The Sizewell C Project

9.57 Acoustic Fish Deterrent Report

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1 EXECUTIVE SUMMARY

1.1.1 NNB GenCo (SZC) Ltd, hereafter SZC Co., is proposing to build a new nuclear power station at Sizewell in East Suffolk, known as Sizewell C.

1.1.2 This report is being provided as a Supplementary Submission to provide an explanation of the fish protection measures proposed for Sizewell C, in particular why an Acoustic Fish Deterrent (AFD) system is not proposed in the suite of mitigation measures proposed.

1.1.3 As part of the Alternatives and Design Evolution Chapter of the Environmental Statement (Volume 2 Chapter 6 [APP-190]), SZC Co presented a description of potential measures to mitigate impacts on fish due to abstraction via the cooling water system and a justification as to why it wasn't feasible to include those measures.

1.1.4 The Environment Agency, Marine Management Organisation, Natural England and the Eastern Inshore Fisheries Conservation Authority, together with several other interested parties, have subsequently requested further justification in particular as to why an AFD is not proposed at Sizewell C.

1.1.5 Sizewell C will abstract a tidally averaged 132.5 $m^3 s^{-1}$ from the Sizewell Bay to cool the steam that turns the electricity generating turbines in the secondary circuit.

1.1.6 To mitigate impacts on fish and crustaceans that would be drawn into the power station with the seawater, two main mitigation measures are incorporated into the Sizewell C cooling water infrastructure design.

1.1.7 A specially designed intake head, in general accordance[1] with Environment Agency recommendations/guidance (Ref 1), that has been suggested to reduce the number of fish being abstracted. The Low Velocity Side Entry (LVSE) intake head abstracts water at a low velocity to enable fish to swim away from the intake should they choose to do; it only draws water in from the side as fish are better able to escape horizontal currents; and is aligned parallel with the tide to avoid tidal currents forcing fish into the intake.

1.1.8 A Fish Recovery and Return (FRR) system, again in general accordance[1] with Environment Agency recommendations/guidance, will also be incorporated into the Sizewell C design. It is recognised that exclusion of fish from the cooling water system is not feasible so the FRR is designed to

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[1] Some elements of the UK European Pressurised Reactor (UKEPR) design mean that complete agreement is not always possible however the design meets set criterias as much as possible and justifications are available where criteria are not met.

recover any fish that are abstracted and return as many as possible to the sea safely.

1.1.9 An AFD system would also ordinarily be considered a standard part of the fish mitigation measures. Whilst such a system can be provided on shore-based cooling water abstraction points, the Sizewell C intakes will be located more than 3 km from the shore. AFD systems have never been installed in such locations and detailed optioneering and engineering work undertaken for the twin UKEPRs presently being constructed at Hinkley Point has shown that the safe installation and maintenance of an AFD system at such offshore locations is not feasible.

1.1.10 The Sizewell C intake heads will be located >3km from shore, in water depths of approximately 12 m, and exposed to high turbidity and current velocities from tidal flows. The only way to install and maintain an AFD system in these locations is to utilise either Remotely Operated Vehicles (ROVs) or divers. There is no ROV presently available that would be able to maintain position in the tidal flows at Sizewell, be small enough to safely manoeuvre around the safety classified intake heads or has the required mechanical dexterity to perform the necessary tasks of uncoupling/recoupling electrical cables and manipulating the AFD system or its mounting frame.

1.1.11 SZC Co is of the view, therefore, that AFD systems are not available (‘Best Available Technique’) nor used in practice (‘Best Environmental Practice’) at offshore intake heads with conditions as at Sizewell.

1.1.12 As part of its Environmental Impact Assessment (EIA), SZC Co has assessed the potential impacts of cooling water abstraction on fish species and populations with and without each of these mitigation measures (LVSE and FRR). With LVSE intake heads and an FRR already incorporated successfully as part of the cooling water system design, the cooling water abstraction of Sizewell C will not have a significant impact on either individual fish species or fish populations or stocks.

1.1.13 While it is acknowledged that incorporation of an AFD system could potentially mitigate further the impacts of Sizewell C on certain fish species, for example sprat and herring, SZC Co does not consider the potential additional benefits justify the attendant significant safety risks to its workforce or contractors.

1.1.14 At a superficial level, a less effective system, for example with fewer AFD units, might appear to mitigate potential safety concerns by requiring a less frequent maintenance schedule and/or smaller scale of maintenance regime. However, in reality the majority of the same constraints still apply and, given the assessed lack of significant impacts without an AFD system, there remains no justification for installation of a sub-optimal system.

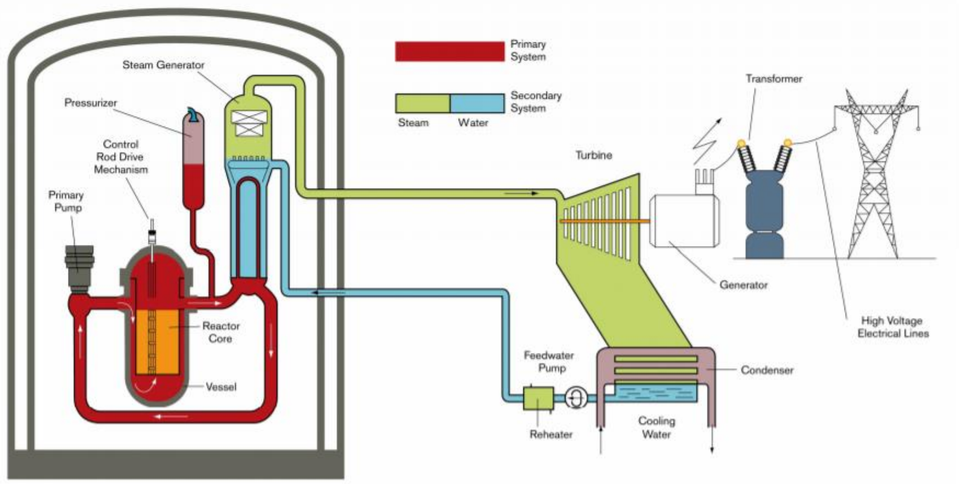
2 INTRODUCTION

2.1 Sizewell C Nuclear Power Station

2.1.1 The proposed Sizewell C nuclear power station would comprise two UKEPR units with an expected net electrical output of approximately 1,670 megawatts (MW) per unit, giving a total site capacity of approximately 3,340MW. The design of the UKEPR units is based on technology used successfully and safely around the world for many years, which has been enhanced by innovations to improve performance and safety. The UKEPR design has passed the Generic Design Assessment (GDA) process undertaken by the United Kingdom (UK) regulators (Office for Nuclear Regulation and Environment Agency) for construction and operation in the UK. The first UKEPR is already under construction at Hinkley Point in Somerset (Hinkley Point C; HPC) and Sizewell C would be the second in the UK. Once operational, Sizewell C would be able to generate enough electricity to supply approximately six million homes in the UK.

2.1.2 The cooling water infrastructure of the UKEPR is formed of three cooling systems, comprising primary, secondary and tertiary systems (the tertiary circuit is an open circuit). These are shown schematically in **Figure 1-1**. A summary of the parameters associated with the cooling water infrastructure proposed at Sizewell C is provided within the Sizewell C Development Consent Order (DCO) application Environmental Statement (Volume 2, Chapter 2: Description of Permanent Development [APP-180]).

Figure 2.1 Basic UKEPR Schematic



2.1.3 In order to minimise potential impacts on fish from the abstraction of 132.5 m^{-1} s^{-1} of seawater for the tertiary circuit, several mitigation measures exist – these are detailed in the Environment Agency's 2010 guidance document "*Cooling Water Options for the New Generation of Nuclear Power Stations*" (Ref 1) and considered in the Alternatives and Design Evolution Chapter of the Environmental Statement (Volume 2 Chapter 6 [APP-190]).

2.1.4 Three principal measures, in order they are encountered by fish, are: Acoustic Fish Deterrents (AFDs) that are installed at the intake heads to create a large sound field that scares some species of fish away from the intake; an intake head that draws water in at flows low enough that fish can swim away (a Low Velocity, Side Entry, or LVSE, intake); and a system that recovers any fish that *are* drawn in with the flow and puts them back to sea (a Fish Recovery and Return, or FRR, system).

2.1.5 Sizewell C has successfully incorporated the LVSE intake heads and the FRR system into the design but is not proposing to install an AFD system as it is unable to install and maintain such a system safely.

2.2 Environmental Impact Assessment

2.2.1 The methods used in the Environmental Impact Assessment (EIA) and shadow Habitats Regulations Assessment (sHRA) to determine the impacts of the cooling water abstraction on the marine environment at Sizewell C at the point of DCO submission are considered to represent best practice.

2.2.2 Fish (and other marine organisms) that are drawn into the cooling water abstraction have one of two outcomes:

a) Those that are small enough to pass through the power station's fine filtration screens are '*entrained*': they transit the entire cooling water system and are finally ejected in the main cooling water system discharge via the cooling water outfall 3 km from shore;

b) Those that are too large to pass through the fine filtration screens are '*impinged*': they are removed by the screens, transit through the FRR system and are discharged via the FRR outfall a few hundred metres from shore.

The impact assessment must consider both those organisms that are entrained and those that are impinged – the term "*entrapment*" is used to describe this combined effect

2.2.3 Monitoring of fish at the filtration 'drum' screens at Sizewell B (adjacent to the proposed Sizewell C site) was used to estimate the species, number and size of fish likely to be entrapped by Sizewell C – this is achieved by scaling up the number of fish trapped at Sizewell B to account for the larger volume of water being abstracted by Sizewell C.

2.2.4 Entrainment was monitored at Sizewell B in a similar fashion, by pumping water from the forebay into collection vessels and using microscope techniques to identify and count the organisms therein. The species and number of organisms entrained at Sizewell B were scaled up to Sizewell C abstraction volume in a similar manner to those impinged.

2.2.5 The sampling programme for impingement and entrainment followed an intensive (up to 28) 24h long sampling visits, randomly chosen to account for diurnal (light and tide) and seasonal variation in presence of marine organisms. This ‘comprehensive’ sampling technique (Ref 2) was developed specifically for Sizewell C (and Hinkley Point C) and is endorsed by the Environment Agency (Ref 3).

2.2.6 Having estimated the number of each species of fish likely to be entrapped by Sizewell C based purely on the size of the Sizewell C flow, the predicted effects of various mitigation measures are applied, for Sizewell C these are the benefits of fitting LVSE intake heads and a FRR system.

2.2.7 Having considered the effects of proposed mitigation, the predicted numbers of fish entrapped are then adjusted to account for the fact that of those fish would naturally be lost form the ecosystem anyway. Impinged fish are typically small juvenile fish and, along with entrained eggs and larvae, typically suffer very large mortalities naturally due to predation, disease etc. Put simply, many of the fish that are impinged or entrained would not naturally survive to adulthood (and therefore not contribute to the spawning stock) so it would not be appropriate to attribute their loss entirely to Sizewell C. To account for this, a calculation is made to provide an “equivalent adult value” – that is to say if, for example, species *A* would naturally only have a 50% chance of survival to adulthood, the number of entrapped fish would be subject to a 50% reduction to account for this.

2.2.8 Finally, the number of ‘equivalent’ adult fish are then compared with the baseline fish numbers to ascertain whether the numbers removed by SZC are significant.

2.2.9 The EIA and sHRA for Sizewell C both concluded that Sizewell C when fitted with an LVSE intake head and FRR system, but without an AFD, would not have a significant impact on fish species or populations.

2.2.10 Since the Sizewell C application was made in May 2020, considerable further discussion on methods for estimating impingement and entrainment has been undertaken with the Environment Agency as part of the Hinkley Point

C project, where HPC Co. has applied to remove the need for an AFD system, and the methods used in the entrapment assessments have undergone further scrutiny through the process of an environmental appeal against deemed refusal of that application

2.2.11 **Table 2.1** summarises the elements of the entrapment assessment that are agreed and not agreed between SZC Co and the Environment Agency

Table 2.1: Entrapment Assessment Elements and Current Position with the Environment Agency

Element	Agreed?	Summary	Position
LVSE mitigation	Partially	The EA argues that the LVSE without an AFD system will have no benefit. SZC Co contends that the LVSE intake will provide some benefit even without an AFD	Agreed ratio of 1:1 for scaling up from SZB intake to SZC intake. SZC Co believes this to be highly precautionary
FRR survival	Y	EA published survival rates in its 2010 document which SZC Co used in the EIA. EA has subsequently revised those rates.	SZC will use EA's revised rates
EAV	N	EA requests an additional step (SPF = spawner production foregone) to be included in the EAV calculation to account for 'repeat spawners' (those fish that spawn over several years). SZC Co. argues the SPF step introduces further uncertainty, does not include certain key parameters (e.g., loss of the fish due to fishing etc) and is not compatible to compare with baseline. Ultimately the SPF extension	Remains disputed

Element	Agreed?	Summary	Position
		does not result in the calculation of an ‘annual rate of mortality’ and therefore is not a correct basis for ascertaining the annual impact of SZC.	
Baseline	N	SZC Co have used internationally recognised ICES[2] stock areas for the baseline but the EA have argued these are too large. SZC Co has subsequently provided a much more localised assessment based on likely depletion from the abstraction zone, with caveats.	Remains disputed

2.2.12 It is important to note that the Marine Management Organisation agrees that the EAV factor that has been used (i.e. without the SPF addition) and the scale of assessment (i.e. using ICES stock areas) are appropriate (see [REP2-082]).

2.2.13 However, the Marine Management Organisation agrees that while it is feasible that an LVSE intake without an AFD system will mitigate fish impingement, there is no evidence to corroborate the assertion (see [REP2-082]).

2.2.14 In recognition of the disputed methods and efficacy of proposed mitigation, and at the request of the Marine Management Organisation, a sensitivity analysis is being undertaken to assess the impact of Sizewell C operating without any mitigation being provided by the LVSE intake head design or FRR.

2.3 Purpose of this report

2.3.1 This report is being provided as a Supplementary Submission to provide an explanation of the fish protection measures proposed for Sizewell C, in

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[2] International Council for the Exploration of the Sea

particular why an Acoustic Fish Deterrent (AFD) system is not proposed in the suite of mitigation measures proposed.

2.3.2 As part of the Alternatives and Design Evolution Chapter of the Environmental Statement (Volume 2 Chapter 6 [APP-190]), SZC Co presented a description of potential measures to mitigate impacts on fish due to abstraction via the cooling water system and a justification as to why it wasn't feasible to include those measures.

2.3.3 The Environment Agency, Marine Management Organisation, Natural England and the Eastern Inshore Fisheries Conservation Authority, together with several other interested parties, have subsequently requested further justification in particular as to why an AFD is not proposed at Sizewell C.

2.3.4 In the main, this report builds upon the considerable engineering exercise that was undertaken for, and lessons learned from, Hinkley Point C but applying site-specific considerations for Sizewell in order to reach a judgment on the need for, and viability of, an AFD.

2.4 History

2.4.1 In its 2010 evidence report "*Cooling Water Options for the New Generation of Nuclear Power Stations in the UK*", the Environment Agency makes the statement "To meet Best Practice, the intake should be fitted with an acoustic fish deterrent (AFD) system" (Ref 1, Table 5.2).

2.4.2 In the early stages of the planning of Sizewell C, an acoustic fish deterrent was proposed. This was a reference to the Environment Agency 2010 report. At that stage, no design was available (not even a basic design), and the commitment was simply an indication that Best Practice would be followed and a belief that such system could be engineered for the novel Sizewell C intakes.

2.4.3 However, during that same period, considerable optioneering and detailed design work was undertaken for Hinkley Point C where, for the same reason, an AFD system had been proposed, again on the assumption in principle that a system could be engineered, rather than based on any detailed design. In fact, the Hinkley Point C DCO application did propose a design that had the sound projectors mounted on spars at the end of each intake head, powered by tidal turbines but, at the detailed design stage, the proposed design was found to be unfeasible, in terms of engineering, power supply terms and sound field efficacy.

2.4.4 Approximately 2 years-worth of optioneering and detailed design followed at Hinkley Point C and concluded that installation of an AFD was extremely challenging due to a number of issues but, more importantly, that maintenance of the system would require extensive diver work that was considered an unacceptable safety risk. At that point, an assessment of potential impacts of fish impingement without an AFD system was made and HPC Co. applied to have the AFD system removed from the proposed cooling water system design.

2.4.5 Due to the findings of the HPC detailed design process, the Sizewell C project made a comparative assessment for the cooling water system design at Sizewell and found that all of the constraints encountered at Hinkley Point C also applied at Sizewell. For that reason, an AFD system was no longer included within the emerging Sizewell C proposals

2.4.6 This report provides the rationale for why an AFD system is not proposed for Sizewell C, drawing on the large body of evidence available from studies at HPC.

2.4.7 This report also considers the opinions of Fish Guidance Systems Limited (FGS Ltd.) submitted to the Sizewell C Examining Authority at Procedural Deadline B "*Sizewell C Acoustic Fish Deterrent (AFD)*" [PDB-061]. FGS Ltd. is arguably the only potential supplier of an AFD system for Sizewell C, and therefore has a strong commercial interest in seeking to persuade the Secretary of State that such a system is both feasible and necessary.

2.4.8 FGS Ltd. argues that it can provide an AFD system that is feasible and safe to install and maintain at Sizewell C. This report also examines the claims made by FGS Ltd. to help the ExA and Secretary of State to form a view as to the feasibility of an AFD system at Sizewell C.

2.4.9 The feasibility of installing an AFD system is also considered against the EIA and sHRA findings that Sizewell C, operating with an LVSE intake head design and FRR system, would not have a significant impact on fish species or populations if an AFD system is not fitted.

3 BACKGROUND TO THE SIZEWELL C COOLING WATER SYSTEM

3.1 Introduction

3.1.1 Design of the heat sink (the means by which the station loses the heat from its condensers) is an extremely important aspect of system design for nuclear power stations, in terms of both safety and efficiency as well as environmental impacts.

3.1.2 Considerable work has preceded the selection of the preferred cooling water system specified within the DCO (with Deemed Marine Licence) application. An overview is provided below with further details available within the Sizewell C DCO application Environmental Statement (Volume 2, Chapter 4: Description of Operational Development) [APP-187].

3.2 Key Components of the Sizewell C Cooling Water System

3.2.1 The key components of the SZC cooling water system are summarised in **Table 3.1** below.

Table 3.1: Cooling Water System Components (asterisk denotes elements that have been agreed as part of system design at Hinkley Point C that will be replicated at Sizewell C).

System / Building	Description
Cooling Water System Intakes	Low Velocity, Side-Entry (LVSE) intake head*
	Intake shaft*
	Intake tunnel*
Forebay	Forebay*
Cooling Water Pump House	Debris rack and rake*
	Bandscreen*
	Drum screen*
	Connection gutters*
Filtering Debris Recovery Pit	Filtering debris recovery pit basin
	Debris rack and rake*
Fish Return Tunnel	Fish return tunnels
	Fish return outfall structure*
Cooling Water System Outfalls	Outfall tunnel
	Outfall shaft*
	Outfall head*

3.2.2 The optimisation of the design of the cooling water system buildings, structures, systems and components has been carried out to ensure that they perform their primary functions (i.e., provision of adequate and reliable supply of cooling water to meet all plant operating states) taking into account a range of other variables including:

- Nuclear safety;
- Industrial safety;
- Fish protection;
- Other environment and sustainability concerns;
- Constructability;
- Operability and operator burden;
- Maintenance burden;
- Supplier experience; and
- Cost (proportionality assessment).

3.3 Intake Locations

3.3.1 Establishing cooling water intake and outfall locations is an activity that must be carried out very early in the concept development for a large, direct cooled power station as the provision of adequate volumes of cooling water and safe dispersion of the thermal plume are critical to the safe operation and siting of a new facility.

3.3.2 The two key requirements for the appropriate positioning of the cooling water intake structures are:

- The need for safe and efficient operation (including the requirement to incorporate redundancy against hazards in the design); and
- The consideration of environmental sensitivities.

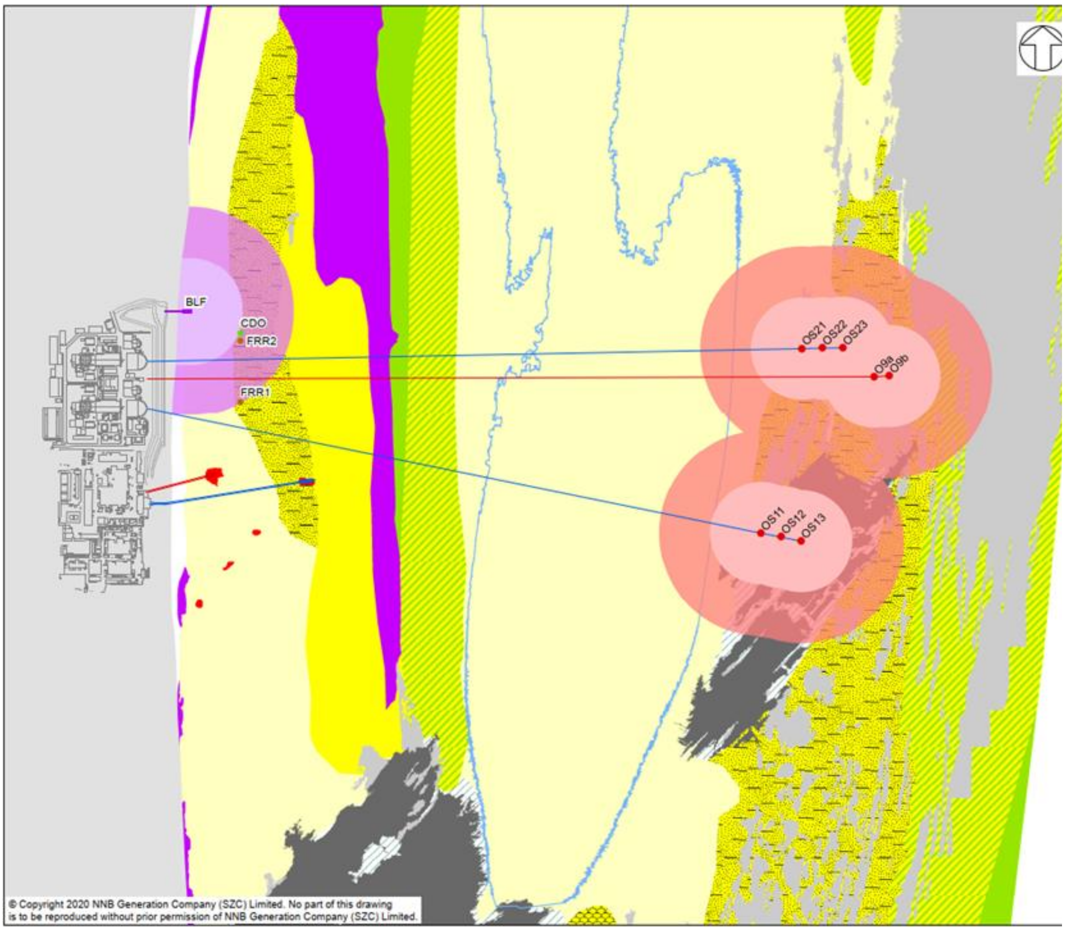
3.3.3 In addition to these key requirements, the intake structures must also:

- Be sufficiently robust to provide a supply of suitable water that will be constant and consistent for the duration of the power plant operation (60 years) in the exposed coastal environment along the Sizewell frontage where there are very limited opportunities for future maintenance;

- Abstract water at a sufficient depth so as to not cause a surface vortex or draw in air during extreme tidal conditions or wave troughs;
- Avoid interactions with bed sediment transport to avoid entraining solids that may accumulate and block the cooling water system;
- Reduces the amount of biota abstracted with the water intake;
- Be geologically suitable (i.e., comprises suitable bedrock for construction and is inactive in respect of faulting or tectonic movements);
- Not cause a hazard to navigation by ships (to minimise risk of impact on the headworks);
- Be sufficiently far away from the associated cooling water outfall headworks, so that water discharged from the outfall is not recirculated back into the intake; and
- Be as close to the station as possible to reduce the pumping capacity required by the system cooling water system.

3.3.4 At Sizewell, an offshore intake position was selected as the preferred option; **Figure 3.1** below highlights the intake locations.

Figure 3.1: Intake Locations (blue lines; 2 from 3 locations on each tunnel to be selected)



3.4 Intake Heads

3.4.1 The Environment Agency has issued several reports detailing criteria for the types of measures that should be adopted at new direct cooled power stations to reduce the potential environmental impacts associated with abstracting large volumes of seawater for cooling and specifically. This guidance is summarised below:

- Screening for Intake and Outfalls: a best practice guide (Environment Agency, February 2005).
- Cooling water options for the new generation of nuclear power stations in the UK (Environment Agency, June 2010);

- Protecting biota from cooling water intakes at nuclear power stations – Scoping study (Environment Agency, August 2018);
- Nuclear power station cooling waters: evidence on 3 aspects (Environment Agency, April 2019); and
- Nuclear power station cooling waters: protecting biota (Environment Agency, April 2020).

3.4.2 As Environment Agency 2010 (Ref. 1) explains, the selection of potential impingement mitigation measures involves a complex consideration of the likely effectiveness of each measure in the marine environment at the station location, engineering feasibility and operational safety for staff and the plant.

3.4.3 For Sizewell C, a detailed consideration of the effectiveness and feasibility of the available impingement mitigation options has been conducted and is summarised within Volume 2 Appendix 22i of the ES [APP-326] and Volume 3 Appendix 2.17A of the ES Addendum [AS-238]. In relation to the intake heads specifically, these studies demonstrate that the use of LVSE intakes is feasible for the Sizewell C site.

3.4.4 LVSE intake heads have already been designed, approved for use and built at Hinkley Point C (see **Figure 6.4**). These very large intake structures are designed to minimise impingement by:

- reducing vertical velocities by means of velocity caps on the intakes from which fish are ill equipped to resist;
- reducing intake velocities into the head to a target velocity of 0.3m/s over as much of the length of the intake surface which will maximise the possibility of most fish avoiding abstraction; and,
- removing the exposure of the intake surfaces to the tidal stream and in so doing reduce the risk of impingement for fish swimming with the tidal stream. i.e., to reduce the cross-sectional area of the intake to the prevailing tidal directions by mounting the head parallel to the tidal flow.

3.4.5 LVSE intakes have the advantage of reducing impingement for all fish species at risk of abstraction for the UK EPR^{TM} and those at Hinkley Point will be the first deployment of this technology on operational power stations worldwide; they represent a considerable advance in the design of intake heads.

3.4.6 The LVSE intake head for Sizewell C will be a modified version of the design approved by the EA, MMO, NE and NRW for Hinkley Point C:

a) Many of the internal baffles, intended to create a more linear abstraction flow, have been removed. The baffles would provide an increased surface area that would be prone to colonisation ('fouling') by sedentary marine animals such as mussels which would then serve to decrease the aperture size, thereby affecting flow rates.

The Sizewell C intake heads are too far offshore to chlorinate reliably (and, if they were, would mean that fish transiting the intake tunnels would be exposed to chlorinated water). Instead, a modified LVSE design has been proposed. To reduce the biofouling risk, it has been necessary to remove as many of the internal baffles (vertical faces to 'smooth' the intake flow along the length of the intake head) as possible and to reduce the surface area flow within the head

b) The 'nose' pieces at the end of each structure, which are suspended isometric triangles in the Hinkley Point C design, will be simplified to triangular wedges that will sit on the seabed. This is an engineering change for constructability purposes that modelling has confirmed does not impact hydraulic performance

3.5 Fish Recovery and Return System

3.5.1 A FRR system is designed to return robust species (particularly flatfish, eels, lampreys and crustacea and to a lesser extent demersal species such as bass, cod and whiting) that are impinged on the drum and band screens safely back to sea.

3.5.2 For the UKEPR, a FRR system has been designed and, following intensive design scrutiny, has been received regulatory approval for Hinkley Point C.

3.5.3 The whole Sizewell C project will replicate the design of Hinkley Point C as much as possible so the HPC FRR design will be also replicated as much as possible for at Sizewell C.

3.5.4 However, the reduced tidal range at Sizewell compared with Hinkley allows several design changes that are improvements over the Hinkley Point C design:

a) The reduced tidal range means that the drum screens can be smaller – the diameter will be 4 m less than at Hinkley Point C which means that the rotation time (and time that fish and biota will be in the bucket will be shorter than Hinkley Point C);

b) Due to the reduced tidal range, and the elevations of buildings on the power station platform, the debris recovery building is at a suitable elevation to drain back to sea under gravity directly from its floor. At Hinkley Point C due to the large tidal range the material needs to be elevated to platform level by use of an Archimedes screw – which obviously involves an additional element of "fish handling" (i.e., manipulation) within the FRR. An Archimedes screw is not required at Sizewell.

c) And finally, again due to the reduced tidal range and lack of the need for an Archimedes screw, each UKEPR unit will have its own, dedicated FRR tunnel to return fish to sea from the debris recovery building which is more direct and therefore reduces transit time for fish through the system.

3.5.5 The drum and band screens are fine, stainless steel mesh filters to remove impinged organisms from the cooling water flow. The default mesh size for the UKEPR reactor is 5 mm square as opposed to the 10 mm mesh screens employed at Sizewell B. However, after consideration of the risk of clogging in the summer by swarms of ctenophores (a gelatinous marine organism, rather like jellyfish), it is proposed to fit 10 mm mesh, which has been proven not to cause clogging at Sizewell B.

3.5.6 In the ES, mitigation from both the LVSE and FRR were predicted to provide various levels of mitigation as demonstrated in **Table 3.12**.

3.5.7 However, considerable further discussion in terms of the mitigating influence of LVSE intake heads without an associated AFD system and the FRR system.

3.5.8 In addition, some supporting documents have been updated following an audit of the raw data by the Environment Agency under the WDA permit. The changes do not alter the assessment outputs, but the precise numbers of fish reported are different in places. Once discussions with the Environment Agency have concluded SZC Co will update the impingement assessment report (Volume 1 Chapter 3 Appendix 2.17A of the ES Addendum [AS-238]; See TR406) to reflect the revised numbers. The updated report will be submitted at Deadline 8.

3.5.9 Furthermore, at the request of the MMO, SZC Co is performing a sensitivity test to ascertain how important the proposed mitigation effects are in terms of the overall EIA.

3.5.10 In its response to Examining Authority question BIO1.245 the MMO asserts that "*it is feasible that the LVSE design, on its own, will provide some benefit in terms of reductions in fish impingement*" but without any evidence to corroborate this has requested an impingement assessment that does not take any benefit of the LVSE.

Table 3.2: Predicted reduction in impingement mortality for SZC fitted with LVSE and FRR

Group	Example Species	Mortality Reduction
Pelagic fish	sprat, herring, anchovy, shad	62%
Demersal fish	bass, cod, whiting, grey mullet	77-79%
Epibenthic fish	eel, lampreys, sole, sand goby	92%
Shellfish	eel, lampreys, sole, sand goby	92%

4 APPROACH TO THE DETAILED AFD ENGINEERING PROCESS UNDERTAKEN FOR HINKLEY POINT C

4.1 Introduction

4.1.1 Following the decision to fix intake locations at Hinkley Point C, a comprehensive consideration of the design, construction, operation and maintenance of an AFD system was undertaken. Costain, the contractor responsible for the construction and delivery of the Cooling Water System at the time, were selected to undertake this work.

4.1.2 Costain's extensive knowledge of operations in marine environments and delivery of complex offshore and subsea solutions, together with their existing responsibility for delivery of the intake head design, meant that they were ideally placed to undertake the design and delivery of the AFD system.

4.1.3 Prior to Costain's appointment, a comprehensive multi-disciplinary team were involved in various elements of the Cooling Water System design and critical review process. This included civil engineers, structural engineers, subsea engineers, electrical engineers, mechanical engineers and marine ecologists. The process was also supported by a range of specialised companies, summarised below:

- ROVCO - Specialist Remotely Operated Vehicle (ROV) expertise
- James Fisher - Specialist Diving expertise
- HR Wallingford – Hydraulic Modelling
- FGS – Acoustic Modelling and AFD system design

4.1.4 The detailed AFD optioneering and design development phase took place over the course of approximately two years.

4.1.5 Key phases of the engineering process are summarised in **Table 4.1**.

Table 4.1: Summary of Engineering Process

Stage	Description
Pre-optioneering	• Resolution of technical queries • Supplier appraisal • Lessons learned from other projects • Definition of selection criteria • Brainstorming and selection of options for more detailed assessment
Optioneering	Technical and cost estimate of a selection of options for: • Speakers location • Mounting Structure • Electrical distribution • Shore crossing
Selection Workshop	Review of options

NNB Technical Committee	Validation of the preferred options
Consolidation Phase	Optimisation of the selected option
Design Development	• Maintenance strategy • Detailed design of the structures to support the speakers

4.1.6 It is important to recognise that at the time of this process being undertaken, the amount of evidence and credible scientific data associated with the design, installation, operation and maintenance of AFD systems in offshore environments was extremely limited (in fact completely lacking).

4.1.7 This is endorsed by the Environment Agency, who summarise that "*Few studies cover off-shore intakes at coastal or estuarine environments similar to UK nuclear power station requirements. Information on maintenance and reliability of the technologies is limited*" (Ref 4).

4.1.8 The process undertaken at Hinkley Point C therefore, represents an unprecedented, detailed investigation into detailed design of AFD for offshore intakes in the UK (and probably further afield).

5 REQUIREMENT FOR AN AFD

5.1.1 There is no legislative or policy requirement for the installation of an AFD on a direct-cooled new build Nuclear Power Station in the UK. Nor is there a legislative or policy requirement for the installation of a LVSE intake head design nor a FRR.

5.1.2 EN1 states that development should '*aim to avoid significant harm to biodiversity…including through mitigation*…'. Under the Habitats Regulations mitigation can be taken into account in the conduct of the appropriate assessment.

5.1.3 The EIA for Sizewell C concludes that there would be no significant adverse impact upon fish species or populations. The sHRA concludes that any impacts upon fish species or populations would not cause an adverse effect on the integrity of any European Site. These assessments have been conducted for the development as applied for, i.e., with no AFD in place. This is important as it demonstrates that there is no legal or policy basis for requiring an AFD, particularly in circumstances where it would be unsafe to install and maintain it.

5.1.4 In its 2010 report, the Environment Agency makes a specific statement on the need for inclusion of AFD: "*To meet Best Practice, the intake should be fitted with an acoustic* fish deterrent (AFD) system" (Ref 1, Table 5.2). However, the issues of feasibility (including the safety of those installing and maintaining the system) clearly need to be taken account of in assessing what is 'best practice' for the SZC project.

5.1.5 In its draft Statement of Common Ground (SoCG) with SZC Co. [REP2-068], the Environment Agency makes the statement "*EA considers SZC Co have not demonstrated "good design" of cooling water system. In particular there is little justification for omitting "repulsive technologies" including AFD*". It is unclear what the Environment Agency means by 'good design' in this context. If this is shorthand for the provision of an AFD representing a 'best available technique' then SZC Co disagrees. Whilst the provision of an AFD may represent best available technique at onshore locations, it is simply unfeasible at the offshore location of Sizewell C. It is therefore not an 'available' technique at Sizewell C. Further, it is not a 'best' technique due to the risk it presents to human life.

5.1.6 The inclusion of a feature which is both unnecessary, unfeasible and presents an unacceptable risk to human life cannot properly be regarded as representing "good design".

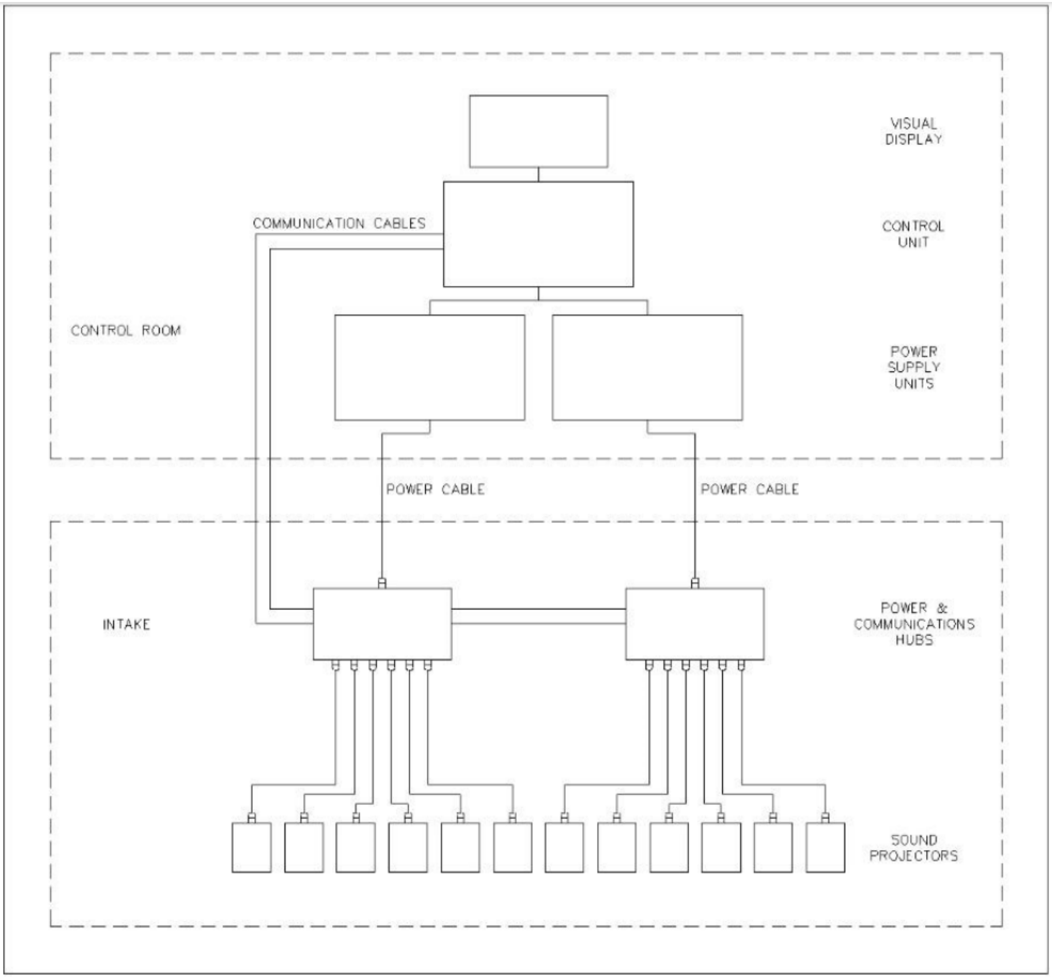
5.1.7 These issues are addressed further below.

6 AFD DESIGN AND COMPONENTS

6.1.1 While the Sound Projectors (SPs) themselves (i.e. components that actually make the sound) are the most obvious component of an AFD system, the system itself will comprise a number of other components including power and communication cables, power and communication hubs and mounting frames, as well as the software and land-based control equipment).

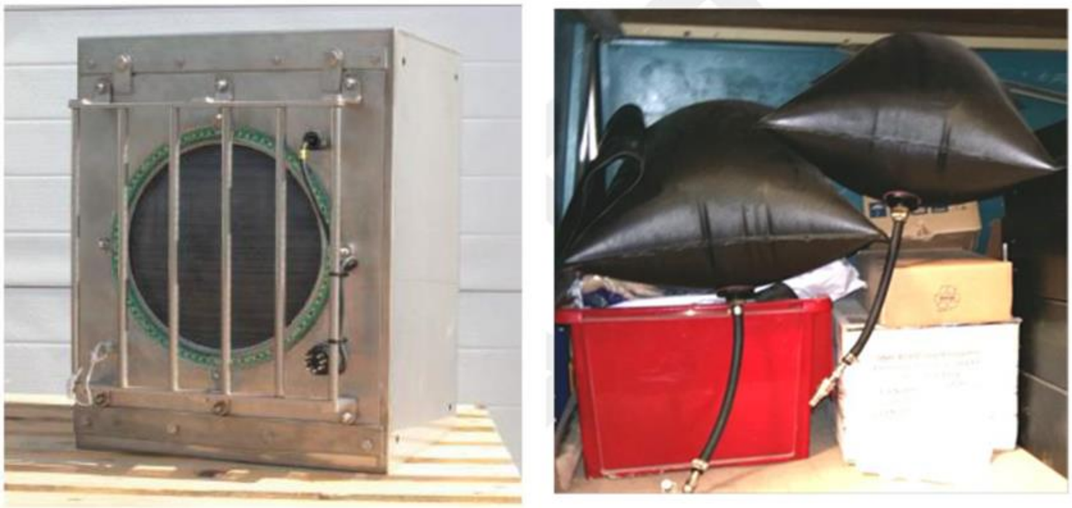
6.1.2 **Figure 6-1** illustrates the typical components of an AFD system.

Figure 6-1: Typical components of an AFD system (FGS Ltd. 2021; Ref 6)



6.1.3 The technology used to generate the required frequencies is similar in principle to a normal SP, with an electromagnetic coil which is excited by an electrical current in order to move a flexible diaphragm, generating sounds (**Figure 6-2**, **left**). So that the SP can operate underwater, initial designs were equipped with an internal pressure compensation bladder or ‘airbag’ which acted to balance the inward pressure on the diaphragm generated by the hydrostatic water pressure (which increases linearly with water depth) (shown in **Figure 6-2, right**).

Figure 6-2: An early design single sound projector unit (left) and associated pressure compensator (right)



6.1.4 The air-bag design was prone to failure meaning maintenance intervals were short and FGS have sought to address this. The latest sound projector design available from FGS Ltd. incorporates an Active Pressure Compensation System (APCS); see **Figure 6.3** (Ref 6)

Figure 6.3: Active Pressure Compensation System (APCS) sound projector design.

6.1.5 The incorporation of the APCS design instead of air bladders for pressure compensation has allegedly increased the maintenance interval to 18 months (or beyond) (PDB-061) but there is no real world evidence to support this.

6.1.6 Sizewell C will have 4 separate LVSE intake heads. As discussed, these will be a variation of the Hinkley Point C intake head (see **Figure 6-1**).

6.1.7 Each intake head will therefore have two intake apertures running along each side of the long axis (approximately 40 m each side). It is along these apertures that the sound projectors would need to be mounted to deflect fish form entering the intake (the ‘deflection principle’).

6.1.8 Sound field modelling for Hinkley Point C, undertaken by FGS Ltd., found that each intake head would require 72 sound projector units (i.e., a total of 288 sound projector units for all 4 intake heads).

6.1.9 In its submission for Procedural Deadline B, FGS Ltd. (PDB-061) makes the statement that if one considers each intake head a separate installation the system at Sizewell would not be considered particularly big. However, this ignores the fact that Sizewell C would still be required to operate and maintain all 4 systems – a system of 4 x 72 sound projectors in a co-ordinated manner. Such a system cannot reasonably be described as ‘small’.

6.1.10 Of significance is that although the installations themselves might be considered 4 separate systems, the requirement to supply power and control/communication to the sound projectors from shore remains a single task.

Figure 6.4: one of the Hinkley Point C intake heads being constructed. A similar design will be installed at Sizewell C.

6.1.11 In its Procedural Deadline B submission (PDB-061), FGS Ltd. outlines the improvements that have been made in the cabling and software components of its system. The latest power and communication hubs are reported to:

- Incorporate an internal Power Supply, that reduces the size of the cables required between the Control Equipment and the Sound Projectors and enables the projectors to be located at greater distances from the Control Equipment without any significant drop in power;
- Have an improved communication system, enabling more data to be handled by the PCB, allowing more parameters to be monitored and larger systems to be deployed, with 100% redundancy;
- Connect to up to eight Sound Projectors, instead of the original six projectors, enabling larger systems to be deployed; and
- Use fibre optics to enable data to be sent over longer distances and allow the systems to be monitored and controlled from shore.

6.1.12 These all appear to be useful developments in the local power and control mechanisms of the system but again there is limited evidence for the long-term reliability of these components.

6.1.13 For the system to be effective even when individual components fail, a significant degree of “redundancy” needs to be built in. At its simplest level this might be to include an excess of sound projectors into the design such that, even if a small number of sound projectors fail, a sufficient number remain operational to create the required sound field.

6.1.14 However, to ensure redundancy across the system there needs to be similar redundancy in the cabling as well as a design that links different sound projectors to different power and control cables. If all the sound projectors on one intake head (or even along one side) are linked to a single cable set and that cable set fails, then the whole array for that head (or side) is lost – this is known as a ‘*single point of failure*’. To remove the single point of failure multiple cables and multiple linkages would be required to ensure continued sound projection in the event of individual components failing. This can increase the number of cables and connections significantly and lead to complex cabling routing at the heads. **Figure 3.1** indicates how complex a large system with many sound projectors would be.

6.1.15 Improvements in power and control hubs and cables also does not address the wider issue of the actual power supply needed to power the units themselves.

6.1.16 While improvements have been made in the design of the sound projectors, cabling options and control software, the most significant issue in deploying AFDs in remote offshore locations like Sizewell is access to the units for maintenance.

6.1.17 A detailed optioneering exercise was undertaken for Hinkley Point C to identify a concept and then design a means by which sound projectors could be installed on the LVSE intake heads in a manner that would (a) not interfere with the hydraulic performance of the LVSE intake itself; (b) require minimal maintenance of the mounting structure itself; and, (c) provide accessibility to the sound projectors for maintenance purposes.

6.1.18 The preferred option was to incorporate the sound projectors into frames that would be mounted along the base of the LVSE such that they were be situated just below the intake apertures (see **Figure 6.5**).

Figure 6.5: Preferred design for installation of sound projectors on an LVSE intake head

6.1.19 However, ultimately, considering the conditions at HPC and, in particular, the ongoing maintenance requirements of the system with its attendant safety risk to divers, a decision was made to apply to vary the water discharge permit at that site. Whilst Sizewell is a different site to HPC many of the same considerations apply. These are addressed in the next section.

7 CONSTRAINTS ASSESSMENT FOR SIZEWELL

7.1 Availability of AFD Evidence

7.1.1 FGS Ltd. acknowledges that there are to date no/few offshore installations of AFD systems "*While all of these* [cited examples] *feature onshore cooling water intakes*…..".

7.1.2 The Environment Agency also notes that "'[…] *Very few studies discuss the cost of installing, operating and maintaining the systems. The safety of operating and maintaining the systems is rarely addressed, especially for nuclear power plants where continued cooling water supply is of vital importance for the safe running of the plant. Equally there are very few studies that discuss the feasibility of installing the behavioural deterrent technologies in a range of environments and for different sites'* […] (Ref 4).

7.1.3 The fact remains there is no experience of installing large AFD systems in offshore locations like Sizewell.

7.1.4 For example, Pembroke Combined-Cycle Gas Turbine power station is direct cooled, abstracting water from Milford Haven. It has an array of sound projectors mounted at its cooling water intake; however, the intake is shore-based and the AFD units are easily accessible – essentially, they are mounted on frames that can be raised remotely from the water and accessed at the surface (see **Figure 7.1**).

Figure 7.1: Sound projector units at Pembroke CCGT

7.1.5 The nuclear power station at Doel in Belgium is cited by FGS Ltd as being a good example of an offshore AFD installation: "…*the estuary-cooled nuclear plant at Doel (Maes et al., 2004) has operated AFD at an offshore-sited intake for more than 25 years, with excellent results*". However, this is the only example offered for an offshore AFD installation and is in no way comparable to what would be required at Sizewell C.

7.1.6 Doel abstracts water from the Scheldt estuary and the intake is only 50 m from the shore (see **Table 7.12**). As with the Pembroke design, the AFD units can be raised to the surface for servicing purposes, effectively removing the risks to divers involved in maintenance

7.1.7 By comparison, the intake heads for Sizewell C will be more than 3 km offshore in open water (see **Figure 2.1**). The heads will be at water depths of more than 10 m and will not extend above the water surface

Figure 7.2: Doel power station with (left) estuarine intake and (right) AFD units

7.2 Additional Sources of Information

7.2.1 As stated, FGS Ltd is arguably the only known commercial supplier that could potentially provide a system suitable for Sizewell C, and SZC Co recognises the continued development work that FGS Ltd has achieved since 2017.

7.2.2 In August 2020, in response to the Hinkley Point WDA variation request to remove the requirement to install an AFD system for the cooling water system FGS Ltd published a news article on the potential application of AFD at HPC. Much of this material is repeated in the FGS Ltd. submission to the Examining Authority at Procedural Deadline B [PDB-061] (Ref. 6).

7.3 Operational Function and Nuclear Safety

7.3.1 The intake heads are nuclear safety classified structures and as such, the AFD system must not adversely impact on the ability of the intake heads to fulfil the Design Basis High Level Safety Function (HLSF) of providing the safety critical cooling water to the land-based power generating plant. This has the following implications for the design of the structures upon which the AFD sound projectors will be mounted with regard to the seismic stability element of nuclear safety:

- If the units are sufficiently compact and lightweight such that they are unable to cause damage to the intake heads and impair the HLSF in the event of collapse, seismic qualification of the structures is not required; or

- If the structures are of a size and mass which are capable of impairing the HLSF, the structures must either be seismically qualified, or installed a sufficient distance from the head such that they are unable to impact the head in the event of collapse. However, this has an impact on the effectiveness of the sound field generated.

7.4 Location

7.4.1 The intake heads would be located > 3 km from the shore, which presents two major challenges:

- **Powering the AFD:** as the AFD needs to be powered from the shore, the power supply has to be transmitted over a long distance and then distributed to each of the four intake heads, which increases the complexity of the power transmission.

- **Accessing the AFD:** the distance from the shoreline renders access to the AFD possible only by boat, making maintenance and inspection much more time and labour intensive than at other sites already equipped with AFD systems. This means exposure to potentially hazardous conditions offshore of the Sizewell coast so maintenance times would be restricted to suitable weather windows.

7.5 Hydrodynamics

7.5.1 The tidal currents in the Greater Sizewell Bay are semi-diurnal with a range of 2.2 m. Water movement is dominated by tidal currents that flow south and north as the tide floods (rises) and ebbs (falls), respectively. Flood tides peak at about 1.15 m s^{-1} seaward of Sizewell Bank and ebb tides peak at about 1.10 m s^{-1}.

7.5.2 High current velocities are challenging in the respect that they are difficult for remotely operated vehicles (ROVs) to operate (maintain position in the flow while manipulating the AFD components) and limit the types of operations that a diver perform.

7.6 Waves

7.6.1 The offshore wave climate at Sizewell has been monitored with a Datawell Directional Wave Recorder buoy (DWR), 4 km from shore, just seaward of Sizewell Bank and in 18 m depth of water. This is very close to where the offshore intake and outfall locations will be sited. The main features of the wave climate there, based on the ten-year record, are:

- The bi-directional wave climate, with the most frequent waves arriving from north-east (23.16%), south (20.25%) and south-east (15.13%). Most waves (93%) have periods of less than 8 seconds. For the decade 2008-2018, wave heights greater than 1.5 m occurred 7.87% of the time (directions from east-north-east and south).

- The largest fetch is towards the north (up to 3,000 km) and correspondingly the largest and longest waves arrive from the N-NE sector. Waves with periods greater than 8 seconds approach exclusively from the north-east to east-north-east sector.

- Waves from the south through south-east sector are generated over a much shorter fetch (up to 150 km) and are therefore typically smaller than waves from the north, even though 4 m waves have been recorded, propagating from the south – south east.

7.6.2 The overall wave environment within the Greater Sizewell Bay is typical of an exposed, coastal UK location (see Volume 2, Chapter 20 Appendix 20A of the ES for further information [APP-312]).

7.6.3 Significant wave heights are challenging because they can limit the safe operation of ROVs, and diver support, from vessels at the site.

7.7 Turbidity

7.7.1 The suspended sediment concentration (SSC) in the waters around the Greater Sizewell Bay is depth dependent, seasonal and variable throughout the tidal cycle due to processes of deposition and resuspension.

7.7.2 Between November 2018 and February 2019, optical backscatter sensors were mounted on two seabed landers deployed seaward of the Sizewell-Dunwich Bank at the proposed cooling water intake head locations.

7.7.3 The mean SSC was 452 mg l^{-1} and 513 mg l^{-1} at the northern and southerly positions, respectively. At both locations maximum SSC exceeded 2,000 mg l^{-1} (see **Table 7.1**). These conditions are considered “Very Turbid” (the Water Framework Directive threshold for “Very Turbid”, the highest category, is an annual mean of >300 mg l^{-1}).

7.7.4 High turbidity in a coastal environment might seem surprising, when physical factors are compared with those in an estuary, but **Figure 7.3** clearly shows that high turbidity is experienced off the Suffolk Coast.

Figure 7.3: Satellite image of the UK showing turbid waters offshore Suffolk (Image Courtesy of Nasa; February 2021)

Table 7.1: Offshore suspended sediment concentration (mg l^{-1}) at 1.4 m above the seabed at the location of the proposed cooling water intakes

SSC statistic	Northern intake location (SZ1)	Southern Intake location (SZ2)
Minimum	105	100
Maximum	2,246	2,131
Mean	452	513

7.7.5 High turbidity is a challenging as it limits visibility, either for an ROV operator via cameras (though the use of sonar can mitigate this to some extent) or visibility of divers to perform the necessary tasks safely or at all.

7.8 System Capabilities

7.8.1 As identified above, the environment of the Greater Sizewell Bay is characterised by challenging operating conditions both in terms of tidal range, water velocity, wave energy, turbidity and biofouling. The next step is to therefore consider the AFD system itself and the likely technical specification it would need.

7.9 AFD Subsystems

7.9.1 As described in Section 6, an AFD comprises three key subsystems, the requirements of which are summarised below:

- **Sound Projectors:** The SPs are responsible for generating the sound waves which deter the fish. The SPs need to be able to output sound across the required frequency range and the larger the SPL the fewer the number of SPs required to achieve the target sound levels. The reliability of the SPs is important and the Mean Time to Failure (MTTF) determines the number of additional (spare) SPs required to meet the requirements of maintenance operations to replace failed units, ensuring maintenance of the correct sound field.

- **Sound Projector Mounting Structures:** The individual SPs need to be mounted in banks or arrays on mounting structures and the number of SPs will be constrained by the size of the mounting structure. The size, shape and positioning of the mounting structures determines the shape of the sound field produced and the acoustic gradient. A key consideration for the mounting structure is the impact of these structures on the operation of the intake heads, nuclear safety classified structures, and how these mounting structures will be retrieved during maintenance operations.

- **Power and Communications Supply:** The AFD system requires an electrical power supply, as well as the relevant communications and diagnostics links. Continuity of supply is important and cannot be intermittent. Reliability of all the components making up the power supply system is essential to maximise availability and minimise maintenance.

7.10 Lessons Learned

7.10.1 A summary of key learning points from Doel and Pembroke power plants, and their implications for Sizewell C is summarised below in **Table 7.2**.

Table 7.2: Summary of Lessons Learned

Key Learning Point from Doel / Pembroke	Implications and Applicability to Sizewell C
In order to deflect fish effectively, the sound projectors must be located as close as possible to the intakes.	The design of the Sizewell C intakes would in theory allow for the sound projectors to be close to the intake structure.
Without regular cleaning (every six months at Doel and every nine months at Pembroke) or other special measures, marine growth can cause potential maintenance issues.	Sizewell C intakes will be located in an area prone to biofouling. Regular cleaning is expected to be necessary (as has been required at Doel and Pembroke). Works at the intake heads could only occur at designated outages when the power station is not operating.
The new APCS sound projectors are reported to have a longer maintenance interval (18 months and potentially beyond) but that is still very short when compared to the maintenance schedule for Sizewell C.	The failure rate of the APCS is untested in an offshore location like Sizewell C. The outage cycle for each UKEPR unit is 18 months and not long enough to do a full maintenance service on the two intake heads of that unit. Furthermore an 18-month cycle would not align with summer weather windows likely to be required for such maintenance activities. FGS Ltd has 25-years' experience in design and build of AFD systems and 18 months remains the maximum maintenance interval, indicating that further improvements are not likely to occur in a suitable timescale, if at all.

7.11 AFD System Requirements

7.11.1 Taking into account the information collected about the currently available AFD sound projector technology and suppliers, power supply options, site constraints and lessons learnt from other sites, a list of requirements for any AFD system installed at Sizewell C is summarised below:

- The sound envelope must maintain a strong acoustic gradient with sound projector levels (SPLs) reducing with distance from the intake screens;
- SPL generated has to be > 160 dB across the whole surface of the intake screens (at the entrance to the intake heads) with minimal interference and acoustic nulls;
- SPL has to be maintained for all states of tide;
- The sound signal should be within the frequency range of 30 – 600 Hz, with the capability of operating up to 2000 Hz;
- The AFD’s control system needs to be programmable so that it can emit different sound patterns (chirp, sweep, etc.);
- To ensure the AFD system meets operational needs the AFD system design should be based on proven technologies;
- The entire AFD system (including SPs) must be designed to withstand fluctuating water depths between approximately 5 – 20 m (tide + wave height) and current speeds between 0 – 1.2 m/s;
- The entire AFD system is to be powered from onshore via submarine cable(s);
- To ensure the AFD system acts as a deterrent, as planned, the entire AFD system must meet a minimum availability of 90%, including downtime for both planned and unplanned maintenance
- The system needs to be designed to ensure operability on an 18-month replacement cycle for sound projectors;
- Maintenance activities of the AFD systems and associated mechanical and electrical power supply infrastructure should not interfere with, or risk damage to, the cooling water intake structures;
- Diving activities must be minimised; and
- The mounting structure must meet SC2 seismic requirements (as its failure could impact on a safety classified structure (the intake head) of SC1 seismic requirement.

8 ENGINEERING OPTIONEERING PROCESS

8.1 Introduction

8.1.1 A detailed optioneering process was undertaken for Hinkley Point C for installation of an AFD system on an LVSE intake head at offshore locations. Given the similarity in physical constraints (location of shore, depth, current velocities and turbidity (the latter two reduced compared with Hinkley Point but not significantly so)), the same process applies for the Sizewell intakes and the outputs described below. In summary, it was a process broken into four key work packages:

- SP location for acoustic field generation;
- AFD mounting structures (onto which the individual SPs are mounted);
- Electrical power supply/distribution and communications; and
- Shore crossing (the connection between the power supply on land and the submarine cable feeding the AFD).

8.2 Sound Projector location for acoustic field generation

8.2.1 The conclusion of the initial sound modelling was that Deflection Principle 2[3] should be taken forward, with a focus on trying to reduce the offset between the SPs and the intake head as far as possible to improve the sound field around the intakes and maximise the probable effectiveness of the AFD.

8.2.2 This decision was taken for the following reasons:

- Deflection Principle 1[4] differs from Environment Agency 2005 best practice (Ref 5), which recommends SPs are located closed to the intake opening, forming a steep acoustic gradient, free from acoustic nulls.
- All the SP configurations associated with Deflection Principle 1 performed poorly in sound modelling and did not provide an adequate sound field compared with the SP configurations associated with

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[3] In this configuration, the SPs are mounted along sides of intakes. This method consists of mounting SPs along the sides of the intakes to deflect fish to a distance from the intake where they do not risk being entrained. In this scenario, unless the SPs are mounted directly on or very close to the intake heads, some degree of upstream deflection may be required to ensure that fish remain on the correct side of the SPs and the sound pressure gradient when they are carried towards the intake heads at higher tidal velocities (as the distance between the SPs and the intake heads increases, the upstream deflection distance increases).

[4] In this configuration, SPs are mounted at the end of the intakes.

Deflection Principle 2, which performed well in sound modelling and provide a good sound field (on the proviso that the offset distance between the SPs and the intakes is kept as low as possible).

- The real-world performance of Deflection Principle 1 is based on fish reacting to sound and swimming laterally to a distance great enough to avoid being able to drift back towards the intake. Given the high and fluctuating current speeds at the Hinkley Point C intake location, not only does this lead to a very large sound field envelope requirement (long at high current speeds to provide sufficient upstream deflection and wide at low current speeds to provide sufficient lateral deflection), but it is also reliant on being able to accurately predict both the fishes' swimming direction and speed in response to the sound and there is no available evidence that this technique would be effective.

- Operational AFD systems installed at Pembroke and Doel power stations, which have proven efficiency in deflecting fish, are based on Deflection Principle 2. There are currently no operational AFD systems based on Deflection Principle 1. In addition, the AFD at Doel initially had the SP arrays mounted away from the intake heads and proved ineffective, with the current performance levels only being attained once the SPs were relocated on to the intake heads.

8.3 AFD mounting structures (onto which the individual sound projectors are mounted)

8.3.1 Twelve possible solutions were identified and evaluated in a two-phase process against the key considerations. Five designs were taken forward for consideration in the detailed optioneering stage, and a subsea discrete lightweight structure was considered the most viable option (see Figure 7.36.5). Acknowledging that the maintenance challenge would need to be addressed, this option was the only design that allowed the sound projectors to be mounted close enough to the intake heads to provide effective fish deterrence, and also the most acceptable from a nuclear safety perspective with regard to the impact of having large, heavy structures around the intake heads.

8.4 Electrical power supply/distribution and communications

8.4.1 The most viable AFD power supply network identified consisted of a shore-based power source linked to a central hub by submarine cable capable of carrying a 10 kV 3 phase high voltage power supply. The central hub would require a supra-surface monopile to house a transformer (including back up) to step the 10 kV power down to the level required for distribution to each intake head and the individual SP clusters via submarine cable. A subsea transformer is not viable.

8.4.2 All cables would need to cross the intertidal shore as well as any sub-tidal bathymetric features.

8.5 Applicability to Sizewell C

8.5.1 The design principles for installing an AFD system to an LVSE intake head in an offshore location like Sizewell C are summarised in **Table 8.1** below.

Table 8.1: Summary of Relevance to Sizewell

Work Package	Applicability to SZC
SP location for acoustic field generation	It remains the case that SPs are recommended to be located close to the intake opening, forming a steep acoustic gradient and free from acoustic nulls. Modelling undertaken for Hinkley Point C which considered the performance of Deflection Principle 1 remains relevant (it found that the system performed poorly and did not provide an adequate sound field). Our understanding continues to be that Deflection Principle 2 provides best performance. Operational AFD systems installed at Pembroke and Doel power stations, which have proven efficiency in deflecting fish, are based on Deflection Principle 2. It continues to be the case that there are no operational AFD systems based on Deflection Principle 1. To be suitable for Sizewell C the SPs would need to be mounted along the intake apertures of the intake head.
AFD mounting structures	Lightweight ‘discrete’ mounting structures as proposed for Hinkley Point C remains the optimum design for Sizewell C (there is a clear concern from a nuclear safety perspective associated with large, heavy structures being present around the intake heads).
Electrical power supply/distribution and communications	Due to the location of the Sizewell C intakes > 3km offshore, a high voltage supply (10 kV 3 phase) would be required together with a supra surface transformer mounted on a monopile. The cable from shore to the AFD units would need to extend beyond the Sizewell Bank. The Sizewell Bank is an important geomorphological feature that is known to provide some protection to the Sizewell frontage from waves etc. The means by which a cable could be laid across the bank without causing some localised impacts from scour or physical damage are not obvious (potential solutions of tunnelling or laying the cable around the feature are not desirable due to cost of tunnelling and access to cables in tunnels or the considerable extra length of cable required, respectively).
Shore crossing	The Sizewell frontage is noted for its recreational and wider landscape value and is afforded a range of protections, including the Suffolk Coast and Heaths AONB. Horizontal directional drill would likely be would be the preferred method for crossing this sensitive environment, and a means to cross the sea-defences without affecting their integrity needed.

9 AFD MAINTENANCE

9.1.1 Maintenance of an AFD system would be required and different components of the system would require differing amounts of intervention during the lifetime of the power station.

9.1.2 The exact maintenance requirements are unknown but would be expected to include:

- Maintenance and testing of the offshore monopile central hub and equipment;
- SP removal, repair and replacement;
- Repairs and/or replacement to electrical equipment and cabling; and
- Repairs and/or replacement to the structural frame that supports the SP clusters (including the means by which it is recovered for SP removal).

9.2 Constraints

9.2.1 A number of key constraints are summarised below.

Water Velocity

9.2.2 The conditions at the Sizewell intake head locations, beyond the seaward flank of the Sizewell Bank, results in comparatively high water-velocities which will restrict the time that divers or ROVs will be able to operate. The high water-velocities and proximity to the bank also contribute to poor visibility due to movement of sand and sediment.

9.2.3 Key considerations, associated with water velocities attributable to states of tide, are:

- The maximum velocity on an ebbing tide is approximately 1.10 m s^{-1};
- The maximum velocity on the flood tide is approximately 1.15 m s^{-1}; and
- Maximum turbidity values occur at just after low water as the tide begins to flow.

9.2.4 By comparison, the allowable working limits for divers performing light work, as stated in the International Marine Contractors Association (IMCA) guidelines (Ref 7) is 0.5 m s^{-1} (1.0 knot).

9.2.5 Remotely Operated Vehicles are capable of working in greater water velocities than divers and ROV technology has developed since the review undertaken in 2017 for Hinkley Point C

9.2.6 To the best of our knowledge, based upon discussions with an experienced ROV operator and manufacturer, ROVs are now able to operate at tidal current speeds in excess of 2.5 m s^{-1} forward and 1 m s^{-1} sideways. Together with sonar technology to help in low visibility environments these ROVs are very well suited to visual inspections along linear transects (for example a pipeline). However, the work required to access the large number of units (> 250 across all 4 intake heads) that would be required to be placed around the Sizewell C intake heads requires considerable manoeuvrability that simple velocity thresholds do not address.

9.2.7 It is also the case that the types of ROVs that are able to operate at the higher tidal current velocities are large – the size of a small car – and not suited to the type of work required.

9.2.8 A final, highly important factor is the dexterity of the ROV manipulator arm that is required to be able to manipulate the AFD system and cable connections underwater while maintaining a steady position in the water column. No advances in manipulator arm design have been made since 2017 - the Schilling T4 manipulator arm is still the leading arm today.

9.2.9 It remains the case that a ROV that can operate in the high flows and turbidities experienced at the Sizewell C locations and can conduct the required maintenance activities is not available. While developments are being made, there is no indication that sufficient progress that would allow the work required for maintain an AFD system at Sizewell C will be made in the near future, if at all.

9.2.10 FGS Ltd. in its submission at Procedural deadline B [PDB-061] (Ref.5) acknowledges that further work is required to develop an ROV that would be suitable for the required task and assumes that SZC Co. can develop one or that FGS Ltd could develop one at the behest of SZC Co. There is no confidence that such a design can be achieved and it would not be a responsible approach to safety to install a system known to present serious maintenance hazards to divers in the hope that a solution based on ROVs would be developed at some indeterminate time in future

Turbidity

9.2.11 Suspended sediment levels at the Sizewell C intake head locations peak at >2200 mg l^{-1} and average > 500 mg $l^{-1,}$

9.2.12 Low to zero visibility conditions have significant implications for operations underwater. Both diver and ROV operations will be significantly restricted, and this will result in increased time requirements for maintenance operations.

Marine Growth

9.2.13 Sizewell is an area prone to biofouling and it is likely that marine growth will develop on parts of the AFD structure, potentially complicating the maintenance operation (either the mounting structure, the cables or the SPs themselves). Marine growth on the AFD system components could result in result in:

- Growth around electrical connectors restricting mating / unmating;
- Obscuring of subsea identification markings; and
- Covering of lifting points.

9.2.14 Cleaning of components could be required prior to maintenance activities even starting (a task that is considered particularly difficult for an ROV operator to perform remotely, potentially requiring sonar to visualise the work area).

9.3 AFD Maintenance Conclusions

9.3.1 As part of the option selection and concept design of the AFD system, the maintainability of the AFD system has been one of the key considerations. Based on detailed investigations at Hinkley Point, SZC Co has drawn the following conclusions:

- SP technology is presently capable of producing the sound field required at Sizewell C, but it requires frequent maintenance to ensure reliability. The APCS SP design is currently reported to have a maintenance interval of 18 months – this is the absolute minimum required to align with the UKEPR maintenance (outage) programme. Even at 18-month intervals, alignment with suitable offshore conditions for maintenance works is unlikely.
- Having regard to the marine conditions at Sizewell, including water velocity and turbidity ROV technology is not currently available to perform the maintenance tasks required. SZC Co would therefore have to rely upon divers to maintain the system.

- The low visibility environment results in a higher risk of entanglement of diver umbilicals or ROV tethers with intake structures. Even with the best design, it would not be possible to remove all the risk of entanglement or even diver entrapment on the head itself.

- Tidal velocities at Sizewell often exceed the 0.5 knots recognised as being safe for divers to perform manipulative tasks. Time windows across each tide for diver works are therefore reduced due to currents on the flood and ebb tides that exceed the safe working limits of divers.

- Working within the limitations of water depth and water velocities, the duration available to perform the SP maintenance activities is limited and exceeds the time available at the 18-month routine outages. For the avoidance of any doubt, EDF health and safety regulations would not allow divers to access the intake heads while the unit is on load, that is to say while abstracting the full cooling water flow. FGS Ltd. states that intake velocities are low and the "risk of a divers umbilical being entrained is very low" [PDB-061] but this is simply not acceptable given that entrainment into the intake head (where water velocities rapidly increase to > 2 m s^{-1}) would likely result in a fatality, were it to occur.

- The operation of the maintenance vessel in the vicinity of the safety classified intake heads structures raises significant risks of entanglement with the intake heads.

- Considering the significant safety concerns identified in relation to the use of divers, HPC Co commissioned Bureau Veritas to undertake a quantitative assessment of the risk of injury and fatality for divers during the proposed operations at Hinkley Point C.

9.3.2 The findings are presented in the "*Acoustic Fish Deterrent Health and Safety Review*" (Ref 8). Findings 2 – 5 addressed the risk assessment process itself, but Findings 1, 6, 7 and 8 refer to the risks identified:

Finding 1: If the AFD system is to be further developed, ROV technologies and capabilities should be continually reviewed to establish if diving activity can feasibly be reduced/eliminated, and the safety risk analyses carried out should consider the most likely viable solution, either diving or ROV (or a combination).

Finding 6: For the preferred AFD option divers are the most at risk worker category and diving risk during AFD installation and maintenance is the major contributor to overall fatality risks in all activities that involve at least some diving.

Finding 7: For the preferred AFD option all offshore workers will be subjected to individual risks of fatality per annum of less than 10^{-3}, with divers subjected to 9.2×10^{-4}.

Finding 8: Over the course of a 70-year plant lifetime it is estimated that NNB GenCo can expect 0.39 fatal injuries associated with AFD installation, maintenance and operation.

9.3.3 The report concluded:

"*This study has also found that fatality risks associated with the preferred AFD option are tolerable (if As Low As Reasonable Practicable – ALARP) based on HSE thresholds for individual risk of workers, with diving risks only marginally below the unacceptable risk threshold. This is considered to be a realistic estimate of the risk which is, out of necessity given the paucity of activity-specific and location-specific historical accident data, based on some assumptions which are neither unduly cautious nor overly optimistic*".

9.3.4 The report points very clearly to the need to use ROV wherever possible (Finding 1) but, as described, ROV technologies have not advanced to remove the need for diver operations and it would not be a responsible approach to hope that a solution based on ROVs would be developed at some indeterminate time in future.

9.3.5 Given that no significant adverse impacts on fish species or populations are predicted for Sizewell C operating without an AFD system, no risk of fatality can be seen as acceptable. While a risk of 0.39 might seem low, this is based on an assessment and assumptions that are not worst case; and risk of injury or other incidences would be higher.

9.3.6 For context, it is necessary to understand the regulatory framework in place in the UK to control the risks presented to workers.

9.3.7 Part 1, Paragraph 2 of The Health and Safety at Work etc. Act 1974 specifies the general duty on employers to their employees:

"(1) It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees.

(2) Without prejudice to the generality of an employer's duty under the preceding subsection, the matters to which that duty extends include in particular:

a) *the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health;*

b) *arrangements for ensuring, so far as is reasonably practicable, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances;*

c) *the provision of such information, instruction, training and supervision as is necessary to ensure, so far as is reasonably practicable, the health and safety at work of his employees;*

d) *so far as is reasonably practicable as regards any place of work under the employer's control, the maintenance of it in a condition that is safe and without risks to health and the provision and maintenance of means of access to and egress from it that are safe and without such risks;*

e) *the provision and maintenance of a working environment for his employees that is, so far as is reasonably practicable, safe, without risks to health, and adequate as regards facilities and arrangements for their welfare at work*."

9.3.8 The general duty described above forms the legal basis for the development of all subsequent health and safety legislation, policies, procedures and methods of working.

9.3.9 These general duties are further reinforced by The Management of Health and Safety at Work Regulations (1999). These regulations require (amongst other things) employers to carry out competent risk assessments and where possible eliminate the risks or reduce them to tolerable levels.

9.3.10 From a design and construction perspective, The Construction (Design and Management) Regulations (2015) aim to ensure health and safety issues are appropriately considered during the development of construction projects. The overall goal is to reduce the risk of harm to those who have to build, use and maintain structures.

9.3.11 It is clear even from the basic descriptions of these Statutory Instruments that there is a fundamental, legal basis for employers to place high importance in the welfare of employees and to drive the levels of risk to which they are exposed to levels that are As Low As Reasonably Practicable (ALARP). Aside from the ethical issues of failing to ensure that risks are ALARP, failure to comply could result in prosecution and if found guilty, a potentially large fine or imprisonment under the Health and Safety at Work etc. Act (1974) and the Management of Health and Safety at Work Regulations (1999).

9.4 Sub-Optimal AFD Systems

9.4.1 Consideration has also been made for the possibility and merit of installing a sub-optimal system that may provide some mitigation benefit but with reduced risks associated with installation and maintenance.

9.4.2 At a superficial level, a less effective system, for example with fewer AFD units, might appear to mitigate potential safety concerns by requiring a less frequent maintenance schedule and/or smaller scale of maintenance regime. However, in reality the majority of the same constraints still apply:

a) the sound projectors would still need to be deployed near to the intake head in mounting structures as described earlier in conditions of fast tidal currents, high turbidity, >3 km offshore and in depths of >10 m;

b) the sound projectors would still require a high voltage power supply from shore that would need to be stepped down (transformed) offshore to a suitable voltage;

c) a degree of redundancy would still be required (to eradicate single points of failure that could lead to complete absence of a sound field) requiring complex cabling configurations;

d) diver access, albeit reduced per intake head, would still be required for installation and maintenance in the absence of suitable ROV technology.

9.4.3 Although, therefore, a system of fewer components would decrease the scale of the installation and maintenance task it would not provide the perceived benefit of the full system yet still incur some, albeit reduced, necessity for diver intervention and the constraints and risks described earlier.

9.4.4 Given the assessed lack of significant impacts without any AFD system, there remains no justification for installation of a less effective, sub-optimal system that does not completely remove risk to divers.

10 CONCLUSIONS

10.1.1 The detailed AFD assessment undertaken for Hinkley Point C represented the first in-depth exploration of the practical challenges associated with the installation, operation and maintenance of AFD on a LVSE intake head in an exposed, offshore UK coastal environment.

10.1.2 Sizewell C will also have LVSE intake heads located several km from shore and so an assessment of the installation, operation and maintenance feasibility has been undertaken for Sizewell by applying the data from Hinkley Point to the specific conditions found at Sizewell.

10.1.3 Sizewell has a lower tidal range, slower tidal velocities and lower levels of turbidity than Hinkley Point. However, the Sizewell C intakes locations are in a deeper depth (over the whole tidal cycle) and will be prone to biofouling.

10.1.4 Although conditions at Sizewell are considered less extreme than those at Hinkley Point, they nevertheless pose significant challenges for installing, operating and maintaining an AFD system. Principal among the concerns, in the absence of suitable ROV technology, is the need for diver access to manipulate (recover/install) the AFD units. Conditions at the Sizewell C intakes are considered not suitable, or at best highly constrained, for diver access.

10.1.5 The Environmental Impact Assessment concludes that the cooling water system as proposed (i.e., without an AFD) will not lead to significant adverse environmental effects. The shadow HRA concludes that the proposed system would not adversely affect the integrity of any European Site. As such, the provision of an AFD is not necessary mitigation. Further, the significant safety risks which its installation and maintenance present to divers mean that it cannot and should not be provided in any event.

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