KEADBY
NEXT GENERATION
POWER STATION
Hydrogen-enabled flexible power

A collaboration between SSE Thermal and Equinor

The Keadby Next Generation Power Station Project

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The Keadby Next Generation Power Station Development Consent Order 2025

Environmental Statement (ES)

Volume II – Appendix 11F Aquatic Ecology Survey Report

The Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure Regulations 2009 – Regulation 5(2)(l) The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017'

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Glossary

Abbreviation	Description
ASPT	Average Score Per Taxon
BMWP	Biological Monitoring Working Party
CCI	Community Conservation Index
CCS	Carbon Capture and Storage
ES	Environmental Statement
FSSR	Fine Sediment Sensitivity Rating
INNS	Invasive Non-native Species
LWS	Local Wildlife Site
PEA	Preliminary Ecological Appraisal
PSI	Proportion of Sediment-sensitive Invertebrates
RDL	Red Data List
WFD	Water Framework Directive
WHPT	Whalley, Hawkes, Paisley & Trigg

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1.1. Introduction

Background

1.1.1. This Aquatic Ecology Survey Report has been prepared by AECOM in support of the ecological impact assessment (EcIA) of the Proposed Development. The terms of reference used to describe the Proposed Development in this report are consistent with those defined within the main chapters of the Environmental Statement (ES) (**ES Volume I, Application Document Ref. 6.2**).

1.1.2. The Proposed Development Site encompasses an area of approximately 77.1 hectares (ha), of which approximately 26.7ha of land is proposed for construction laydown.

1.1.3. The Site is divided into the following areas of permanent and temporary land use (the proposed use is described in more detail in **ES Volume I Chapter 3**: Site and Surrounding Area (**Application Document Ref. 6.2**):

- Main Site;
- Ancillary Facilities;
- Water Connections;
- Electricity Connections;
- Waterborne Transport Off-loading Area;
- Construction Laydown Areas;
- Access routes (emergency, permanent and construction);
- Connections to Keadby 1 and Keadby 2 power stations; and
- Additional areas for landscaping and biodiversity provision.

1.1.4. The Proposed Development is an alternative to the Keadby 3 Carbon Capture and Storage (CCS) Power Station ('Keadby CCS Power Station') which has already been consented and would be located within the same Site. AECOM undertook the ecological impact assessment (EcIA) for Keadby CCS Power Station in 2021 and this has informed the survey work undertaken for the Proposed Development.

1.1.5. This report accompanies **ES Volume I Chapter 11:** Biodiversity and Nature Conservation (**Application Document Ref. 6.2**) and describes the approach and findings of the aquatic ecology surveys undertaken within the

Proposed Development Site and its wider zone of influence for noise disturbance from the Proposed Development.

Survey Scope

1.1.6. An initial Preliminary Ecological Appraisal (PEA) of the ecological constraints and opportunities associated with the Proposed Development Site was made by AECOM in March 2024, including identification of the requirements for further protected species survey. The findings of the habitat and scoping survey were compiled as a Preliminary Ecological Appraisal (PEA) report (**ES Volume II Appendix 11C:** Preliminary Ecological Appraisal, (**Application Document Ref. 6.3**), which should be referred to for a more detailed overview of the site conditions and habitats present.

1.1.7. This habitat information was used to identify locations within the potential zone of influence of the Proposed Development where there was potential for aquatic habitats to experience impacts and effects from construction, operation and/ or decommissioning of the Proposed Development. If affected there would also be potential for impacts and effects on aquatic macroinvertebrate, plant and/or fish species.

1.1.8. The relevant waterbodies had previously been assessed by AECOM in 2020 for the Keadby CCS Power Station Development Consent Order (DCO) with the survey scope encompassing:

- four field drains (Drains 1 (part of Glew Drain), 2, 3 and 4) in association with the Main Site, where construction works for the Proposed Development would be focussed;
- the Stainforth and Keadby Canal due to it being considered as a potential water supply for the Proposed Development; and
- Keadby Boundary Drain Local Wildlife Site (LWS) because it is located adjacent to the Main Site and is connected to and downstream of the four field drains identified above.

1.1.9. Given the limited protections afforded to aquatic macroinvertebrate, plant and fish species, the detailed prior data, and the lack of any substantive habitat change, it was not considered proportionate to repeat the scope of

these prior surveys as the findings were sufficient for the purposes of robust EcIA.

1.1.10. The following supplementary aquatic ecology survey work was completed in 2024 for the Proposed Development:

- fish environmental DNA (eDNA) survey of the Stainforth and Keadby Canal at the location of the proposed Cooling Water Abstraction.

1.1.11. Watercourses that would only be affected by very localised and short duration construction works (e.g. potential installation of electrical connections and/ or replacement of existing bridges) were scoped out as the potential ecological impacts and effects are sufficiently understood and the gathering of aquatic macroinvertebrate, plant and fish survey data was not needed to inform EcIA. The drains scoped out on this basis were Keadby Common Drain adjacent to Chapel Lane (Drains B and C), Drain D (part of Glew Drain) and the Hatfield Waste Drain. Relevant information on these drains is provided in **ES Volume II Appendix 11C:** PEA Report (**Application Document Ref. 6.3**).

1.1.12. There are other waterbodies associated with the Proposed Development Site however these either will not be affected by the Proposed Development (i.e. North Soak Drain) or only hold water in the wetter months of the year (i.e. Drain 5, **Figure 11F.1**). Therefore, these waterbodies were scoped out and are not considered further within this report. Similarly, the River Trent as a tidal river reach has been scoped out – refer to **ES Volume II Appendix 11C** (**Application Document Ref. 6.3**) for further explanation of the reasons for this.

1.1.13. The purpose of the survey work completed, and this report is to:

- provide species data and information on the aquatic macroinvertebrate[1], aquatic plant[2] and fish species and assemblages within the relevant areas of the Proposed Development Site;

[1] Aquatic macroinvertebrates are those invertebrate species that are easily visible without magnification i.e. species and life stages greater than 0.5 mm in size (The British Standards Institution, 2012).

[2] Restricted to 'macrophytes' i.e. larger plants of fresh water which are easily seen with the naked eye, or which usually form colonies, including all aquatic vascular plants, bryophytes, stoneworts (Characeae) and macro-algal growths (The British Standards Institution, 2014).

- present the above data in a manner that allows the results to be used to support an assessment of relative nature conservation value, including review against relevant criteria (see Section 2 of this report);
- identify potential aquatic invasive non-native species (INNS) constraints to construction and operation of the Proposed Development; and
- inform the options for impact avoidance, mitigation and/ or compensation to be considered.

Summary Habitat Conditions

1.1.14. The PEA report (**ES Volume II Appendix 11C**, **Application Document Ref. 6.3**) provides a summary of the habitat conditions present within each of the waterbodies which may experience impacts from construction, operation and/ or decommissioning of the Proposed Development. Photographs of the waterbodies are also provided in the PEA report.

1.1.15. Further information on each of the waterbodies surveyed is provided below to support the interpretation of the results highlighted in this report. The locations of the waterbodies is provided on **Figure 11F.1**.

Drain 1 (part of Glew Drain)

1.1.16. Drain 1 (part of Glew Drain) is a linear drainage ditch located on the northern boundary of the Main Site. It is an extension of the drainage ditch designated as the Keadby Boundary Drain LWS but Drain 1 is not part of the LWS. As such, the designated and undesignated sections have been surveyed, assessed and reported separately (see below for information on the LWS).

1.1.17. Drain 1 has a channel width between 1 and 2m and a substrate dominated by silt. Water depths range between 0.1 and 0.6m, with water depths shallowest towards the eastern end of the drain. The drain is over-deepened with steep earth banks approximately 3m in height and supporting rank semi-improved grassland. Bankside trees are absent and there is no shading of the channel. Flow noted during surveys was negligible (less than 10cm/sec).

1.1.18. The other drainage ditches associated with Keadby Common/ the Main Site flow into Drain 1 (Drains 2 to 5, Drain 4 connects via Drain 3).

Drain 2

1.1.19. This linear drainage ditch is located on the southern boundary of the Main Site. The channel width is approximately 2-3m with water depths between 0.2 and 0.5m recorded during the survey in 2020, although it was dry in 2024. The substrate within the drain is dominated by silt and flow was

observed to be negligible (less than 10cm/sec). The drain has earth banks, and the southern bank is dominated by dense willow scrub which overhangs the drain and casts heavy shade over approximately 70% of the channel.

Drain 3

1.1.20. This linear drainage ditch is located on the western boundary of the Main Site between the Main Site and the former Keadby Ash Tip. The channel width is approximately 1m with water depths between 0.2 and 0.5m recorded during the survey in 2020, although it was dry in 2024. The substrate within the drain is dominated by silt and flow was observed to be negligible (<10cm/sec). The drain has earth banks, one of which supports dense scrub, shading approximately 20% of the channel.

Drain 4

1.1.21. This linear drainage ditch bisects the Main Site. The channel width is approximately 0.5m – 1.0m. The water depth is very shallow (0.1m) and the channel was dry in places. No flow was apparent at the time of survey. The substrate within the drain is dominated by silt and at the time of survey there was no flow. The drain has earth banks.

Stainforth and Keadby Canal

1.1.22. The Stainforth and Keadby Canal is a navigable canal. It is designated as Stainforth and Keadby Canal Corridor LWS for its rich aquatic flora, and also for the mosaic of associated bankside habitats.

1.1.23. At the location of the Proposed Development Site, it is approximately 40m wide and greater than 1m in depth, with a substrate dominated by silt. At the time of survey flow was negligible (less than 10cm/sec). The banks of the canal are vertical and where visible are concrete. Bankside trees and scrub are present on the northern bank of the canal, however given the width of the canal, shading to the channel is negligible. The southern bank supports a tow path with mown grassland margins.

1.1.24. The canal is relevant to the Proposed Development because it is the proposed source of cooling and raw water for the Proposed Development. Any water abstraction from the canal would be subject to the regulatory regimes applicable to the approved abstraction for Keadby 2 Power Station.

Given these considerations, a detailed analysis of the macroinvertebrate community was not considered.

Keadby Boundary Drain Local Wildlife Site (LWS)

1.1.25. This is a linear drainage ditch that is connected to the west of, and functionally part of, Drain 1 (Glew Drain). The LWS appears to discharge to Warping Drain to the north of the Main Site.

1.1.26. The drain is over-deepened with a channel width of approximately 2m. Water depths are variable but in the order of 0.3-0.7m, and flow is negligible (less than 10cm/sec). The substrate within the drain is equal parts clays and silts.

1.2. Relevant Legislation

1.2.1. The Wildlife and Countryside Act 1981 (as amended) (the WCA) (UK Government, 1981) affords:

- specific protection to a small number of aquatic macroinvertebrate species and their habitat under Schedule 5 of the WCA;
- specific protection to flora is listed on Schedule 8 (flora, fungi and lichens); and
- the WCA also contains measures for preventing the establishment of non-native species which may be detrimental to native wildlife, including prohibiting the planting and spread of plants listed in Schedule 9.

1.2.2. Certain aquatic macroinvertebrate, fish and aquatic plant species are also listed as 'Species of Principal Importance for Nature Conservation in England' pursuant to Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 (UK Government, 2006). Section 40 of the NERC Act requires that local planning authorities further the conservation and enhancement of biodiversity in England, when carrying out their normal functions.

1.2.3. The Government has published standing advice (Natural England and Department of Environment, Food and Rural Affairs (Defra), 2023) to guide decision-makers on the determination of proposals with potential to affect protected species, including invertebrates and fish. The guidance sets out responsibilities and minimum requirements for survey and mitigation.

1.2.4. The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (UK Government, 2017) transpose the requirements of The Water Framework Directive (WFD; EC Directive 2000/60/EC) into English law. Any proposed developments or activities that have the potential to affect the water environment require a WFD Assessment (WFDa). Compliance with the WFD means attainment of good ecological status, prevention of deterioration in status, and prevention of failure to achieve future attainment of good status where it is not already achieved within waterbodies. The aquatic macroinvertebrate and plant data presented in this report can be used to support subsequent WFDa of the Proposed Development, if required.

1.3. Methods

Desk Study

1.3.1. A desk study was undertaken as part of the scope of works for the PEA, as described in **ES Volume II Appendix 11C** (**Application Document Ref. 6.3**). Protected and notable aquatic macroinvertebrate and aquatic plant records were obtained from Lincolnshire Environmental Records Centre (LERC) and the Environment Agency Ecology and Fish Explorer Database (Environment Agency, 2024), for a search radius of 1km out from the Proposed Development Site. Records were restricted to those collated since 2010, as these are most likely to reflect the current (rather than historic) baseline conditions associated with the study area.

1.3.2. Anecdotal information on fish species using the canal was obtained from the website of the Scunthorpe Amalgamated Anglers (SAA) (SAA, 2022).

Field Surveys

1.3.3. The macroinvertebrate, plant and fish field survey data collected for the Proposed Development Site includes results from surveys completed in 2020, and a previous survey of Keadby Boundary Drain LWS completed by AECOM in 2017. The latter watercourse is outside the Proposed Development Site but has hydrological connectivity to it. The results of the 2017 survey, which confirmed the notable aquatic ecology interest of the LWS, remain valid and appropriate for use for EcIA and there was no need to repeat this survey given the habitat conditions were confirmed as unchanged.

Fish eDNA Survey 2024 – Keadby and Stainforth Canal

1.3.4. Fish eDNA survey is a technique for establishing the presence/ absence of fish species within a waterbody without having to undertake invasive fish surveys e.g. electrofishing. It has been demonstrated to be extremely sensitive (more accurate with less survey effort) for detecting fish species and consistently correlates with fish abundance estimates made using other survey methods (Hänfling *et al*., 2016; Gouette *et al*., 2020; Hallam *et al*., 2021).

1.3.5. Fish eDNA is found in water derived from their faeces, mucous, gametes, shed skin and carcasses etc. As this is diluted and distributed in the water it can be analysed through the collection of water samples.

1.3.6. The fish eDNA survey was undertaken on the 20th August 2024. The eDNA sampling method employed was informed by guidance received from the specialist laboratory (NatureMetrics) that would undertake the sample

analysis. Three water samples were recommended to increase the likelihood that most species present within the watercourse are identified.

1.3.7. The three water samples were collected around the proposed Canal Water Abstraction, at positions upstream, downstream and adjacent to the proposed location (**Figure 11F.1**). Within each survey location, 20 sub-samples were collected from a range of habitats. The 20 sub-samples from a single location were pooled together, thoroughly mixed, and immediately filtered to extract the eDNA. The filtered sample was then preserved with a lysis solution in-situ to maintain DNA integrity at ambient temperatures until the DNA could be abstracted for laboratory analysis.

1.3.8. The results of this analysis provide the percentage of the total eDNA present within the sample attributable to each of the identified species. These percentages can be used to infer the relative abundance of each species within the wider community but this should only be relied on as a coarse (rather than an exact) measure because the amount of eDNA collected for each species can be unavoidably influenced by other factors such as the life stages present, behaviour (free swimming or bottom dwelling), body condition and environmental parameters (e.g. temperature or pH).

1.3.9. The laboratory analysis is provided to the maximum taxonomic resolution possible for the water samples collected. However, in some instances the eDNA could not be identified to species level. This can be for multiple reasons, including limitations related to similar DNA 'barcodes' between species. However professional judgement has been used to further refine the results where relevant and possible i.e. the genus *Leuciscus* which only has two British representatives (dace *Leuciscus leuciscus* and ide *Leuciscus idus*) has been altered to reflect this.

Aquatic Macroinvertebrate Survey 2020 – Field Drains

1.3.10. Aquatic macroinvertebrate sampling of the four drains was carried out on 19th May 2020 by an experienced AECOM freshwater ecologist supported by an assistant.

1.3.11. The survey methods used were based on the aquatic macroinvertebrate sampling procedures standardised by the Environment Agency (Environment Agency, 2014). These methods allow characterisation of aquatic macroinvertebrate communities and can be used to determine whether rare or notable species or communities are present.

1.3.12. An aggregate aquatic macroinvertebrate sample was taken along a 50m section of each drain, making sure to sample the full range of habitat conditions present. Due to the consistency in the habitat conditions present,

it was considered that the drains would support a similar assemblage along their full length, and therefore sampling a 50m subset of each drain was considered appropriate to obtain representative samples of the aquatic macroinvertebrates present.

1.3.13. The samples were taken using a standard Freshwater Biological Association (FBA) pattern pond net (mesh size: 1mm). The habitats present were sampled by kick sampling for three minutes, followed by a one-minute hand search of larger substrates in accordance with the standard methods.

1.3.14. The samples collected were subsequently preserved in Industrial Methylated Spirits (IMS) for laboratory processing by AECOM.

Aquatic Macroinvertebrate Survey 2020 – Stainforth and Keadby Canal

1.3.15. The aquatic macroinvertebrate sampling of the canal was carried out on 14th July 2020 by two experienced AECOM freshwater ecologists.

1.3.16. A single sample was collected from the southern bank of the canal in proximity to the Canal Water Abstraction Option (sample location SE 82794 11447).

1.3.17. The survey method used was based on the Predictive SYstem for Multimetrics (PSYM) canal survey method (Pond Action, 2002). This method was used to characterise the aquatic macroinvertebrate community present in the canal and identify the presence of any INNS.

1.3.18. The method use comprised three components:

- one-minute hand search;
- two-minute sampling using a standard FBA pattern pond net (mesh size: 1mm) of the canal margin and any emergent plant habitats present; and
- four dredge hauls from deeper bottom sediments.

1.3.19. The sample was then ‘site-sorted’ for approximately 30 minutes on the banks of the canal to identify some of the macroinvertebrate families present and identify any potential INNS. Any taxa which required further identification (such as any non-native shrimps) would have been collected

for laboratory analysis if appropriate. However, no further analysis was deemed necessary based on the results of the site sort.

1.3.20. Once the sample was collected following the above standardised techniques, further sampling of the canal was undertaken in vicinity of the Canal Water Abstraction Option at suitable intervals along approximately 600m between SE 82636 11464 and SE 83232 11424. This used a combination of the dredge and hand net to ensure any INNS potentially relevant to the Proposed Development were identified.

Aquatic Macroinvertebrate Survey 2017 – Keadby Boundary Drain LWS

1.3.21. Aquatic macroinvertebrate sampling of Keadby Boundary Drain LWS was carried out on 3rd May 2017 by an experienced AECOM freshwater ecologist and an assistant. The survey followed the same methods used during the 2020 survey of Drains 1-4 on Keadby Common.

Analysis of Aquatic Macroinvertebrate Samples

1.3.22. Each of the samples collected (excluding the Stainforth and Keadby Canal sample) was sorted and analysed in a laboratory setting by suitably trained and experienced aquatic ecologists. Lists of the aquatic invertebrate taxa present were produced in line with Environment Agency guidance (Environment Agency, 2014). The aquatic macroinvertebrate samples were identified to 'mixed taxon level[3]' using a stereo-microscope. Most groups were identified to species level (where practicable), with the exception of the following:

- the crustacean *Crangonyx pseudogracilis/ floridanus* which was treated as a species complex[4];

[3] As described in Environment Agency (last issue: 2014) Freshwater macroinvertebrate analysis of riverine samples, Operational instruction 024_08

[4] *Crangonyx pseudogracilis* was first introduced to the UK in the 1930s is now widespread and common in many areas. Until recently it was the only non-native species of this genus known to be present in the UK. However, in 2017 a related non-native species *Crangonyx floridanus* was identified in the UK for the first time (Mauvisseau *et al*., 2018) but it may have been overlooked previously. The identification features available to distinguish the two species are slight and it is often not possible to place samples to species using routine laboratory identification techniques. Given this, and consistent with good practice, records of *Crangonyx* are treated in an aggregate sense within this report. For purposes of use of CCI scores later in this report, records

- amber snails (Succineidae), which were identified to family;
- pea mussels (*Pisidium* species), which were identified to genus;
- worms (Oligochaeta) which were identified to order;
- mites (Hydracarina and Oribatei) which were identified to order;
- weevils (Curculionidae), which were identified to family;
- truefly larvae, which were identified to the maximum resolution possible;
- butterfly/ moth larva (Lepidoptera), which were identified to family;
- springtails (Collembola) which were identified to order; and
- immature or damaged specimens, which were identified to the maximum resolution possible on a case-by-case basis.

1.3.23. The survey data was used to calculate metrics that can be used to inform an assessment of relative nature conservation value.

1.3.24. A Community Conservation Index (CCI) (Chadd & Extence, 2004) was calculated for the waterbody. The CCI classifies many groups of freshwater macroinvertebrates according to their scarcity and nature conservation value in Great Britain (as understood at the time that the classification was developed). Species scores range from 1 to 10, with 1 being very common and 10 being endangered (**Table 11F.1**). However, in some cases, the references used in the CCI classification to define scarcity and value have since been superseded by more recent assessments (e.g. Seddon et al., 2014; Foster, 2010). The CCI cannot be modified to take account of such new information, but such information has been considered when making the wider assessment of nature conservation value provided in this report.

Table 1F.1: Conservation scores from the Community Conservation Index

Conservation score	Conservation status
10	Red Data Book (RDB) 1 (Endangered)
9	RDB2 (Vulnerable)
8	RDB3 (Rare)
7	Notable (but not RDB status)
6	Regionally notable

of the aggregate are assigned the same score originally allocated to *Crangonyx pseudogracilis* before it was known that two species were present.

Conservation score	Conservation status
5	Local
4	Occasional (species not in categories 10-5, which occur in up to 10% of all samples from similar habitats)
3	Frequent (species not in categories 10-5, which occur in up to >10-25% of all samples from similar habitats)
2	Common (species not in categories 10-5, which occur in up to >25-50% of all samples from similar habitats)
1	Very common (species not in categories 10-5, which occur in up to >50-100 % of all samples from similar habitats)

1.3.25. The overall CCI derived provides an indication of the relative conservation value of the community sampled, based on a combination of the rarity of the different aquatic macroinvertebrate taxa present and overall community richness, as explained below in **Table 11F.2**. As indicated above, in some cases expert judgment has been used to moderate these assessments with reference to current information on status and distribution.

Table 1F.2: Community Conservation Index Interpretation Guidance (Chadd & Extence, 2004)

Community Conservation Index (CCI)	Expected conservation value
<5	Low
5 to 10	Moderate
10-15	Fairly high
15 to 20	High
>20	Very high

1.3.26. Calculations were also made to determine the proportion of sediment sensitive aquatic macroinvertebrates present using the Proportion of Sediment-sensitive Invertebrates (PSI) index (Extence *et al*., 2013). Using this approach, individual taxa of aquatic macroinvertebrate are assigned a Fine Sediment Sensitivity Rating (FSSR) ranging from A to D, as detailed in the **Annex 1**. The PSI score for each aquatic macroinvertebrate sample was derived from individual species scores and abundances. The derived PSI

score corresponds to the percentage of fine sediment-sensitive taxa present in a sample and ranges from 0 to 100, where low scores correspond to waterbodies with high fine sediment cover. The PSI score therefore provides an indication of the extent to which waterbodies are influenced by fine sediments, and therefore by inference the potential sensitivity of the associated aquatic macroinvertebrate community to changes in silt load and deposition.

1.3.27. The aquatic macroinvertebrate data were also analysed to generate Whalley, Hawkes, Paisley & Trigg (WHPT) and Average Score Per Taxon (ASPT) values (WFD-UKTAG, 2014). This assigns numerical value to taxa according to their sensitivity to organic pollution. The average of the values for each taxon in a sample, known as ASPT is a stable and reliable index of organic pollution. Therefore, these assessments indicate to what extent an aquatic macroinvertebrate community is exposed to organic pollution (further information is provided in **Annex 2**). It is important to note that these indices can vary between geological regions and habitat types. Ditches for example are unable to support many of the high-scoring taxa associated with fast flowing habitats. Therefore, the resultant metrics should be reviewed with an awareness of their potential limitations and the site-specific context.

Aquatic Plant Survey 2020 – Field Drains

1.3.28. The boundary drains were surveyed on 15th July 2020 to record their associated emergent and aquatic flora. The survey was completed by an appropriately experienced and trained botanist who is also an aquatic plant specialist. The lead surveyor was supported by an experienced assistant.

1.3.29. The survey was made by walking within the channel of the drains, where safely accessible and not obstructed by dense growth of emergent flora. These latter areas were bypassed as necessary before re-entering the channel at the next available access point. A list of all emergent and aquatic plant species encountered was made for each drain and their relative abundance recorded using the 'DAFOR' scale as follows:

- D = Dominant (greater than 75% total cover);
- A = Abundant (51 to 75% total cover);
- F = Frequent (26 to 50% total cover);
- O = Occasional (11 to 25% total cover; and
- R = Rare (1 to 10% total cover).

1.3.30. The prefix L is used where species were noted as Local (patchy) in distribution. If a species appeared to be intermediate between two categories, it has generally been assigned to the lower category.

1.3.31. The aquatic plant community of the field drains was reviewed during the updated riparian mammal surveys undertaken in August 2024. Given the data previously collected remained valid, the purpose of this was not to repeat the survey but reconfirm the habitat conditions and to identify if there had been habitat changes that may influenced the results of the previous assessment. These could have included changes in hydrology or increased levels shading to the watercourses, where identified and relevant, these are referred to in Section 4.

Aquatic Plant Survey – Stainforth and Keadby Canal

1.3.32. The aquatic plant survey of the Stainforth and Keadby Canal was carried out on 14th July 2020 by two experienced AECOM freshwater ecologists, including an aquatic plant specialist.

1.3.33. The survey was made by walking the tow path along the southern bank of the canal in the vicinity of the Canal Water Abstraction option at that time (which is within 10m of the currently proposed location). It therefore covered (approximately 300m total survey length, 150m either side of the location of the proposed Canal Water Abstraction. All aquatic and marginal plant species observed were recorded and their relative abundance recorded using the DAFOR scale as detailed above. Deeper water areas were sampled by grapnel, and the northern bank of the canal was inspected using binoculars.

Aquatic Plant Survey 2017 – Keadby Boundary Drain LWS

1.3.34. Aquatic plant survey of Keadby Boundary Drain LWS was carried out on 17th July 2017 by an experienced AECOM freshwater ecologist and followed the same methods as the other aquatic plant surveys conducted on the drains in 2020. An update survey was not considered necessary given the original survey found a notable aquatic plant assemblage. As there had been no noticeable change in the habitat conditions present since the original survey, this notable community can be assumed to persist.

Nature Conservation Evaluation

1.3.35. Evaluation of the relative nature conservation value of the identified ecological features within a site (encompassing nature conservation designations, ecosystems, habitat and species) is required to inform EcIA. This report presents the evaluation for aquatic macroinvertebrate and aquatic plant species, and the impact assessment is presented in **ES**

Volume I Chapter 11: Biodiversity and Nature Conservation (**Application Document Ref. 6.2**).

1.3.36. The method of evaluation that has been utilised has been developed with reference to the Chartered Institute of Ecology and Environmental Management (CIEEM) Guidelines for Ecological Impact Assessment in the UK and Ireland (CIEEM, 2024). These guidelines give advice on scoping and carrying out environmental assessments and place appraisal in the context of relevant policies. Data received through consultation, desk-based studies and field-based surveys are used to allow ecological features of nature conservation value or potential value to be identified, and the main factors contributing to their value described and related to available guidance. This data can also be used to identify other relevant values e.g. socio-economic or ecosystem services values, but this is beyond the remit of this report and requires the involvement of other relevant specialists.

1.3.37. Aquatic macroinvertebrate, plant and fish communities and individual species can be of nature conservation value for a variety of reasons, and their relative value should always be determined on a case by case basis to demonstrate a robust assessment process. Value may relate, for example, to the uniqueness of the assemblage, or to the extent to which species are threatened throughout their range, or to their rate of decline. The value of the species assemblages associated with the Proposed Development Site has been defined with reference to the geographical level at which it is considered to matter. This assessment has been made with reference to published guidance and criteria where available e.g. criteria to assess relative value within the context of Lincolnshire are given in Local Wildlife Site Guidelines for Lincolnshire (Greater Lincolnshire Nature Partnership (GLNP), 2013) and nationally in Guidelines for the Selection of Biological Sites of Special Scientific Interest (SSSIs) (Bainbridge et al., 2013).

1.3.38. The identified guidance and criteria are not definitive, and other criteria have been applied as relevant and appropriate to reach a decision on relative nature conservation value. For example, the previously described CCI index

has been used to inform assessment of nature conservation value for aquatic macroinvertebrates.

Limitations

1.3.39. There are no significant limitations to the work undertaken.

1.3.40. All surveys in 2017 and 2020 were undertaken in appropriate favourable weather conditions, and in the appropriate seasons for the habitats being assessed.

1.3.41. All plant species found were identified to species level, where technically feasible based on the material available and the season of survey. Certain plant species cannot always be identified reliably if they lack the features necessary to allow identification, for example mature fruit are typically required to allow certain identification of water-starwort species (*Callitriche* agg.) and watercress (*Nasturtium officinale* agg.).

1.3.42. Given the nature of aquatic macroinvertebrate surveys it is not possible to be certain that all of the species present in a waterbody will be detected. Where juvenile or damaged specimens were collected, species level identification is not always possible. Not all macroinvertebrate species that use waterbodies are present at all times of year and therefore some may be overlooked when surveying. Other species that may be present at other times of year, sporadically and/ or in small numbers may not have been recorded. This is not considered a significant limitation as standard methods were applied, and the data collected is considered representative of the conditions present and appropriate for assessment of value.

1.4. Results

Desk Study

Aquatic Nature Conservation Designations

1.4.1. LERC identified two freshwater nature conservation designations where there is potential for impacts from the Proposed Development. The Keadby Boundary Drain LWS is designated for the botanical interest of both the drain habitat and the semi-improved neutral grassland on its banks. The LWS was last surveyed in 2010. Limited information on the botanical interest of the LWS is included on the citation, but it notes that:

> "*Aquatic vegetation is abundant throughout, including water-starwort, Nuttall's waterweed, and common and ivy-leaved duckweed, as well as the locally uncommon whorled water-milfoil, water-violet and needle spike-rush. Some of the many other wetland plants present are purple-loosestrife, water mint, water-plantain, water-cress, yellow iris, false fox-sedge, reed sweet-grass, reed canary-grass and common reed.*"

1.4.2. Stainforth and Keadby Canal LWS is designated for the botanical interest of the canal and its adjacent habitats. This LWS extents approximately 10km along the length of the canal and was last surveyed in 2010. Information on the botanical interest of the LWS is included on the citation as follows:

> "*The canal supports a rich aquatic flora that throughout its length includes common, fat and greater duckweed, spiked water-milfoil, fennel and perfoliate pondweed and the non-native curly and Nuttall's waterweed. Other widespread water plants are arrowhead, unbranched bur-reed, yellow water-lily, flowering-rush, amphibious bistort, yellow iris, gypsywort, water dock, reed sweet-grass, reed canary-grass and common reed. The canal banks are mostly vertical, but gently sloping wet edges created by anglers hold a variety of further species such as skullcap, marsh woundwort, angelica, water figwort, hemlock water-dropwort, common fleabane, yellow loosestrife and false fox-sedge.*"

Fish

1.4.3. The SAA are the angling association with fishing rights on the Stainforth and Keadby Canal. The SSA website (SAA, 2022) states that the canal supports the following fish species:

- roach (Rutilus rutilus)
- bream (Abramis brama)

- perch (Perca fluviatilis)
- roach/ bream hybrids
- tench (Tinca tinca)
- rudd (Scardinius erythrophthalmus)
- European eel (Anguilla anguilla)
- pike (Esox lucius)
- chub (Squalius cephalus)
- dace (Leuciscus leuciscus)
- bleak (Alburnus alburnus)

Aquatic Macroinvertebrates

1.4.4. No records of rare or protected aquatic macroinvertebrate species were returned during the desk study within the study area. The Environment Agency has undertaken macroinvertebrate sampling within Keadby Warping Drain on two occasions within the last 10 years (2013 and 2016). This drain is 320m north of Proposed Development Site and is designated as a LWS for its aquatic flora and habitats. Four species were recorded during the surveys in 2013, while a total of 28 were recorded in 2016. These results indicate that the drain supports a typical assemblage of aquatic macroinvertebrates for the habitats present including a range of beetle, caddisfly, dragonfly and truefly taxa.

1.4.5. Only a single non-native species record was identified from Keadby Warping Drain; the amphipod *Crangonyx pseudogracilis/ floridanus*.

1.4.6. Records also indicate that in 2007, the Environment Agency recorded the presence of non-native Dreissenidae mussels within the Stainforth and Keadby Canal, approximately 500m downstream of the proposed Canal Water Abstraction for the Proposed Development. The only British members of this group of mussels are the INNS zebra mussel (*Dreissena polymorpha*)

and quagga mussel (*Dreissena bugensis*). The species present in the canal was not determined.

Aquatic Plants

1.4.7. The desk study returned no additional records of native aquatic plant species other than those included within the details of the nature conservation designations summarised above.

1.4.8. Some records of plant Invasive Non-Native Species (INNS) were returned. These were:

- water-fern (*Azolla filiculoides*) in the Stainforth and Keadby Canal. This species can go through phases of 'boom and bust' being affected by the weather in any given year, and does not always persist long-term;
- Nuttall's waterweed (*Elodea nuttallii*), numerous records including from the Stainforth and Keadby Canal and Keadby Boundary Drain; and
- curly waterweed (*Lagarosiphon major*) from the Stainforth and Keadby Canal.

Field Survey Results

1.4.9. The aquatic macroinvertebrate species recorded are detailed in **Annex 4**. No aquatic macroinvertebrate species were recorded that receive specific legal protection via Schedule 5 of the WCA, or that are listed on Section 41 of the NERC Act as being of principal importance for nature conservation in England. This does not remove the need to further assess the species recorded for their nature conservation importance. There are other criteria for nature conservation value, and legal protections do not always provide a true or current reflection of all species of nature conservation concern.

1.4.10. The aquatic plant species recorded are detailed in **Annex 5**. This includes identification of plant species relevant to the identification of sites of importance for their aquatic plant interest (based on Table 11 and Criteria FW2 and FW3 of the LWS Guidelines for Lincolnshire (GLNP, 2013)). No aquatic plant species were recorded that receive specific legal protection via Schedule 8 of the WCA, or that are listed on Section 41 of the NERC Act as being of principal importance for nature conservation in England.

However, as highlighted above, this does not remove the need to further assessment.

1.4.11. Further detail on the results obtained for each of the surveyed waterbodies is provided below.

Stainforth and Keadby Canal

Fish

1.4.12. The fish species identified by the eDNA survey, and their percentage contribution (as a mean of the three survey samples) to the total fish eDNA detected, are given in **Table 11F.3.** The detailed results from each transect are given in **Annex 3**.

1.4.13. Fourteen fish species were recorded. The fish community was dominated by roach and perch representing 80% of the eDNA detected. The only notable species recorded were European eel and spined loach (*Cobitis taenia*), both of which are indicated to represent a minor component of the fish community (1.1% and 0.4% of the eDNA detected respectively).

1.4.14. Zander (*Sander lucioperca*) is an INNS species listed on Schedule 9 of the WCA. This species appears to be only a minor component of the fish community (0.3% of the eDNA detected).

Table 1F.3: The mean percentage of the fish community detected via eDNA analysis

Common name	Latin name	Mean percentage recorded
European eel	*Anguilla anguilla*	1.1%
Spined loach	*Cobitis taenia*	0.4%
Common bream	*Abramis brama*	3.4%
Common bleak	*Alburnus alburnus*	0.0%
Silver bream	*Blicca bjoerkna*	5.4%
Dace/ ide	*Leuciscus sp.*	0.7%
Roach	*Rutilus rutilus*	35.3%
Common rudd	*Scardinius erythrophthalmus*	1.8%
Tench	*Tinca tinca*	3.8%
Cyprinidae sp.	Unidentified Cyprinidae	0.1%

Northern pike	*Esox lucius*	2.3%
Ruffe	*Gymnocephalus cernua*	0.5%
Perch	*Perca fluviatilis*	44.7%
Zander	*Sander lucioperca*	0.3%

Aquatic Macroinvertebrates

1.4.15. The site sort identified that the canal supported a typical assemblage of aquatic macroinvertebrate found within canals including snails (Viviparidae, Lymnaeidae, Planorbidae), caddisflies (Limnephilidae) and mayflies (Baetidae).

1.4.16. The following INNS species were identified. None of these species recorded are listed on Schedule 9 of the WCA.

- zebra mussel (*Dreissena polymorpha*). Although this species is not listed on Schedule 9 of the WCA, it is highly invasive. It is unlike all other native mussel species in that it colonises and grows on hard substrates which can lead to a number of potential impacts including the clogging of water intake pipework and screens (GB Non-native Species Secretariat, 2020). The survey confirms this species to be well established within the canal. Large numbers of live animals were found during sampling, and there were also large numbers of old shells visible on the canal bed;
- demon shrimp (*Dikerogammarus haemobaphes*). This species was first recorded in the UK in 2012 and has spread rapidly. It is a highly efficient predator altering the diversity and abundance of other aquatic macroinvertebrates species;
- Caspian mud shrimp (*Corophium curvispinum*). This species was first recorded in Britain in 1935 and now widespread in the south-east and midlands of England (Dobson, 2012); and
- New Zealand mud snail (*Potamopyrgus antipodarum*).

Aquatic Plants

1.4.17. Eighteen aquatic plant species were present, of which eight of these are scoring species under the GLNP 2013 criteria. The dominant submerged plant species was Nuttall's waterweed, which formed dense beds over most of the visible channel. Nuttall's waterweed is a controlled weed species

listed on Schedule 9 of the WCA. Other species were mostly either limited to the margins of the canal and/ or were present at low cover.

1.4.18. Filamentous green algae was also present at a relatively high cover within the canal. The presence of such algae may be indicative of poor water quality, particularly nutrient enrichment, when found at high abundances.

1.4.19. Although the survey was of limited extent and was not undertaken along the full extent of the LWS, the limited number of GLNP scoring plant species recorded in the area surrounding the preferred Canal Water Abstraction Option is not characteristic of the interest of the LWS as a whole. This relatively poor assemblage of scoring species is likely to be due to combination of factors include the dominance of Nuttall's waterweed, proximity to boat moorings and the canal lock on the River Trent, and the limited marginal habitat due to the dominance of vertical concrete banks.

Drain 1 (part of Glew Drain)

Aquatic Macroinvertebrates

1.4.20. A moderate/ high diversity of aquatic macroinvertebrates was recorded (45 taxa, 26 identified to species) and the community is considered fairly typical for the conditions present i.e. a small, heavily modified, slow flowing drain. The assemblage was dominated by a range of snail, crustacean, beetle and truefly taxa. The CCI score calculated was 14.8 indicating that the drain is of fairly high conservation value. The majority of the species present are of occasional to very common status. The exceptions to this were:

- white-lipped ramshorn snail (*Anisus leucostoma*). This is classified as being of local status within the CCI. More recent information on the status of this snail establishes that it remains widespread within its native range and it is not currently considered threatened (Seddon *et al*., 2014);
- the water beetle (*Rhantus suturalis*). This is classified as notable within the CCI. However, it is of favourable status and appears to be increasing in range (see Table 3). Therefore while it requires due regard it is not as notable as implied by the CCI; and
- the diving beetle (*Rhantus exsoletus*). This is classified as being of local status within the CCI. There is no more recent information to indicate that the status of this species has changed since the CCI was established.
- Two non-native species were recorded. The amphipod (*Crangonyx pseudogracilis/ floridanus*) and the New Zealand mud snail. The New Zealand mud snail was first introduced to the UK in 1852 and is now

naturalised, widespread and common in many areas (Seddon *et al*., 2014).

- All of the aquatic macroinvertebrate species present are tolerant of fine sediments (PSI: 1.6), as would be expected for a slow flowing drain of the type sampled. The biological quality of the drain is moderate (WHPT: 97.3, ASPT: 4.2). Only a single pollution-sensitive taxon was recorded (the beetle *Gyrinus substriatus*), with the drain supporting a range of taxa defined as having a moderate tolerance to pollution.

Aquatic Plants

1.4.21. Drain 1 (Glew Drain) supported 23 aquatic plant species (excluding algae) which included a range of submerged, floating and emergent species. Of these, 16 are scoring species under the GLNP 2013 criteria. No rare or notable species were present, and the assemblage is considered fairly diverse for the habitat conditions present.

1.4.22. A single non-native plant species was recorded, Nuttall's waterweed which was abundant along the length of the drain. This is a controlled weed species listed under Schedule 9 of the WCA, as such it is an offence to cause it to spread in the wild.

Drain 2

Aquatic Macroinvertebrates

1.4.23. A moderate diversity of aquatic macroinvertebrates was recorded (37 taxa, 14 identified to species) and the community is considered fairly typical of a small, heavily shaded, slow flowing drain. The assemblage was dominated by a range of snail, crustacean, beetle and truefly taxa. The CCI score calculated was 7.3 indicating that the drain is of moderate conservation status. All of the species present are of common to very common conservation value. The only exception to this was the white-lipped ramshorn snail which, as highlighted above for Drain 1 (part of Glew Drain), remains widespread within its native range and it is not currently considered threatened.

1.4.24. The New Zealand mud snail was the only non-native species recorded.

1.4.25. All of the aquatic macroinvertebrate species present are tolerant of fine sediments (PSI: 0), as would be expected for a slow flowing drain of the type sampled. The biological quality of the drain is moderate (WHPT: 76.1,

ASPT: 4). No pollution-sensitive taxa were recorded but the drain supported a range of taxa defined as having a moderate tolerance to pollution.

Aquatic Plants

1.4.26. Drain 2 supported six aquatic plant species, and only two of these are scoring species under the GLNP criteria. Species diversity was limited by the combination of heavy shading from trees and the dominance of common reed (*Phragmites australis*). Where this species was dominant, it excluded other flora and occurred as mono-specific stands. No rare or notable species were recorded, and the assemblage present is considered typical of the habitat conditions. No non-native plant species were recorded.

Drain 3

Aquatic Macroinvertebrates

1.4.27. A low/ moderate diversity of aquatic macroinvertebrates was recorded (22 taxa, nine identified to species) and the community is considered fairly typical of a small, slow flowing drain. The assemblage was dominated by a range of snail, beetle and truefly taxa. The CCI score calculated was 8.8 indicating that the drain is of moderate conservation value. All of the species present are of frequent to very common status. The only exception to this was the white-lipped ramshorn snail, which as highlighted above for Drain 1 (part of Glew Drain), remains widespread within its native range and it is not currently considered threatened. No non-native species were recorded.

1.4.28. All of the aquatic macroinvertebrate species present are tolerant of fine sediments (PSI: 0), as would be expected for a slow flowing drain of the type sampled. The biological quality of the drain is moderate (WHPT: 49.3, ASPT: 4.1). No pollution-sensitive taxa were recorded, but the drain supported a range of taxa defined as having a moderate tolerance to pollution.

Aquatic Plants

1.4.29. Drain 3 supported nine aquatic plant species, and only four of these are scoring species under the GLNP 2013 criteria. Species diversity was limited by the shading of the channel by trees and the dominance of common reed. Where common reed was dominant, it excluded other flora and occurred as monospecific stands. No rare or notable species were recorded, and the

assemblage present is considered typical of the habitat conditions. No non-native plant species were present.

Drain 4

Aquatic Macroinvertebrates

1.4.30. A low diversity of aquatic macroinvertebrates was recorded (19 taxa, six identified to species) and the community is considered fairly typical of a small, slow flowing field drain. The assemblage was dominated by a range of snail, crustacean, caddisfly, beetle and truefly taxa. The CCI score was 9 indicating that the drain is of moderate conservation value. All of the species present are of very common status. The only exception to this was the white-lipped ramshorn snail, which as highlighted above for Drain 1 (part of Glew Drain), remains widespread within its native range and it is not currently considered threatened. No non-native species were recorded.

1.4.31. All of the aquatic macroinvertebrate species present are tolerant of fine sediments (PSI: 0), as would be expected for a slow flowing drain of the type sampled. The biological quality of the drain is moderate (WHPT: 37.2, ASPT: 4.1). No pollution-sensitive taxa were recorded but the drain supported a range of taxa defined as having a moderate tolerance to pollution.

Aquatic Plants

1.4.32. Drain 4 supported four aquatic plant species, of which three are scoring species under the GLNP criteria. The only species recorded were tall emergent species which dominated the channel. This in combination with the shallow water depth limited the species diversity present. No rare or notable species were recorded, and the assemblage present is considered typical of an arable field drain. No non-native plant species were recorded.

Keadby Boundary Drain LWS

Aquatic Macroinvertebrates

1.4.33. A moderate diversity of aquatic macroinvertebrates was recorded (30 taxa, 17 identified to species) and the community is considered fairly typical of a small, heavily modified, slow flowing drain. The assemblage was dominated by a range of snail and beetle species. The CCI score calculated was 12.8 indicating that the drain is of fairly high conservation value. The majority of the species present are of frequent to very common status. The exceptions to this were:

- the water beetle (*Anacaena bipustulata*). This is classified as regionally notable within the CCI. However, it is of favourable status (see **Table**

11F.4), therefore while it requires due regard, it is not as notable as implied by the CCI.

- White-lipped ramshorn snail. This is classified as being of local status within the CCI. More recent information on the status of this snail establishes that it remains widespread within its native range and it is not currently considered threatened (Seddon *et al*., 2014).

1.4.34. Two non-native species were recorded the amphipod *Crangonyx pseudogracilis/ floridanus* and the New Zealand mud snail.

1.4.35. All of the aquatic macroinvertebrate species present are tolerant of fine sediments (PSI: 0), as would be expected for a slow flowing drain of the type sampled. The biological quality of the drain is moderate (WHPT: 70, ASPT: 3.7). No pollution-sensitive taxa were recorded but the drain supported a range of taxa defined as having a moderate tolerance to pollution.

Aquatic Plants

1.4.36. The LWS supported 32 aquatic plant species (excluding algae), of which 20 are scoring species in the GLNP criteria. The assemblage is considered diverse for the habitat conditions and supported a range of submerged, floating and emergent species. Two notable species were recorded:

- Whorled water-milfoil (*Myriophyllum verticillatum*) is a species of calcareous freshwaters with good water clarity. It has declined substantially nationally and is of unfavourable status (Red Data List (RDL) Vulnerable). It was recorded as occasional during the survey and the LWS was judged to support a healthy viable population.
- Water-violet (*Hottonia palustris*) is of patchy distribution in Britain. It has declined substantially nationally and is of unfavourable status (RDL Vulnerable). It was recorded as occasional during the survey and the LWS was judged to support a healthy viable population.

1.4.37. A single non-native plant species, Nuttall's waterweed, was recorded and was abundant along the length of the drain. This is a controlled weed

species listed under Schedule 9 of the WCA, as such it is an offence to cause it to spread in the wild.

Table 1F.4: Summary of the notable aquatic macroinvertebrate species recorded (Conservation Scores > 6)

Species	Waterbody	Habitat and distribution	Current status
Rhantus suturalis	Drain 1 (part of Glew Drain)	This species is found across the whole of England and is currently expanding its range into Scotland. It is commonly found in lowland stagnant waters including recently created habitats (Foster and Friday, 2011).	Previously regarded as Notable (Conservation Score 7) in the CCI system but with no statutory designation or protection. It is judged to have increased in recent years (Hammond, 2017) and as such, a recent review assessed that this species is too widespread to qualify as Nationally Scarce (Notable in the CCI) (Foster, 2010).
Anacaena bipustulata	Keadby Boundary Drain LWS	This species is associated with slow moving waterbodies with clay and silt substrates. It has been recorded within ponds, drains and canals (Hammond, 2017). It has a predominately south-eastern British distribution. With the most northerly British records coming from North Yorkshire (Hammond, 2017).	Previously regarded as Regionally Notable (Conservation Score 7) in the CCI system but with no statutory designation or protection. A recent review assessed that this species is not under threat or in decline (Foster, 2010) and there is evidence that it is either becoming more frequent or is otherwise better recorded now than in the past (Hammond, 2017).

1.5. Conclusions and Nature Conservation Evaluation

Overview

1.5.1. This section provides a final assessment of the aquatic macroinvertebrate, aquatic plant and fish species and assemblages recorded in association with the Proposed Development Site, to translate the preceding analysis to the geographic scale of nature conservation value used for EcIA.

Fish Species Evaluation

1.5.2. The majority of the fish species recorded were common and typical of the habitat conditions. It would be expected that similar communities are present in other comparable habitats such as larger drains and within other reaches of the canal. It is therefore concluded that assemblages present are of local (site level) nature conservation value.

1.5.3. The notable fish species recorded were limited to European eel and spined loach

1.5.4. European eel is listed on Section 41 of the NERC Act as being of principal importance for nature conservation in England. Although it is still relatively common it has decreased substantially and is considered to be at extremely high risk of extinction globally (Pike *et al*., 2020). European eel eDNA was only detected at low levels during the survey, suggesting that it forms a small part of the regular fish community. It is therefore concluded that the Stainforth and Keadby Canal at this location is of local (site level) nature conservation value for eel. Irrespective of this value, the requirements of The Eels (England and Wales) Regulations 2009 (UK Government, 2009) will still need to be met by the Proposed Development. This should be considered further in the EcIA for the Proposed Development.

1.5.5. Spined loach is also listed on Section 41 of the NERC Act. It is restricted in distribution to river catchments in the east of England, including the River Trent. Its population trend is unknown but it is still widespread within its historic range, and it is does not receive any specific legal protection. Whilst spined loach is listed on Annex II of the Habitats Directive, meaning that Special Areas of Conservation (SACs) should be established to support the conservation of the species, neither the canal nor the River Trent is designated for the conservation of spined loach. Given that spined loach is not uncommon and that the survey data indicates that this section of the

Stainforth and Keadby Canal is not specifically important for this species, the population is considered to be of local nature conservation value.

1.5.6. Additional contextual information on fish is provided in **Annex 6** which contains a technical appendix that accompanied the Keadby CCS Power Station DCO application to inform understanding and assessment of the potential effects of underwater sound on fish species, particularly those of conservation importance.

1.5.7. The potential underwater sound impacts and effects of the Proposed Development are much less than could have resulted from construction of Keadby CCS Power Station given that no construction work (and specifically no use of a cofferdam) is proposed within the River Trent. Instead, the only construction works for the Application that could produce adverse levels of underwater sound relate to the construction of a small cooling water abstraction structure on the Stainforth and Keadby Canal. Whilst construction of this might still necessitate installation of a cofferdam, the relative size, installation methods and duration of works for the cofferdam would be much reduced relative to those that would have been required for Keadby CCS Power Station, given the River Trent is a large tidal river. Acknowledging this differing context, the underwater sound technical note is still considered to retain relevance for the understanding of the potential impacts and effects of the Proposed Development on fish.

Aquatic Macroinvertebrate Species Evaluation

1.5.8. The only relatively notable species recorded within any of the waterbodies were the beetles *Anacaena bipustulata* and *Rhantus suturalis* (recorded in Keadby Boundary Drain LWS and Drain 1 (part of Glew Drain) respectively, see **Table 11F.3**). Although previously assessed as Regionally Notable, these species are either expanding in range or have been under recorded previously (or a combination of both factors). Neither are threatened and both can occur in a range of habitats and therefore the CCI is judged to inflate the significance of this species. There are also no grounds to expect that these species are restricted in range in the local area, and instead can reasonably be expected to occur wherever there are comparable drain habitats. On this basis these populations are not considered to be of more than local value.

Aquatic Plant Species Evaluation

1.5.9. Two notable plant species were recorded, water-violet and whorled water-milfoil, both of which were recorded within Keadby Boundary Drain LWS.

No notable plant species were recorded from waterbodies within the Proposed Development Site.

1.5.10. Whorled water-milfoil has declined substantially nationally due to eutrophication of its habitats and is now primarily concentrated in the drainage systems of North Lincolnshire and the fenland of south Lincolnshire and Cambridgeshire (Stroh *et al*., 2020). These strongholds are important for the maintenance of the species nationally. Given the unfavourable status of the species (RDL Vulnerable) it is likely to be considered a key part of the nature conservation interest of Keadby Boundary Drain LWS and as such it is assessed to be of county value.

1.5.11. Water-violet is of patchy distribution in Britain, with its distribution concentrated in areas where there are, or were historically, extensive networks of suitable shallow freshwater habitat. As such, it was formerly widespread in the drainage ditches of North Lincolnshire. The species has declined markedly as a result of eutrophication of freshwater habitats, and its distribution is now much reduced (Stroh *et al*., 2020). Given the unfavourable status of the species (RDL Vulnerable) it is likely to be considered a key part of the nature conservation interest of Keadby Boundary Drain LWS and as such it is assessed to be of county value.

Aquatic Macroinvertebrate and Plant Assemblage Evaluation

1.5.12. The aquatic macroinvertebrate and plant assemblage for each of the waterbodies have been considered together. This is because if the waterbody does not meet the GLNP (2013) criteria for the identification for either group, there is an alternate criterion that allows the data assemblage to be assessed in combination (criterion FW3 of GLNP, 2013).

Drain 1 (part of Glew Drain) and Keadby Boundary Drain LWS

1.5.13. Both Drain 1 and Keadby Boundary Drain LWS meet GLNP (2013) criteria for the identification of freshwater habitats of county value for ecology and nature conservation. This is because the criterion for aquatic plant flora (criterion FW2) is met and also the alternate criterion that allows the aquatic macroinvertebrate assemblage to be assessed in combination with aquatic plant data (criterion FW3).

1.5.14. This data re-confirms the previous third-party LWS assessment in 2010 that Keadby Boundary Drain is of county value, but also indicates that this value also extends to Drain 1 which is not currently included as part of the LWS.

These two waterbodies should therefore be considered to be of county nature conservation value.

1.5.15. The aquatic macroinvertebrate communities are largely comparable between the LWS and Drain 1. The minor differences observed between them are likely to be the result of slight differences in micro-habitats and/ or sampling effort. Mobile species (for example the beetles *Anacaena bipustulata* and *Rhantus suturalis*), will likely move between these areas using suitable niches as they become available.

1.5.16. However, the two waterbodies differed in terms of their botanical interest. Although both waterbodies meet the relevant LWS criterion, Keadby Boundary Drain LWS was found to support a markedly more diverse aquatic plant assemblage (nine more species and four additional GLNP scoring species). This included two notable species (whorled water-milfoil and water-violet, which are assessed as being of county value), both of which were absent from Drain 1.

1.5.17. Neither of these drains is considered to be of greater than county value at this time. The desk study undertaken for the PEA (**ES Volume II Appendix 11C, Application Document Ref. 6.3**) identified a large number of similarly designated drains and other waterbodies in the local area (within a 1km radius of the Proposed Development Site), of which the drains associated with the Proposed Development Site represent only a small proportion. While the extent of the drain network is not automatically an indicator of comparable aquatic value, it seems likely that other drains supporting a similar assemblage of species will occur more widely in within the landscape within which the Site is located (the Humberhead Levels Natural Character Area (NCA)).

Drains 2, 3 and 4

1.5.18. The remaining drains (Drain 2, 3 and 4) do not support aquatic macroinvertebrate and plant assemblages that meet the criteria established for the identification of sites of waterbodies of county value, either in isolation or in combination of the data. Similar arable field drains supporting a similar composition of species are likely to be very common in the wider landscape. On this basis, these waterbodies are considered to be of local value only for their aquatic macroinvertebrate and plant assemblages. However, as these drains are hydrologically linked to Drain 1 (part of Glew Drain) and Keadby Boundary Drain LWS, they may have a value in terms

of the contribution they make to supporting the nature conservation interest of these higher value waterbodies.

Invasive Non-Native Species

1.5.19. Two species listed on Schedule 9 of the Wildlife and Countryside Act were recorded from the Proposed Development Site: Nuttall's waterweed and zander. Nuttall's waterweed was recorded from Drain 1 (part of Glew Drain), Keadby Boundary Drain LWS and the Stainforth and Keadby Canal. Zander was only recorded within the canal. The WCA makes it illegal to cause the spread of these species in the wild. Measures to prevent this should therefore be identified in the EcIA of the Proposed Development if there is potential for these species to be dispersed to new waterbodies.

1.5.20. Although not listed on Schedule 9 of the WCA, the presence of zebra mussel (combined with the dominance Nuttall's waterweed) within the Stainforth and Keadby Canal may lead to issues relating to the clogging of water supply pipework and intake screens for the Proposed Development in the event that the preferred Canal Water Abstraction option is selected as this could affect the operation of the Proposed Development, as well as increase the frequency and cost of essential maintenance and repairs. Given this, the implications arising from the presence of zebra mussel should be considered further during detailed design to mitigate the potential risk to the effective operation of the Proposed Development.

1.5.21. The life cycle of the zebra mussel consists of a microscopic planktonic free swimming veliger (larval stage), a settling juvenile stage and a settled (sessile) adult stage. It is the larval stage that is most likely to be drawn into water supply pipework and lead to settling of juveniles and adults within pipes and on screens. Zebra mussels generally spawn when water temperatures exceed 12^{o}C, however the species has a very varied reproductive cycle and spawning can be restricted in duration (as short as six weeks) or can occur throughout the year (Maguire & Sykes, 2004).

1.5.22. Once spawning is completed, the veligers will then remain in the plankton for eight to 240 days before settling onto surfaces where they metamorphose into juveniles and then develop into the adult form. Zebra mussels will settle on a wide range of substrates, including rocks, pipes and screens. There is also evidence that this species can successfully colonise soft, muddy substrates. Densities of adults can be extremely high with densities of 2,500 to 36,990 mussels per square metre recorded in Ireland (Maguire & Sykes, 2004). This is the primary reason they have such an

adverse impact on infrastructure, as this high biomass inevitably leads to clogging of pipework or impedance of screens, and associated damage.

1.5.23. The other non-native species recorded are also not listed on the Schedule 9 of the WCA but are considered a significant design constraint. It is possible that species such as the demon shrimp may further compound the blocking of pipework, as they are known to occur at high densities but if steps are taken to overcome the issues relating to the zebra mussel and Nuttall's waterweed, this is likely to mitigate the potential risk posed by this species.

1.5.24. It is important to highlight that given the number of INNS recorded within Stainforth and Keadby Canal, this demonstrates that there are a number of existing pathways (but particularly boat traffic) that have facilitated the spread and establishment of these aquatic INNS in the local area. Given this, there is likely to be an ongoing risk of other INNS becoming established which may further impact operation of the preferred Canal Water Abstraction Option on the Stainforth and Keadby Canal. Such INNS might include high risk species such as quagga mussel (*Dreissena bugensis rostrigormis*) and floating pennywort (*Hydrocotyle ranunculoides*), both of which can also block pipework). Therefore, it is recommended that the detail design also consider this risk so that the Proposed Development is resilient to potential additional INNS risks.

1.5.25. The final Construction Environmental Management Plan (CEMP) will set out any necessary measures to minimize the risk of off-site spread of the identified INNS during construction; a Framework CEMP will be prepared to accompany the final application.

1.5.26. The recorded INNS are not likely to pose a specific risk to the River Trent through construction and operation of the Proposed Development, given the existing hydrological connectivity between the canal and the river (there are no current barriers to prevent INNS dispersal, and dispersal can therefore be assumed). However, there would be a risk of spread of these species to waterbodies elsewhere in the landscape e.g. through movements of plant and machinery during and after the construction period.

1.5.27. INNS may also be relevant during decommissioning, and this should be reappraised at that time based on current survey information and with reference to legal requirements at that time.

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Revision: 0 Drawn: MAB Checked: SM Approved: DB Date: 2025-08-20

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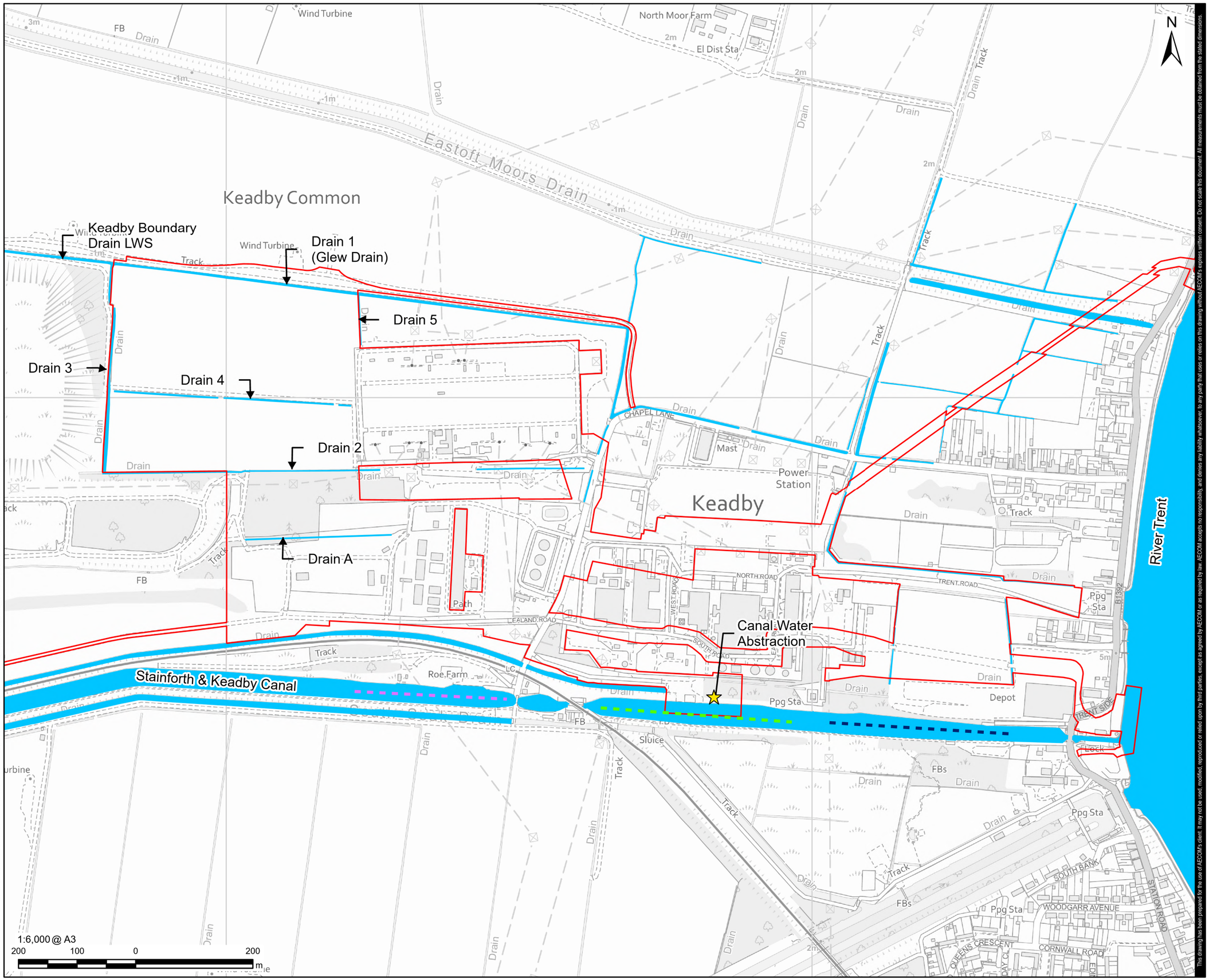

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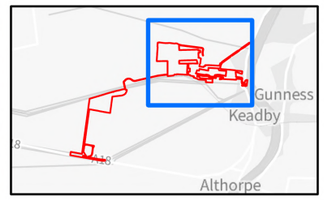
LEGEND

- Proposed Development Site
- Waterbodies
- Canal Water Abstraction

Fish eDNA Sampling Location

- Upstream of Canal Water Abstraction
- Adjacent of Canal Water Abstraction
- Downstream of Canal Water Abstraction



NOTES

ISSUE PURPOSE

AQUATIC ECOLOGY SURVEY REPORT

PROJECT NUMBER

60721867

FIGURE TITLE

Location of Watercourses Surveyed

FIGURE NUMBER

Figure 11F.1

Annex 1

11FA.1 Proportion of Sediment-Sensitive Invertebrates Methodology

11FA.1.1 The Proportion of Sediment-sensitive Invertebrates (PSI) index allows an assessment of the extent to which a waterbody is composed of, or covered by, fine sediments. This follows the method stated in Extence *et al*., 2013. Under this system, individual species of aquatic macroinvertebrates are assigned a Fine Sediment Sensitivity Rating (FSSR) as detailed in **Table A1**, and abundance rating based on LIFE scores as detailed in **Table A2**. The PSI score for the aquatic macroinvertebrate sample is then derived from the individual species scores and abundances, as detailed in **Table A3**. The PSI score corresponds to the percentage of fine sediment-sensitive taxa present in a sample and ranges from 0 to 100, with low scores corresponding to waterbodies with high fine sediment cover.

Table A1: Fine Sediment Sensitivity Rating (FSSR) groups used to derive PSI scores

FSSR group	Description
A	Highly sensitive
B	Moderately insensitive
C	Moderately insensitive
D	Highly insensitive

Table A2: Abundance categories used to derive PSI scores

FSSR group	Abundance			
	1-9	10-99	100-999	>999
A	2	3	4	5
B	2	3	4	5
C	1	2	3	4
D	1	2	3	4

Table A3: Interpretation of PSI scores

PSI	Description
81-100	Minimally sedimented
61-80	Slightly sedimented
41-60	Moderately sedimented
21-40	Sedimented
0-20	Heavily sedimented

Annex 2

11FA.2 Whalley, Hawkes, Paisley & Trigg (WHPT) Metric

11FA.2.1 There are approximately 4,000 species of aquatic macroinvertebrates in the British Isles. To simplify the analysis of the samples and the data, individual species are not identified, but instead only the major types (taxa), mostly at the family taxonomic level. A key piece of information is the number of different taxa at a site. A fall in the number of taxa indicates ecological damage, including pollution (organic, toxic and physical pollution such as siltation, and damage to habitats or the river channel).

11FA.2.2 The WHPT scoring system (WFD-UKTAG, 2014) is based upon the sensitivity of macroinvertebrate families to organic pollution. It replaces the Biological Monitoring Working Party (BMWP) system (Hawkes, 1997) previously used in the UK.

11FA.2.3 The WHPT system assigns a numerical value to about 100 different taxa (known as the WHPT-scoring taxa) according to their sensitivity to organic pollution. In addition to the presence of macroinvertebrate taxa at a sampling site, as in the BMWP scoring system, the WHPT system also uses another type of information, this being the abundances of different scoring taxa.

11FA.2.4 Taxa abundances are classified in four categories (Class 1: 1 to 10 individuals, Class 2: 11 to 100 individuals, Class 3: 101 to 1,000 individuals, and Class 4: > 1,000 individuals). A score (Pressure Sensitivity Scores (PSs) is then assigned to each taxa, depending on the taxa sensitivity and abundances recorded.

11FA.2.5 The total WHPT score for a sample corresponds to the sum of PSs of scoring taxa recorded. The Average Score Per Taxon (ASPT) values are calculated as the Sum PSs divided by the number of scoring taxa (NTAXA). As such, three metrics are calculated:

- WHPT score;
- NTAXA; and
- ASPT.

11FA.2.6 Some animals are more susceptible to organic pollution than others, and the presence of sensitive species indicates good water quality. This fact is considered by the WHPT metrics.

11FA.2.7 The most useful way of summarising the biological data was found to be one that combined the number of taxa and the ASPT. The best quality is

indicated by a diverse variety of taxa, especially those that are sensitive to pollution. Poorer quality is indicated by a smaller than expected number of taxa, particularly those that are sensitive to pollution. Organic pollution sometimes encourages an increased abundance of the few taxa that can tolerate it. However, maximum achievable values will vary between geological regions. For example, pristine lowland streams in East Anglia will always score lower than pristine Welsh mountain streams because they are unable to support many of the high-scoring taxa associated with fast flowing habitat. WHPT scores and ASPT for different types waterbody are dependent on the quality and diversity of habitat, natural water chemistry (associated with geology, distance from source etc.), altitude, gradient, time of year the sample was taken and other factors.

Table B1: A guide to interpreting WHPT and ASPT Score

ASPT	Interpretation
<3.0	Very poor, heavily polluted
3.0-4.3	Poor, polluted or impacted
4.3-4.8	Moderate, moderately impacted
4.8-5.4	Good, clean but slightly impacted
>5.4	Very good, unpolluted, unimpacted

Annex 3 Fish eDNA Results

Common Name	Latin Name	Proportion of eDNA in the upstream sample	Proportion of eDNA in the adjacent sample	Proportion of eDNA in the downstream sample
European Eel	*Anguilla anguilla*	0.48%	2.06%	0.73%
Spined loach	*Cobitis taenia*	-	0.72%	0.58%
Common bream	*Abramis brama*	2.3%	6.61%	1.43%
Common bleak	*Alburnus alburnus*	-	0.10%	-
Silver bream	*Blicca bjoerkna*	8.28%	2.92%	4.97%
Dace/ ide	*Leuciscus sp.*[1]	0.76%	0.75%	0.62%
roach	*Rutilus rutilus*	45.46%	13.66%	46.83%
Common rudd	*Scardinius erythrophthalmus*	3.03%	-	2.37%
Tench	*Tinca tinca*	2.79%	4.32%	4.38%
Cyprinidae sp.	Unidentified Cyprinidae	-	0.40%	-
Pike	*Esox lucius*	1.82%	1.26%	3.82%
Ruffe	*Gymnocephalus cernua*	0.52%	1.03%	-
Perch	*Perca fluviatilis*	34.56%	65.24%	34.27%
Zander	*Sander lucioperca*	-	0.93%	-

1 – The data returned only stated *Leuciscus* sp. However, given there are only two British representatives of this genus (dace *Leuciscus leuciscus* and ide *Leuciscus idus*), the data has been altered to reflect this.

Annex 4 Aquatic Macroinvertebrate Survey Data

Family	Species	WHPT score (presence only)	Conservation Score	FSSR Score	Drain 1	Drain 2	Drain 3	Drain 4	Keadby Boundary Drain LWS
Flatworms								2	
Planariidae	*Polycelis nigra / tenuis*	4.9	1	D		1			
Snails									
Lymnaeidae	Lymnaeidae (juvenile / damaged)	3.3		D	134	1	2		
Lymnaeidae	*Stagnicola sp.*	3.3	-	D			1		
Lymnaeidae	*Stagnicola palustris*	3.3	2	D					4
Lymnaeidae	*Lymnaea stagnalis*	3.3	1	D					2
Lymnaeidae	*Radix sp.*	3.3	-	D	1	10			
Lymnaeidae	*Radix auricularia*	3.3	2	D		8			
Lymnaeidae	*Radix balthica*	3.3	1	D	17	3			
Valvatidae	*Valvata piscinalis*	3.2	1	C					100
Hydrobiidae	*Potamopyrgus antipodarum*	4.2	1	C	116	5			20
Bithyniidae	*Bithynia tentaculata*	3.7	1	D	594		1	10	70
Physidae	Physidae (juvenile / damaged)	2.4		D	7				
Physidae	*Physa fontinalis*	2.4	1	D	11				

Family	Species	WHPT score (presence only)	Conservation Score	FSSR Score	Drain 1	Drain 2	Drain 3	Drain 4	Keadby Boundary Drain LWS
Zonitoides	*Zonitoides nitidus*	-	4		1				
Succineidae	-	-				1		1	2
Planorbidae	*Planorbis planorbis*	3.1	1	D	233	20			20
Planorbidae	*Anisus sp.*	3.1	-	D	10			20	
Planorbidae	*Anisus vortex*	3.1	1	D	30				10
Planorbidae	*Anisus leucostoma*	3.1	5	D	55	5	30	5	5
Planorbidae	*Armiger crista*	3.1	2	C	21				
Limpets and mussels									
Sphaeriidae	Sphaeriidae (juvenile / damaged)	3.9	-	D			10	5	
Sphaeriidae	*Pisidium sp.*	3.9	-	D	4	20	140	25	150
Worms									
Oligochaeta		2.7	-	D		5			20
Leeches									
Glossiphoniidae	*Glossiphonia complanata*	3.2	1	C					3
Erpobdellidae	*Erbodella octoculata*	3.1	1	C					2
Hirudinidae	*Haemopis sanguisuga*	-0.8	4	D	3				
Mites									

Family	Species	WHPT score (presence only)	Conservation Score	FSSR Score	Drain 1	Drain 2	Drain 3	Drain 4	Keadby Boundary Drain LWS
Hydracarina		-			4	2	1		
Oribatei		-					1	2	
Crustaceans									
Crangonyctidae	*Crangonyx sp. (floridanus/pseudogracilis)*	3.9	-		1				150
Asellidae	*Asellus sp.*	2.8	-	D		1		3	
Asellidae	*Asellus aquaticus*	2.8	1	D	1	30	10	3	80
Mayflies									
Baetidae	Baetidae (juvenile / damaged)	5.5		A					1
True bugs									
Gerridae	*Gerris lacustris*		1		1	1			1
Veliidae	Veliidae (nymph / damaged)	4.5				1			
Corixidae	Corixidae (nymph / damaged)	3.8		D	5				
Corixidae	*Hesperocorixa sahlbergi*	3.8	2	D	1				
Notonectidae	Notonectidae (nymph / damaged)	3.4			10				

Family	Species	WHPT score (presence only)	Conservation Score	FSSR Score	Drain 1	Drain 2	Drain 3	Drain 4	Keadby Boundary Drain LWS
Notonectidae	*Notonecta glauca*	3.4	1		1				
Beetles									
Haliplidae	Haliplidae (larvae / damaged)	3.6		D					2
Haliplidae	*Haliplus confinis*	3.6	2	D					3
Haliplidae	*Haliplus immaculatus*	3.6	4	D	2				
Haliplidae	*Haliplus lineaticollis*	3.6	1	C	11	1	1		
Haliplidae	*Haliplus ruficollis group*	3.6			10				5
Gyrinidae	*Gyrinus substriatus*	8.2	1		3				
Dytiscidae	Dytiscidae (larvae / damaged)	4.5		D		20	10	5	1
Dytiscidae	*Hydroporus sp.*	4.5	-	D	1	4			
Dytiscidae	*Hydroporus palustris*	4.5	1			4			
Dytiscidae	*Hydroporus planus*	4.5	2	D		2			
Dytiscidae	*Hydroporus tesselatus*	4.5	2	D	1				
Dytiscidae	*Graptodytes pictus*	4.5	3	D	4				
Dytiscidae	*Rhantus exsoletus*	4.5	5	D	1				
Dytiscidae	*Rhantus suturalis*	4.5	7	D	1				

Family	Species	WHPT score (presence only)	Conservation Score	FSSR Score	Drain 1	Drain 2	Drain 3	Drain 4	Keadby Boundary Drain LWS
Hydrophilidae	Hydrophilidae (larvae / damaged)	6.2	-	D	9	7			
Hydrophilidae	*Helophorus sp.*	6.2	-	D		2			
Hydrophilidae	*Helophorus brevipalpis*	6.2	1	D	1				
Hydrophilidae	*Hydrobius fuscipes*	6.2	1	D			2		
Hydrophilidae	*Anacaena bipustulata*	6.2	7	D					1
Hydrophilidae	*Anacaena limbata*	6.2	1	D	5	2	8	3	
Hydrophilidae	*Anacaena lutescens*	6.2	3	D			1		
Hydrophilidae	*Laccobius bipunctatus*	6.2	2	D	1				
Hydraenidae	*Hydraena sp.*	8.9	-	B	1				
Curculionidae	Curculionidae	-	-		6				
Alderflies									
Sialidae	Sialidae (juvenile / damaged)	4.3	-	D					
Sialidae	*Sialis lutaria*	4.3	1	D					26
Caddisflies									
Limnephilidae	Limnephilidae (juvenile / damaged)	6.2	-	B		1	2	4	1
Limnephilidae	*Limnephilus lunatus*	6.9	1	C		5	1	1	

Family	Species	WHPT score (presence only)	Conservation Score	FSSR Score	Drain 1	Drain 2	Drain 3	Drain 4	Keadby Boundary Drain LWS
Limnephilidae	*Limnephilus auricula*	6.9	3	C					1
Leptoceridae	*Athripsodes aterrimus*	6.7	1	D	1				
Trueflies						4	1	2	
Chironomidae	Chironomidae (damaged / pupea)	1.1	-			30		5	1
Chironomidae	*Tanypodinae*	1.1	-			30			45
Chironomidae	*Orthocladiinae*	1.1	-		1	322	70	2	10
Chironomidae	*Chironomini*	1.1	-		2	733	10	8	10
Chironomidae	*Tanytarsini*	1.1	-			176	10		15
Limoniidae		5.9	-	B	2			1	
Psychodidae		4.4	-	D		1			
Empididae		7.1	-	-		4			
Ceratopogonidae		5.5	-	-	2		2		
Stratiomyidae		3.6	-	C	2	1	2		
Culicidae		2.0	-	-		1			
Muscidae		3.9	-	-	2				
Sciomyzidae		3.4	-	-		2			
Other Taxa									

Family	Species	WHPT score (presence only)	Conservation Score	FSSR Score	Drain 1	Drain 2	Drain 3	Drain 4	Keadby Boundary Drain LWS
Lepidoptera		-	-	-		1			
Collembola		-	-	-					1
Total number of taxa		-	-	-	45	37	22	19	30
Total Number of species		-	-	-	26	14	9	6	17
CCI Score		-	-	-	14.8	7.3	8.8	9.0	12.8
CCI Score required to meet GLNP (2013) criteria for LWS quality based on aquatic macroinvertebrate data alone		-	-	-	15				
PSI Score (species)		-	-	-	1.6	0.0	0.0	0.0	0.0
NTAXA (WHPT)		-	-	-	23.0	19.0	12.0	9.0	19.0
Number of non-scoring families (WHPT)		-	-	-	3.0	2.0	1.0	1.0	1.0
Total number of families		-	-	-	26.0	21.0	14.0	11.0	20.0
WHPT score		-	-	-	97.3	76.1	49.3	37.2	70.0
ASPT (WHPT)		-	-	-	4.2	4.0	4.1	4.1	3.7

Annex 5 Aquatic Plant Survey Data

Common name	Latin name	Drain 1	Drain 2	Drain 3	Drain 4	Stainforth and Keadby Canal	Keadby Boundary Drain LWS
GLNP (2013) scoring freshwater flora		DAFOR D = Dominant (greater than 75% total cover) A = Abundant (51 to 75% total cover) F = Frequent (26 to 50% total cover) O = Occasional (11 to 25% total cover R = Rare (1 to 10% total cover) L (used where species were noted as Local (patchy) in distribution)					
Common water-plantain	*Alisma plantago-aquatica*	R					R
Water-starwort species	*Callitriche agg.*						LA
Blunt-fruited water-starwort	*Callitriche obtusangula**	A					F
Various leaved water-starwort	*Callitriche platycarpa**	F					
Greater pond sedge	*Carex riperia*	A					O
Common hornwort	*Ceratophyllum demersum*					O	
Floating sweet grass	*Glyceria fluitans*	F					A
Greater sweet-grass	*Glyceria maxima*				LA	R	A
Water-violet	*Hottonia palustris*						O
Yellow iris	*Iris pseudacorus*	F		O			O
Fat Duckweed	*Lemna gibba*						LO

Common name	Latin name	Drain 1	Drain 2	Drain 3	Drain 4	Stainforth and Keadby Canal	Keadby Boundary Drain LWS
Common duckweed	*Lemna minor*	A					R
Ivy-leaved duckweed	*Lemna trisulca*	O					R
Purple loosestrife	*Lythrum salicaria*	R					O
Water mint	*Mentha aquatica*						R
Tufted water forgot-me-not	*Myosotis laxa*	O	R				
Spiked water millfoil	*Myriophyllum spicatum*					O	
Whorled water-milfoil	*Myriophyllum verticillatum*						O
Watercress	*Nasturtium officinale*	F					
Watercress species	*Nasturtium officinale agg.*						R
Yellow water-lily	*Nuphar lutea*					R	
Reed canary-grass	*Phalaris arundinacea*	A		F	A		LA
Common reed	*Phragmites australis*	F	D	D	A	O	LA
Curled pondweed	*Potamogeton crispus*	F					A
Fennel pondweed	*Potamogeton pectinatus*						O
Perfoliate pondweed	*Potamogeton perfoliatus*					O	
Water Figwort	*Scrophularia auriculata*					R	
Branched bur-reed	*Sparganium erectum*						O

Common name	Latin name	Drain 1	Drain 2	Drain 3	Drain 4	Stainforth and Keadby Canal	Keadby Boundary Drain LWS
Marsh woundwort	*Stachys palustris*					R	
Bulrush	*Typha latifolia*	O		O			LO
Water speedwell	*Veronica anagallis-aquatica*	O					
Other emergent and aquatic flora		**DAFOR**					
Sweet Flag	*Acorus Calamus*					R	
Creeping bent	*Agrostis stolonifera*	A					O
Wild angelica	*Angelica sylvestris*		F	A			
Hedge bindweed	*Calystegia sepium*						LO
False-fox sedge	*Carex otrubae*	F		R			R
Nuttall's waterweed	*Elodea nuttallii*	A				D	O
Greater Willowherb	*Epilobium hirsutum*		O	A	F	R	R
Hoary willowherb	*Epilobium parviflorum*	R					
Field horsetail	*Equisetum arvense*			F			
Meadowsweet	*Filipendula ulmaria*		F			R	O
Soft rush	*Juncus effusus*						LO
Hard rush	*Juncus inflexus*						LO
Blunt-flowered rush	*Juncus subnodulosus*						LF
Yellow loosestrife	*Lysimachia vulgaris*						R

Common name	Latin name	Drain 1	Drain 2	Drain 3	Drain 4	Stainforth and Keadby Canal	Keadby Boundary Drain LWS
Peppermint	*Mentha piperita*					R	
Hemlock water dropwort	*Oenanthe crocata*					R	
Amphibious bistort	*Persicaria amphibia*	O				R	O
Celery-leaved buttercup	*Ranunculus sceleratus*	O	R				
Clustered dock	*Rumex conglomeratus*						O
Bittersweet	*Solanum dulcamara*			O		R	
Greater duckweed	*Spirodela polyrhiza*	O				A	
Negative Indicators (Algae)							
Green filamentous algae	-					F	O
An algae	*Enteromorpha intestinalis*						R
Total - all species excluding algae		23	6	9	4	18	32
Total - scoring species only		16	2	4	3	8	20
Number of scoring species required to meet GNLP (2013) criteria for LWS quality based on botanical diversity alone		10					
* Water-starwort species are treated as an aggregate for scoring purposes so there is only one point scored regardless of the number of species recorded in this genus							

Annex 6 Technical Note on Underwater Sound Effects on Fish

The Keadby 3 Low Carbon Gas Power Station Project

Document Ref: 6.3

Planning Inspectorate Ref: EN010114

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

Land at and in the vicinity of the Keadby Power Station site, Trentside, Keadby, North Lincolnshire

Environmental Statement
Volume II - Appendix 11H: Underwater Sound Effects on Fish

The Planning Act 2008

The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017

Applicant: Keadby Generation Limited

Date: May 2021

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GLOSSARY

Abbreviation	Description
ANSI	American National Standards Institute
dB	Decibel
MLWS	Mean Low Water Springs
NSR	Noise Sensitive Receptor
PTS	Permanent Threshold Shift
SEL	Sound Exposure Level
SPL	Sound Pressure Level
SSL	Sound Source Level
TTS	Temporary Threshold Shift

CONTENTS

TABLES

1.0 INTRODUCTION

1.1 Overview

1.1.1 This Technical Appendix provides additional detail in relation to the potential effects of underwater sound on relevant fish species (species of conservation importance) to supplement and inform the ecological impact assessment of the proposed construction works within either (depending on the final choice on the cooling water supply for the Proposed Development) the River Trent or the Stainforth and Keadby Canal. The ecological impact assessment is provided in **Chapter 11**: Biodiversity (ES Volume I – **Application Document Ref. 6.2**). The construction activity most relevant to fish and therefore the related ecological impact assessment is construction of a cofferdam, due to the associated requirements for piling (as described below in Section 1.2) which can generate underwater sound and vibration.

1.1.2 The relevant fish species likely to be present in the River Trent are river and sea lamprey (*Lampetra fluviatilis* and *Petromyzon marinus* respectively), European eel (*Anguilla anguilla*) and Atlantic salmon (*Salmo salar*).

1.1.3 Only European eel is likely to be found in association with the Stainforth and Keadby Canal given this watercourse is not favourable habitat for the other species and due to the presence of physical barriers to access (canal locks). Given that similar construction works have relatively recently been consented and completed within the Stainforth and Keadby Canal for the Keadby 2 Power Station cooling water intake, it is considered that it is reasonable to assume that European eel was considered for that consent and that no impact on conservation status was considered likely. Given this, it is considered that this presumption can be re-applied for the Proposed Development. Accordingly, no further assessment of the works in the canal is required within this appendix, and the focus of the assessment is on relevant fish species associated with the River Trent.

1.1.4 As a designating feature of the Humber Estuary SAC and Ramsar site, the effect of underwater sound in relation to river and sea lamprey are also considered in the Habitat Regulations Assessment Screening Report (**Application Document Ref. 5.12**).

1.2 Cofferdam Construction

1.2.1 The activities required for the construction of a cofferdam for the Proposed Development cooling water intake are described in **Chapter 5**: Construction Programme and Management (ES Volume I – **Application Document Ref. 6.2**) and are anticipated to produce impulsive sounds (where hammer pile-driving is required) and continuous sounds (where vibratory pile-driving is undertaken, and from the movement of project vessels). These activities will be sources of underwater sound and vibration within the river, which in turn has the potential to affect fish. However, the proposed cofferdam is relatively small in scale and

the construction period and associated duration of the sound and vibration impact is expected to be of relatively limited duration (refer to paragraph 1.2.2).

1.2.2 The exact materials to be used for the construction of the cofferdam are not known and so the assessment is informed by typical cofferdam construction methods within marine and tidal conditions and is based on previous AECOM project experience and information available in literature. The cofferdam construction assumptions used as the basis for this assessment are therefore as follows:

- vibratory or press piling will be used where this is reasonably practicable, but it is often necessary to drive the final stages of a pile with a hammer and thus the impacts of (hammer driven) piling and vibratory piling have both been assessed;
- sheet piles, such as an AZ-36 700N (100 x 600 mm) would be used for the construction of the cofferdam;
- the cofferdam would require approximately 100m of sheet piles which equates to approximately 200 individual piles;
- based on the relatively shallow depth of water in which the cofferdam is proposed, it is assumed that the cofferdam will comprise a single wall, but the structure will require bracing and pile ties to secure the cofferdam wall before dewatering. Thus, periods of piling activity will be regularly interspersed with other construction activities that will not generate underwater sound;
- it is estimated that each pile will take 1-2 hours to install, depending on conditions, and that 4-5 piles can be installed per day based on the core construction working hours from 07:00 to 19:00 (**Chapter 5**: Construction Programme and Management (ES Volume I - **Application Document Ref. 6.2**));
- on this basis, the estimated piling installation time (vibratory and impact) for the cofferdam will be 25 days. This will be spread throughout the construction period which is expected to also involve bracing and addition of pile ties as the construction progresses. Piling will therefore be intermittent throughout the cofferdam construction programme, with gaps between piling even when no underwater sound is produced; and
- a jack-up barge will be required for installation of the piles below Mean Low Water Springs (MLWS).

1.2.3 The above approach is supported by wider requirements for responsible construction given the proximity of the proposed cofferdam residential noise sensitive receptors (NSR) along Trentside, Keadby village. This is further described in **Chapter 9**: Noise and Vibration (ES Volume I – **Application Document Ref. 6.2**).

1.3 Underwater Sound Background

1.3.1 Sound travels about four-and-a-half times faster in water than in air. The absorption of sound at frequencies where man-made sound generally has the most energy is much smaller in water than in air. As a result, sound is typically audible underwater over much greater distances.

1.3.2 Sound is usually categorised according to whether it is impulsive or continuous in nature. Impulsive sounds are of short duration and can occur singularly, irregularly, or as part of a repeating pattern. Activities generating impulsive sound includes impact piling and explosions, as well as geophysical and seismic survey works. In contrast, continuous sounds occur without pauses or pulses and arise from activities that include vessel movements, drilling and vibratory piling.

1.3.3 The impact of underwater sound on fish ranges from behavioural responses to auditory injury, with the magnitude of impact dependent on the intensity and duration of the sound. In the most extreme cases, such as explosions from the detonation of unexploded ordnance, underwater sound results in tissue injury or mortality.

1.3.4 Not all fish species are equally sensitive/ vulnerable. The impact of underwater sound on fish is, to a large extent, determined by the physiology of fish, particularly the presence or absence of a swim bladder and the potential use of the swim bladder to improve the hearing sensitivity and range of hearing. These morphological features have been used to define three categories of fish, related to their sensitivity (how they might be affected by) to underwater sounds (Popper *et al*., 2014), as described below:

- **high hearing sensitivity fish** – species in which hearing involves a swim bladder or other gas volume (e.g. herring and other Clupidae species). These species are susceptible to barotrauma (e.g. rupture of swim bladder) and detect sound pressure as well as particle motion.
- **medium hearing sensitivity fish** – species with swim bladders in which hearing does not involve the swim bladder or other gas volume (including priority species such as Atlantic salmon and European eel). These species are susceptible to barotrauma although hearing only involves particle motion, not sound pressure.
- **low hearing sensitivity fish** – species with no swim bladder or other gas chamber (e.g. all lamprey species and elasmobranchs) are less susceptible to barotrauma. Hearing in these species involves detecting particle motion rather than sound pressure.

1.3.5 Where more sensitive fish species (i.e. those with swim bladders, so excluding lamprey species) are in very close proximity to a sound source of very high sound pressure level, such as impact pile driving of very large steel piles, physical injury (e.g. swim bladder rupture) and subsequent mortality could occur. The extent of injury is related to sound intensity (the sound pressure

level) and the number of pile-driving strikes (Halvorsen *et al*., 2012). A range of other physiological effects (e.g. barotrauma[1] induced effects such as haemorrhaging, embolism and bulging eyes) and physical damage to the auditory system structures (i.e. inner ear/sensory hair cells and otoliths) may also occur (Nedwell *et al*., 2006).

1.3.6 Behavioural responses can also occur (and this can also have a bearing on the likelihood of injury occurring, as explained later) and include startle reactions, changes in swimming patterns and orientation, disrupted schooling patterns, altered horizontal or vertical distributions, disrupted feeding, and displacement. The behavioural response to adverse underwater sound levels are of most concern when works are being undertaken during periods of high seasonal sensitivity. In particular, underwater sound can lead to abandonment of fish spawning sites and diversion or delay of fish migration. In most situations this is only a potential concern when the affected species are of conservation concern (threatened or specifically protected).

[1] Barotrauma is physical damage to body tissues caused by a difference in pressure between a gas space inside, or in contact with, the body, and the surrounding gas or fluid.

2.0 TECHNICAL ASSESSMENT

2.1 Impact Piling – European Eel and Atlantic salmon

2.1.1 The most up-to-date underwater sound thresholds for fish are the 2014 guidelines published by the American National Standards Institute (ANSI) (Popper *et al*., 2014). Table 1 below summarises the thresholds defined for impulsive sound, such as impact piling, for each of the three fish hearing sensitivity categories for impact criteria ranging from injury to behavioural responses.

2.1.2 For impulsive sound, the injury thresholds are expressed as dual criteria including a single strike peak sound pressure level (SPL) and the cumulative energy over a period of impulses, called the sound exposure level (SEL_{cum}). The thresholds cover physical injury (mortality/ mortal injury and recoverable injury), and auditory injury which is called temporary threshold shift (TTS) and is an elevation in hearing threshold resulting in a temporary reduction in hearing sensitivity.

2.1.3 There are no generally accepted quantitative thresholds available for behavioural responses, largely due to a lack of experimental evidence and high levels of context specific variation in behaviour depending on factors such as sex, age, size and motivation (e.g. foraging) of individual fish. Instead behavioural impact criteria are provided in terms of a relative risk (high, moderate, low) at a distance from the impulsive sound source defined in relative terms as 'near' (N), 'intermediate' (I), and 'far' (F) (Table 1). Whilst absolute values cannot be ascribed to these categories, near can be defined to be in the range of tens of metres from the source, intermediate in the hundreds of metres, and far in the thousands of metres.

Table 1: Underwater sound impact thresholds for fish in relation to impulsive sound sources

Fish Hearing Sensitivity	Mortality/mortal injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behaviour
Low e.g. lamprey	213dB$_{peak}$ 219dB SEL_{cum}	213dB$_{peak}$ 216dB SEL_{cum}	186dB SEL_{cum}	(N) High (I) Moderate (F) Low
Medium e.g. Atlantic salmon	207dB$_{peak}$ 210dB SEL_{cum}	207dB$_{peak}$ 203dB SEL_{cum}	186dB SEL_{cum}	(N) High (I) Moderate (F) Low
High e.g. Herring	207dB$_{peak}$ 207dB SEL_{cum}	207dB$_{peak}$ 203 dB SEL_{cum}	186dB SEL_{cum}	(N) High (I) High

Fish Hearing Sensitivity	Mortality/mortal injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behaviour
				(F) Moderate
Eggs and larvae	207 dB_{peak} 210 dB SEL_{cum}	-	-	(N) Moderate (I) Low (F) Low

2.1.4 The SPL is a measure of the amplitude or intensity of a sound. For impulsive sound sources this is typically measured as a peak value (i.e. the highest amplitude of the pulse). In contrast, the SEL is a time-integrated measurement of the sound energy, which takes account of the level of sound as well as the duration over which the sound is present in the acoustic environment. The assessment of effects to fish and other marine species is based on dual criteria, with a threshold for both the SPL and the SEL metric, and the impact zone is determined by whichever results in the largest estimated distance.

2.1.5 To determine whether impact piling activities are likely to generate sound levels which may exceed the sound thresholds of fish, literature values of the zone of influence, based on geometric spreading calculations for impact piling of a very wide range of pile types have been used (as agreed with by AECOM with regulators previously for the Uig Harbour Redevelopment EIA, see AECOM, 2019). These literature values, provided below in Table 2, include predicted impact zones for large tubular piles, known to generate high sound levels, and so this represents a worst-case that covers sound levels produced during the installation of the sheet piles used to construct a cofferdam.

2.1.6 For the determination of the distance at which the thresholds are met based on SEL, the calculations have assumed an impact piling strike every 15 seconds over a 15-minute accumulation period for a single pile. In practice, as explained previously in Section 1.2, hammer driven piling is generally short term, with its use limited to driving the final section of the pile into the ground. In addition, construction is intermittent with regular breaks to allow for tolerance checks and the addition of bracing and pile ties required for the stability and strength of the cofferdam. Thus, underwater sound from impact piling will be short-term and intermittent, occurring for a period of around 15 minutes, 3-4 times per day. However, the TTS zone of influence is also provided for an uninterrupted piling period of one hour, although it is not likely that it would continue for this long.

2.1.7 The predictions are based on a stationary receiver and a stationary source assumption, and do not take into account any movement of the source or receiver, the frequency spectrum of the sound source or the hearing sensitivity weightings of the receptor species. In addition, geometric spreading calculations over-estimate the effect at distance.

Table 2: Estimated worst case impact distances (m) for fish in relation to underwater sound from impact piling (based on geometric spreading calculations)

Fish Hearing Sensitivity	Metric	Mortality/ mortal injury (m)	Recoverable injury (m)	TTS (m)
Low e.g. Lamprey	SPL SEL_{cum}	<10 <10	<10 <10	40 (15 mins) 101 (60 mins)
Medium e.g. Atlantic salmon	SPL SEL_{cum}	<10 <10	<10 <10	
High e.g. Herring	SPL SEL_{cum}	<10 <10	<10 <10	
Eggs and larvae	SPL SEL_{cum}	<10 <10	<10	

2.1.8 Sound propagation calculations indicate that physical injury to fish, even species with the most sensitive hearing, based on both the SPL and the SEL thresholds, is highly unlikely to occur unless fish are in very close proximity i.e. within 10m of the sound source from impact piling.

2.1.9 A temporary impairment in the hearing of all fish species (TTS) is predicted up to a maximum distance of 40m from the sound source for a 15-minute exposure. This increases to 101m for a continuous 60-minute exposure. It is anticipated that impact piling is only likely to occur without interruption for a period of between 15 and 30 minutes, after which there will be a break in the underwater sound produced. So, the zone of influence for potential hearing impairment will be somewhere between these two distances.

2.1.10 While acknowledging these potential pathways for impact, it is required that standard mitigation for impact piling in marine waters be adopted (JNCC, 2010). Thus, a soft-start or slow ramp-up of piling hammer power will be employed at the commencement of any impact piling activity or after a break of more than 10 minutes. This will assist in allowing sound levels to increase gradually, and any fish in the immediate vicinity of piling has an opportunity to make a behavioural response to the sound and move away before any permanent or temporary injury is likely to occur.

2.1.11 Thus, no injury or impairment to hearing, either permanent or temporary, is likely to occur in any fish species, including species of conservation concern.

2.1.12 Some disturbance of fish is still likely to occur in response to impact piling, particularly in areas closest to the sound source. Behavioural responses can

range from startle reactions and sudden fleeing to a slight alteration in swimming orientation or position in the water column.

2.1.13 Given the relative thresholds shown in Table 2, there is considered to be a moderate risk that behavioural disturbance in low and medium sensitivity fish (including migratory Atlantic salmon and European eel) will occur at intermediate distance, i.e. within the order of hundreds of metres from the sound source. The risk of behavioural disturbance is only high for fish in close proximity, in the order of tens of metres distance from the impact piling activity. As the River Trent at this location is approximately 150m wide, the behavioural impact from piling could therefore potentially extend across the full width of the river and pose a barrier to fish movements, including the identified species of conservation concern.

2.1.14 While this potential behavioural response is beneficial for reducing likelihood of fish injury or mortality within 10m of the sound source, it could also be adverse if it affected the ability of fish to access key habitats within the wider river. While a behavioural response is likely, the ecological/ fitness consequences of this response for the fish species concerned is likely to be limited, due to the mitigation described above, the timing and intermittent nature of the sound, and the reasonable expectation that there will be gradual habituation of the affected fish species.

2.1.15 Any such behavioural disturbance would be intermittent only, due to the restricting of piling works to core daytime working hours. In combination with soft start, this will provide a significant period of time each day when there is no construction activity and associated underwater sound.

2.1.16 There is no evidence to suggest that there are fish species or life stages exhibiting strong site fidelity within the potential zone of influence of the piling (see **Appendix 11G**: Aquatic Ecology Survey Report (ES Volume II - **Document Reference 6.3**)). The exception to this may be where the behavioural response meaningfully impedes the movement of migratory species.

2.1.17 There are migratory species of conservation concern known to be present, transiting through the study area and that can use areas of the river beyond the impact zone. The proposed restrictions on when piling operations take place have direct relevance to assessment of potential for behavioural impacts on key migratory fish species, as certain life stages (juveniles/smolts of Atlantic salmon and adult European eel) migrate predominately at night (Environment Agency, 2017). Thus, there is limited potential for downstream migration of juvenile Atlantic salmon or adult European eel to be disrupted by the piling works. However, there remains potential for impedance of the upstream migration of adult Atlantic salmon and juvenile European eel as this could occur during daylight hours when piling is ongoing.

2.1.18 To address the risk to adult Atlantic salmon, piling would be subject to a precautionary seasonal restriction, with no piling activity in the period

September to November (while the River Trent is not a major Atlantic salmon river the species is present, and recent projects to remove physical barriers to migration are anticipated to benefit the population over time).

2.1.19 In the case of European eel, upstream migration of juveniles (glass eels) is less seasonal in nature meaning that activity is not concentrated within a limited timeframe, and consequently survival or fitness of juveniles is less likely to be affected (relative to adult Atlantic salmon). The time that juvenile eels spend in estuaries before moving into freshwater can last from a few weeks to years and the tendency for migration is correlated with body condition (Cresci, 2020) therefore there is no clear period in which the overall population is likely be affected. Juveniles also tend to utilise the tidal flood current to assist movement, given the limited period over which such tidal movements occur, this also serves to limit the potential for movements of juvenile European eels to coincide with piling (Cresci, 2020). Given this, European eel is inherently less sensitive to potential disturbance from piling given the restricted timeframe required for these works (estimated as 25 days, see Section 1.2). Therefore, no specific mitigation is considered necessary.

2.1.20 Considering all of the above, including adherence to JNCC guidance and seasonal restrictions on piling, the potential for adverse underwater sound impacts and effects on fish from impact piling is **very limited** and is not likely to affect the conservation status of any fish species.

2.2 Impact Piling – Lamprey Species

2.2.1 While the parameters for assessment are the same as defined above in Section 2.1, given the specific importance of the two lamprey species it is considered appropriate to address these species separately.

2.2.2 Lamprey species are categorised as low hearing sensitivity fish species (Popper *et al*., 2014) because they lack specialist hearing structures and consequently their ear is relatively simple (they have no swim bladder or anatomical structure tuned to amplify sound signals). Instead, lamprey species are generally considered to be sensitive only to sound particle motion within a narrow band of frequencies. Indeed, some research indicates that they may only be sensitive to particle motion (Popper & Hawkins, 2019).

2.2.3 Because of this physiology they are inherently resilient to the kinds of physical injury (e.g. barotrauma) that other fish species can experience as result of adverse levels of underwater sound and vibration and therefore physical injury is highly unlikely to occur.

2.2.4 Regardless of this conclusion, in order to protect other fish species that are not qualifying features of the Humber Estuary SAC, the Proposed Development will adopt the standard mitigation for protection of marine receptors from the effect of underwater sound (JNCC, 2010), specifically a soft-start for all hammer driven piling activity. Whilst these measures are designed for the protection of marine mammals, they also provide protection for fish. These measures ensure

that sound intensity from piling, and any associated particle motion, will increase only gradually before reaching full power. This soft start will allow opportunity for individual lampreys located within the potential zone of influence for an adverse noise or vibration impact (i.e. within 10m of the noise/vibration source) opportunity to move away from the construction area before there is potential for an impact to be realised.

2.2.5 For the reasons given above and in Section 2.1, it is usually considered that adverse changes in behaviour (e.g. behavioural changes that affect migration) as a result of underwater noise and vibration on lamprey are also not likely to occur. Lampreys would need to be very close to a powerful noise source for a behavioural response to occur (Popper, 2005; Popper and Hastings, 2009). Lenhardt and Sismour (1995) carried out experiments on sea lamprey and detected a startle response to frequencies between 20 and 100Hz. However, the response was considered likely to be more due to vibration than waterborne noise. Startles while swimming were rare, suggesting that direct contact with the vibrating surface was needed to trigger the reaction. As further indirect evidence of this, the river lamprey was included in a study on the effect of a playback system (with emission frequencies between 20 and 600Hz) in reducing estuarine fish intake rates at a power plant cooling water inlet (Maes *et al*., 1999 and 2004). No significant reductions in river lamprey catches were observed confirming a lack of behavioural response to the noise deterrent.

2.2.6 The absence of a significant sensitivity or response of lamprey within the above studies combined with the adopted good practice construction methods indicates that it is not likely that the conservation status of lamprey species would be adversely affected by underwater sound and vibration.

2.3 Continuous Sound

2.3.1 Vibratory piling and the movement of vessels (primarily on the River Trent) during construction also has the potential to produce underwater sound. These sound sources are continuous in nature, for which a mixture of qualitative and quantitative thresholds are defined (Popper *et al*., 2014), as set out in Table 3. Thus, whilst vibratory piling is much quieter than impact piling, it does occur for longer and thus any particle motion effects will be of a longer duration.

2.3.2 In relation to vessel movements, the River Trent is an existing well-used navigable river with existing port facilities at various points, including at Keadby, adjacent to the Proposed Development Site (Waterborne Transport Offloading Area). Any vessels deployed are likely to be relatively small due to the depth of the river at the cofferdam location. In addition, the jack-up barge used for piling activities will be stationary for much of the time, with its legs jacked down onto the riverbed. Thus, the limited vessel movements during construction are not anticipated to materially alter the baseline underwater sound conditions or affect fish species. Consequently, the impact assessment is concerned only with additional noise sources from vibratory piling.

2.3.3 Very little information has been found to be available on the impact of particle motion from vibratory piling. Even the most recent studies of the impact of sound on fish (e.g. see Hawkins and Popper, 2017; Popper and Hawkins, 2019) concentrate mainly on the effect of sound pressure. Quantitative thresholds are only available for recoverable injury and TTS in high sensitivity fish. Thus, for the fish species in the river of conservation importance (Atlantic salmon, European eel and lamprey) the only available thresholds are qualitative, using relative risk ratings such as those applicable for behavioural responses to impulsive sound as described in above in Section 2.1.

Table 3: Underwater sound impact thresholds for fish for continuous sound sources

Fish Hearing Sensitivity	Mortality/ mortal injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behaviour*
Low e.g. Lamprey	(N) Low (I) Low (F) Low	N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Medium e.g. Atlantic salmon	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
High e.g. Herring	(N) Low (I) Low (F) Low	170 dB SPL_{rms} (unweighted) re. 1µPa, for 48 hours	158 dB SPL_{rms} (unweighted) re. 1µPa, for 12 hours	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low

2.3.4 The thresholds indicate that the risk of mortality from vibratory piling and vessel movements, for all hearing categories of fish at all distances, even in very close proximity from the activity, is low (Table 3). The potential for recoverable injury is also considered to be of low risk for low hearing sensitivity (lamprey species) and medium hearing sensitivity (Atlantic salmon and European eel) fish species. No species of high hearing sensitivity have been identified as being functionally reliant on the river. Thus, the risk of significant harm to fish of conservation importance from vibratory piling is considered to be negligible.

2.3.5 Table 3 indicates that the most important impact on all fish receptors from continuous sound sources anticipated during construction relates to the potential for behavioural responses (e.g. displacement and disturbance) rather than physical or physiological effects. There is a moderate risk for low and medium sensitivity fish in the near and intermediate distance (probably between 10s to 100s of metres from the sound source). Migratory species such as Atlantic salmon and lamprey species are known to be sensitive to particle motion as well as sound pressure (with lamprey needing to make contact with a vibrating surface for a response to be likely, see Section 2.2).

2.3.6 Behavioural responses are likely to include swimming away and a change of swimming direction, orientation or position in the water column. However, the risk of the more significant responses such as startle reactions from vibratory piling and vessel movements is low.

2.3.7 It is anticipated that most of the piling activity will be vibratory in nature, with each pile expected to take circa 1-2 hours (including impact piling for the last stage of piling) with an average of 4-5 piles installed per day. However, as several construction activities need to take place between piles, vibratory piling will also be highly intermittent. Thus, as soon as the vibratory piling stops, fish may return to areas around the cofferdam construction. Fish are also known to habituate to sound over time, particularly when there is high motivation to do so (Popper *et al*., 2014) e.g. migration or access to feeding habitats.

2.3.8 The commitment to avoid any piling activity in the period September to November is sufficient to manage the potential impact on adult Atlantic salmon (it having already been established that juveniles migrate primarily at night when piling would not take place). The rationale presented for European eel in Section 2.1 also remains relevant, given the relatively limited duration for piling (up to 25 days) are not likely coincide with the majority of movements by this species. Lamprey species are also not a relevant consideration given their inherent lack of sensitivity to underwater sound means that adverse impacts are unlikely (Section 2.2).

2.3.9 Considering the committed mitigation for impact piling, and the seasonal restriction for the protection of migratory Atlantic salmon, and the relatively low magnitude of any potential behavioural responses over the limited period of piling (which includes breaks in activity), any potential impact is considered **negligible** and is not likely to be adverse for the conservation status of any fish species.

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