River Trent HEP Schemes:
Assessment of cumulative impacts

Renewables First

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1. Introduction

1.1 Report purpose

Renewables First proposes to construct low-head hydro-electric power (HEP) schemes at three weirs on the River Trent to the east of Nottingham. Following comments provided by the Environment Agency as part of a pre-application response, APEM Ltd were commissioned to undertake an assessment of each scheme with regards to the following elements:

1. A geomorphology assessment – focusing on hydromorphology and sediment transport processes within each weir pool;
2. Changes in the quality and extent of fish habitat in the weir pools associated with each scheme;
3. An assessment of the upstream passability of each weir structure under the current baseline scenario and the future HEP scenario;
4. Changes to dissolved oxygen (DO) concentrations associated with a reduction in flow over the weir at each site; *and*
5. Impacts of the proposed hydropower scheme on upstream hydromorphology and riparian habitat arising from an increase in the height of weirs on the River Trent at low to medium flows.

The above elements were considered within an individual assessment report for each site. In addition, the EA requested that potential cumulative in-combination impacts should be assessed, which forms the basis of the following document. Cumulative impacts have been considered for a future scenario where all three HEP schemes are constructed and operating concurrently.

1.2 Overview of scheme proposals

A total of three HEP schemes are proposed on the River Trent at Stoke, Gunthorpe and Hazelford weirs. A map showing the location of the proposed schemes is provided in Figure 1-1. The location of the three proposed HEP schemes on the River Trent at Stoke, Gunthorpe and Hazelford weirs.Figure 1-1. A brief overview of the proposals at each site is as follows:

- Stoke: construction of twin Archimedes screw turbines on the far left side of the weir abstracting a maximum of 20 m^3/s (10 m^3/s per turbine), in addition to a co-located multi-species fish pass and separate eel and lamprey pass;
- Gunthorpe: construction of twin Archimedes screw turbines on the far right side of the weir abstracting a maximum of 20 m^3/s (10 m^3/s per turbine), in addition to a co-located multi-species fish pass and separate eel and lamprey pass; *and*
- Hazelford: construction of a single Kaplan turbine on the left bank of the northern weir abstracting a maximum of 55 m^3/s. A multi-species fish pass would also be constructed adjacent to the turbine on the northern weir and an additional fish pass and separate eel and lamprey pass constructed on the southern weir.

More detailed information is contained within the individual assessment reports for each site.

The following sections provide a brief summary of findings at each site for the individual assessment elements, which are then used to inform the assessment of potential cumulative impacts. Depending on the particular element, impacts may be positive or negative in nature relative to the current baseline scenario.

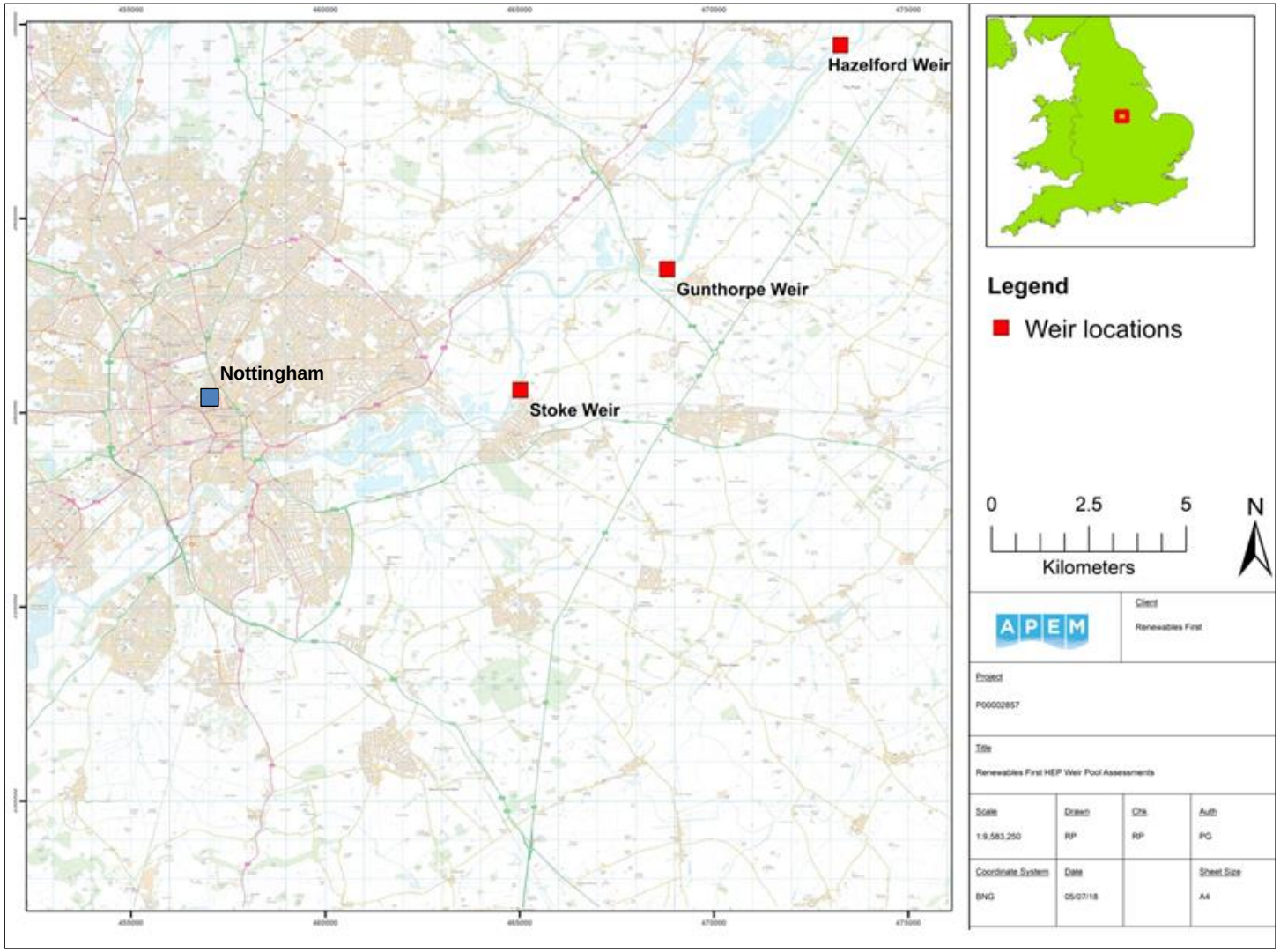

Figure 1-1. The location of the three proposed HEP schemes on the River Trent at Stoke, Gunthorpe and Hazelford weirs.

2. Geomorphology

Detailed information on the focus and methodology of the geomorphology assessment is provided within the main assessment report for each site. The assessment used modelled shear stress values for the baseline and future scenarios in addition to measured sediment data derived from grab sampling to predict potential changes to sediment erosion, transport and deposition within the weir pool/impacted reach at each site.

2.1 Summary of assessment findings

Stoke

Overall, modelling results indicated that the reach downstream of Stoke weir is characterised by low boundary shear stress and relatively coarse bed sediment. As such, geomorphological processes are currently subdued with limited entrainment and transport of bed material at most flows under existing conditions. This situation was not expected to change following installation of the HEP scheme and flows were predicted to remain relatively unaffected given that the HEP scheme reaches maximum abstraction at <Q99. Therefore, flow and shear stress at moderate to high flows were expected to remain relatively unaffected.

There was a small risk that reductions in boundary shear stress at some locations may be sufficient to allow fine sediment (<0.062 mm in diameter) to be deposited locally during low flows (Q75 and below). However, the impact of any such deposition on bed composition was considered likely to be temporary as higher magnitude flows will remain competent to entrain coarse sand and fine gravel at most assessment points within the weir pool. The impact of the changes in flow distribution over the sediment bar was also expected to be minimal as maximum modelled shear stress across the range of flow scenarios considered was lower under proposed conditions compared with the current situation.

Gunthorpe

Overall, the modelling results indicated a limited change in entrainment and transport of material at the majority of sampling points across the weir pool.

However, there is a possible impact from the tailrace discharge on the right-hand bank a short distance downstream of Gunthorpe weir, which coincides with a narrow gravel shoal and mudstone cliff face. The cliff face may be at risk of increased erosion at flows in excess of *ca.* Q10. Erosion of the beach feature and cliff face may lead to further morphological adjustments downstream where eroded sediment is deposited. As such, some form of scour protection may be advisable at this location to minimise risk of morphological changes. Alternatively, consideration could be given to reducing the rate of abstraction above Q10 (when the base of the cliff starts to become wetted), to minimise the risk of erosion.

Hazelford

The proposed HEP scheme was predicted to result in some scour and coarsening of bed material at the turbine tailrace due to the small D50 under current conditions, combined with a notable increase in boundary shear stress under post-HEP conditions.

Slight coarsening of bed material in the order of a maximum single change in size class (e.g. very fine gravel to fine gravel) was also deemed possible in places on the right hand bank downstream of the north weir due to the small D50 at these locations.

The analysis indicated that there may be some fine sediment deposition downstream of the southern weir immediately upstream of the gravel bar due to reductions in shear stress and the frequency of competent flushing flows. Reductions in grain size, frequently in the order of two particle size classes (e.g. coarse sand to fine sand), were therefore deemed possible, assuming fine material is supplied to the reach, which it may not be. However, any such accumulation or ingress of fines would be flushed intermittently, as flushing flows competent to entrain these larger particle sizes would still occur, albeit somewhat less frequently.

2.2 Cumulative impacts

At all three sites, the main anticipated impacts of the proposed HEP schemes on processes of sediment erosion, transport and deposition were caused by changes in the spatial distribution of shear stress downstream of the weirs. These changes were caused by abstraction of flow through the turbines and were expected to result in changes in bed sediment size and possible attendant changes in channel morphology. However, the assessments indicated that the spatial extent of these adjustments was highly localised and the impacts of the modified flow patterns would reduce rapidly with distance downstream as flows from the turbines mix with that over the weir. Given the localised nature of the anticipated changes, a cumulative adverse impact from all three River Trent sites is not expected.

3. Fish habitat

Each of the three proposed HEP schemes will involve changes to hydraulic parameters (depth and velocity) and geomorphology in the associated weir pools, which has the potential to alter the quality or quantity of habitat available for fish (and other species). There have been few studies focusing specifically on weir pools in relation to fish habitat in the UK, although it is generally accepted that they offer important and often locally scarce habitat. The importance of an individual weir pool is determined by the quality of habitat present within it (e.g. the quality of gravels and sedimentation), the local scarcity of similar habitat types (including the proximity to other weir pools on the river system) and the location of the weir pool within the catchment.

The three weir pools considered in this report are located on a lowland stretch of the River Trent which is characterised by a low energy environment and a gentle bed gradient. Consequently, bar and riffle features that often form in association with weir pools are less numerous on these lowland river stretches compared to, for example, steep upland streams. These environments therefore offer locally important habitat for a range of fish species and life stages, including spawning habitat for species such as barbel and chub where clean gravels are present. Additionally, the highly oxygenated water often results in congregations of larger adult fish of rheophilic species.

Therefore, the three weir pools offer locally important habitat for a range of fish species and life stages. However, such weir pool habitats are not excessively rare throughout the lowland Trent given its modified nature. In addition to Hazelford, Gunthorpe and Stoke, further weir pools are present at Sawley, Thrumpton, Beeston, Holme Lock, Averham, Newark and Cromwell over a *ca.* 65 km length. Additionally, the majority of these structures comprise barriers to fish migration and thus there is limited connectivity between the structures at present, resulting in somewhat fragmented fish populations within each reach.

3.1 Summary of assessment findings

Detailed information on the focus and methodology of the fish habitat assessment at each site is provided within the main assessment reports. The fish habitat assessment utilising habitat modelling, focusing on potential impacts to adult, juvenile and spawning life stages of rheophilic coarse fish and roach (as an example generalist/eurytopic coarse fish species). Impacts to lamprey spawning and juvenile (ammocoete) habitat were also considered at all three sites, in addition to salmon spawning habitat at Hazelford.

Stoke

The fish habitat modelling indicated that the proposed HEP scheme would result in a decrease in areas of suitable habitat for rheophilic spawning at low flows (Q95 – Q75), which was driven primarily by the proposed increase in the downstream water level, resulting in sub-optimal water depths. A small decrease in habitat suitability for adult rheophilic life stages was predicted at Q95, but was expected to remain largely unchanged at all other flows. Conversely, a modest increase in habitat suitability for juvenile rheophilic life stages was predicted at low to moderate flows (Q95 – Q50), driven by reductions in water velocity outside of the main HEP flow plume.

Spawning habitat for roach was deemed to be largely absent from the site under the baseline conditions and was predicted to remain unchanged following construction of the HEP scheme. Moderate increases in habitat suitability for juvenile and adult life stages of

roach were predicted following construction of the HEP scheme, driven by reductions in velocity outside of the main HEP flow.

Gunthorpe

Overall, the habitat assessment indicated that the proposed HEP scheme would result in a decrease in areas of suitable habitat for rheophilic spawning at low flows (Q95), driven primarily by changes in velocity associated with the reduced flow over the weir. However, this was somewhat offset by predicted increases in suitability at moderate flows (Q50 – Qmean). Similarly, the scheme was deemed likely to reduce the suitability of the weir pool for adult rheophilic species at low flows (Q95), but was predicted to remain largely unchanged at all other flows.

An increase in areas of suitable habitat for both juvenile rheophilic species and adult and juvenile roach were predicted relative to baseline, due to a reduction in mean velocities outside of the main HEP plume. No significant changes in roach spawning habitat or juvenile lamprey habitat were anticipated due to an absence of such habitat under the current baseline conditions.

Hazelford

An increase in the availability of adult rheophilic habitat in the northern weir pool after construction of the HEP scheme was predicted. In contrast, there was a predicted decrease in juvenile rheophilic habitat. Spawning salmon and lamprey, juvenile lamprey and adult rheophilic habitat suitability were predicted to remain largely unchanged under the HEP scheme in the northern channel.

Habitat availability was predicted to increase for spawning and juvenile rheophilic coarse fish as well as adult roach in the southern reach after commencement of the HEP scheme. Spawning salmon and lamprey and adult rheophilic habitat suitability was predicted to decrease slightly due to reductions in flow and mean velocities through the channel.

The modelled areas in the assessment were deemed to be largely unsuitable for spawning and juvenile roach as well as juvenile lamprey under baseline conditions and thus no significant impacts on these life stages were anticipated.

3.2 Cumulative impacts

The overall net change in modelled habitat area for each species and life stage across the three sites is provided in Figure 3-1.

The habitat modelling suggests that there is likely to be a reduction in rheophilic spawning habitat suitability under low flows at two of the three sites (Stoke and Gunthorpe), although spawning habitat suitability is predicted to remain broadly unchanged or improve marginally under higher flows. Conversely, an improvement in rheophilic spawning habitat quality is predicted for the southern channel at Hazelford, which represents the largest overall area of suitable habitat. Therefore, across the three sites a marginal net increase in rheophilic spawning habitat is predicted and no adverse cumulative impacts are anticipated.

A similar finding was established for adult rheophilic life stages, whereby habitat suitability was predicted to decrease marginally at Stoke, Gunthorpe and Hazelford (south) under low flow conditions, although suitability was predicted to remain unchanged or improve marginally under moderate to high flows. Overall, the modelling indicated that there would be

a small reduction in suitable habitat for adult rheophilic species across the three sites. However, given the large area of habitat available for this life stage at each of the three sites under baseline conditions, no cumulative adverse impacts are anticipated.

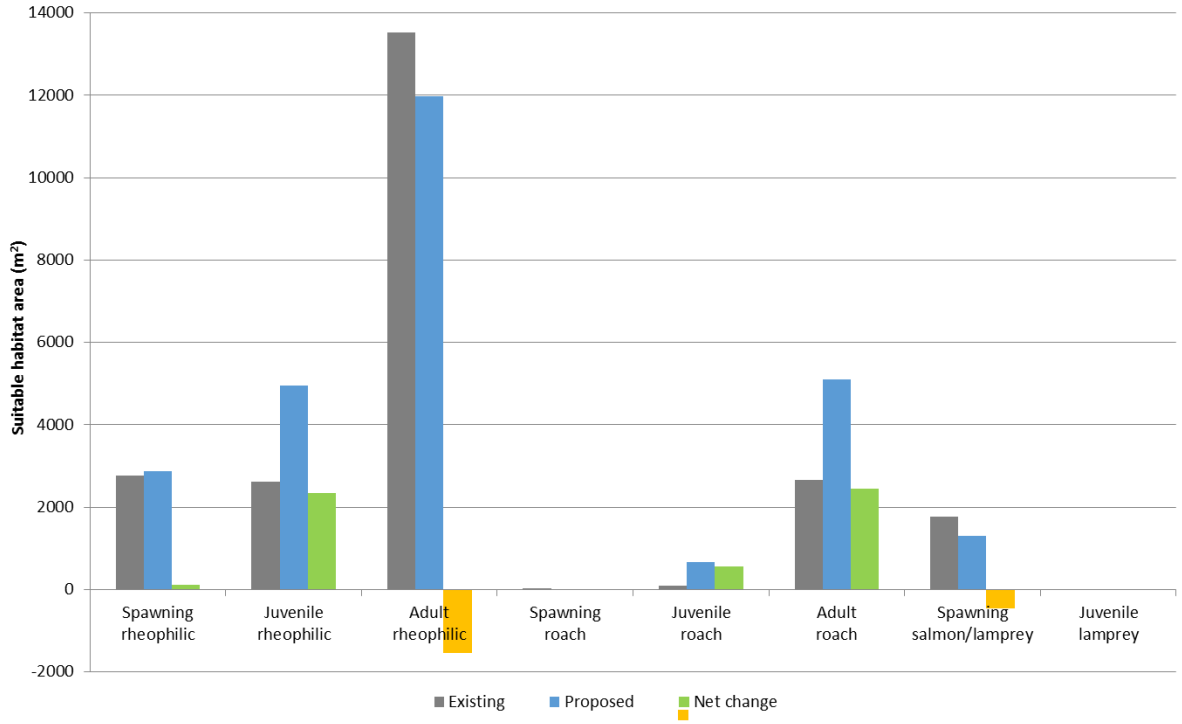

Figure 3-1. Summary of suitable modelled habitat (0.5 – 1.0 suitability rating) summed across all flows (Q95 – Q5) for each species and life stage across the three sites, showing total habitat area under the existing and proposed conditions and the overall predicted net change in habitat area.

Increases in habitat suitability for juvenile and adult roach and juvenile rheophilic species were predicted across all three sites. Increases in the area and quality of habitat were generally modest in magnitude and are unlikely to act in a significant positive cumulative manner across the three sites; instead there may be small, localised benefits at individual sites.

Suitable roach spawning and juvenile lamprey habitat was largely absent from the three weir pools under both the baseline and predicted future scenarios due to the high energy environment of the sites, a coarse substrate and a general absence of plant material. Therefore, no significant changes in habitat availability were predicted (cumulatively or otherwise) for these species and life stages.

4. Fish passage

Detailed information on the focus and methodology of the fish passage assessment is provided within the main assessment reports. A WFD111 assessment methodology was used to consider the change in passability of each weir structure between the baseline conditions and the future HEP conditions.

4.1 Summary of assessment findings

Stoke

Stoke weir was deemed to pose a complete barrier to the upstream passage of cyprinid species, eel and lamprey at all flows under the baseline conditions due to excessive head drops and high velocities over the weir face. The structure was deemed to be a complete barrier to salmon and trout passage at low flows (Q95) and a partial barrier (high impact) for salmon and sea trout at moderate to high flows (Q50 and Q25) under baseline conditions.

Despite a reduction in the passability of the main weir structure due to the addition of an inflatable weir crest associated with the HEP scheme, the overall upstream passability at the site was predicted to increase following construction of the HEP scheme due to the addition of a multi-species fish pass and separate eel and lamprey pass adhering to EA (2010) best practice guidance.

Gunthorpe

Gunthorpe Weir was deemed to pose a complete barrier to the upstream passage of cyprinid species, eel and lamprey under baseline conditions due to excessive head drops and high velocities over the weir face. Additionally, the structure was deemed to be a low impact barrier to salmon and sea trout due to opportunities for upstream passage via the existing pool and traverse fish pass.

Despite a reduction in the passability of the main weir structure due to the addition of an inflatable weir crest associated with the HEP scheme, the overall upstream passability at the site was predicted to increase following construction of the HEP scheme due to the addition of a multi-species fish pass and separate eel and lamprey pass adhering to EA (2010) best practice guidance.

Hazelford

Hazelford Weir was deemed to pose a complete barrier to the upstream passage of cyprinid coarse fish species and lamprey under the baseline conditions due to excessive head drops and high velocities over the weir face. In addition, Hazelford south weir was deemed to pose a complete barrier to the upstream passage of eel and both weirs were deemed to be high impact barriers to the upstream passage of salmon and sea trout.

Despite a reduction in the passability of the main weir structure due to the addition of inflatable weir crests associated with the HEP scheme, the overall upstream passability at the site was considered to increase following construction of the HEP scheme due to the addition of a multi-species fish pass and separate eel and lamprey pass on both the north and south channels.

4.2 Cumulative impacts

The three weir structures are currently deemed to hinder the upstream passage of fish species to varying degrees, ranging from partial barriers for strong swimming species (e.g. resident and migratory salmonids) through to complete barriers for weaker swimming species (e.g. cyprinids). The multi-species fish, eel and lamprey passes that are proposed alongside each of the HEP schemes would increase the passability of all three weir structures.

Providing fish passage at each of the sites on the River Trent would improve connectivity along a *ca*. 20 km of main stem river between Hazelford weir and the next barrier upstream of Stoke weir (Holme Lock), whilst also improving the access to tributaries within this reach. The EA are currently investigating potential fish passage options at Holme Lock which would provide access to a further 19 km of main stem river. These measures have the potential to yield significant benefits for migratory fish species such as eel, salmon and lamprey that are beginning to return to the Trent catchment following improvements in water quality and habitat. Improvements in connectivity would also benefit a number of coarse fish species which typically undertake migrations to access spawning habitat (e.g. barbel, brown trout).

The benefit derived from the improvements to connectivity across the three sites is likely to be greater than providing fish passage at a single site in isolation. For example, a scheme constructed at Stoke weir in isolation would improve connectivity along a 5 km, compared to a >20 km length if all three schemes were developed. Construction and operation of the three schemes concurrently is therefore considered to have a significant cumulative positive impact on fish passage and connectivity.

5. Dissolved oxygen

Detailed information on the focus and methodology of the DO assessment is provided within the main report for each site. The assessment comprised a high level qualitative assessment, informed by historic DO data collected by the EA and ecological and WFD impact thresholds.

5.1 Summary of assessment findings

Stoke

EA monitoring of DO downstream of Stoke weir indicated that concentrations have been consistent with High WFD status during 2017 and 2018. Due to the recent DO concentrations and low HEP abstraction (maximum abstraction would occur at a flow <Q99) it was considered highly unlikely that the scheme would cause a material adverse impact on DO concentrations at the site. No deterioration in the WFD status of the physicochemical element of the Trent waterbody or adverse impacts on fish and invertebrates were anticipated.

Gunthorpe

EA monitoring of DO at Gunthorpe indicated that levels have been consistent with high status during 2017 and 2018. Due to the recent DO concentrations and low HEP abstraction relative it was considered highly unlikely that the scheme would cause a material adverse impact on DO concentrations at the site and no deterioration in the WFD status of the physicochemical element of the Trent waterbody was expected. Additionally, adverse impacts on fish and invertebrates were not anticipated.

Hazelford

EA monitoring of DO at Gunthorpe, upstream of Hazelford, indicated that levels have been consistent with High WFD status during 2017 and 2018. Given recent DO data, in addition to the fact that re-oxygenation of water would still occur via several means at Hazelford following construction of the HEP scheme, no adverse impacts on the WFD status of the waterbody or ecological receptors were anticipated.

5.2 Cumulative impacts

Additionally, the total flow in the River Soar comprises a low proportion of the total River Trent flow at the confluence (< 15 %), providing a significant dilution effect prior to flow reaching the three Trent sites. Between the confluence of the Soar/Trent and the most upstream of the three Trent sites (Stoke weir), water is subject to further re-oxygenation over two weirs on the River Trent which would remain unaffected by the proposed HEP schemes.

The HEP schemes at Stoke and Gunthorpe each reach maximum abstraction at <Q99 and thus for the majority of the year reoxygenation over the weir crests at both sites would remain largely unaffected, meaning cumulative impacts are highly unlikely to occur. Whilst the HEP scheme at Hazelford abstracts a greater proportion of total river flow, a sizeable volume of flow will continue to pass over the weir crests and thus be subject to reoxygenation, leading to a minor impact significance at this site.

Therefore, on the basis of the high DO concentrations currently recorded in the assessment reaches and the minor magnitude of impacts at each individual site, no significant cumulative impacts on DO across the three sites are anticipated.

6. Changes in upstream water level

Detailed information on the focus and methodology of assessment of changes in upstream water level is provided within the main assessment report for each site.

6.1 Summary of assessment findings

Stoke

The proposed HEP scheme includes provision of an additional inflatable weir crest to raise the upstream water level by 0.40 – 0.47 m during low to moderate flows. The increase was not expected to significantly alter the character of the upstream river channel given the occurrence of low velocity glide/pool flow under the current baseline conditions. The addition of the inflatable weir crest would not increase the maximum high water level under high flow events and thus impacts on water vole or otter populations (e.g. due to inundation of burrows) were not anticipated.

The proposed increase in weir crest height was considered unlikely to have a substantial impact on coarse sediment transport processes which are of most importance in influencing channel morphology. This is because the existing structure at Stoke was deemed likely to inhibit the majority of downstream sediment transport, and because the weir crest will not be raised during high flows (>Q10) which are responsible for the majority of coarse sediment transport.

The increase in upstream water level has the potential to create a backwater effect on tributaries of the River Trent between Stoke and the next weir upstream (Holme Lock). A single tributary – Polser Brook – was identified which flows into the River Trent between these two structures, contained within the 'Polser Brook from Cotgrave Brook to Trent' WFD waterbody (GB104028053230). The overall extent of any impact on this waterbody was deemed likely to be relatively small, however, given the 0.47 m maximum increase in water level.

Gunthorpe

The proposed HEP scheme includes provision of an additional inflatable weir crest to raise the upstream water level by 0.32 – 0.36 m during low to moderate flows. The increase was not expected to significantly alter the character of the upstream river channel given the occurrence of low velocity glide/pool flow under the current baseline conditions. The addition of the inflatable weir crest would not increase the maximum high water level under high flow events and thus impacts on water vole or otter populations (e.g. due to inundation of burrows) were not anticipated. The increase in upstream water levels has the potential to create a backwater effect on several tributaries of the River Trent between Gunthorpe and Stoke weirs which are designated as main rivers by the EA and either encompassed within the 'Trent from Soar to The Beck' WFD waterbody or separate waterbodies (e.g. Cocker Beck, Shelford Brook). The extent of any impacts on these tributaries was considered to be relatively small given the maximum 0.36 m increase in water levels.

The proposed increase in weir crest height was deemed unlikely to have a substantial impact on coarse sediment transport processes which are of most importance in influencing channel morphology. This is because the existing structure at Gunthorpe is likely to inhibit the majority of downstream sediment transport, and because the weir crest will not be raised during high flows (>Q10) which are responsible for the majority of coarse sediment transport.

Hazelford

The HEP scheme includes provision of additional inflatable weir crests to raise the upstream water level by 0.30 – 0.37 m during low to moderate flows. The increase was not expected to significantly alter the character of the upstream river channel due to the dominance of low velocity glide/pool flow under baseline conditions. The addition of the inflatable weir crest would not increase the maximum high water level under high flow events and thus impacts on water vole or otter populations (e.g. due to inundation of burrows) were not anticipated.

The proposed increase in weir crest height was deemed unlikely to have a substantial impact on coarse sediment transport processes which are of most importance in influencing channel morphology. This is because the existing structure at Hazelford is likely to inhibit the majority of downstream sediment transport, and because the weir crests will not be raised during high flows (>Q10) which are responsible for the majority of coarse sediment transport.

6.2 Cumulative impacts

The proposed addition of inflatable weir crests at the three sites on the River Trent would increase water levels upstream of each weir during low to moderate flows, resulting in an increase in depth and a marginal decrease in velocities compared to the baseline scenario. The river channel upstream of each weir consists of low velocity pool and glide flow under the baseline scenario and the proposals would not significantly alter the overall character of the river channel upstream of each weir; ecological impacts at each site were therefore deemed to be negligible.

However, when considered together the proposals would increase water levels over a *ca*. 20 km length of the River Trent and potentially a number of tributaries (the overall extent of which has not been quantified). Consequently, it is possible that the proposals may result in an adverse impact when considered cumulatively due to the large spatial extent over which the water level changes would occur. The overall magnitude of any impact is, however, likely to be relatively minor. When viewed in the wider context of the scheme proposals (including improvements to fish passage/connectivity), the proposals are considered unlikely to result in an adverse impact/deterioration to the ecological or overall status of the Trent WFD waterbody, nor biological quality elements.

No impacts on species utilising the riparian habitat zone (e.g. water vole or otter) or geomorphological processes were identified during the assessment and therefore no cumulative impacts related to these elements are anticipated across the three sites.

7. Conclusions

Geomorphology

At all three sites, the main anticipated impacts of the proposed HEP schemes on processes of sediment erosion, transport and deposition were caused by changes in the spatial distribution of shear stress downstream of the weirs. However, the assessments indicated that the spatial extent of these adjustments was highly localised and the impacts of the modified flow patterns would reduce rapidly with distance downstream as flows from the turbines mix with that over the weir. Given the localised nature of the anticipated changes, a cumulative adverse impact from all three River Trent sites is not expected.

Fish habitat

The fish habitat modelling did not identify any significant adverse impacts that are likely to act in a cumulative manner across the three sites. Across the three sites, a negligible change or moderate net increase in suitable habitat area was predicted for six of the eight species. A small net decline in suitable habitat area was predicted for adult rheophilic species across the three sites, although given the abundance of such habitat, the decrease is not expected to result in a cumulative adverse impact. Additionally, a small decrease in suitable salmon/lamprey spawning habitat was predicted across the three sites, although the small magnitude of the change means that there are likely to be cumulative adverse impacts across the three sites. It should also be noted that access to these areas of functional habitat is currently limited for migratory species given the barriers posed by the weir structures. The accessibility of this habitat would be improved by the schemes due to the inclusion of fish passes at each barrier.

Fish passage

The proposals would increase fish passage and habitat connectivity at each individual site. Given an absence of any additional barriers in the intervening reaches, passage improvements at the three sites would cumulatively improve access to a ca. 20 km stretch of main stem river up to Holme Lock for a range of migratory and resident fish species.

Upstream water level

Whilst the proposed increase in upstream water level at each site covers a relatively small length, the total length over which the water level increases extend when considered cumulatively may be sufficient to result in a minor adverse impact. However, when viewed in the context of the overall scheme proposals (including improvements to fish passage/connectivity), adverse impact/deterioration to the WFD status of the biological quality element or overall ecological status of the Trent waterbody is not anticipated.