Eels Regulations: intake screening specifications

South Staffs Water

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Contents

1. Introduction

This document outlines intake screening specification requirements at three intakes owned and operated by South Staffs Water (SSW), as follows:

- Nethertown intake on the River Blithe;
- Trent recirculation intake on the River Trent; *and*
- Hampton Loade intake on the River Severn.

The specific screening requirements at each site are outlined in the following sections.

The primary regulatory driver under which screening upgrades are being investigated is the Eels (England and Wales) Regulations 2009. General information on the mesh size and approach velocity requirements for intake screening installations to protect eel are provided in the EA (2015) 'Screening at intakes and outfalls: measures to protect eel' guidance document. All three intakes are located in middle catchment areas well upstream of the tidal limit (84-129 km) and therefore the intake screening requirements at all sites can be met with a relatively coarse mesh size (9 – 12.5 mm) depending on the size of the local eel stock, as protection is only required for adult eel life stages (termed yellow and silver eels). Details of the specific mesh size and approach velocity requirements for each site are detailed within this document. Initial discussions have been undertaken with the EA and agreement gained on general mesh sizes and approach velocities for the sites.

There is potential however, for additional fisheries and screening legislation to be implemented in coming years which may mandate a finer mesh size and a lower approach velocity to provide protection for juvenile fish. A 'Free Passage of Fish Order', has been proposed by the EA and Defra but is still awaiting enactment. The objectives of the Order would be to afford protection to all fish species and support achievement of WFD objectives. For each site a distinction has therefore, been made between measures that would i) achieve compliance with the present screening requirements under the Eels Regulations, and ii) more stringent screening requirements that may offer an element of 'future proofing' for pending legislation.

2. Nethertown intake

The following options have been specified for the Nethertown intake:

- Option A – River frontage screening that achieves compliance with the Eels Regulations only;
- Option B – River frontage screening that achieves compliance with the Eels Regulations and may also provide an element of future proofing in relation to more stringent (but as yet unconfirmed) screening requirements in future;

The specific requirements of each option are outlined in detail below.

2.1 Screening Option A

Mesh size and approach velocity

The Nethertown Blithe intake is on the River Blithe ~122km upstream of the tidal limit. The current intake is ~7m wide with vertical bar screens with ~30mm bar spacing. The screens are currently manually cleaned. The intake structure is orientated broadly parallel to the direction of river flow, although it is set back approximately 0.5 metres from the adjoining wing walls and river bank and is therefore not currently flush with the river bank.

Figure 2-1. The Nethertown intake structure, with the existing vertical coarse bar screens visible.

If feasible and to be compliant with the preferred best practice screening requirements, the intake and screen structure should be projected out into the river channel so that it is flush with the wing walls and river bank. Under this arrangement, the maximum acceptable mesh size for eel protection would be 12.5 mm with a maximum screen approach velocity of 0.40 m/s.

In certain circumstances however, when the intake is operating there may be no flushing flow across the screen face due to the potential for the intake to abstract all available water upstream of Nethertown weir. In this instance and if it is not possible to bring the screen forward, in accordance with EA (2015) guidance it may therefore, be necessary to adopt a more precautionary mesh size of **9 mm** and a reduced approach velocity of **0.30 m/s** to provide sufficient protection to eel.

Based on the above screening requirements, feasible best practice screen options compliant with the requirements of the Eels Regulations for this intake are likely to comprise of either;

- a self-cleaning travelling screen technology, or a,
- passive wedge wire cylinder (PWWC) screen solution.

PWWC screens may, however, be infeasible due to low water depths during operation. Screening guidance (EA, 2015) recommends that the diameter of cylinders does not exceed half of the low water depth and ideally should be no more than one third of the water depth, equating to a cylinder diameter of 0.22 – 0.15 m. It is recommended that both technologies are investigated however, it would be necessary to consult PWWC screen manufacturers to determine whether there is sufficient space to accommodate the necessary number of cylinders that would be required for the licenced abstraction volume.

Cleaning

It is recommended that the screens should be self-cleaning in nature as follows;

- Cleaning of a vertical travelling screen solution could be achieved using a debris spray bar on the rear of the screens, configured to discharge debris into a chute that returns debris to the river on the downstream side of the intake. Providing that the approach velocity at the screen face does not exceed the 0.40-0.30 m/s threshold there would be no requirement for a fish return chute.
- Cleaning of a PWWC solution is achieved through an air-burst system which lifts debris off the screen to be carried downstream by the river flow.

Depths and flood water levels

The water level at the Nethertown intake fluctuates in relation to river flow and the discharge rate. During periods that the Nethertown intake is abstracting all available flow in the river, analysis of historical stage data indicates that the water level frequently falls to *ca.* 60.40 mAOD during abstraction, and on occasion to below 60.20 mAOD. Based on the concrete bed level adjacent to the intake (59.96 mAOD) this corresponds to a low water depth of 0.24 - 0.44 m. In future it would be beneficial to maintain the minimum water level equal to the upstream invert level of the fish pass (60.35 mAOD) during abstraction to maintain a minimum water depth of *ca.* 0.40 m. It may be necessary to install frequency inverters (variable speed drives) on the pumps to maintain a target water level, such that the pumps can operate at a varying speeds to adjust the rate of abstraction in accordance with the upstream water level. The exact target water level may be subject to further discussion with the EA depending on the potential requirement to maintain a continuous fish pass flow during periods of abstraction in future as part of a licence review for the site.

A vertical travelling screen solution would need to be designed to ensure that the screen motor is sufficiently high to prevent inundation during flood events. Upstream stage data for the site (1997 – 2017) provides a maximum flood water level of 61.762 m AOD. The screens and motors would therefore need to extend to at least this level as a minimum. It is understood that the EA policy is for new structures to be designed to withstand a flood level equivalent to a 1 in 100 year flood event + 20 % allowance for climate change projections and therefore further investigation may be required to determine the stage elevation for such a flow.

2.2 Screening Option B

Future fish screening legislation that may be relevant to the intake screening arrangement at this site predominantly relates to the 'free passage of fish order', which may require intake screens to protect juvenile coarse fish species from entrainment. Due to a smaller body size and weaker swimming ability of these species, it would be necessary to adopt a lower approach velocity to prevent fish from becoming impinged on the screen face and a finer mesh size to prevent fish from becoming entrained into the intake. At the time of writing there have been no recent developments regarding the finalisation or implementation of this regulation (Chris Grzesiok, EA, *pers. comm.*). Consequently, it is not possible at this stage to definitively confirm what mesh size may be required to achieve compliance with future legislation. A reasonable approximation of screening requirements can however, be made by considering existing EA screening documents.

Guidance provided in the EA (2015) eel screening document indicates that a mesh size **≤ 3 mm** and an approach velocity **≤ 0.15 m/s** would be sufficient to exclude fry (juvenile) coarse fish species. In common with Option A, feasible screening technologies to achieve these design parameters would comprise of either a self-cleaning travelling screen or a PWWC screen solution. Similarly, a method of automated cleaning would be necessary (e.g. a debris spray bar and return chute or automated airburst cleaning system) and travelling screens and any motors would need to extend clear of the flood water level.

2.3 Approach velocity calculations

As discussed above it would be necessary for the intake screening to achieve a maximum approach velocity of between 0.15 and 0.40 m/s depending on whether screening option A or B is pursued. The following section outlines the approach velocity for the current intake open area to determine whether the existing intake structure is of a sufficient size to achieve the target approach velocities.

Information on water depths and intake dimensions has been obtained from the topographic survey commissioned for the site (Appendix 1) and a summary of approach velocity calculations are provided in Table 2-1.

Table 2-1. Approach velocity calculations for the Nethertown intake.

Intake concrete bed level:	59.96 mAOD
Minimum/low water level:	60.40 mAOD
Water depth at low water:	0.44 m
Width of existing intake structure:	7.80 m
Intake open area at low water:	3.43 m^2
Maximum licenced abstraction rate:	50 Ml/d (0.578 m^3/s)
Typical abstraction rate:	28 Ml/d (0.324 m^3/s)
Approach velocity at maximum abstraction:	**0.578/3.43 = 0.17 m/s**
Approach velocity at typical abstraction	**0.324/3.43 = 0.09 m/s**

The intake open area is therefore of a sufficient size to achieve approach velocities that would be deemed compliant with option A, although minor remedial measures may be required to achieve a sufficiently low approach velocity if option B was pursued for maximum abstraction. This could include enlargement of the intake (e.g. widening) or extending the length of the fish pass upstream to raise the elevation of the upstream baffle invert (for example, increasing the invert by 0.15 m to 60.50 mAOD would require extending the fish pass by approximately 1.0 m at a 15 % gradient). If extension of the fish pass was pursued then the side walls may need raising to ensure that flow through the fish pass is fully contained up to a flow of Q20 (a modified baffle invert of 60.50 mAOD would contain a maximum water depth of 0.42 m through the fish pass based on the current wall height of 60.92 mAOD).

Alternatively, a less onerous solution may be to set a minimum upstream water level as part of future operational changes at the site to increase the proportion of the intake that is wetted during abstraction. For example, a minimum upstream water level of 60.50 mAOD during periods of abstraction (equivalent to a depth of 0.15 m through the fish pass) would achieve an approach velocity of 0.14 m/s at the maximum abstraction rate.

Due to the uncertainty regarding the requirements under the ‘free passage of fish order’ or any alternative future fish screening legislation, it may also be possible to gain agreement with the EA for an approach velocity slightly above the 0.15 m/s value.

2.4 Eel passage

Nethertown weir is deemed by the EA to pose a partial barrier to upstream eel migration and provision of an eel pass at Nethertown weir has therefore recently been added to SSW’s NEP list for implementation.

An eel pass at Nethertown could either be designed as a gravity-fed structure or a pumped structure. Both types of eel pass typically comprise of either a rectangular metal channel housing bristle substrate or plastic ‘eel tiles’ or vertical ‘cassettes’ of eel tiles. For either design there is a requirement for eel passes to function between flows of Q99 and Q70 at a minimum in accordance with EA guidance (EA, 2010).

Figure 2. A vertical eel tile cassette (left) and eel climbing substrate contained within a rectangular channel (right).

For either pass type, a location on the left side of the weir would be preferable to limit potential exposure of eels to the intake on the right bank after they have moved upstream. On the downstream side of the weir the eel pass would need to extend to the bed level within the pool between the weir toe and the pre-barrage structure (59.68 mAOD), while on the upstream side of the weir it would be necessary to extend the eel pass for several metres upstream of the weir crest to reduce the risk of eels being swept back downstream during periods when there is a flow over the weir.

A gravity fed eel pass may require notching of the weir crest to ensure that delivery of water through the pass is maintained at low flows, as under the current site arrangement the majority of water during low flows is likely to be concentrated through the fish pass and/or via leakage through the weir boards. To determine whether a gravity fed eel pass is feasible at Nethertown it would be necessary to confirm the upstream water levels for Q99 and Q70 flows at the weir. The pass would only require a small volume of flow (1 – 2 l/s) to operate effectively, although if it is set too low there is the risk that additional flow may be discharged through the pass which would be undesirable from a water resources perspective.

A pumped eel pass would negate the potential risk of discharging additional flow as the invert of the pass is located at a higher elevation than the upstream water level. A known volume of water is then delivered through the pass using a submersible pump, sourced from either upstream or downstream of the weir. Power for the pump could be obtained from the adjoining control hut or via a solar panel and storage battery. There would, however, be greater operational expense in maintaining a pumped eel pass in an operable state.

3. River Trent intake

The following options have been specified for the River Trent intake:

- Option A – river frontage screening that achieves compliance with the Eels Regulations only;
- Option B – river frontage screening that achieves compliance with the Eels Regulations and may also provide an element of future proofing in relation to more stringent (but as yet unconfirmed) screening requirements in future;

The specific requirements of each option are outlined in detail below.

3.1 Screening Option A

Mesh size and approach velocity

The Nethertown Trent intake is on the River Trent ~121 km upstream from the tidal limit. The current intake is ~2.5m wide with a trash rack with ~80mm bar spacing. The screens are currently manually cleaned. The existing intake (Figure 3-1) is orientated at < 20 degrees to the direction of river flow. In accordance with EA (2015) eel screening guidance, a maximum mesh size of **12.5 mm** and a maximum screen approach velocity of **0.40 m/s** would therefore, be acceptable for the protection of eel.

Figure 3-1. The River Trent recirculation intake on the left bank of the River Trent (river flowing bottom to top).

The existing intake structure is marginally set back from the river bank and thus there is currently limited sweeping flow across the screen face. Reconstructing the intake so that it is located approximately flush with the adjoining river bank would provide a sweeping flow across the screen face, although this may exacerbate flood risk at the site by constricting the channel width. It has therefore been agreed in principal (Chris Grzesiok, Environment Agency, pers. comm.) that the existing intake location can be retained providing that maintenance works are undertaken periodically by SSW to remove deposited material either side of the intake and thus ensure that the river banks remain approximately flush with the intake. It is recommended that both options are investigated and the best solution taken forward to design.

Due to the relatively shallow water depths at the intake and high levels of siltation, a PWWC screen solution may not be feasible at this site and possible options could therefore be limited to a self-cleaning travelling screen structure. It is recommended however, that both screen solutions are investigated for feasibility.

Cleaning

It is recommended that the screens should be self-cleaning in nature as follows;

- Cleaning of a vertical travelling screen solution could be achieved using a debris spray bar on the rear of the screens, configured to discharge debris into a chute that returns debris to the river on the downstream side of the intake. Providing that the approach velocity at the screen face does not exceed the 0.40-0.30 m/s threshold there would be no requirement for a fish return chute.
- Cleaning of a PWWC solution is achieved through an air-burst system which lifts debris off the screen to be carried downstream by the river flow.

It is understood that power to operate the existing intake pump is sourced from the pump house west of Nethertown weir (approximately 400 m north of the Trent intake) and it is likely that this could be used to power any screen motors and/or cleaning systems required for the future screen installation.

Depths and flood water levels

On-site measurements of water level/stage have been completed at the site as part of previous drought report investigations, although the appropriate datum for the logger is not currently known. Additionally, there are no datum levels stated on design drawings for the intake and therefore the invert level of the intake structure is currently unknown. Further investigation into the low and flood water levels at the site would therefore be beneficial to inform the screening design. Additionally, bed bathymetry in proximity to the intake is not currently known; there is potential that the intake may be operated during periods of drought and thus it is recommended that a cross section survey is completed to obtain bathymetry information. The data would be used to calculate low water levels in relation to the intake structure during drought operation to determine whether remedial works may be necessary to achieve a sufficient water depth for operation of the recirculation pump. The bathymetry survey would need to be accompanied by investigations into stage/water level data during typical drought flows.

The maximum stage value recorded by the logger installation at the Trent intake was 1.76 m on 7 July 2012, corresponding to a flow of 59.7 m^3/s (Q0.2) at the nearby Yoxall gauging station. Assuming that the logger datum is approximately equal to the invert of the intake structure, this would correspond to a water depth of 1.76 m. Given the requirement for designs to withstand a stage level equivalent to a 1 in 100 year flow + 20 % allowance for climate change projections, a high water level in the region of 2.5 m is likely to be a reasonable estimate subject to further confirmation.

3.2 Screening Option B

The Trent intake is located in close proximity to Nethertown (Section 1) and therefore screening requirements under any future regulation are likely to be identical to those outlined for the Nethertown intake in Section 2.3. A screening solution with a mesh size **≤ 3 mm** and an approach velocity **≤ 0.15 m/s** is therefore, likely to be deemed acceptable for the site.

Similarly, a method of automated cleaning would be necessary (e.g. a debris spray bar and return chute or automated airburst cleaning system) and travelling screens and any motors would need to extend clear of the flood water level.

3.3 Approach velocity calculations

As discussed above it would be necessary for the intake screening to achieve a maximum approach velocity of between 0.15 and 0.40 m/s depending on whether screening option A or B is pursued. No information on depths at low water level is currently available for the intake and therefore the calculations have been completed in reverse to identify the minimum water depths that would be necessary to achieve the target velocities of 0.15 and 0.40 m/s (Table 3-1).

Table 3-1. Approach velocity calculations for the River Trent intake.

Maximum abstraction rate:	17 Ml/d (0.197 m^3/s)
Intake width	2.00 m
Intake open area to achieve approach velocity < 0.40 m/s:	0.493 m^2
Minimum water depth required for < 0.40 m/s velocity:	**0.25 m**
Intake open area to achieve approach velocity < 0.15 m/s:	1.31 m^2
Minimum water depth required for < 0.15 m/s velocity:	**0.67 m**

Based on visual observations of water depth during previous site visits at average or high river levels it is considered likely that there would be a sufficient depth of water available (i.e. > 0.25 m) to achieve an approach velocity of < 0.40 m/s (Option A) with the current intake arrangement for the majority of the time. Previous stage data for the site however, suggests that the intake water depth has previously fallen to a minimum of *ca.* 0.07 m, although this is by no means typical. Whilst such shallow depths are not a frequent occurrence and abstraction may be restricted/compromised under such situations, the stage data suggest that the water level does frequently fall below the 0.25 m depth threshold (e.g. the 90th percentile of the stage data is 0.23 m).

It is therefore, recommended that the low water level for the site is investigated further. If low water levels below 0.25 m are confirmed then it may be necessary to enlarge the intake (either deepening or widening) to achieve sufficient approach velocities during periods of low flow.

4. Hampton Loade intake

The following options have been considered for the Hampton Loade intake:

- Option A – installing screening at the river frontage with a mesh size and approach velocity that achieves compliance with the Eels Regulation only;
- Option B – installing screening at the river frontage with a mesh size and approach velocity that achieves compliance with the Eels Regulations and may also provide an element of future proofing in relation to more stringent screening requirements in future;
- Option C – retaining the existing river frontage screening arrangement and implementing fish recovery and return (FRR) measures on the in-works band screens. This measure would achieve compliance with the Eels Regulations but may not be considered compliant with future regulation.

The specific requirements of each option are outlined in detail below.

4.1 Screening Option A

Mesh size and approach velocity

The Hampton Loade intake is on the River Severn ~84 km upstream of the tidal limit. The current intake comprises of 12 intake openings each ~2.1m wide. A coarse bar screen spans the intake length and is designed to protect against larger debris only with a bar spacing of ~25 cm. Immediately behind each intake penstock is a coarse vertical bar screen with ~50 mm bar spacing. There are three in-works rotating band screens in the pump house each with a mesh size of 6 mm. The band screens have debris collection ledges and a debris return chute which returns debris and any collected fish via a pipe arrangement to the River Severn just downstream of the intake. The current intake structure is orientated at < 20 degrees to the river flow and therefore a screening solution with a maximum mesh size of **12.5 mm** and a maximum approach velocity of **0.40 m/s** would be acceptable for achieving compliance with the Eels Regulations.

Based on the above screening requirements, feasible best practice screen options compliant with the requirements of the Eels Regulations for this intake are likely to comprise of either;

- A self-cleaning travelling screen technology, or a,
- PWWC screen solution.

Examples of previous vertical travelling screen and PWWC screen solutions installed at UK river intakes of a comparable scale (*ca.* 200 – 400 Ml/d) are provided in Figure 4-1 and Figure 4-2, respectively.

Figure 4-1. An example of a vertical travelling screen solution at a water intake of comparable scale to Hampton Loade.

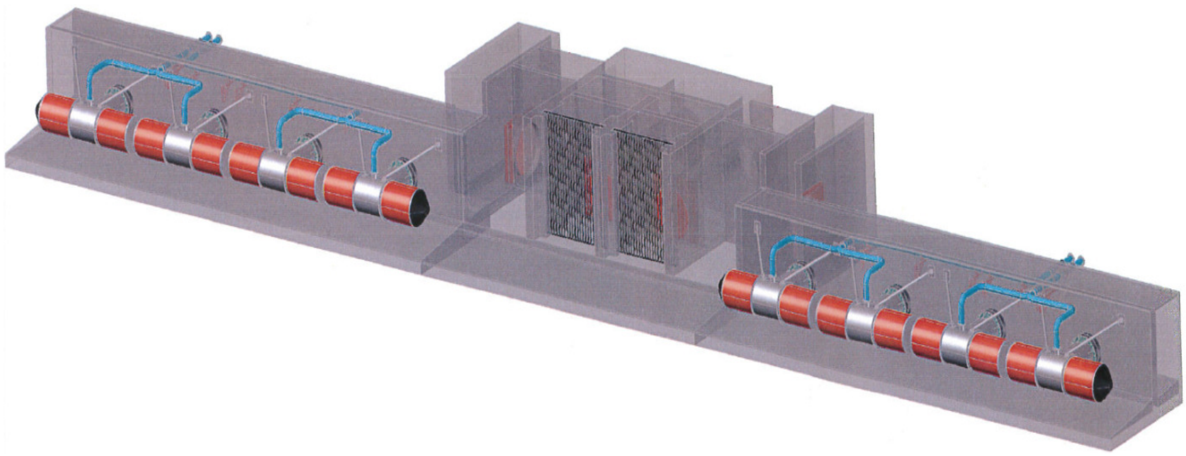

Figure 4-2. An example of a 12 unit PWWC screen array with an 8 mm slot size. The intake abstracts water at a maximum rate of 436 Ml/d (*ca.* 5 m^3/s). The previous intake bays within the centre of the structure are now redundant but were retained to provide scope for emergency capacity.

Cleaning

It is recommended that the screens should be self-cleaning in nature as follows;

- Cleaning of a vertical travelling screen solution could be achieved using a debris spray bar on the rear of the screens, configured to discharge debris into a chute that returns debris to the river on the downstream side of the intake. Providing that the approach velocity at the screen face does not exceed the 0.40-0.30 m/s threshold there would be no requirement for a fish return chute.
- Cleaning of a PWWC solution is achieved through an air-burst system which lifts debris off the screen to be carried downstream by the river flow.

It is assumed that electricity to power the screen motors and/or cleaning systems could be sourced from the pump house.

Depths and flood water levels

Information on low water levels is provided in historical design drawings for the intake. The bar screen cross section drawing (drawing no. 29144) provides a low water level of 75 ftAOD, relative to the intake/river bed level of 73 ftAOD, equating to a low water depth of *ca.* 0.61 m. Analysis of more recent (2011, 2014, 2017) stage data for the intake indicates a recorded low water level of 23.17 mAOD (equivalent to 76 ftAOD), therefore corresponding to a low water depth of approximately 0.90 m.

Based on discussions during the March 2018 site visit a flood water level of 96.00 ftAOD has been assumed based on on-site observations of previous high water levels. Analysis of recent stage data for the site suggests a maximum recent recorded level of 28.03 mAOD (equivalent to 92 ftAOD). The 96 ftAOD is therefore, considered to be a reasonable approximation of flood water levels at this stage given the requirement to design to the equivalent of a 1 in 100 year event + 20 %.

4.2 Screening Option B

Mesh size and approach velocity

Future screening regulations of relevance to the Hampton Loade intake may include the pending 'free passage of fish order' or requirements under a future scenario where the River Severn is afforded protected status. There is an on-going £20m project 'Unlocking the Severn' to restore shad populations to the River Severn through mitigation of barriers to migration and improved habitat connectivity. Allis shad (*Alosa alosa*) and twaite shad (*Alosa fallax*) are both Annex II species designated under the EC Habitats Directive. The specific requirements of this screening option are therefore based on a future scenario where the River Severn may become designated as a Special Area of Conservation (SAC) (or similar designation in the future) subject to the success of the 'Unlocking the Severn' project. In this circumstance, there may be a requirement to implement more stringent screening requirements under a future Review of Consents process as part of the management process for the designated site.

EA (2015) guidance recommends that a **0.25 m/s** approach velocity is sufficient to exclude juvenile and adult shad (EA, 2015). Although no definitive guidance is available on appropriate mesh sizes for shad exclusion, based on fineness ratio curves provided in the 'intake and outfalls' screening guidance (EA, 200x), a mesh size of **3 mm** would be sufficient to exclude juvenile shad of 30 mm length.

It may also be a requirement however, to additionally exclude fry (juvenile) coarse fish species under future legislation. If this were the case then the mesh size of **3mm** is likely to stand however, the approach velocity may need to be reduced further to **≤0.15m/s**.

Cleaning

Due to the fine mesh requirements it would be essential for the chosen screening technology to incorporate an automated cleaning system. For example, for a vertical travelling screen solution this could be achieved using a debris spray bar on the rear of the screens discharging into a debris chute that returns to the river on the downstream side of the intake. For a PWWC screen solution this would be in the form of an air-burst system.

4.3 Screening Option C

Screening modifications

If best practice screening at the river frontage is deemed to be non-cost beneficial or technically infeasible then implementation of FRR modifications may be considered as an alternative measure. The existing in-works screening arrangement comprises of three rotating band screens with a 6 mm mesh size. Each band screen incorporates toothed debris ledges which facilitate the removal of impinged debris (and fish) from the screen into a debris return chute, constructed from stainless steel and measuring approximately 30 cm in diameter. The three debris return chutes (one from each screen) converge to form a single return chute which discharges to the river downstream of the intake. The return chute drops vertically from ground level to the river level in a drain/pipe arrangement.

The current design does not, however, adhere to EA (2014) best practice guidelines for the recovery and return of fish to the river channel unharmed. It may be possible to retrofit FRR adaptations to the existing 6 mm mesh aperture band screens, It should be noted however, that an FRR system would not be considered compliant under the legislative requirements discussed under Option B. Juvenile shad are very delicate and susceptible to mechanical stress from band screen handling and would likely exhibit low survival rates with this technology type. If option B was being pursued for the protection of juvenile coarse fish only then a finer mesh size (≤3 mm) may need to be considered which would require full band screen replacement.

To achieve an FRR arrangement compliant with the Eels Regulations the following structures and/or modifications would be necessary:

- Installation of water-retaining buckets at the base of each band screen panel to collect fish encountering the band screen mesh;
- Installation of a low pressure (<1 bar) spray prior to the high pressure debris spray to remove any fish unharmed;

- A dedicated fish return launder that collects fish after the lower pressure spray and returns them to the river channel. The fish return launder must adhere to best practice guidance, comprising;
    - Swept radius bends,
    - Smoothed joints,
    - Launder diameter 0.3 – 0.5 m,
    - Access hatches for rodding/debris clearance,
    - Discharging below low water river level,
- No use of chlorinated water prior to the fish spray;
- Continuous rotation of the band screens during abstraction.

4.4 Approach velocity calculations

4.4.1 River frontage screen solution

It would be necessary to achieve a maximum approach velocity of 0.15 – 0.40 m/s at the intake depending on whether screening option A or B is pursued. Information on water depths and intake dimensions has been obtained from construction drawings of the intake structure and calculations of approach velocities under two different abstraction scenarios are provided in Table 4-1.

Table 4-1. Hampton Loade intake frontage approach velocity calculations.

Low water level:	75 ft AOD
Intake bed level:	73 ft AOD
Intake water depth at lower water level *(assumes screens are perpendicular to the river bed and not angled as per current arrangement – i.e. most conservative scenario with smallest open screen area)*	2 ft (0.61 m)
Number of intake penstocks:	12
Approximate penstock width:	2.2 m
Total intake open width	12 * 2.2 = 26.4 m
Intake open area at low water level	0.61 * 26.4 = 16.10 m^2
Maximum licenced abstraction rate:	17,100 m^3/hr = 4.75 m^3/s
Typical abstraction rate:	13,300m^3/hr = 3.69 m^3/s
Approach velocity at maximum abstraction:	**4.75/16.10 = 0.30 m/s**
Approach velocity at typical abstraction:	**3.69/16.10 = 0.23 m/s**

The intake open area is therefore of a sufficient size to achieve approach velocities that would be deemed compliant with option A.

If option B was pursued, the calculated approach velocity at typical abstraction would be suitable for the protection of eels and juvenile shad. The calculated approach velocity at maximum abstraction, however, exceeds the recommended velocity for juvenile shad. If the lower approach velocity requirement under option B for the protection of juvenile coarse fish was sought then the current intake opening would need to be modified under both the maximum and typical abstraction rates to achieve the required approach velocity. This could therefore lead to a scenario whereby best-practice intake frontage screening is implemented for Eels Regulations compliance (Option A), but may require significant remedial works (e.g. enlargement/widening of the intake) in future if the intake subsequently needs to comply with more stringent screening regulations.

Band screens

The following section provides an overview of approach velocities in each of the three band screen wells. Although there is no published guidance on approach velocities at band screens where FRR is being investigated, a higher approach velocity of up to ~0.40m/s is generally deemed acceptable as entrained fish must eventually interact with the band screens to be recovered and returned to the river channel.

Approach velocity calculations for the band screens are provided in Table 4-2. It is recommended that the approach velocities that would be achieved with modified band screens are investigated to ensure that fish would be collected and returned effectively and in a short time period as the current approach velocities are quite low which could result in protracted residence in the screen well.

Table 4-2. Hampton Loade band screen well approach velocity calculations.

Low water level:	75 ft AOD
Band screen well bed level:	62.5 ft AOD
Intake water depth at lower water level	12.5 ft (3.80 m)
Number of band screen sumps	3
Approximate width per band screen sump *(width is approximate and has been scaled from design drawings)*	3.10 m
Total open width of band screen sumps	3 * 3.10 = 9.30 m
Open area at low water level	3.80 * 9.30 = 35.34 m^2
Maximum licenced abstraction rate:	17,100 m^3/hr = 4.75 m^3/s
Typical abstraction rate:	13,300m^3/hr = 3.69 m^3/s
Approach velocity at maximum abstraction:	**4.75/35.34 = 0.13 m/s**
Approach velocity at typical abstraction:	**3.69/35.34 = 0.10 m/s**

5. Summary of screening requirements

A summary of the screening requirements for each site is provided in Table 5-1.

Table 5-1 Summary of the screening requirements for each site under the different options

Site/requirements	Nethertown Blithe		Nethertown Trent		Hampton Loade		
Screening option	A	B	A	B	A	B	C
Species requiring protection	Eels	Eels & juvenile coarse fish	Eels	Eels & juvenile coarse fish	Eels	Eels, juvenile shad & juvenile coarse fish	Eels & juvenile coarse fish. Juvenile shad would not be afforded protection by this solution.
Mesh size	9-12.5mm	≤3mm	12.5mm	≤3mm	12.5mm	≤3mm	≤3-12.5mm
Permissible approach velocity	≤0.30-0.40m/s	≤0.15m/s	≤0.40m/s	≤0.15m/s	≤0.40m/s	≤0.15-0.25m/s	≤0.40m/s
Solution options	Self-cleaning travelling screen or PWWC screens	Self-cleaning travelling screen or PWWC screens	Self-cleaning travelling screen or PWWC screens	Self-cleaning travelling screen or PWWC screen	Self-cleaning travelling screen or PWWC screens	Self-cleaning travelling screen or PWWC screens	Fish Recovery and Return system adaptations to existing or new band screens

6. References

Environment Agency, 2010. Environment Agency Fish Pass Manual Document – GEHO 0910 BTBP-E-E.

Environment Agency, 2015. Screening at intakes and outfalls: measures to protect eel. The Eel Manual – GEHO0411BTQD-E-E. Available online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297342/geho0411btqd-e-e.pdf

Turnpenny, A.W.H. and O'Keeffe, N. 2005. Environment Agency Science Report SC030231, Screening for Intake and Outfalls: a best practice guide. Available online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291568/scho0205bioc-e-e.pdf

Appendix 1 – Nethertown Weir Topographic Survey

Topographic survey