others, 1980). Field-based avoidance trials suggest significant avoidance of CBPs at concentrations of 0.05mg l^{-1} in coho salmon to 0.40m l^{-1} l for channel catfish. Lower levels of free chlorine (HOCL) instigated an avoidance response; 0.01 to 0.02mg l^{-1} for coho salmon to 0.04 to 0.12mg l^{-1} for channel catfish, depending upon acclimation temperatures tested (Cherry and others, 1979).

While the plume does extend north beyond the Blyth Estuary, it is still some distance offshore, so does not obstruct the entrance to the Blyth Estuary itself and the offshore values nearest to this location are less than 2ug l^{-1}. These values and the PNEC applied across the plume area as a whole (5ug l^{-1}) are considerably lower than those expected to result in avoidance.

No deterioration of the fish element of the Alde and Ore and Blyth Estuaries is predicted as a result of the bromoform discharge from SZC CWD.

Since this impact is considered negligible, bromoform will not feature further in the in-combination assessment.

5.8.4. Combined impacts of CWD thermal, FRR system, and TRO plumes on fish

In sections 5.7 and 5.8.1 to 5.8.3, the impact of the water quality discharges from the FRR system and CWD have been considered individually, and, where relevant, with the influence of elevated temperature from the thermal discharge on toxicity.

Here, we consider how those remaining pressures may combine with each other to affect fish in the Blyth and Alde and Ore Estuaries. The only in-combination issue for the FRR system and CWD discharges we have taken forward from sections 5.7 and 5.8 is the spatial interaction of TRO and the thermal plume.

This is best described by considering the combined footprint of the TRO plume with the degree of overlap or contiguity with the SZC thermal footprint.

Seasonal chlorination is proposed through the CW outfall (the FRR system won't be chlorinated). Chlorine TRO EQS used is 10ugl^{-1}as a 95%ile. The TRO EQS mixing zone is predicted to be 338ha at the surface and 2.1ha at the seabed in a narrow, tidally transported plume forming parallel to the coast and remaining separate from the plume from SZB.

For comparison, the thermal uplifts of >2 degrees C (as a 98th percentile) is predicted to occur over an area of 7,899ha at the surface and 6,241ha at the seabed during operation of both SZC and SZB.

Figure 13 shows the predicted TRO plumes above 10ugl^{-1} and 1ugl^{-1}. At the surface, the 1ugl^{-1} plume stretches parallel to the shore from Orford to north of Southwold. This is about the same length of plume as the thermal 2 degrees uplift surface water plume (Fig. 4) but is narrower and stays offshore. Spatially, the area impacted by chronic effects from TRO will fall within the area impacted by the thermal plume. We already agree that the impact of elevated temperature on the toxicity of the TRO plume is insignificant (section 5.8.2).

Figure 7 shows that potential thermal avoidance thresholds are predicted to occur over 25% of a hypothetical Sizewell fish corridor/transect for less of the time during the summer months than the winter months. This would also reduce the opportunity for synergistic effects during the months when chlorine dosing is likely.

Given the TRO plume will fall within the same spatial area as the thermal plume from SZC, there is not expected to be any additional spatial extent barrier to fish moving along the coast in addition to that created by the thermal plume itself.

No deterioration of the fish element of the Alde and Ore and Blyth Estuaries is predicted as a result of the combined interaction of the FRR system and CWD discharges from SZC to that predicted for the thermal plume alone.

5.9. In-combination/cumulative impacts

5.9.1. Guidance on cumulative and in-combination assessments

Clearing the Waters for All (CtW) states that applicants should include information about other activities that could affect the same receptors. These activities could be taking place now or be planned for the future. They must consider the effect of their activity together with these other activities.

So, we need to assess the impact of the water discharge activities applied for, together with other sources of the same pressure (a cumulative impact), and with other pressures that affect the same waterbody receptor (an in-combination impact).

HRA guidance provides a further break down of effects with other activities, plans and projects as follows:

- additive - the total effect of a number of effects is equal to the sum of the individual effects
- synergistic - the effect of the interaction of a number of effects is greater than the sum of the individual effects
- neutralistic - the effects counteract each other, reducing the overall effect
- overlapping - affecting the same spatial area of a feature and/or the same attributes of the feature, for example, the mixing zones of two separate discharges overlap
- discrete - affecting different areas and different attributes of the feature, for example, 2 separate discharges affect geographically discrete areas of a habitat within a site

In combination, the total area of habitat affected may be unacceptable in terms of site integrity.

5.9.2. Scope of cumulative and in-combination assessment

In EDF 2021a, the applicant considers project-wide effects and effects with other projects. The applicant's assessment of project-wide effects is restricted to operational water-based discharges to the marine environment. We have expanded the scope to also consider the effects of operational water-based discharges in combination with:

- other project wide activities that could affect water quality (such as combustion activities and dredging)
- water-based discharges planned for the construction phase of the project

We haven't considered plans or projects that are unlikely to affect water quality in this assessment. However, other pressures, such as alteration of coastal processes or entrapment of fish, should be considered in combination within the DCO process.

5.9.3. Project-wide effects: between operational discharges

Table 12 contains a summary of which project-wide operational discharges have the potential for cumulative effects, showing that both the FRR system (waste stream H) and the ST5.9.3W discharge (waste stream G) may need considering together when assessing the risk of nutrient enrichment and impacts from un-ionised ammonia. These cumulative effects are considered on water quality in sections 5.4.1 to 5.4.3 and on ecology from 5.5 to 5.7 alongside the FRR system assessment.

We have considered in-combination effects of different pressures (such as thermal and chemical) from the same waste stream on a specific quality element (such as fish), in section 5.8.4.

Table 12. Risk of potential cumulative effect between the 3 operational permits.

Pressure	WDA waste streams A to F		WDA waste stream G	WDA waste stream H
	Thermal plume	Chemical plume	STW	FRR system
Thermal	Yes	No	No	No
Chemical	No	Yes	No	No
Nutrient enrichment	No	No	Yes	Yes

Pressure	WDA waste streams A to F		WDA waste stream G	WDA waste stream H
Un-ionised ammonia	No	No	Yes	Yes

5.9.3.1. Cumulative effects from waste streams G (STW) and H (FRR system)

Waste stream G discharges via the cooling water outfalls, which lie about 3km offshore and about 1km seaward of the Suffolk coastal water. The 2 FRR system outfalls discharge around 400m offshore into subtidal waters at approximately 4m depth (EDF, 2021b).

Table 13. Summary of potential effects from waste streams G and H, and whether each should be considered cumulatively.

Effect	Does this need to be considered in-combination/cumulatively?
Material is deposited on the seabed around each outfall causing organic enrichment gradients	**No:** The effect 'alone' from each cooling water outfall is not predicted to impact the Suffolk waterbody because the STW discharge would be treated to remove readily settleable solids during the treatment stages and the effluent would be highly diluted by cooling water prior to discharge. **We do not expect the cumulative effect on a WFD waterbody to be greater than the effect from the FRR system outfalls alone.**
The biochemical oxygen demand (BOD) of the discharges affects the amount of dissolved oxygen	**No:** The STW effluent would be highly diluted by cooling water and BOD level of the discharge is not predicted to exert a significant dissolved oxygen demand. **We do not expect the cumulative effect on a WFD waterbody to be greater than the effect from the FRR system outfalls alone.**
Discharges affect levels of unionised ammonia and EQS compliance	**No:** The STW effluent would be highly diluted by cooling water and levels of ammonia are not predicted to cause significant EQS exceedance.

Effect	Does this need to be considered in-combination/cumulatively?
	We do not expect the cumulative effect on a WFD waterbody to be greater than the effect from the FRR system outfalls alone.
Level of nutrient inputs increase the risk of eutrophication	**Yes:** Dilution of the STW effluent is less relevant when assessing the risk of nutrient inputs because it is important to consider the loadings and timings of inputs. **Consider cumulative effect of nutrient inputs from STW and FRR system waste streams.**

The FRR system and STW are the only 2 potential sources of nutrient and organic enrichment.

These were considered in combination in the assessment for the FRR system discharge in sections 5.4 and 5.5. This demonstrates that the discharges from the STW and FRR systems combined will not result in a change to nutrient and organic enrichment in the Suffolk Coast waterbody nor prevent WFD objectives being achieved.

5.9.4. Project-wide effects: operational discharges in combination with other project-wide activities

The following project-wide activities could impact on water quality and are considered in the sections below in combination with the proposed operational discharges:

- discharges that would occur during the construction and commissioning phases, due to a risk of residual effects overlapping with effects from operational discharges
- operational combustion activities, due to a risk of airborne contaminants becoming deposited onto water or washed into water once deposited onto land
- dredging activities, due to a risk of effects on water quality adding to the effects from operational discharges

5.9.4.1. Cumulative/in-combination effects with construction/commissioning phase discharges

The construction permits associated with the project have not yet been applied for and information on construction discharges was not provided as part of the application for operational discharges. An indicative timeline, submitted as part of the DCO process, indicates that the following construction/commissioning discharges into the Suffolk coastal water may be needed and applied for in the future:

- Groundwater dewatering – routine dewatering may occur from year 3 of construction up until SZC is operational (year 13), with the worst case for trace heavy metals expected to occur during the first year of dewatering. The applicant states, in the DCO Environmental Statement, that it predicts contaminant levels would exceed thresholds over a small area for a short period (one month).
- Treated surface water run-off from wider site, including deep excavation area.
- Construction phase sewage treatment effluent – from the start of year 3 until operational phase. The applicant states, in the DCO Environmental Statement, that it predicts negligible residual effects.
- Cold commissioning water, which would contain hydrazine, with the worst case expected to occur in year 4 of construction. The applicant states, in the DCO Environmental Statement, that it predicts minor adverse effects.
- Water from concrete wash and tunnel construction for intakes and outfalls – indicative timeline stretches up until operational phase, with worst-case tunnel chemicals expected in year 5 of construction. The applicant states, in the DCO Environmental Statement, that it predicts minor adverse effects.

We have insufficient information to be certain about the timing, duration or the size of plumes from construction and commissioning discharges at this stage. However, the effects of any interaction between construction, commissioning and operational discharges are likely to be only temporary and are unlikely to change the individual assessments of effects. When the construction permit applications are submitted, further information will become available. This will allow a further WFD assessment of those discharges to be carried out when those construction permit applications are determined, including an assessment of the construction discharges in combination with the operational discharges.

5.9.4.2. Cumulative/in-combination effects with combustion activities

12 diesel generators would be used during commissioning, routine testing operations and in the event of loss of off-site power (operation would be infrequent: estimated as less than 60 hours per year). The applicant did not consider combustion activities as part of its compliance assessment with the Water Environment Regulations, but it has assessed the risk of combustion activities to the features of national network sites, including marine sites, as part of its shadow HRA. The applicant screened for likely significant effects from combustion activity alone by assessing modelled emissions of sulphur dioxide and nitrogen oxide against environmental standards. It also assessed nitrogen deposition and acid deposition against site-specific critical loads.

The applicant predicts that the emissions from combustion activities alone would be below critical levels/loads that could have a likely significant effect on HRA features of national network sites. This is apart from Minsmere to Walberswick Heath and Marshes, where levels of nitrogen oxide and increases in nitrogen and acid deposition are predicted to exceed screening thresholds.

The applicant concluded that emissions would have an insignificant environmental impact (and likely significant effect can be excluded) for the qualifying features of the Alde-Ore, Butley and Outer Thames Estuaries, and the Southern North Sea. Some of the qualifying features considered in that assessment, such as saltmarsh, are also relevant quality elements for this WER assessment. We are satisfied that where the impact of the combustion activity alone is insignificant, it is unlikely to change the outcome of our assessment of the operational water discharge permit activities, even though some diffuse nitrogen deposition into the marine environment could occur.

The applicant carried out a stage 2 appropriate assessment of the combustion activity for Minsmere to Walberswick, where coastal dune habitat, dry heath and fen/swamp are predicted to experience increases in nitrogen and acid deposition above critical loads. The applicant noted that background levels of nutrient and acid deposition already exceed the critical load. It concludes that, since the process contributions would be short term and temporary and background deposition rates are high, the process contributions are unlikely to result in significant changes in species composition, and adverse effect on the integrity of the sites would not occur. There is limited connectivity between the marine and freshwater environments at Minsmere Sluice, which allows seawater into the freshwater marshes under specific flow conditions.

Nitrogen from the cooling water outfall is predicted to equate to 0.2% of daily exchange, and when combined with the FRR system discharge, is predicted to equate to 0.3%. We are satisfied that any interaction between the CW/FRR system with CA deposition is unlikely to change the individual assessment of effects from the CA on Minsmere due to the minimal predicted effect from the water discharge activities on marine water quality at the coastline and the fact that seawater can only enter the sluice under specific flow conditions.

5.9.4.3. Cumulative/in-combination water quality effects with dredging activities

During the operational life of the project, the navigational channel leading up to the beach landing facility may require dredging each time before the beach landing facility can be used for abnormal indivisible loads. The applicant predicts (in its Environmental Statement) that the beach landing facility would be used once every 5 years during the SZC operational phase (most likely April to October). Sediment contamination levels are not expected to be significant, therefore the main pressure with the potential to affect water quality is resuspension of sediment. The applicant predicts that maintenance dredging would create a transient plume, with up to 28ha of sea surface expected to experience >100mgl^{-1} above background suspended sediment concentrations on each occasion. The scale of dredging is small in relation to the size of the Suffolk coastal water and any impacts after each period of dredging activity would be temporary. Therefore, we are satisfied that any interaction between operational water discharge activities with dredging is unlikely to change the individual assessment of effects from the cooling water and FRR system outfalls.

5.9.5. In-combination/cumulative effects with other projects

The applicant has screened out all other projects from a shortlist (agreed as part of the DCO EIA process) with a spatial/temporal link to the operational phase of the SZC project from its WFD assessment. Projects were screened out mainly because the effects from other projects are not predicted to be significant (due to limited spatial scale or temporary nature of effects). We are satisfied with the applicant's screening assessment of other projects.

6. Conclusions

This document reviewed the assessments made to date with regards to the compliance of activities associated with SZC with the Water Framework Directive. The applicant's Water Framework Assessment (EDF, 2021a) screened in many activities that could affect compliance with WFD. That assessment concluded that SZC would not jeopardise compliance with WFD.

We evaluated this assessment and carried out further work to re-evaluate the biota discharged out of the fish recovery and return system.

- The revised biota figures demonstrate an increase in the modelled area of impact but do not give rise to any additional impacts that could compromise WER objectives for water quality, habitats or fish.
- The potential thermal impacts on smelt (due to the cooling water plume) was a concern as the available scientific evidence was not sufficient to demonstrate whether smelt will avoid the area of the thermal plume at the 2°C or 3°C uplift, or what effect absolute temperatures will have on this species. A breeding population of smelt is known to exist in the Alde and Ore waterbody. Smelt have also been recorded in the Blyth waterbody, but there is insufficient evidence to confirm a breeding population. Avoidance of or delays due to the presence of a thermal plume while undertaking a spawning migration has the potential to affect reproductive success. While there remains some uncertainty in this assessment, it is considered that the risk of deterioration due to significant avoidance as a result of the thermal plume remains low. So no deterioration is expected.
- It is important to note that no in-combination assessment that considers the abstraction impacts has been provided in the applicant's assessment or this review, as that is being led through the WER assessment for the DCO.

It is useful to note that suitable agreement on mitigation measures is being secured through the SZC DCO (via its Deed of Obligation and Deed of Covenant), and a robust monitoring programme put in place which would trigger additional compensation if required. We feel that risks to the transitional fish populations due to the uncertainties in the data could be managed.

This agreement will include the installation of fish passes at Snape Sluice on the Alde and Blyford Bridge Sluice on the Blyth prior to the abstraction of any cooling water from the station. Should a population deterioration be observed to smelt as a result of the operation of SZC in the Alde and Ore water body, then further funding will be released to undertake additional compensatory improvements in this water body.

Improving fish passage in the barriers in the Alde and Ore and Blyth Estuaries will help smelt breed more successfully in these water bodies; this will help smelt populations in these water bodies be more resilient to human impacts.

NNB GenCo (SZC) has also committed to undertake entrapment monitoring of all species once the SZC station becomes operational. Should a population deterioration be observed that can be attributed to the operation of SZC, then further funding (which has been secured through the Deed of Obligation and Deed of Covenant) will be released to undertake additional mitigation. Should the increased risk of deterioration to the fish element under the WER be anticipated in the Alde and Ore water body, which can be attributed to the operation of SZC, this would also trigger the release of funds to deliver mitigation through habitat improvements for fish.

We have general agreement that our own in-combination assessment has demonstrated that there will be no compromise to WER objectives when considered alongside the other activities associated with the construction or operation of the site**. However, since the applicant has not formally provided information on the construction permits, our conclusions on these are informative/indicative only and subject to a formal assessment at the time these are considered in the application process.**

Considering the limitation of the scope of this assessment for in-combination, and with the measures in place under the Deed of Obligation and Deed of Covenant, our assessment of these impacts concludes that there is minimal risk of these activities affecting compliance with WER and compromising achievement of WER environmental objectives.

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