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Idle and Torne High Flow Study

Phase 2a

Environment Agency

April 2020

DRAFT

Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
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1. Introduction

1.1 Project Appreciation

The Idle and Torne catchments are closed to any new consumptive abstraction[1] because there is a lack of an evidence base to prove whether high flow abstraction has an ecological effect or not, with regard to the following:

- Uncertainty over the role and importance of high flows in maintaining the geomorphological and ecological functioning of the river systems.
- A degree of uncertainty with respect to water levels and connectivity to floodplain washlands.
- Uncertainty over the importance of high flow in supporting downstream estuarine habitats associated with the river Humber.
- Concerns regarding the over-abstracted nature of the underlying aquifer.

Both systems, encompassing 1,200km^2 in total, are hydrologically complex being comprised of a number sub-catchments including a number in the lower reaches which are pumped.

Abstractions of high flows greater than the Environmental Flow Indicator (EFI) in both catchments is being considered. The EFI for the Torne is equivalent to the Q_{15} while the EFI for the Idle is equivalent to the Q_{18}.

The purpose of the overall project is to derive an evidence base to demonstrate whether abstraction at high flows on the Idle and Torne would have an adverse environmental impact or not. Specifically the project aim is to understand the importance of high flows for supporting the **current** and potential **future** ecological status of the river catchments with respect to compliance with relevant environmental protection obligations.

We undertook the first study of this project culminating in October 2015 in the production of a feasibility study report[2]. This identified the next steps from which the current project (Phase 2) has resulted.

1.2 Phase 2 Objectives

The key objective of Phase 2 is to understand the significance of high flows and floodplain connections for in-stream, riparian and terrestrial habitats that are hydraulically connected to the rivers and their floodplains.

Through developing this baseline understanding we would be able to determine the effects of potential abstraction of flows above the EFI.

Phase 2 is separated into two parts, as follows:

- Phase 2a: Review of hydraulic and groundwater models to examine their suitability of use in this study and updated and expanded review of the environmental baseline.
- Phase 2b: Undertake more detailed investigations (activities to be determined on completion of Phase 2a).

This report presents our findings from Phase 2a. This includes our recommendations for Phase 2b.

[1] Idle and Torne Licencing Strategy, Environment Agency, February 2013.

[2] AECOM (2015) - High Flow Abstraction for Multiple Environmental Benefits in the Idle and Torne Catchments – A Feasibility Study - Phase 1 Report

1.3 Report Structure

The remainder of this (Phase 2a) report is broken down as follows:

- Phase 2a methodology;
- Physical environmental baseline;
- Environmental features baseline and sensitivity review;
- Model reviews; and
- Summary and phase 2b recommendations.

2. Phase 2a Methodology

2.1 Overview

Phase 2a is split into two main parts. The methodology for these is described next.

- Environmental baseline (physical environment and environmental features) baseline review, data gap analysis and sensitivity appraisal; and
- Hydraulic and groundwater model reviews.

2.2 Environmental Baseline Review and Sensitivity Appraisal

Failure to plan across a full array of cross-sector, hydromorphological and ecological river services can have undesirable and unanticipated consequences. Abstraction is known to have many impacts on the functioning of a river and subsequently the aquatic biota. Nevertheless, it should not be considered in isolation, it is important to understand the complexities caused by multiple pressures present that can exacerbate the impacts associated with abstractions.

A preliminary sensitivity map (excluding hydromorphological sensitivity) was produced as part of the previous Feasibility Study[3]. This provided an initial visual summary of the key river reaches and their relative sensitivity to additional abstraction. During the previous study, it was concluded that the most likely sensitive reaches would be those largely unmodified and those reaches susceptible to changes in out of bank flows (i.e. with lateral connectivity remaining in the absence of embankments).

As part of Phase 2a more up to date information was obtained and reviewed, to refine and build upon this initial map. Further efforts have been undertaken with regard to developing our understanding of the physical environment (including a more detailed hydrological review and water quality appraisal). In addition further hydromorphological information has been obtained and analysed.

Up to date Environmental Feature (ecological) information has also been obtained and reviewed in order to refine our understanding of areas that may be sensitive to changes in high flow. Data that has been obtained has included the following:

- Water Framework Directive (WFD) Monitoring data (including fish, macroinvertebrate, macrophytes);
- Fish stock and habitat data;
- Biological record centres data and Magic Maps website (designated sites, including SSSIs);
- RHS data; and
- Previous WFD walkover investigation reports.

A summary of data sets and sources is provided in Table 2.1 below.

Table 2.1 Ecological data sets and sources

Feature/ Receptor	Source of data
Statutory and non-statutory sites for nature conservation	Nottinghamshire Biological and Geological Records Centre Greater Lincolnshire Nature Partnership (BRC) Environment Agency
Protected riparian species - Water vole (*Arvicola amphibious*) - Otter (*Lutra lutra*) - White clawed crayfish (*Austropotamobius pallipes*)	
Invasive species	

[3] AECOM (2015) - High Flow Abstraction for Multiple Environmental Benefits in the Idle and Torne Catchments – A Feasibility Study - Phase 1 Report

River Habitat Survey	Environment Agency
WFD monitoring data - Macroinvertebrates - Fish - Macrophytes and diatoms	
WFD walkover investigation reports	

Given the size of the catchments, the aim of Phase 2a review was to screen the data (on the Physical Environment, defined here as hydrogeology, hydrology, water quality and hydromorphology, or ecological receptors), for flow sensitive river reaches and sites. The results of the screening would then be to inform more detailed assessment of the impacts of high flow abstractions on discrete more sensitive areas. In addition potential affects have been examined and screened. Receptors were examined with regard to their importance (i.e. statutory and non-statutory sites for nature conservation and protected riparian species) and availability of monitoring data.

The physical environmental baseline is presented in Section 3 of the report whilst the environmental features baseline is presented in Section 4. Topic specific methodologies are described at the beginning of their respective baseline sections.

2.3 Model Reviews

2.3.1 Hydraulic models

Since the Feasibility Study (completed in 2015), new hydraulic models of both River Idle and Torne have been constructed. These are both strategic scale linked 1D/2D hydraulic Flood Modeller Pro (FMP)-TUFLOW flood models and were completed in 2019.

The review was necessary to ascertain if both models were suitable for use this study (i.e. to help determine abstraction impacts during high flows). The models were built to examine flood risk extents and levels while the minimum flood they were designed to simulate was the 1 in 2 year flood (50% Annual Exceedance Probability (AEP) event). High flows considered in this study are generally lower than the 1 in 2 year flood so the model is not calibrated for flows of importance to this study and may not function reliably. For reasons such as this the appropriateness of the models have been reviewed. A strategic model is constructed at a catchment basis and may not be appropriate to investigate smaller scale effects at a reach level.

This was considered important as the models were built at a strategic level and for flood mapping purposes.

The model reviews were undertaken using a modified version of our standard review proforma which AECOM have employed previously on numerous Environment Agency projects to provide a commentary of the suitability of a hydraulic model. This proforma includes a traffic light comments system and has been adapted to provide an evaluation of key criteria necessary for modelling the impacts of high flow abstraction on floodplain connectivity, and in-stream hydraulic parameters required for geomorphological and eco-hydrological assessment.

2.3.2 Groundwater model review

As part of Phase 2a, AECOM have also undertaken a review of the East Midlands Yorkshire groundwater model) hosted by the National Groundwater Modelling System (NGMS), to examine its potential usefulness in the study.

3. Physical Environment Baseline and Sensitivity

3.1 Background

The physical environmental baseline has been developed and expanded from the Feasibility Study that was undertaken in 2015[4]. The baseline is presented through this section and includes the following:

- Catchment Overview;
- Geology and Hydrogeology;
- Hydrology;
- Hydromorphology; and
- Water Quality.

A discussion of the physical environment sensitivity is presented at the end of this section. This is informed by the categories bulleted above. For example from a hydromorphological perspective it is considered that the most likely sensitive reaches would be those largely unmodified and those reaches susceptible to a reduction in out of bank flows (i.e. with lateral connectivity remaining in the absence of embankments).

3.2 Catchment Overview

3.2.1 General information

The Idle and Torne catchments are indicated in Figure 3.1. The figure indicates the main tributaries of both systems as well as the lowermost level dependent pumped sections of the watercourses. 75% of the Torne catchment is a pumped level dependent system (total catchment size of around 520km^2). Around only 10% of the Idle catchment is a pumped level dependent system (total catchment size of around 880km^2). The low lying level dependent area of both catchments is collectively referred to as the Isle of Axholme. Watercourses in non-pumped sections of both system flow under gravity.

[4] AECOM (2015) - High Flow Abstraction for Multiple Environmental Benefits in the Idle and Torne Catchments – A Feasibility Study - Phase 1 Report

Figure 3.1 Idle and Torne River Network

In the free flowing part of the Torne catchment land cover is reported to be 12% woodland, 47% arable, 17 % grassland and 22% urbanised[5]. The lower level dependent section is mainly agricultural although grassland and urban areas are also present.

At the Mattersey flow gauge on the River Idle, the elevation of the gauge is 5.7m AOD. At the gauge the catchment is reported to be 17% woodland, 47% arable, 17% grassland, 2% mountain/ heath/ bog and 16% urban[6]. The River Ryton joins downstream of this gauge and at its lowermost, and now closed gauge (at Serlby Park/ elevation 7.1m AOD) the Ryton is reported to be 12% woodland, 55% arable, 16% grassland and 16% urban[7].

The River Idle and River Torne catchments are moderate to lowland catchments dominated by intensive agriculture. The catchments surfaces have been intensively modified from historic woodland and grassland coverage to agriculture, and large extents of the rivers' channels have also been modified by realignment, re-sectioning, and due to construction of near-channel or set-back embankments. All of these modifications are associated with flood protection and drainage engineering for agricultural land use gain. They also influence how high and flood flows manifest through the catchment, i.e. patterns of bankfull and out-of-bank flooding. The local economy relies heavily on agriculture, and in turn groundwater and surface water abstractions (principally for irrigation), hence availability of high flow abstractions for irrigation is an important consideration.

[5] National Flow Archive- Torne at Auckley. https://nrfa.ceh.ac.uk/data/station/info/28050

[6] National Flow Archive- Idle at Mattersey. https://nrfa.ceh.ac.uk/data/station/info/28015

[7] National Flow Archive- Ryton at Serlby Park. https://nrfa.ceh.ac.uk/data/station/info/28016

Keadby pumping station lies at the end of the Torne catchment while West Stockwith is the terminal pumping station at the end of the Idle catchment. Both discharge into the tidal Trent.

3.3 Geology, Hydrogeology and Groundwater

3.3.1 Geology and Hydrogeology

The headwaters of the River Torne include the Ruddle (Paper Mill Dyke) and St Catherine's Well Stream. These rise over Permian strata including the Cadeby Formation, the Edlington Formation and Brotherton Formation to the south of Doncaster and near Maltby. These units are classified as a Principal Aquifer, comprising predominantly limestone. The tributaries subsequently flow over Triassic strata, which predominantly comprise the Nottingham Castle Sandstone Formation, the main unit of the Sherwood Sandstone Group in the study area, and then the Mercia Mudstone in the vicinity of the Isle of Axholme.

The headwaters of the River Idle include the Oldcotes Dyke (near to Maltby), Anston Brook, Broad Bridge Dyke, Millwood Brook, Poulter, Meden, Maun and Rainworth Water. Oldcotes Dyke, Anston Brook, Broad Bridge Dyke and the Meden rise over Carboniferous strata including Wickersley Rock, the Pennine Upper Coal Measures Formation, the Pennine Middle Coal Measures Formation and Mexborough Rock. The Milwood Brook, Poulter and Maun rise over the Cadeby Formation (Permian strata). Rainworth Water rises over the Nottingham Castle Sandstone Formation and, similar to the River Torne, the bedrock geology underlying much of the catchment downstream of the headwaters listed above comprises the Nottingham Castle Sandstone Formation.

The headwaters often overlie bedrock classified as Secondary A aquifer[8] locally. However generally the rivers' headwaters cross the Cadeby Formation aquifer and in much of the lower catchment cross Sherwood Sandstone Group formations, both classified as Principal aquifers, which supports a number of groundwater abstractions.

The Sherwood Sandstone aquifer increases in transmissivity from west to east with increasing thickness, with transmissivity falling deeper into the confined aquifer. The unconfined aquifer is considered to have higher transmissivity to the south compared to the north[9].

In the underlying Cadeby Formation transmissivities are similar to the Sherwood Sandstone units, but aquifer storage is low in comparison. There is an upward gradient for groundwater flow in the Cadeby Formation aquifer to the Sherwood Sandstone. These units are separated by aquitards (Middle Permian Marls) but in areas of faulting through the aquitards there is the potential for upward flow into the Sherwood Sandstone. Several faults have been identified in the study area with a displacement considered significant to potentially bring the Cadeby Formation and Sherwood Sandstone into hydraulic contact.

The thickness of the intervening formations between the Cadeby Formation and Sherwood Sandstone thickens toward the east.

At the Auckley gauge on the River Torne, bedrock geology is reported to be 91% highly permeable and 9% mixed permeability[10]. The baseflow index calculated (BFIHOST) is an indication of catchment responsiveness accounting for soil type on runoff rates and the extent that groundwater enhances river flows in the upstream catchment (i.e. the interaction between groundwater and surface water).

[8] Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers

[9] East Midlands-Yorkshire Sherwood Sandstone Modelling Project. April 2009. Entec and Environment Agency.

[10] National Flow Archive- Torne at Auckley. https://nrfa.ceh.ac.uk/data/station/info/28050

The BFIHOST reported at the gauge (for river and its contributing catchment up to the gauge) is reported to be 0.78 indicating the importance of groundwater contributions and runoff to river flow at times when groundwater levels are above the bed of the river.

At the Mattersey flow gauge on the River Idle, bedrock geology is reported to be 77% highly permeable and 23% mixed permeability[11]. The BFIHOST at the gauge us reported to be 0.79, again indicating importance of groundwater contributions to river flow at times when groundwater levels are above the bed of the river.

3.3.2 Groundwater Monitoring

3.3.2.1 Monitoring data

Groundwater monitoring data for a number of sites was obtained from the Environment Agency. Most of these generally related to monitoring of the Sherwood formation and some of this was for the deeper Cadeby Formation. The data has been reviewed and information presented for a number of sites of particular relevance to this study. These sites are indicated in Figure 3.2 and include long term monitoring sites in both catchments with long term records and superficial monitoring from Hatfield Moors in the Torne catchment (the only such monitoring received for both catchments).

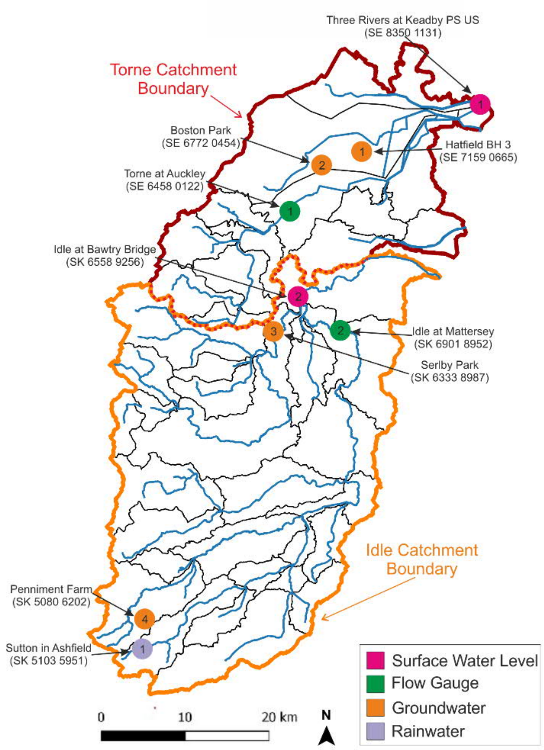

Figure 3.2 Location of Groundwater and Surface water flow monitoring at sites in the Idle and Torne catchments described in this section

3.3.2.2 River Torne catchment

Pertinent groundwater monitoring for the Torne catchment is presented in Figure 3.2 along with the flow record for the Torne at Auckley gauge. Figure 3.4 provides further context on the number of days

[11] National Flow Archive- Idle at Mattersey. https://nrfa.ceh.ac.uk/data/station/info/28015

in each year where flow was greater than the Q_{15}/ EFI at the Torne at Auckley flow gauge (and relatively whether each calendar year could be considered as above average ('wet' with elevated precipitation causing higher flows), below average ('dry' likely linked to a lack of high precipitation events) or typical year in terms of higher flows (and precipitation rates). Table 3.1 presents the information from Figure 3.4 in a tabular format and also includes a ranking of the 20 years since 2000 in terms of number of days flow in each respective year was greater than the Idle and Torne EFIs. From this a relative assessment of wet (5 years with highest number of days above the EFI), dry (5 years with lowest number of days above the EFI) or typical year (the other years) has been made.

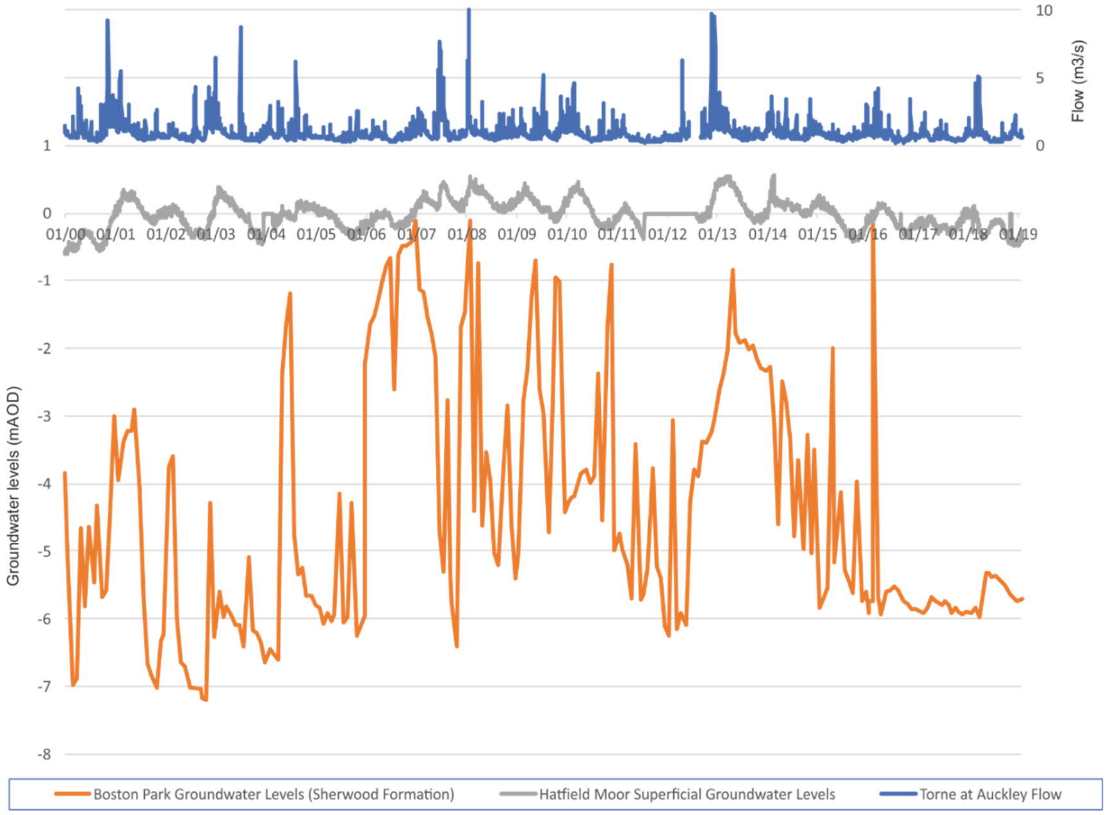

Figure 3.3 Groundwater and correspondent flow monitoring at sites in the Torne catchment

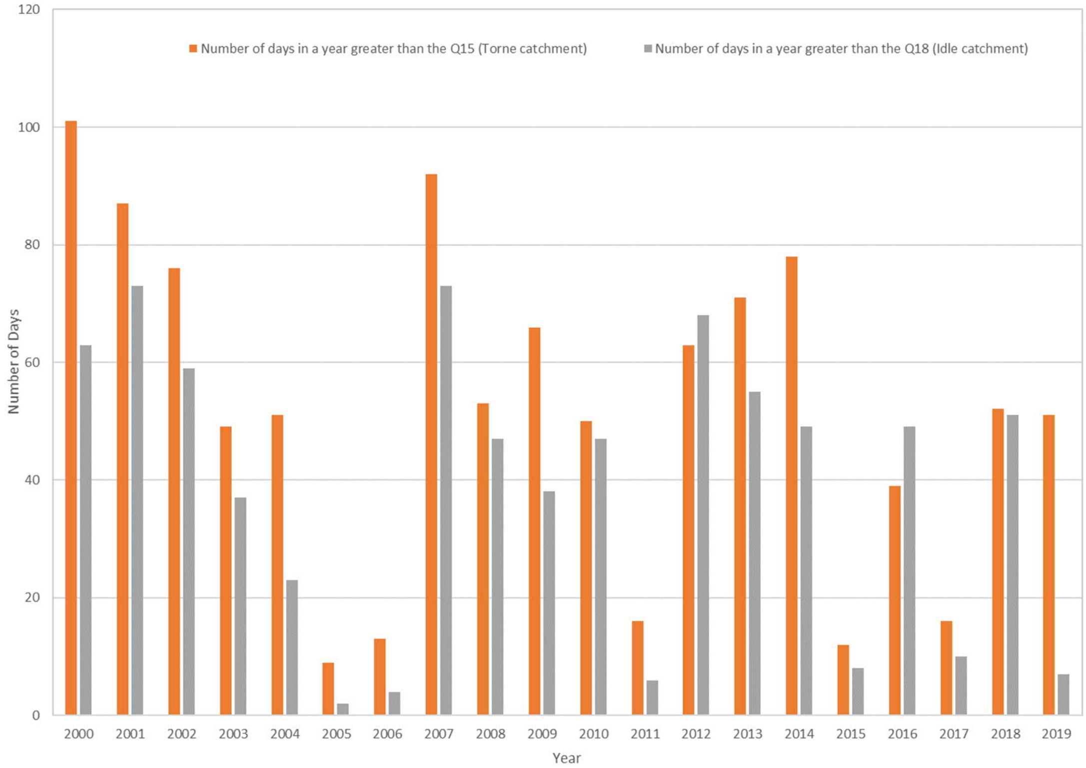

Figure 3.4 No. of days in each calendar year (Jan 2000 – Sept 2019) when daily mean flows (at the Torne at Auckley and Idle at Mattersey gauges) were > their respective EFIs

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Table 3.1 Number of days in a calendar year above the EFI flow statistic for the Torne and Idle catchments (at the Torne at Auckley and Idle at Mattersey gauges) and relative rankings

	Torne at Auckley		Idle at Mattersey	
Calendar Year	**N Days Q>EFI**	**Rank (of 20)**	**N Days Q>EFI**	**Rank (of 20)**
2000	101	1st Wet	63	4th Wet
2001	87	3rd Wet	73	1st Wet
2002	76	5th Wet	59	5th Wet
2003	49	14th Typical	37	13th Typical
2004	51	11th Typical	23	14th Typical
2005	9	20th Dry	2	20th Dry
2006	13	18th Dry	4	19th Dry
2007	92	2nd Wet	73	2nd Wet
2008	53	9th Typical	47	10th Typical
2009	66	7th Typical	38	12th Typical
2010	50	13th Typical	47	11th Typical
2011	16	16th Dry	6	18th Dry
2012	63	8th Typical	68	3rd Wet
2013	71	6th Typical	55	6th Typical
2014	78	4th Wet	49	8th Typical
2015	12	19th Dry	8	16th Dry
2016	39	15th Typical	49	9th Typical
2017	16	17th Dry	10	15th Typical
2018	52	10th Typical	51	7th Typical
2019 (to Sept)	51	12th Typical	8	17th Dry

There is larger variation in groundwater levels at Boston Park in the Sherwood Formation (levels varying by ~7m between 2000 and 2019) than in the superficial monitoring of Hatfield Moors (levels varying by ~1.2m between 2000 and 2019). Groundwater levels at Boston Park are strongly influenced by Boston Park public water supply abstraction and we have been advised that the large fluctuations at the site are not representative of the wider sandstone catchment which may be expected to vary seasonally between 1 – 2m.

As expected groundwater levels reduce during dry conditions (typically drier through the summer although also dropping during dry years and winters). This is most apparent in the Hatfield Moor monitoring. Refill occurs under wetter periods though a time lag is apparent on review of the Boston Park sandstone formation record.

Level at Boston Park indicate a large drop in groundwater levels in 1983 compared to earlier levels, which is likely when the nearby public water groundwater abstraction began. Since then (1983) groundwater levels in the Sherwood Formation steadily increased through the 1990s through to around 2006.

Levels in the Hatfield Moor are refilled by local rainfall. Winter refill at Hatfield Moor was low in the winters of 2005/ 06, 2010/11 and since 2016/17.

3.3.2.3 River Idle catchment

Pertinent groundwater monitoring for the lower Idle catchment is presented in Figure 3.2 along with the flow record for the Idle at Mattersey and water level monitoring for the Idle at Bawtry Bridge. Groundwater levels do increase over extended periods of wet weather (with flow also increasing) and drop during extended drier periods. Responses are lower and smoothed out when compared to the surface water monitoring, as would be expected. Between 2000 and present the groundwater levels at Serlby Park varied by not much more than 1m, which is several metres less than at the Torne site examined in Section 3.3.2.2 (noting that the latter may be heavily influenced by nearby abstractions).

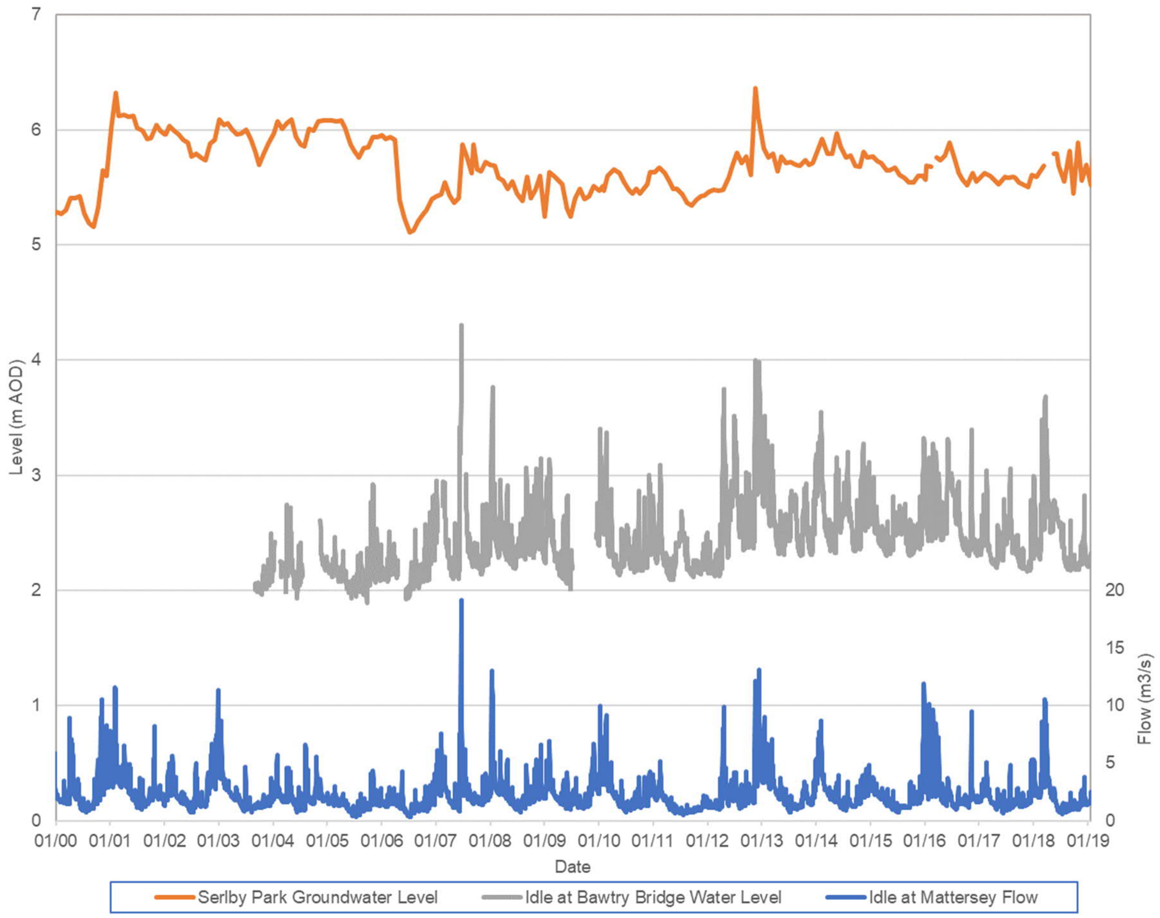

Figure 3.5 Groundwater and correspondent flow monitoring (River Idle at Mattersey flow gauge) at sites in the lower Idle catchment

Groundwater levels in the upper catchment, at Penniment Farm, were also examined as indicated in Figure 3.6. Winter rises, correspondent to periods of high and extended rainfall, such as from the spring of 2012, and summer drawdown patterns are apparent. Decreases were apparent in the period 1990 -2010 which may be related to abstraction patterns.

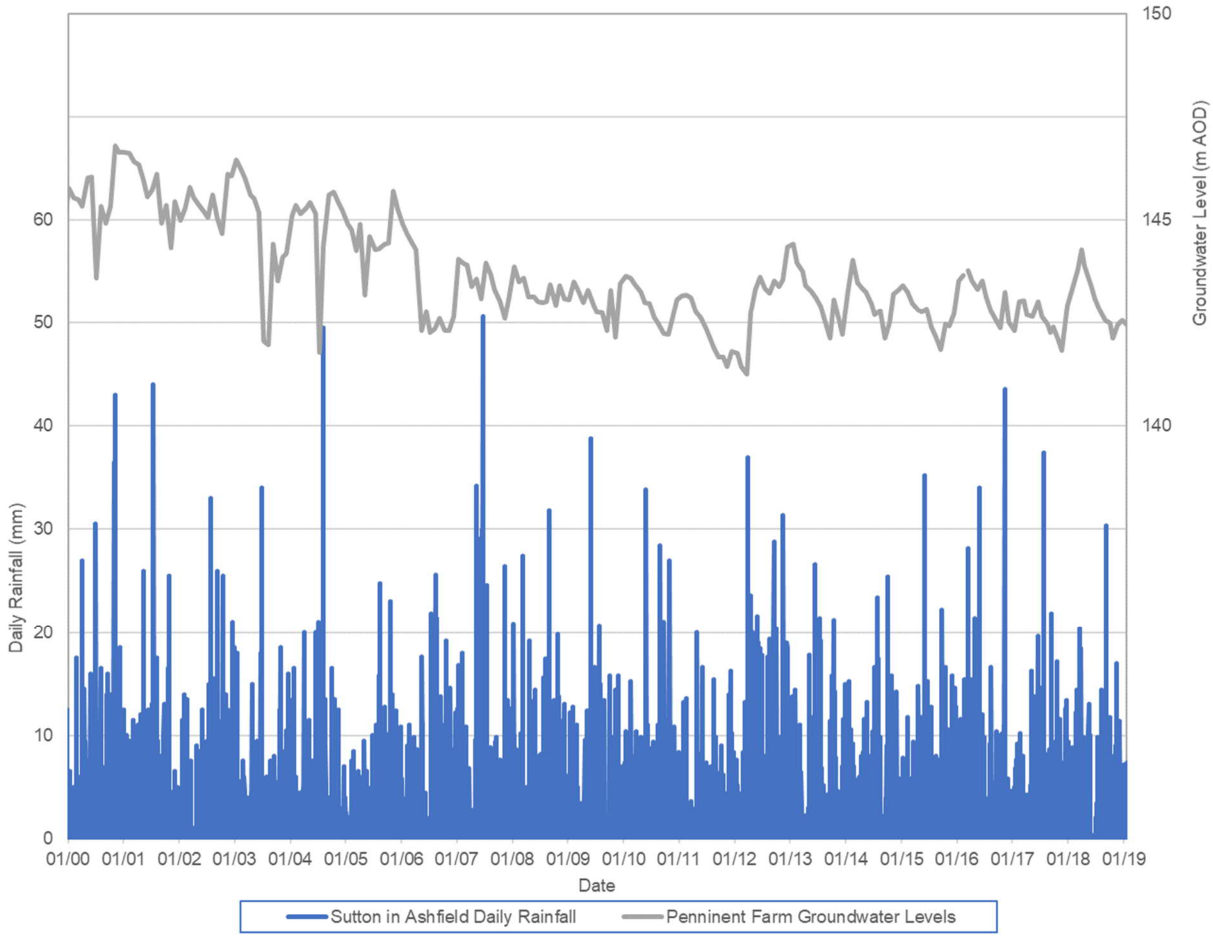

Figure 3.6 Groundwater and correspondent flow monitoring at sites in the upper Idle catchment

3.3.3 Groundwater Conceptualisation

The 2015 Feasibility Study[12] stated that groundwater recharge may be impacted by abstraction of high river flows, where losing sections of river may enable surface water to recharge the aquifer, particularly where groundwater abstractions drawdown the groundwater level in the vicinity of surface water courses.

However, overall, the recharge to the aquifer is expected to largely occur through the mechanism of rainfall recharge over the wider permeable catchment. Considering that the Sherwood Sandstone aquifer supports a significant amount of groundwater abstraction, localised recharge from flow losses could not support such volumes of abstraction.

Stream flow hydrographs are available for gauges situated where the rivers overlie the Cadeby Formation aquifer and the Sherwood Sandstone Group aquifer. In the rivers Poulter, Meden and Maun accretion occurs across the Cadeby Formation and there is limited or no accretion evident across the Sherwood Sandstone. Some streams do not flow over the Cadeby Formation and tend to have no flow during summer compared to streams with Cadeby Formation baseflow contributions.

[12] AECOM (2015) - High Flow Abstraction for Multiple Environmental Benefits in the Idle and Torne Catchments – A Feasibility Study - Phase 1 Report

Less accretion tends to occur nearer to the eastern edge of the Sherwood Sandstone outcrop which may reflect proximity to drawdown caused by groundwater abstractions in the confined aquifer.

The pattern of the hydrographs at the downstream gauge for each river is very similar to that of the upstream gauge which represents baseflow from the Cadeby Formation. As the nature of the hydrograph changes little downstream across the Sherwood Sandstone this also indicates that little accretion occurs, and flow is dependent on the upstream Cadeby Formation baseflows.

Significant levels of groundwater abstraction from the Sherwood Sandstone are considered to have lowered groundwater levels such that rivers lose flow to the unconfined Sherwood Sandstone aquifer.

Accretion data are geared around low flows but due to relatively constant abstraction for public water supply it is likely that at high flows the water table remains below riverbed elevation across many reaches overlying Sherwood Sandstone and flow losses continue to occur.

Groundwater contouring in the Sherwood Sandstone indicates that significant extents of these rivers do not gain baseflow from the Sherwood Sandstone at high groundwater levels. There is no convergence of groundwater contours to the River Poulter to indicate discharge of groundwater to form baseflow. The River Meden may gain flow in its central reaches while not accreting in upper reaches and losing in lower reaches. The River Maun may gain in the upper reaches and lose in the lower reaches across the Sherwood Sandstone. The River Idle flows northerly close to where the Sherwood Sandstone outcrop ends and becomes confined by overlying Mercia Mudstone. Groundwater contours indicate there is no discharge of groundwater to the River Idle and groundwater flows north easterly into the confined aquifer. In the north the River Torne may gain baseflow through superficial deposits in the lower catchment level-dependent areas.

Therefore river flows across the Cadeby Formation are very important for maintaining flow across the Sherwood Sandstone. A reduction in flow in the rivers overlying the Cadeby Formation would mean lower flows further downstream which may lead to environmental flow issues.

Water quality in public water supply groundwater abstractions adjacent the Rivers Poulter (Elkesley), Idle (Everton), and Meden (Budby) has been noted to be similar to surface water quality and considered to be an indication of the abstractions drawing surface water through the aquifer.

There have also been reports since the 1970s of stream bed fissures appearing suddenly as a result of underground mining subsidence, and causing flow loss, in Rainworth Water (including Rufford Lake drying out), and the rivers Maun, Meden and Poulter. Stream bed repairs including reprofiling and bed-sealing have been undertaken. The most significant impacts have been around the confluence of the Rivers Maun and Meden. Therefore in these locations in particular there is potential for flow loss related to former collieries where further subsidence may occur and the remedial works may deteriorate over time.

By their nature the reported fissures are the large visible features, while it can be expected that there will be many more smaller fissures which will increase the permeability of the Sherwood Sandstone and alongside abstraction may be contributing to the lack of baseflow accretion across this aquifer.

3.4 Hydrology

3.4.1 Hydrological Monitoring network

An overview of the hydrological monitoring network sites is provided in Figure 3.7 below. Flow gauges are present through the free flowing parts of both catchments while surface water (river) level monitoring is more extensive in the low lying pumped sections in which levels are managed.

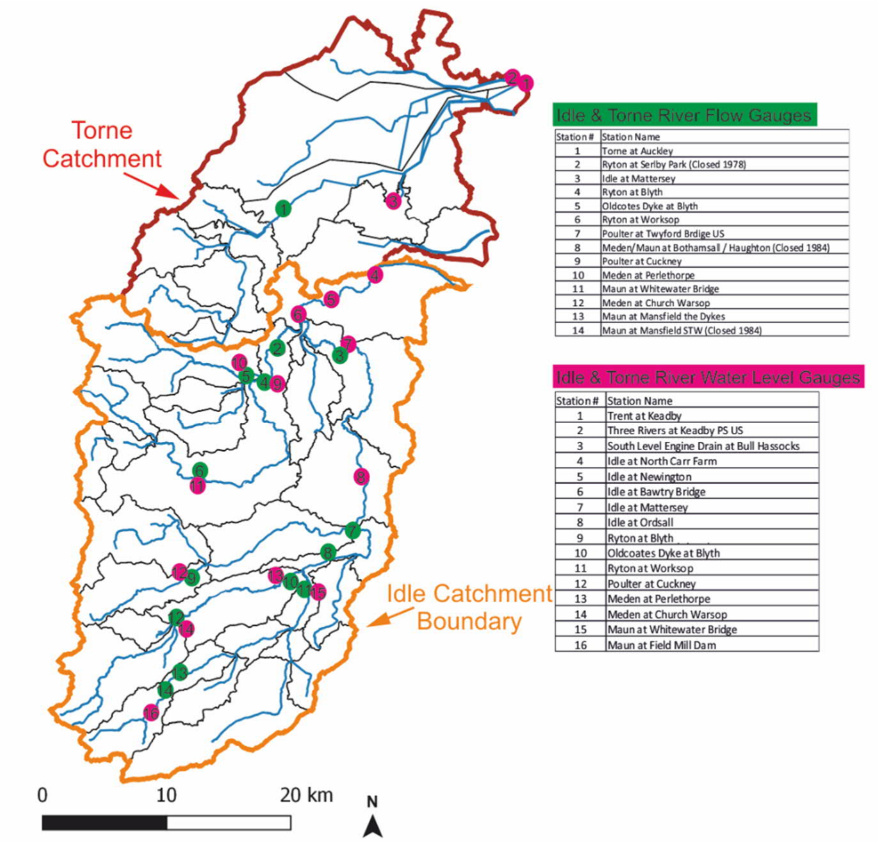

Figure 3.7 Flow and River Level Monitoring in the Idle and Torne catchments

3.4.2 River Torne catchment

3.4.2.1 Flows

Flow is monitored in the River Torne at Auckley (see Figure 3.7 above). The flow record extends from 1971 to present. Elevation at the gauge is 2.2m AOD while the maximum altitude in the catchment is 150m AOD and median altitude is 23m AOD. A Flood Attenuation by Reservoirs and Lakes (FARL) index of 0.97 indicates limited presence of attenuating waterbodies, such as lakes or reservoirs, upstream of the gauge. The average annual rainfall between (SAAR 1961-1990) is reported to be 617mm[13], which is below average for England.

Key flow statistics for the gauge are indicated in Table 3.2 below while a hydrograph is provided in Figure 3.8. Flows above theQ15 may be reduced if the catchment were opened up to abstractions. An indication of “wet” years (2000, 2001, 2002, 2007 and 2014) and “dry” years (2005, 2006, 2011, 2015 and 2016) is apparent from Figure 3.4 and Table 3.1, presented above.

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[13] National Flow Archive- Torne at Auckley. https://nrfa.ceh.ac.uk/data/station/info/28050

Table 3.2 Flow Statistics for the River Torne at Auckley Gauge

Flow Statistic	All Year	Hydrological Summer (Apr-Sept)	Hydrological Winter (Oct- Mar)
Q_{99}	0.26	0.23	0.33
Q_{95}	0.33	0.30	0.41
Q_{70}	0.52	0.45	0.63
Q_{50}	0.66	0.56	0.81
Q_{30}	0.90	0.71	1.08
Q_{15}	1.28	0.97	1.50
Q_{10}	1.56	1.21	1.81
Q_{5}	2.26	1.85	2.43

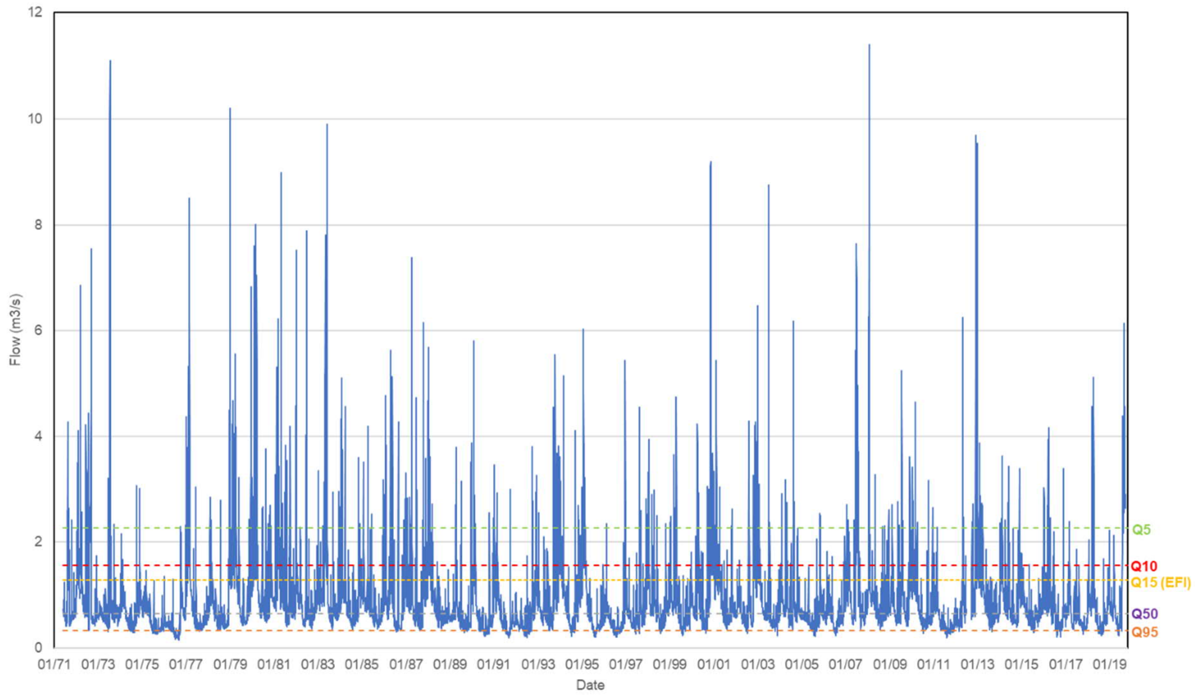

Figure 3.8 Torne at Auckley Hydrograph

3.4.2.2 Levels

There are three surface water (river) level monitoring gauges in the Torne catchment. Another is located just downstream in the Tidal Trent while one is associated with lake levels (at Hatfield Lake).

Water levels are monitoring in the "Three Rivers", which forms as the Torne converges with South Engine Drain and Hatfield Waste Drain, just upstream of Keadby pumping station (which discharges into the Tidal Trent). A summary of the surface water level statistics at this sites are provided in Table 3.3 below. The level range between the maximum and minimum recorded levels is less than 2m while 90% of the time levels are between 0.18 and 0.52m AOD indicating a small range.

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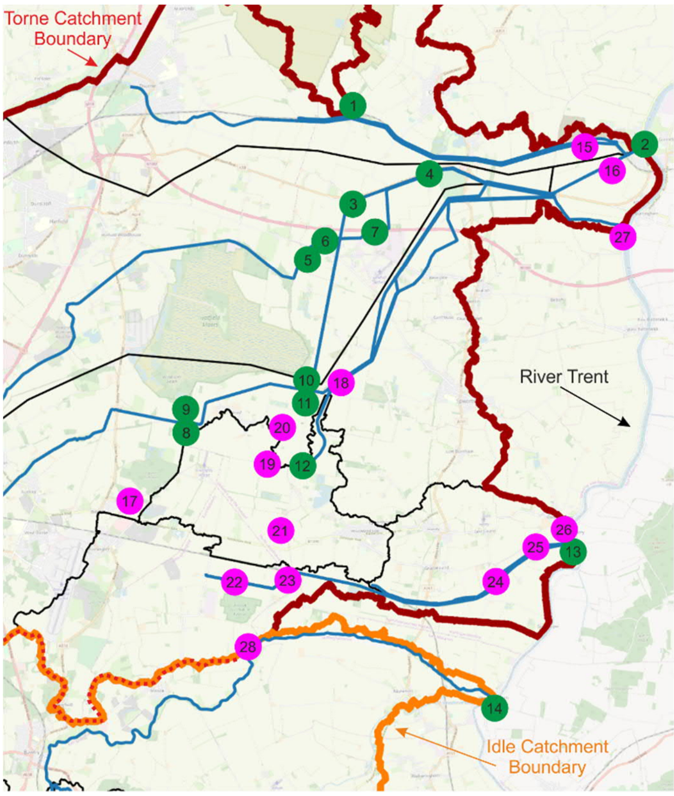
Table 3.3 Level flow statistics for the Three Rivers at Keadby PS US (1997 -2019)

Level statistic	Level (m AOD)
Maximum	1.19
H_5	0.54
H_{10}	0.52
H_{30}	0.47
H_{50}	0.41
H_{70}	0.35
H_{95}	0.18
Minimum	-0.63

Levels are also monitored upstream in South Engine Drain although the records seems to indicate notable drift, particularly through 2013 to 2016 which would make the level statistics unreliable. Hence this record has not been considered further as part of this study.

A map of pumping station across the Isle of Axholme is provided in Figure 3.9 below. Most of these are located in the lower Torne catchment.



EA Operated Pump Stations

Reference #	Pumping Station	Discharging to	Op Auth
1	New Zealand	North Soak Drain	EA
2	Keadby	River Trent	EA
3	Dirtness	South Level Engine Drain	EA
4	Belton Grange	Hatfield Waste Drain	EA
5	Goodcop	Hatfield Waste Drain	EA
6	Low Bank	River Trent	EA
7	Woodcarr	Hatfield Waste Drain	EA
8	Candy Farm South	River Torne	EA
9	Candy Farm North	River Torne	EA
10	Tunnel Pits North	River Torne	EA
11	Tunnel Pits South	River Torne	EA
12	Bull Hassocks	South Level Engine Drain	EA
13	Snow Sewer Drainhead	River Trent	EA
14	West Stockwith	River Trent	EA

IDB Operated Pump Stations

Reference #	Pumping Station	Discharging to	Operation Authority
15	North Soak Drain	North Soak Drain	Tween Bridge
16	Althorpe	Three Rivers	Althorpe IDB
17	Blaxton Quarry	River Torne	Hatfield Chase IDB
18	Greenham	South Level Engine Drain	West Axholme IDB
19	South Thorne Bank	(South Level Engine Drain)	Hatfield Chase IDB
20	Franklins	(South Level Engine Drain)	Hatfield Chase IDB
21	Cadmans	(South Level Engine Drain)	Hatfield Chase IDB
22	Snow Sewer	Warping Drain	Finningley IDB
23	Park Drain	Warping Drain	
24	Four Bridges	Warping Drain	South Axholme IDB
25	Three Bridges	Warping Drain	South Axholme IDB
26	South Street	River Trent	South Axholme IDB
27	Derrythorpe	River Trent	West Axholme IDB
28	Idle Stop	River Idle	

Figure 3.9 Map of Environment Agency and IDB pumping stations through the Isle of Axholme

3.4.3 River Idle catchment

3.4.3.1 Flows

The River Idle forms at the confluence of the Rivers Maun and Poulter. Key tributaries of the Maun include the River Meden and Rainworth Water. Close upstream of Bawtry Bridge (beyond which the Idle is level dependent) the River Ryton joins the River Idle. Key tributaries of the River Ryton are Old

Cotes Dike and Anston Brook. Flow is and has been monitored throughout the River Idle catchment at a number of sites encompassing many key tributaries (see Figure 3.7 previously). Summary flow information for those sites in the Idle catchment is provided in Table 3.4 below.

Table 3.4 Summary flow information for gauges in the River Idle catchment

Name	Catchment Area (km^2)	Start	End	Flow statistic (m3/s)						
				Q_{95}	Q_{70}	Q_{50}	Q_{10}	Q_5	QMED*	POT threshold*
Ryton at Serlby Park	231	1965	1978	0.45	0.98	1.27	3.23	4.42	-	-
Idle at Mattersey	529	1982	ongoing	0.86	1.52	2.02	4.55	5.73	10.2	6.934
Ryton at Blyth	231	1984	ongoing	0.59	0.95	1.19	2.69	3.67	11.5	6.318
Old Coates Dyke at Blyth	85.2	1970	ongoing	0.26	0.39	0.50	1.16	1.59	14.1	4.254
Ryton at Worksop	77	1970	ongoing	0.09	0.19	0.28	0.92	1.34	5.47	2.636
Poulter at Twyford bridge	128.2	1969	ongoing	0.23	0.40	0.50	0.94	1.18	-	-
Meden/ Maun at Bothamsall/ Haughton	262.6	1965	1984	0.78	1.18	1.41	2.68	3.42	-	-
Poulter at Cuckney	32.2	1969	ongoing	0.16	0.23	0.28	0.50	0.60	-	-
Meden at Perlethorpe	97	1994	ongoing	0.35	0.51	0.62	1.11	1.36	-	-
Maun at Whitewater Bridge	157	1997	ongoing	0.47	0.64	0.75	1.36	1.75	-	-
Meden at Church Warsop	63	1965	ongoing	0.25	0.37	0.48	1.06	1.39	4.75	3.558
Maun at Mansfield the Dykes	31.5	1992	ongoing	0.46	0.55	0.62	1.05	1.31	13.2	6.862
Maun at Mansfield STW	28.8	1964	1984	0.24	0.32	0.37	0.72	0.96	11	6.777

* From the National Flow Archive.

Flow in the River Idle catchment is not measured in the downstream level dependent pumped section. It is measured in the low lying part of catchment upstream of the level dependent section, however. Specifically flow in the River idle is measured at the Mattersey gauge This gauge is located on the River Idle upstream of its confluence with the River Ryton. Flow in the River Ryton is also measured upstream of its confluence with the River Idle (at Blyth). Further flow information at both of these low lying gauges is provided in Table 3.5 below (including the EFI of Q_{18} – flows greater than this are being assessed for abstraction impact).

Table 3.5 Flow Statistics for the River Idle at Mattersey and River Ryton at Blyth

Flow Statistic	Idle at Mattersey			Ryton at Blyth		
	All Year	Hydrological Summer (April to September)	Hydrological Winter (October to March)	All Year	Hydrological Summer (April to September)	Hydrological Winter (October- March)
Q_{99}	0.34	0.30	0.62	0.59	0.49	0.98
Q_{95}	0.59	0.45	0.77	0.86	0.74	1.24
Q_{70}	0.95	0.85	1.15	1.52	1.27	1.87
Q_{50}	1.19	1.02	1.49	2.02	1.66	2.48
Q_{30}	1.59	1.25	1.96	2.82	2.23	3.35
Q_{18}	2.05	1.53	2.48	3.65	2.94	4.12
Q_{10}	2.69	1.95	3.21	4.55	3.94	5.15
Q_5	3.67	2.73	4.29	5.73	4.82	6.53

A Flood Attenuation by Reservoirs and Lakes (FARL) index of 0.90 indicates limited presence of attenuating waterbodies, such as lakes or reservoirs, upstream of the gauge. The average annual rainfall between (SAAR 1961-1990) is reported to be 650mm[14], which is below average for England.

3.4.3.2 Levels

Surface water levels are measured at 13 sites throughout the Idle catchment. As mentioned above, Bawtry represents the location where the Idle changes from being free flowing to level controlled via a network of pumping stations, embanked sections and a terminal pumping station located at West Stockwith. Three of the 13 sites are located downstream of Bawtry, while ten are situated at (specifically at Bawtry Bridge) or upstream of Bawtry. Summary level statistics for sites downstream of Bawtry are provided in Table 3.6 while statistics for the other sites are provided in Table 3.7.

As in the level dependent section of the Torne, there is limited variation in levels in the level dependent section of the Idle. 90% of the time they are within 0.35m at Ordsall, 0.66m at North Carr Farm and 0.67m at Newington.

Table 3.6 Level flow statistics for the River Idle level gauges (level dependent lower section)

Data information or Level (H) statistic	Level (m AOD)		
	Idle at Ordsall	Idle at North Carr Farm	Idle at Newington
Record Start Date	15/10/2001	06/06/1997	14/05/1997
Record End Date	27/10/2019	27/10/2019	27/10/2019
Maximum	1.52	3.53	3.82
H_5	0.55	2.50	2.73
H_{10}	0.49	2.35	2.56
H_{30}	0.37	2.11	2.29
H_{50}	0.31	2.03	2.16
H_{70}	0.26	1.95	2.06
H_{95}	0.20	1.84	1.91
Minimum	0.00	1.62	1.65

[14] National Flow Archive- Idle at Mattersey. https://nrfa.ceh.ac.uk/data/station/info/28015

AECOM

Table 3.7 Level flow statistics for the River Idle catchment (free flowing section)

Data information or Level (H) statistic	Level (m AOD)				
	Idle at Bawtry Bridge	Idle at Mattersey	Maun at Field Mill Dam	Old Coates Dyke at Blyth	Ryton at Blyth
Start Date	07/09/ 2003	26/04/1961	07/01/ 2003	01/08/ 1971	01/04/ 1990
Record End Date	23/10/ 2019	24/10/2019	25/10/ 2019	23/10/ 2019	23/10/ 2019
Maximum	4.30	5.24	108.46	12.49	9.86
H_5	3.01	4.03	107.74	10.97	8.76
H_{10}	2.83	3.81	107.71	10.92	8.66
H_{30}	2.52	3.48	107.66	10.86	8.52
H_{50}	2.37	3.32	107.64	10.83	8.46
H_{70}	2.24	3.21	107.62	10.80	8.41
H_{95}	2.08	3.05	107.59	10.77	8.33
Minimum	1.90	2.80	107.50	10.57	7.89
Data information or Level (H) statistic	Level (m AOD)				
	Ryton at Worksop	Poulter at Cuckney	Meden at Perlethorpe	Meden at Church Warsop	Maun at White-water Bridge
Start Date	18/06/1970	24/07/ 1969	01/01/ 1994	01/01/ 1970	28/09/ 1992
Record End Date	23/10/2019	23/10/ 2019	24/10/ 2019	23/10/ 2019	24/10/ 2019
Maximum	33.76	46.02	32.71	54.65	31.26
H_5	32.29	45.81	32.03	53.93	30.59
H_{10}	32.24	45.79	32.00	53.88	30.54
H_{30}	32.17	45.74	31.94	53.77	30.48
H_{50}	32.13	0.13	31.92	0.26	30.45
H_{70}	32.10	0.11	31.90	0.20	30.43
H_{95}	32.06	0.08	31.87	0.15	30.39
Minimum	32.01	0.06	31.58	0.12	30.30

3.5 Hydromorphology

3.5.1 Overview

During the 2015 Feasibility Study, it was concluded that the most likely sensitive reaches would be those largely unmodified and those reaches susceptible to a reduction in out of bank flows (i.e. with lateral connectivity to the floodplain remaining in the absence of embankments). Modified channels can be over-widened, over-deep and straightened resulting in a lack of habitat and flow diversity and disconnection from the floodplain. They may also suffer from excessive siltation, with oversized channels reducing velocities, which can smother habitat or spawning grounds, such as gravel beds. Connectivity with the floodplain is important as it provides, amongst others, additional ecological habitat and increases the potential for removal of fine silt from river systems. A reduction in the magnitude of high flows, as a result of abstraction, can reduce connectivity with the floodplain and reduce the likelihood of fines being flushed.

A review of the hydromorphology in the Idle and Torne catchments has been undertaken. This involved the following:

- A review of the catchment;
- A review of River Habitat Survey (RHS) information;
- A review of British Library Records Annual Account Records for the catchments;

- A review of River Idle and River Torne topographical survey information provided to us (including a longitudinal channel profile information);
- A review of 2 year flooding extents from the recently constructed Flood Modeller Pro models of the River Idle and River Torne;
- A review of Environment Agency ecological monitoring of relevance to hydromorphology; and
- Calculation and review of sediment fluxes in both catchments.

The review has focussed on assessing the hydromorphological sensitivity of the waterbodies in the catchment, for the reasons described above.

3.5.2 Catchment Review

The maximum elevation in the Torne and Idle catchments is 205 mAOD[15] in the southwest headwaters of the River Idle, and whilst the headwater locations have some moderately steep areas, the majority of the catchments and channels drain gentle lowland relief, and surface hydrology is strongly influenced by groundwater.

Given the nature of catchment drainage, the River Torne and River Idle channels are predominantly low energy, slow flowing systems.

The natural channels of the headwater streams (e.g. the Maun) would be inherently sinuous. Their typology would be a pebbly, gravel bed channel with relatively feeble secondary currents insufficient to erode the bends in the floodplain. However many of the streams have historically been modified by pressures such as flood and land drainage works, localised straightening and milling, all with the potential for erosion and release of sediment to reaches downstream. The main stems of the Idle and Torne are generally “artificial channels” constructed many hundreds of years ago. They replace or augment the original channels which map evidence seems to indicate had a more sinuous lowland course. Again these channels do not actively migrate across the floodplain (either naturally or in modified form). Given the low slopes they have potential to form sediment sinks, into which fine sediment washed from adjacent farm land may deposit/ accumulate. Historic dredging records indicate the scale of desilting that has been needed (see Section 3.5.4).

Parent fluvial sedimentology is predominantly sands, with Sherwood Sandstone the main underlying geology, and fine material with gravels. Survey records provided by the Environment Agency report gravel bedded channels in places, and this is typical of natural channels in this setting, since the matrix of fine parent material tends to be winnowed by hydraulic action to leave less mobile larger substrates. These in turn form valuable channel bed habitats including fish spawning gravels.

Both catchments are dominated by agriculture and horticulture (some 50% of the catchment areas) and areas of grassland and woodland. There are also areas of urbanisation, notably in the southwesterly headwaters and central regions of the Idle catchment (mainly associated with the towns of Mansfield, Worksop, and East Retford). The soils in the catchment are amongst the most susceptible to aeolian erosion in the UK (Downs and Thorne, 1998). All of these land uses are prone to delivering excess fine sediment into river channels. The channels are also influenced by intermittent weirs and other structures which can trap sediments in the channels.

Catchment land use strongly influences channel morphology, and bed composition and structure in particular. The main impact is anthropogenically-influenced excessive fine sediment delivery into the channels. This is combined with extensive channel modifications for flood management (i.e. floodplain disconnection) for land use gains, including channel over-widening and over-deepening, and

[15] General catchment data are available at the Centre for Ecology and Hydrology: http://www.ceh.ac.uk/data/nrfa

construction of embankments, which restricts the ability of the rivers to deposit sediment outside of their channels.

The "Geomorphological Monitoring Guidelines for River Restoration Schemes" report includes a case study on the River Idle, and describes the river as having experienced substantial sedimentation following cross-section enlargement and re-sectioning for flood defences between 1978 and 1982. Whilst the flood embankments were constructed over much of the course of the River Idle, the sinuosity of the channel was largely maintained (Environment Agency, 2007). The low gradient and corresponding low stream powers, accompanied by over-widening, means that extensive in-channel sediment deposition has created a uniform bed topography and as a result a low habitat diversity[16]. This pattern is likely to have been modified by periodic channel maintenance as well as capital works.

3.5.3 RHS Sites

River Habitat Survey (RHS) is a method for gathering data and assessing the physical character and quality of the river, including whether channels are modified, and riparian habitats. As such the data is considered useful for this study. However, it is noted that the data is limited insofar as it does not assess processes, which are of importance to this study, although the data has been reviewed in order to establish the baseline and inform reach sensitivity.

RHS data is routinely collected by the Environment Agency as part of their monitoring network to establish the baseline and change characteristics of 500m river reaches of interest. RHS data have been collected throughout most of the River Idle and Torne catchments.

Since Phase 1[17] the Environment Agency has indicated that no they have not collected further RHS data in the idle and Torne catchments. Data provided during Phase 1 has hence been re-examined, covering 29 sites in total.

RHS data assessment includes a numerical Habitat Modification Score[18] (HMS) relating to the artificial modification of the channel. Sites are assigned to 5 different classes based on their HMS score (see Table 3.8). Since this study is focussed on looking at potential impacts associated with changes in winter flow levels within the channel, HMS scores were seen as a good indicator of the naturalness of the channel sections recorded during the RHS surveys.

Table 3.8 Habitat Modification Classes and Descriptions

Class	Description
1	Pristine and Semi Natural
2	Predominantly unmodified
3	Obviously modified
4	Significantly modified
5	Severely modified

The survey locations and HMS classes for each of the 29 sites are indicated in Figure 3.10. Of the 29 sites, 19 were classed as 'Severely modified' (Class 5), three were classed 'Significantly modified' (Class 4) and two were classed as 'Obviously modified' (Class 3). A further three were classed

[16] Environment Agency (2007) Geomorphological Monitoring Guidelines for River Restoration Schemes. Bristol, United Kingdom

[17] AECOM (2015) - High Flow Abstraction for Multiple Environmental Benefits in the Idle and Torne Catchments – A Feasibility Study - Phase 1 Report

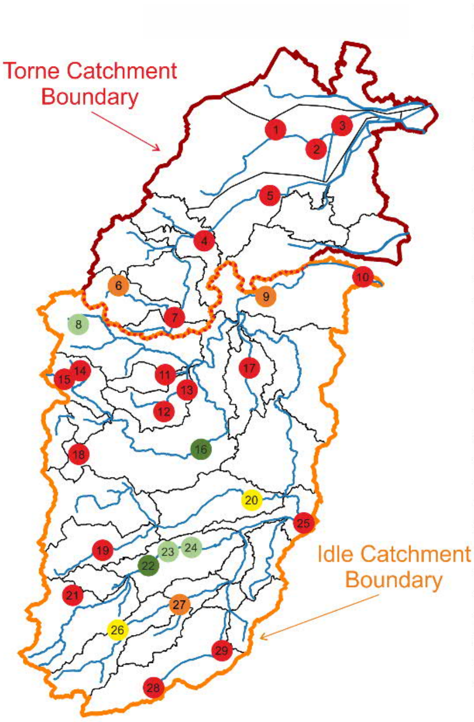
[18] http://www.riverhabitatsurvey.org/rhs-doc/habitat-assessment/ accessed 28/01/2020

'Predominantly unmodified' (Class 2) while the remaining two site were classed as 'Semi-natural or Pristine' (Class 1). Results are indicated in Figure 3.10 below.

Three of the five sites classed as either Class 1 or 2 were located in the Meden from Sookholme Brook WFD waterbody. No RHS monitoring is located on the Meden upstream and potentially the Meden may also be relatively unmodified in this waterbody. RHS data from one site in the Ryton also indicates that the watercourse is Class 1 (Ryton from Anston Brook to the Idle WFD waterbody).

It is considered that these largely unmodified sections would be more sensitive to abstractions of high flows as this may reduce out of bank flows (i.e. with the rivers likely to be more connected laterally to their natural floodplains in the absence of embankments).

Aside from these sites and based on a limited dataset, the RHS data indicates that much of the remaining catchment channel is severely modified, which is to be expected within a lowland catchment, heavily influenced by agriculture and horticulture and in some areas, urbanisation. Artificial, heavily modified and embanked waterbodies are more likely to be severed from their natural floodplain and therefore, subject to higher and more linear flows, which potentially have a detrimental impact on instream ecology. Embanked waterbodies can also lead to higher in channel velocities which may help keep gravel lenses free from silt, providing an ecological benefit.



Reference #	NGR of Site	Watercourse	HMS Class
1	SE6921308943	Fores Drain	5
2	SE7298007410	Waste Drain	5
3	SE7534009530	Hatfield Waste Drain	5
4	SK6257999122	Torne	5
5	SE6888903196	Torne	5
6	SK5476194773	Ruddle	4
7	SK5962391760	Unnamed	5
8	SK5101891138	Trib Of Maltby Dyke	2
9	SK6825693813	Idle	4
10	SK7740895547	Idle	5
11	SK5900686360	Hodstock Brook	5
12	SK5890783225	Owland's Wood Dyke	5
13	SK6105984996	Unnamed	5
14	SK5102386851	Cramfit Brook	5
15	SK4995085884	Anston Brook	5
16	SK6212279589	Ryton	1
17	SK6674587108	Rainskill Brook	5
18	SK5092479058	Unnamed	5
19	SK5313870386	Poulter	5
20	SK6722774789	Poulter	3
21	SK5055866107	Trib Of Meden	5
22	SK5754269022	Meden	1
23	SK5954770228	Meden	2
24	SK6140070517	Meden	2
25	SK7210873142	Trib Of Maun	5
26	SK5508962966	Maun	3
27	SK6037365016	Maun	4
28	SK5772357486	Rainworth Water	5
29	SK6414960887	Rainworth Water	5

Figure 3.10 RHS Location Points and HMS Classes

3.5.4 British Record Library Review

Several reports and books describing the artificial nature of the Idle and Torne are held in the British Library and were consulted in December 2019 for this study at the Reading Rooms in London. Historically the Idle and Torne have been highly modified. Prior to 1628, much of the area through which the River Torne now passes was wet marshland and the river channel followed a different path. At that time the River Don flowed across Hatfield Chase from Stainforth to Adlinfleet. The River Idle routed northwards from a point then called Idle Stop, and joined the Don close to Sandtoft. The Torne formed two channels to the west of Wroot, both joining the Idle. In 1626, a Dutch river engineer Cornelius Vermuyden was given the task of draining Hatfield Chase, and he radically altered the position of the rivers. The Idle became dammed at Idle Stop, and routed eastwards to join the Trent at West Stockwith (its current location). This left the Torne with no outfall into the Idle with the outcome that a new channel needed to be constructed, embanked along both sides, and a completely new channel was constructed for it, which was embanked on both sides. This channel runs ~10km in a north-easterly direction from Wroot, then traversing the Isle of Axholme. The channel the turns east for ~5 km, entering the River Trent at a sluice near Althorpe. Several artificial drains were also built to drain the land. The new route of the Torne was not entirely successful, as the embankments frequently failed, flooding agricultural land. In the 1760s, there were further plans to construct a new channel for the Torne to drain Potteric Carr, an area of wetland south of Doncaster. Work between 1765 and 1768 involved construction of a Mother Drain together with two branch drains. By the time the scheme was completed, 7km of the river channel had become rerouted, the Mother Drain had been extended to 7km, and in addition ~5 km of catchwater drains had been formed.

Subsequently between 1783 and 1789 following various studies separate outfalls were built at Althorpe for the Torne and the southern drain. In 1813, the South Engine Drain was routed under the Torne through a syphon, and became the third of the Three Rivers. The 1887 Ordnance Survey map shows only the Torne flowing eastwards from Pilfrey Bridge. It then splits into two at Althorpe using two sluices to drain into the Trent. As early as 1946, maps show a connection between the Torne and the middle of the Three Rivers, with a connection between the middle channel and the east channel downstream of Pilfrey Bridge. By 1966, the channels had become inter-connected much as they are at the current time.

Both the Torne and Idle have very low river gradients and must act as fine sediment sinks. Channels of this type are not natural gravel-bed rivers (i.e. those that actively transport sediment and adjust their planform) and instead are waterbodies that have been heavily modified in the past. Local movement of eroded bed and bank material occurs in the channels although silt predominates.

The search of the British Library in December 2019 for this study has revealed details of subsequent capital and maintenance works of both the Idle and Torne, and other river channels within the catchments. The information comes from the Statutory Annual Reports, for the period 1952 to 1966, of the Trent River Board, Nottingham. These searches are summarised in Figure 3.11 respectively.

For the Idle and Torne the maintenance and capital works records for the period 1952 – 1966, show activities that would be expected of a low gradient artificial channel with embankments and (for the Torne) sluices. Only the most spatially extensive works are included in Figure 3.11. Site-specific capital works such as bridge replacement and inverted syphons have been excluded from our analysis because they are limited in extent and few in numbers. The more continuous maintenance works are generally likely to have had little or no morphological impact by virtue of their nature e.g. trimming of overhanging trees; disposal of trees uprooted in high winds; and removal of silt and shoals by hand labour. The more extensive capital works are likely to have had a greater impact including channel regrading which can be defined as lowering of the bed (including removal of accumulated sediment deposits) to improve water levels for drainage purposes[19].

Other activities such as embankment construction/ replacement/ repair will also have a hydromorphological effect by severing connectivity with the floodplain. Extensive regrading works have also been completed on the Meden and Ryton. The Maun at Mansfield has experienced capital works though has recovered due to higher stream energies[20]. Sediment dislodged/ sourced from these upstream tributaries (from arable and urban surfaces) would be expected to accumulate in the downstream sediment sinks of the Idle and Torne.

[19] Brookes (1988) Channelized rivers: Perspectives for environmental management, Andrew Brookes, Wiley, Chichester

[20] Brookes, A. (1987) River channel adjustments downstream from channelization works in England and Wales – Earth Surface Processes and landforms., 12, 337-351

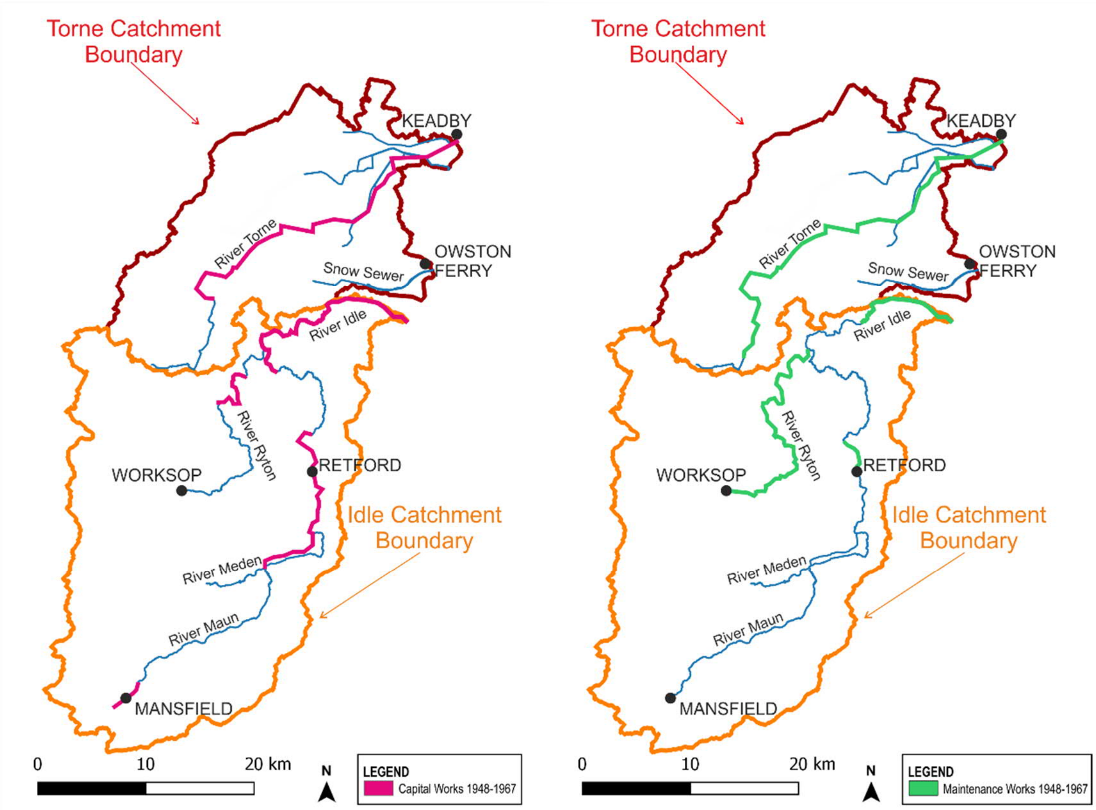


Figure 3.11 Capital and Maintenance Works from British Library Records

3.5.5 Channel surveys

3.5.5.1 Description

Topographical surveys (specifically channel cross sections) were undertaken for the Torne by Maltby Land Surveys ltd in November 2013 and Idle by Tower Surveys Ltd in March 2015 in support of the hydraulic models that were built and recently completed for both the Idle and Torne. The models are described further in Section 5.2 although the survey data has been provided to us and has been reviewed with regard to hydromorphology.

The locations of the topographical surveys are indicated in Figure 3.12 below. The cross- sectional profiles for the Torne are spaced at roughly 30m intervals spanning a range of widths from 30 – 50 meters. The cross-sectional profiles for the Idle are spaced at roughly 150m intervals spanning a range of widths from 30 – 50 meters. Survey data that was provided for the River Torne is limited to a small section towards the lower end of that system. Provided survey data for the Idle covers most of this river (noting that the names of river upstream of where it starts are different), with a gap of around 5.4km . Data on the other contributing catchments, such as the River Meden, River Maun and River Ryton has not been provided and it is likely that these have not been surveyed in detail.

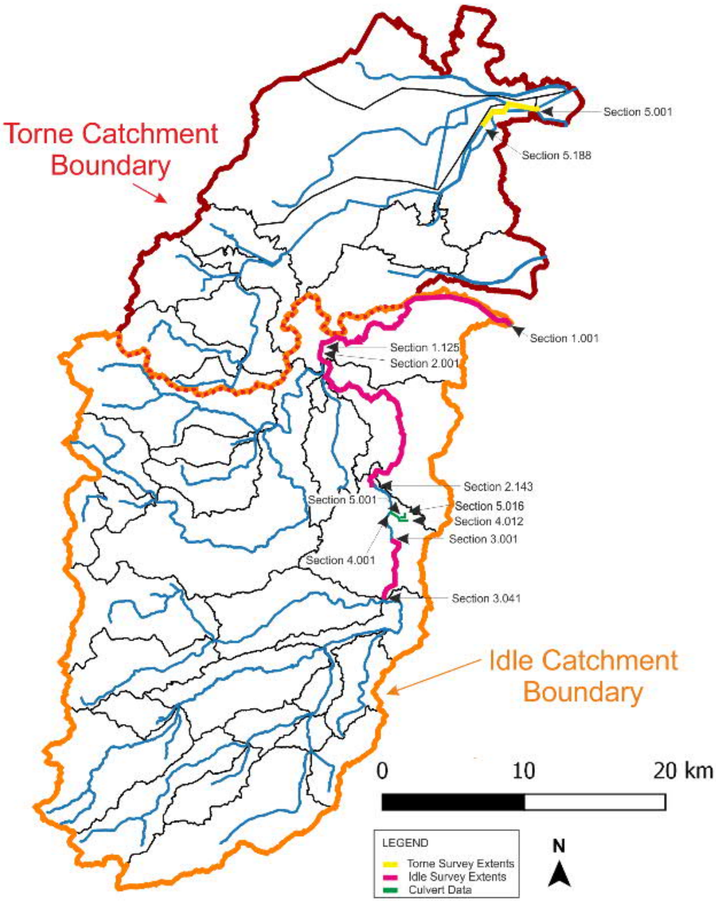


Figure 3.12 Location of recent Idle and Torne topographical and silt surveys

A map of flood defences in the River Idle and River Torne catchments is provided in Figure 3.13. The figures shows that flood defences (embanking anticipated) are most prevalent in the lower (downstream) and central parts of both catchment (although they extend into the upper parts of the catchments too).

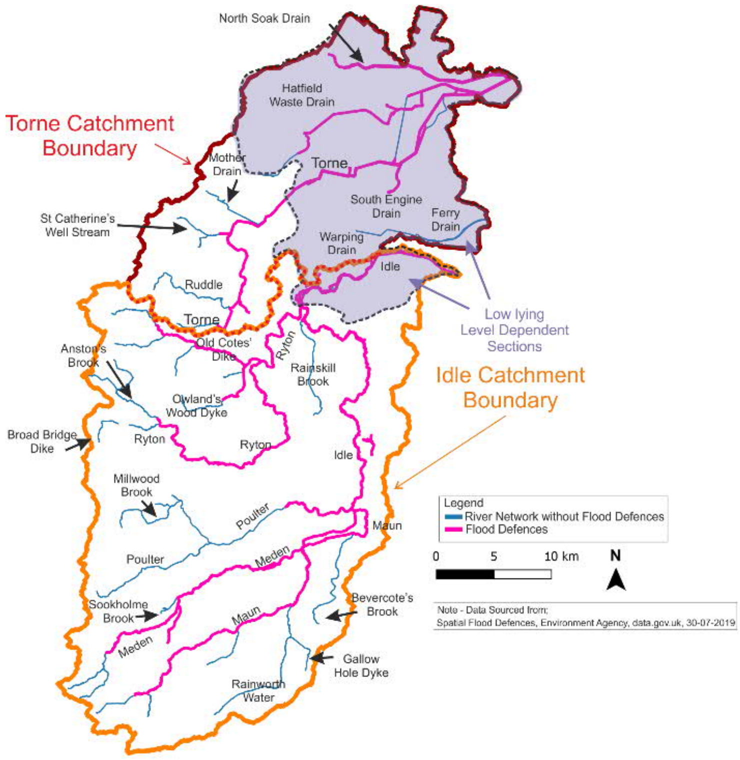


Figure 3.13 Location of Idle and Torne Flood Defences

3.5.5.2 Long sections and silt surveys

A longitudinal channel profile section from the Torne survey is provided in Figure 3.14 (interpolated between cross sections). The section illustrates a flat channel, with a slope of 0%. The long profile indicates that the water levels on the day of the survey are generally 1m below the bank levels along the small length of river reach surveyed. The average depth of silt throughout the surveyed reach was 0.41m, the maximum and minimum silt depth was 1.51m and 0m respectively, and the 25th and 75th percentile was 0.27m and 0.53m respectively. The character of the river appears to change at main roads that cross the river (roads are indicated on Figure 3.14). In the stretch around the A161 silt depths are at their lowest with the hard bed appearing to be higher than elsewhere in the surveyed reach.

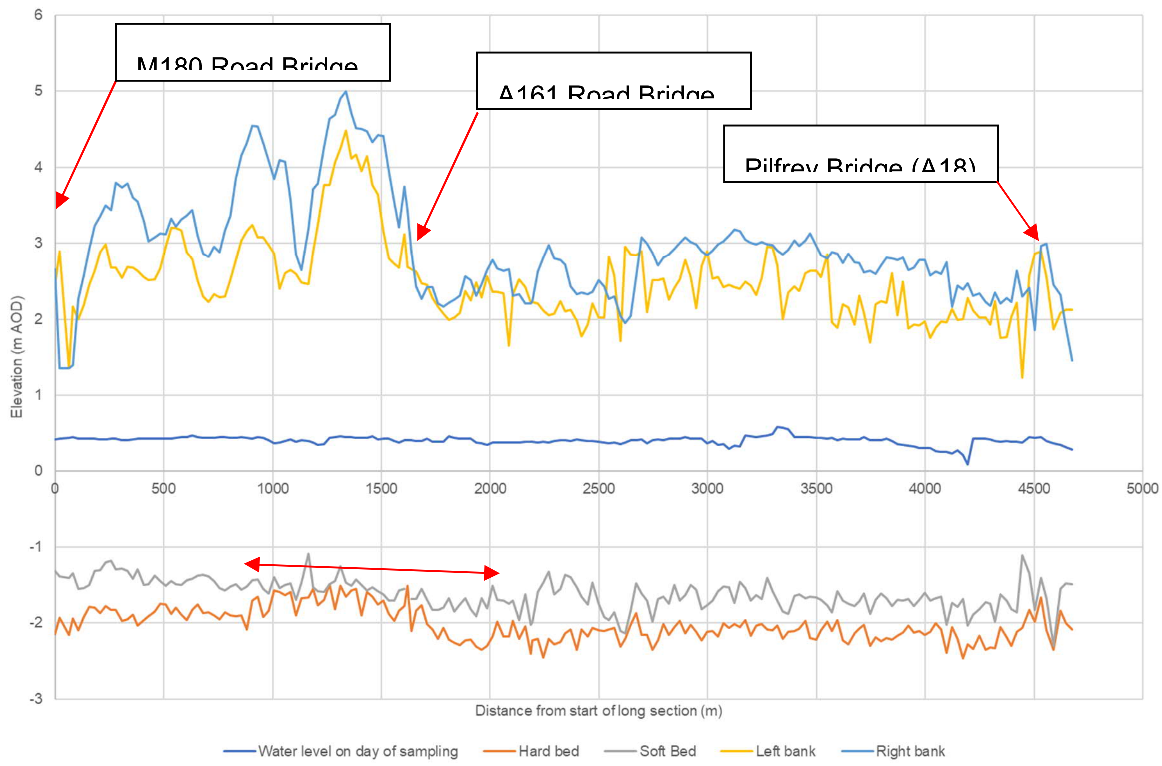


Figure 3.14 River Torne survey long section *(extent indicated on Figure 3.12)*

A longitudinal channel profile section, including hard bed levels and right and left bank levels, interpolated from the Idle cross sectional surveys is given in Figure 3.15. Right bank levels at the top of the Idle are recorded as slightly more than water levels on the day of surveying, indicating that out of bank flows into the floodplain in this area may occur quite frequently. Through the remainder of the surveyed central Idle stretch, flow into the floodplain via out of bank flooding is considered likely to be more infrequent, however, with bank levels being around 1-2m higher than water levels in the channel at the time of the survey. Measured water levels through this stretch were generally between 0.5 and 1m on the day of the survey.

In the lower Idle out of bank flow into the floodplain could potentially occur at times of high or flood flows, with bank levels being of the order of 0.2m above measured water levels at a number of cross section locations, on the day of the topographical survey. This section is level controlled however which would likely reduce level variations through this stretch. Water levels on the day of sampling in this area were indicated to be around 2m .

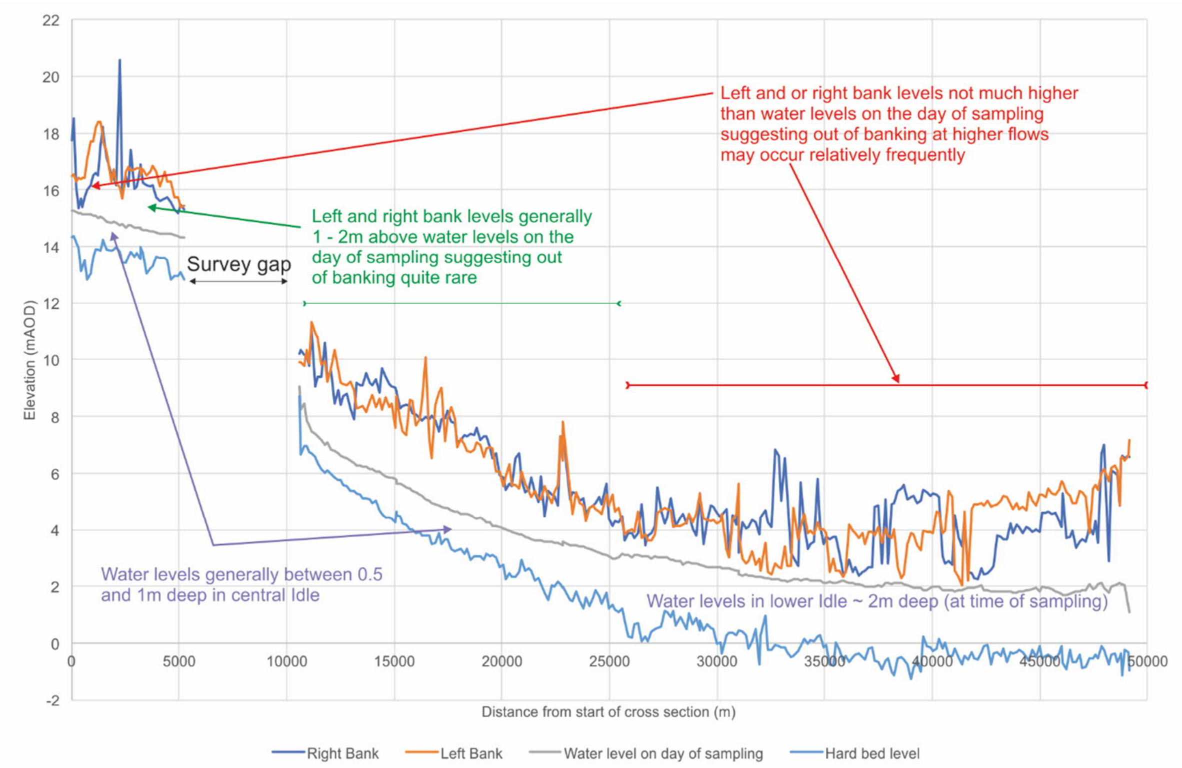


Figure 3.15 River Idle survey long section

Silt depths in the lowermost reach of the Idle were also measured during the topographical survey (section 1.001 to 1.125 on Figure 3.12). These were indicated on a plot that is reproduced in Figure 3.16. This indicates silt depths of frequently 0.4 to 0.8m in the upstream sections and reduced silt depths throughout the central and downstream sections that were surveyed (generally up to 0.4m).

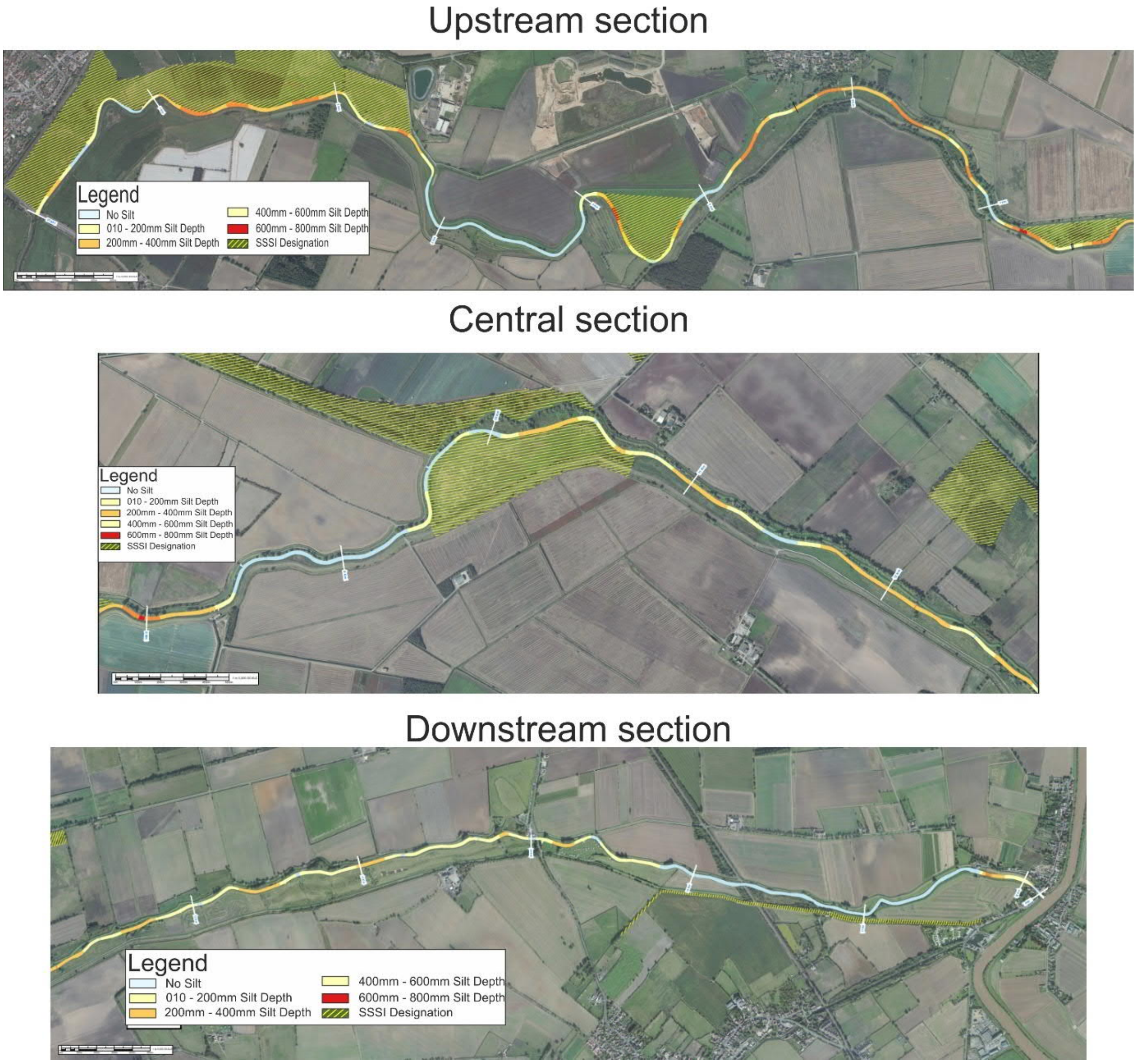


Figure 3.16 Hanson Aggregates Silt survey results (sampling occurred in 2015)[21]

3.5.6 Existing Hydraulic Modelling

New hydraulic models have been produced since the 2015 Feasibility Study and the suitability of their use for this current study is considered in Section 5.2. Nevertheless, the lowest event for which these models have already been run is the 50% AEP event (hereon referred to as the 1 in 2 year flood). High flows up to the 1 in 2 year flood are considered to be those which would be most frequently reduced by an abstraction of high flows (larger flows would occur less frequently).

The 1 in 2 year flood map of the Torne is indicated in Figure 3.17. This indicates that there is limited out of banking in the Upper Torne under the 1 in 2 year flood, particularly upstream of the low lying level dependent/ pumped section. Some out of bank flows are observed in the north-west part of the Torne catchment and to the south of Hatfield Moss (designated site). A greater floodplain area is inundated as a result of out of bank flow, is indicated in the lowermost part of the Torne catchment. The small area surveyed in the lower Torne is not associated with overtopping during the 1 in 2 year

[21] Hanson Aggregates (2015) River Idle Silt Sampling

flood, corroborating the review of bank levels against water levels through this section (see 3.5.5.2). Areas of the floodplain inundated as a result of out of bank flows at flows less than the 1 in 2 year flood (and flows most likely to be reduced by abstractions at times of high flow/ down to the EFI flow) are not known though would be less than areas indicated in Figure 3.17.

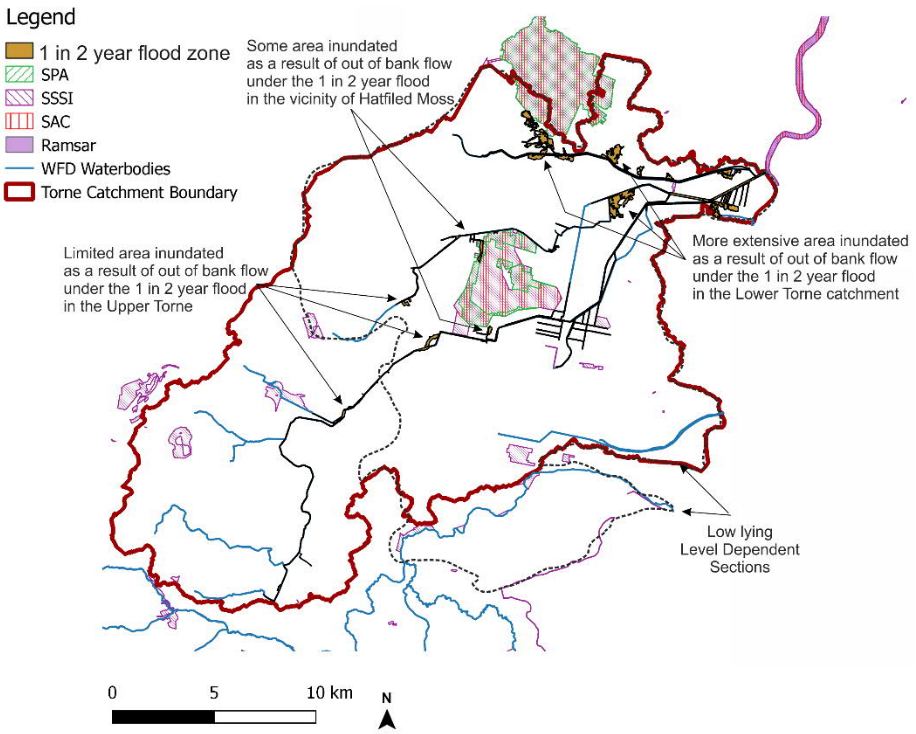


Figure 3.17 Torne 1 in 2 year flood extent

The 1 in 2 year flood map of the Idle is indicated in Figure 3.18. This indicates that flow is contained in the channel through the central section of the Idle (no floodplain inundation). Floodplain inundation as a result of out of bank flow is extensive in the low lying pumped section of the Idle while it is also quite extensive in the upper 5km of the Idle. This generally corroborates our interpretation of the topographical survey data presented in Section 3.5.5.2.

Note the River Idle 2d hydraulic modelling, discussed above, does not cover the main tributaries of the Idle, such as the River Ryton, River Meden, River Poulter or the River Maun (which continues into the River Idle in Retford).

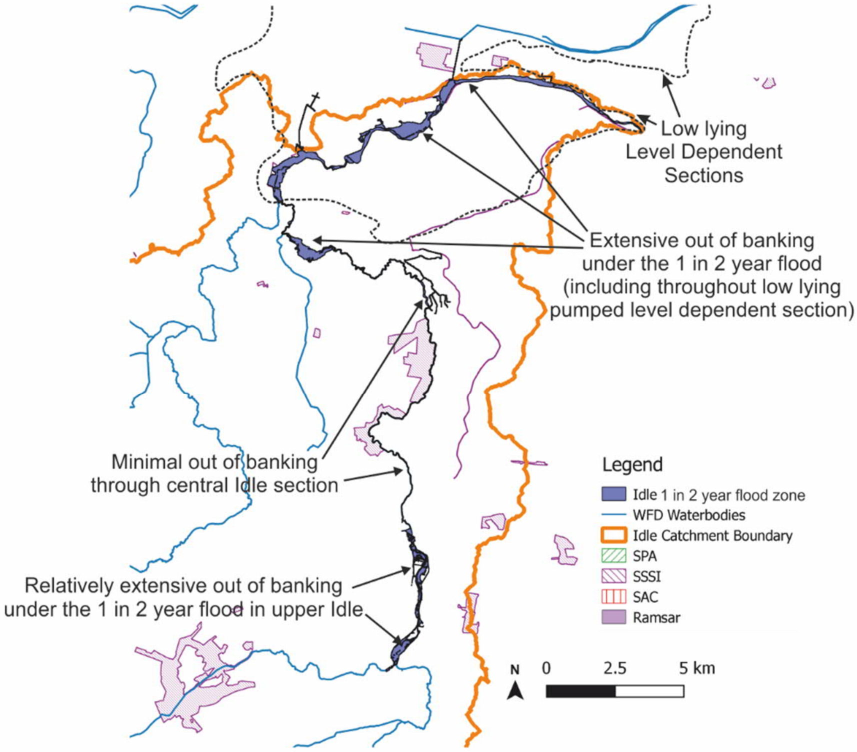


Figure 3.18 Idle 1 in 2 year flood extent

3.5.7 Sediment Loads

Annual suspended sediment loads (tonnes/ year) have been calculated at a number of water quality monitoring sites (see Section 3.6) in the vicinity of flow monitoring sites. Load calculations are determined by multiplying measured suspended sediment concentrations, measured at the routine Environment Agency water quality monitoring sites with correspondent daily mean flows (flow on the day of the water quality sampling and as measured at nearby flow gauges).

There is only a flow gauge in the Torne and so annual sediment loads have been estimated from the nearest water quality monitoring site (Torne at Auckley). Annual suspended sediment loads since 2009 are presented in Figure 3.19. The catchment size at the Auckley water quality monitoring site is 130.6km^2. Total load is lowest in 2011, which was considered a dry year (see Table 3.1). Calculated loads in 2009 and 2010 were greater than in 2013 even though 2013 experienced more days of flow in the Torne being higher than the EFI (see Table 3.2). This suggests that flows lower than the EFI (though likely above average) delivered a steadier (smaller but more frequent) load in 2009 and 2010 compared to 2013.

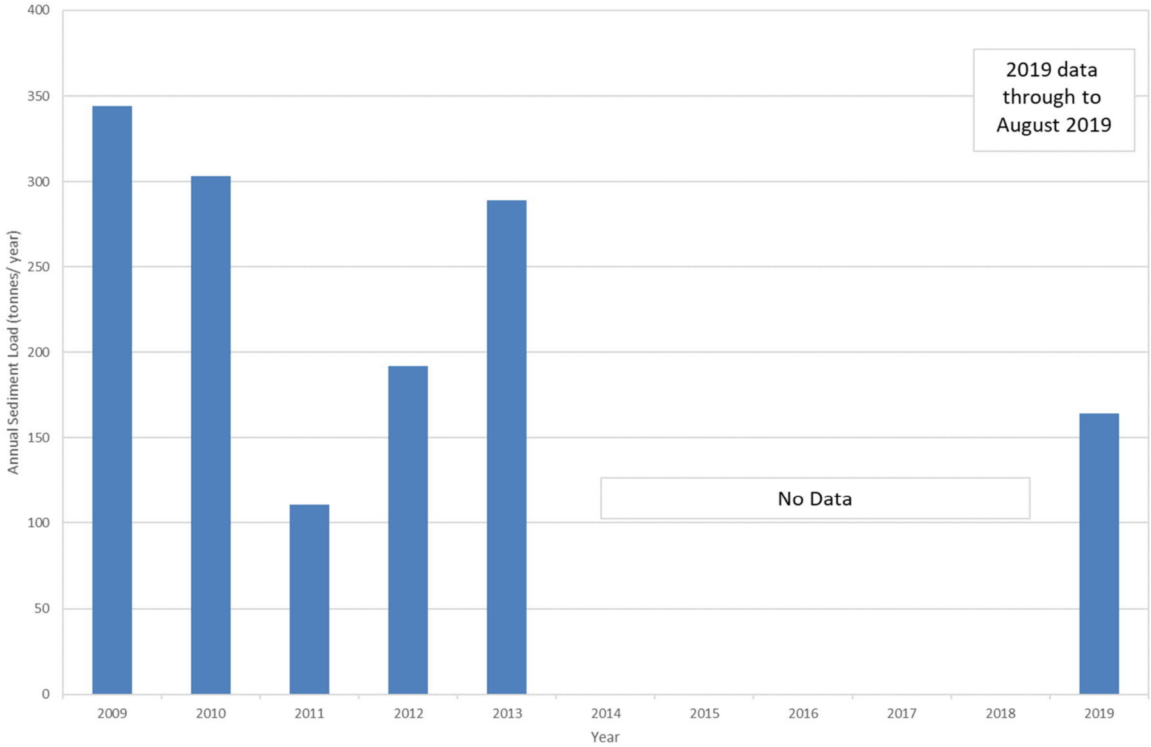


Figure 3.19 Annual Suspended Sediment Load Estimates in the Torne at Auckley

Annual suspended sediment loads for various water quality locations in the Idle catchment which have flow gauges near to them (enabling loads to be calculated) are presented in Figure 3.20. No data was collected between 2014 and 2018 and elsewhere data prior to 2019 was not collected at a number of the sites on smaller systems. Nevertheless a few observations have been made:

- Suspended sediment loads (tonnes) from the Meden and Maun appear to be higher and potentially combine to provide most of the loads that at calculated in the Idle downstream (at Mattersey);
- The Poulter system seems to provide a low load of suspended sediment to the Idle downstream (despite it having a similar catchment size to the Meden and Maun at their respective water quality monitoring points);
- Idle itself is relatively flat and is likely to be comprised of sediment transfer and sink sections (rather than sediment sources); and
- Calculated suspended sediment loads from the River Ryton are half of those determined in the Idle catchment. The catchment size of the River Ryton is around half of that in the idle suggesting that suspended sediment loads in both are proportionate to one another.

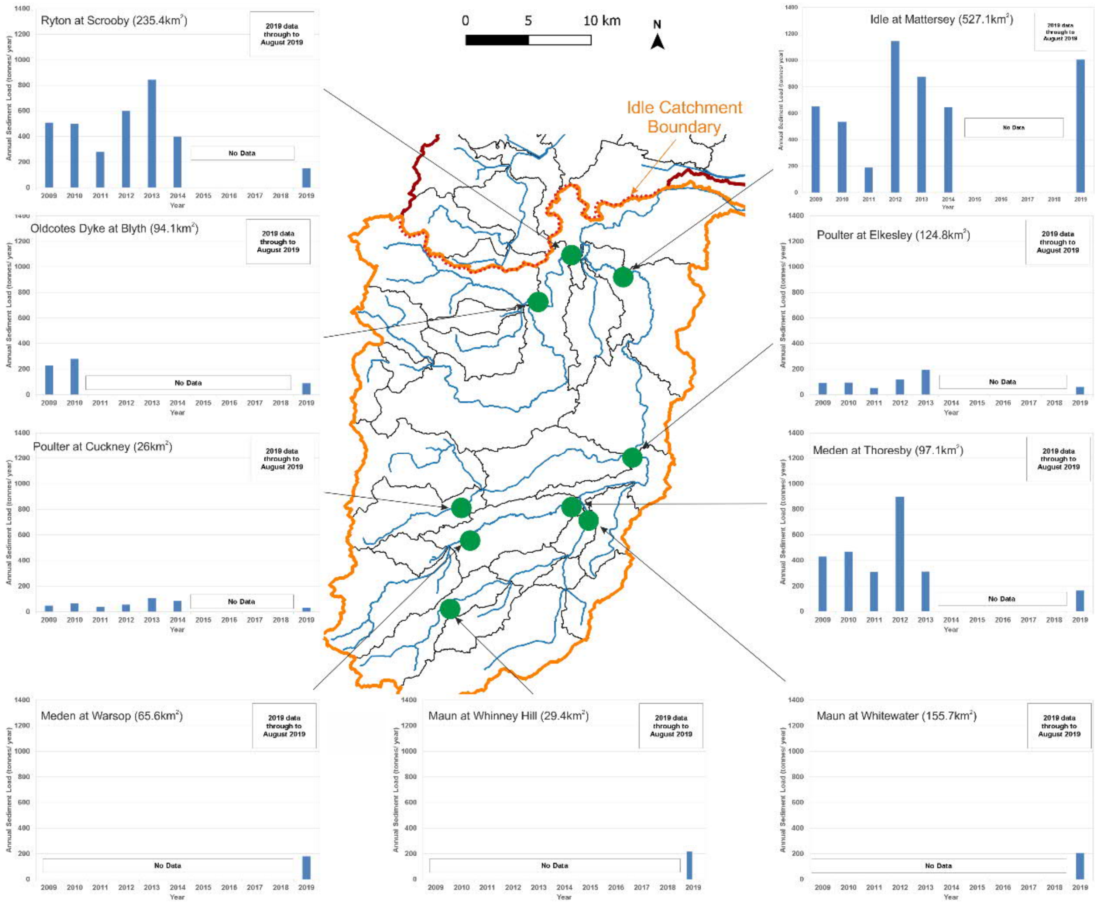


Figure 3.20 Annual Sediment Load Estimates in the Idle catchment

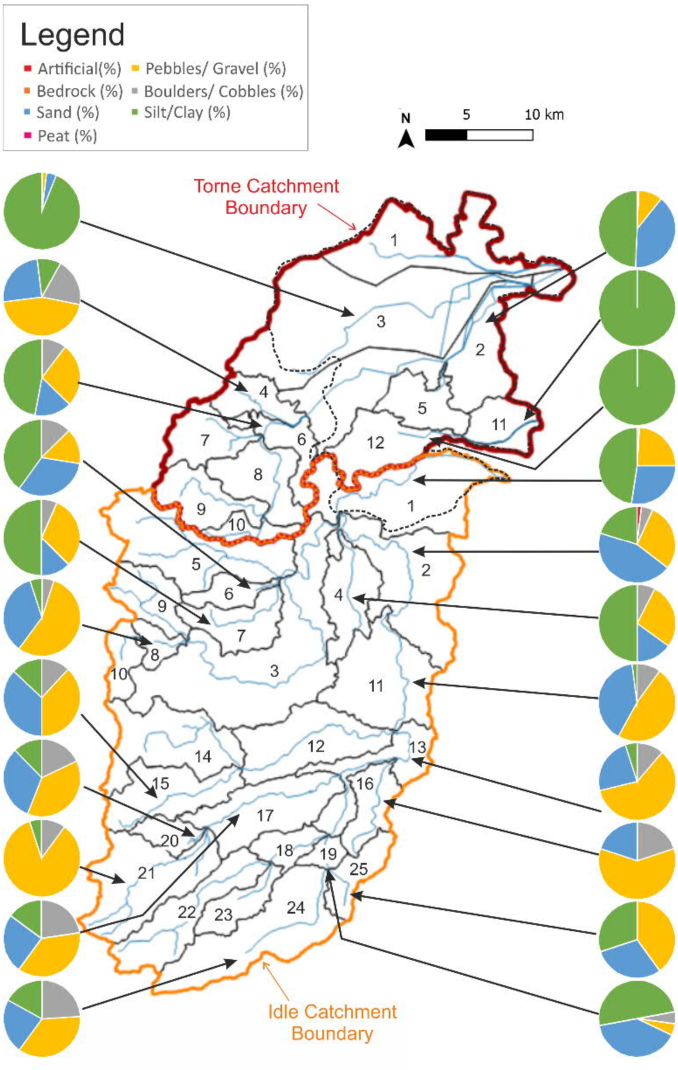
3.5.8 Environment Agency Ecological Monitoring information

3.5.8.1 Channel substrate

Information on channel substrate (% different types) has been gathered during routine Environment Agency ecological (macroinvertebrate, macrophyte and fish) monitoring surveys. This information has been analysed at a waterbody level (with sites in that waterbody grouped together) and is summarised in Figure 3.21. It is noted that the averaging of results may result in certain more seemingly high valuable sites being less apparent or hidden.

The Torne is heavily silted, especially in its lowest lying reaches. A high proportion of pebbles and gravels was recorded in Mother Drain in particular though.

High proportions of boulder, cobbles, pebbles and gravels (typically at least 50% of the substrate) were observed throughout much of the upper waterbodies in the Idle catchment with silt and sand more dominant in the low lying parts of the system too. The prevalence of silt is less marked in the lower (downstream) parts of the Idle catchment, compared to the Torne though.



Torne WFD Catchments

#	Waterbody Name
1	North Soak Drain (trib of R Torne / Three Rivers)
2	Torne / Three Rivers from Mother Dr to R Trent
3	Hatfield Waste Dr (trib of Torne/Three Rivs)
4	Mother Drain from Source to R Torne
5	S Lev Engine Dr / Upper Warping Drain Catch
6	Torne from St Catherine'S Well Strm to Mother Dr
7	St Catherine's Well Stream from Source to R Torne
8	Torne from Ruddle to St Catherine's Well St
9	Ruddle (Paper Mill Dyke) from Source to R Torne
10	Torne from Source to Ruddle (Paper Mill Dyke)
11	Ferry Drain
12	Warping Drain Catch (trib of Trent)

Idle WFD Catchments

#	Waterboday Name
1	Idle from River Ryton to River Trent
2	Idle from Tiln to River Ryton
3	Ryton from Anston Brook to Idle
4	Ranskill Brook Catchment (trib of the River Idle)
5	Oldcotes Dyke
6	Hodsock Bk (to Oldcoates Dyke)
7	Owlands Wood Dyke from Source to Hodscok Brook
8	Ryton (to Aniston Brook)
9	Anston Brook from Source to River Ryton
10	Broad Bridge Dyke (to Canal)
11	Idle from Maun/Poulter Conf to Tiln
12	Poulter from Millwood Brook to River Maun
13	Maun from Rainworth Water to River Poulter
14	Millwood Brook from Source to River Poulter
15	Poulter from Source to Millwood Brook
16	Bevercotes Beck Catchment (trib of River Maun)
17	Meden from Sookholme Brook to River Maun
18	Maun from Vicar Water to Rainworth Water
19	Rainworth Water from Gallow Hole Dyke to R Maun
20	Sookholme Brook from Source to River Meden
21	Meden from Source to Sookholme Brook
22	Maun from Source to Vicar Water
23	Vicar Water from Source to R Maun
24	Rainworth Water from Source to Gallow Hole Dyke
25	Gallow Hole Dyke from Source to Rainworth Water

Figure 3.21 Channel substrate composition percentages (from ecological surveys)

3.5.8.2 Other information

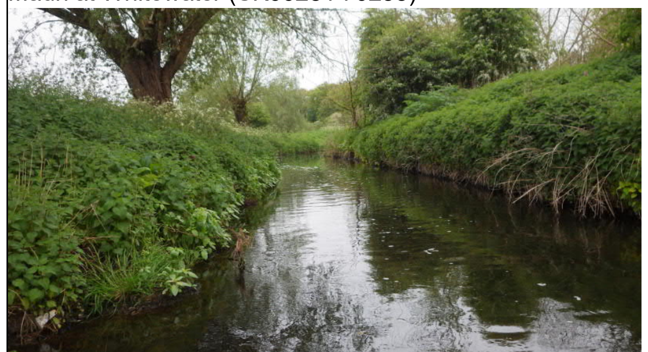
A number of images and Environment Agency WFD Reasons for Failure (RFF) documents for various waterbodies in both catchments have been provided to us, indicating the nature of the watercourse at various locations. Images are provided in Table 3.9 along with a brief description of the site, from a hydromorphological perspective (where information was available).

Table 3.9 Compilation of imagery from ecological monitoring sites and WFD reports and watercourse hydromorphological description

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Idle waterbodies		
Anston Brook from Source to River Ryton	No imagery provided	-
Bevercotes Beck Catchment (trib of River Maun) [22]	  Upper Bevercotes Beck upstream (Wellow) and downstream (Lound Hall) of Boughton STW	Both channels look to have been historically managed, straightened, and deepened, so are likely to have poor lateral connectivity, which would benefit flood management. However, it would also mean that out-of-channel wetland areas are absent or depleted and sensitive to any further hydrological change. Similarly, in-channel fine sediment (and associated pollutant) loads may be excessive due to reduced capacity for floodplain deposition, and high flow abstraction could exacerbate this and reduce sediment flushing capacity in the channel. Homogeneous nature of watercourse reported, resulting in lack of species diversity, Bank erosion in the steeper sections of the beck is reported in the RFF report.
Broad Bridge Dyke (to Canal)	No imagery provided	-
Gallow Hole Dyke from Source to Rainworth Water	No imagery provided	-
Hodsock Bk (to Oldcoates Dyke)	No imagery provided	-
Idle from Maun/Poulter Conf to Tiln	No imagery provided	-
Idle from River Ryton to River Trent	 Idle at Bawtry (SK65602 92740)	All channels appear engineered (realigned and deepened) and embanked, which will have impacts on lateral connectivity and sediment loads. Flows in these images appear to be near bankfull though waterbody is low lying and level dependent (with levels generally controlled within a narrow level envelope). In the right hand (turbid) image of the Idle at Misterton, marginal habitats appear inundated that would usually be dry. Some species and assemblages may be dependent on particular inundation regimes (depths and frequencies) which could be affected by high flow abstraction.

[22] Environment Agency (2016) Bevercotes Beck Macrophyte/ Phytobenthos Failure

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	  Idle @ Misterton (SK76466 96231)	
Idle from Tiln to River Ryton	 Idle Tiln (SK70299 84241)  Idle Chain Bridge Lane (SK7135685787)	Both channels appear engineered (realigned and deepened) so existing degraded habitats may be sensitive to new hydrological changes. The Idle at Tiln is very uniform with a well defined baseflow channel and what appear to be managed grass banks (i.e. vegetation cut back to mitigate flood debris and blockage risks). This could mean high flow abstraction has relatively little impact, because there is little diversity of habitats to be affected. The Idle at Chain Bridge appears to have been photographed at low flow (as shown by the exposed bare silt margin).

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Maun from Rainworth Water to River Poulter	 Maun at Ollerton (Sk65472 67804)  Maun at Whitewater (SK66281 70255)  Maun at Whitewater (SK6636770406)	Images show an engineered channel (realigned and deepened) which would be of reduced sensitivity to new hydrological changes. The Maun at Ollerton is physically very uniform with continuous and single species of macrophyte (which appears to Himalayan Balsam but not confirmed from the image available). This could mean high flow abstraction has relatively little impact, because there is little diversity of habitats to be affected. The Maun at Whitewater is also physically uniform, but at least has some low diversity of species, which appears to be layered according to height above water level. There is a marginal community at the bridge, and possibly some trailing or even emergent species around water level in the other image compared more terrestrial species higher up the profile.
Maun from Source to Vicar Water	No imagery provided	-
Maun from Vicar Water to Rainworth Water	No imagery provided	-

AECOM

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Meden from Sookholme Brook to River Maun	 Meden at the Carrs (SK5675568341)  Meden at the Carrs Warsop (SK56755 68341)  Meden at Budby (SK61797 70176)	The Meden at the Carrs and at Budby looks to be high value habitat and much less impacted by historic management than other rivers in the catchment, so these sites could be more sensitive to deterioration. Both appear to have aquatic and submerged macrophyte populations. Budby seems to have surface bed gravels, so bed habitats may be vulnerable to reduced fine sediment transport (less flushing / increased deposition) if high flows are abstracted. The Meden at Carrs Warsop is physically very uniform with managed vegetation above bank side macrophytes opposite concrete and little diversity of habitats.

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Meden from Source to Sookholme Brook[23]	 Example of bank erosion (SK49109 61774)  Meden at Pleasley (SK49600 63300)	The Meden from source to Sookholme brook has a diverse range of habitats including engineered reaches and what appear to be natural and high quality habitats. Modified reaches such as at Pleasley and Newbound Mill and where there are culverts and concrete banks are generally uniform so high flow abstraction would have little impact. Bank erosion is unlikely to be significantly affected by high flow abstraction. More natural reaches with a diverse range of habitats may be more sensitive to changes in peak flows, with marginal or riparian habitats likely to have some dependency on an inundation regime; sensitive species may be detrimentally affected if they are not wetted as frequently, but the effects of reduced peak flows due to abstraction may be counter-balanced by increased flow peaks due to climate change. Riffles and runs that exist at baseflow should not be significantly affected by high flow abstraction.

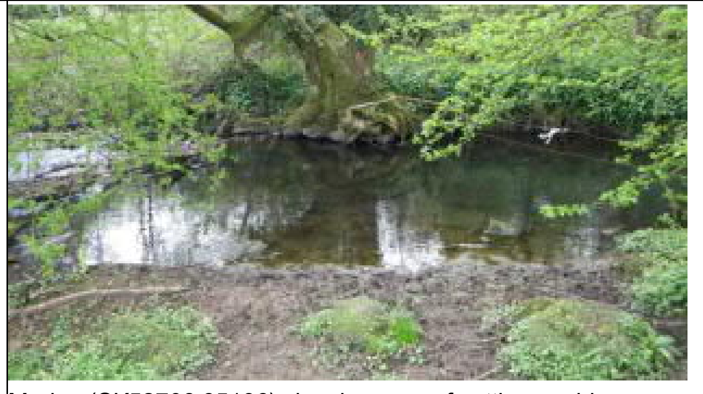
[23] Environment Agency (2016) WFD Investigation Meden from source to Sookholme Brook.

AECOM

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Meden d/s Newbound Mill (SK49621 63286)  Barrier to fish migration (SK50542 64224)  Meden (SK50548 64270)	

AECOM

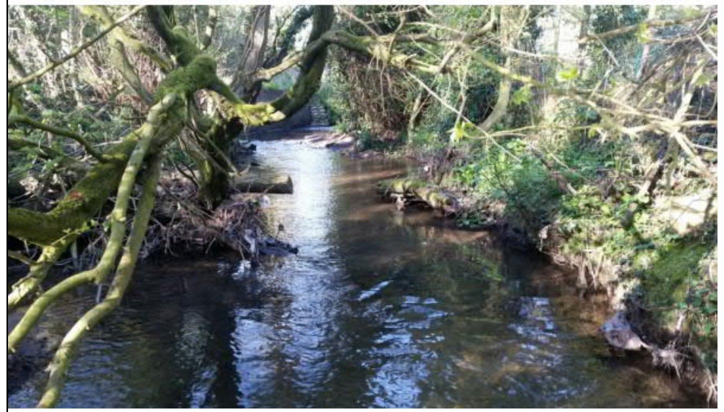
WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Meden (SK50578 64363)  Meden (SK50720 64756)  Meden (SK50782 64822)  Meden (SK52848 65178)	

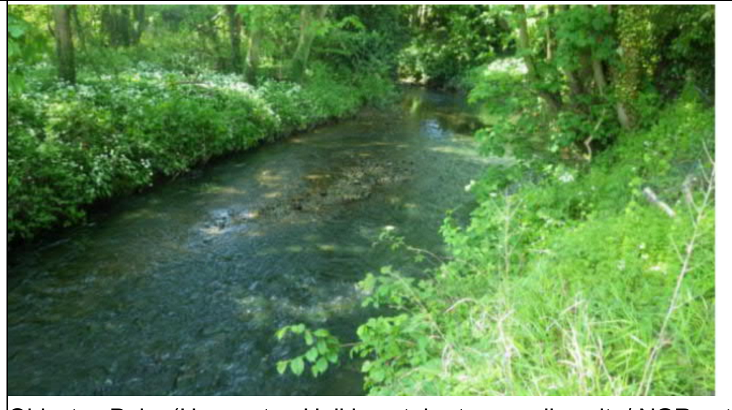
WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Meden (SK52708 65136) showing area of cattle poaching  Meden (SK52856 65175)  Meden at Littlewood (SK53177 65282)	

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Meden at Hammerwater Bridge (SK55587 67509) showing excessive algal growth and siltation  Meden at Hammerwater Bridge (SK55600 67531)  Meden d/s Hammersmith Bridge (SK55606 67570). Accumulated silt evident	
Millwood Brook from Source to River Poulter	**Hooton Dyke (trib):**	-

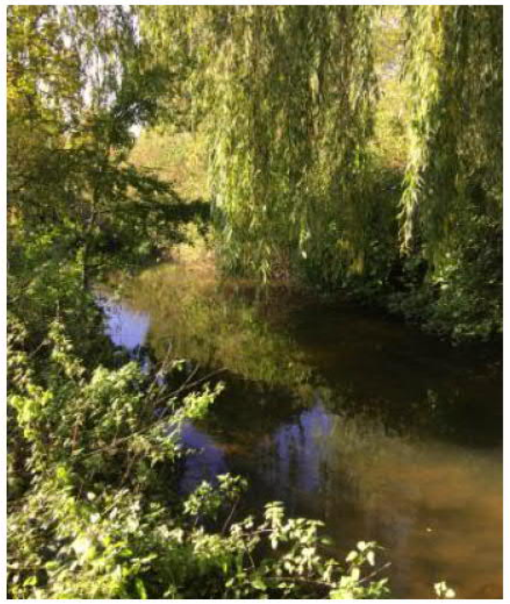
WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Oldcotes Dyke[24]	 Hooton Dyke (NGR not provided though looking upstream of Riddings Close)  Hooton Dyke with high proportion of Cladophora overlaying silt on the substrate (NGR not provided)  Hooton Dyke upstream of Slade Hooton (NGR not provided)	Hooton Dyke upstream to Riddings Close appears to have a well connected floodplain and wetlands, so high flow abstraction could be detrimental to water dependent habitats outside of the channel. Elsewhere, high silt loads may be associated with waste water discharges and other adjacent land uses, and a reduction in peak flows is likely to mean less flushing of pollutants, higher pollution retention time, and less pollutant dilution. Maltby Dyke and Oldcotes Dyke look to be diverse, high value habitats where channel – floodplain – wetland connections will serve important functions. High flow abstractions could be detrimental to both in-channel and out of channel habitats. Oldcotes Dyke at Blythe Old Bridge appears to be overdeep due to historic realignment, so may already have poor lateral connectivity that could be exacerbated by peak flow reductions.

[24] Environment Agency (2016) Oldcotes Dyke Catchment (trib of Ryton)

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Hooton Dyke downstream of Slade Hooton (NGR not provided)  Maltby Dyke (Maltby invertebrate site/ NGR not provided)  Maltby Dyke (Bullatree Hill invertebrate sampling site/ NGR not provided)	

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Oldcotes Dyke (Hermeston Hall invertebrate sampling site/ NGR not provided)  Oldcotes Dyke (Blythe Old Bridge invertebrate sampling site/ NGR not provided)	
Owlands Wood Dyke from Source to Hodsock Brook	 Owlands Wood Dyke @ Cornmill Farm (SK57285 83656)	Owlands Wood Dyke is an incised channel that appears to have been historically straightened, but has a range of in-channel flow habitats at baseflow, which high flow abstraction should not impact to a large extent.

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Poulter from Millwood Brook to River Maun	  Poulter at Crookford (SK67079 75258)  Poulter at Elkesley (SK69965 75245)	The Poulter at Crookford appears to have a ford but is otherwise a shallow channel, which suggests good floodplain connectivity. High flow abstraction may negatively affect out-of-channel habitat inundation. Elkesley appears to be a gauging station.
Poulter from Source to Millwood Brook	  Poulter at Nether Langwith (SK53034 70407)	The Poulter from source to Millwood Brook appears mainly natural and high quality habitat, with a diverse range of aquatic, marginal and riparian species that will have developed according to the existing flow regime. One of the reaches appears to have bank toe protection, and high flow abstraction is unlikely to significantly affect erosion.

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Poulter at Cuckney (SK56134 71131)	
Rainworth Water from Gallow Hole Dyke to R Maun	 Rainworth Water at A614 (SK64725 66713)	Uniform reaches are unlikely to be significantly affected by high flow abstraction, but marginal vegetation could be negatively affected by decreased peak flows.

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Rainworth Water from Source to Gallow Hole Dyke	 Rainworth Water at Rainworth (NGR not indicated though Rainworth is upstream of site below)  Rainworth Water @ Robin Dam Bridge (SK64182 62079)	Uniform reaches are unlikely to be significantly affected by high flow abstraction, but marginal vegetation diversity could depend on the existing flow depth and inundation regime, and so could be negatively affected by decreased peak flows.
Ranskill Brook Catchment (trib of the River Idle)	 Ranskill Brook at B6045 (SK66854 88723)	Ranskill Brook at this location is likely to have strong lateral connectivity, which could be depleted by high flow abstraction.
Ryton (to Anston Brook)	No imagery provided	-

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Ryton from Anston Brook to Idle	No imagery provided	-
Sookholme Brook from Source to River Meden[25]	No imagery provided	WFD investigations indicate a failure for fish in the upper Meden catchment with the reason for failure being associated with morphology (barriers) and sedimentation (from agricultural diffuse sources) however 'other' pressures, such as water quality are considered as likely to be contributing to the failure.
Vicar Water from Source to R Maun	No imagery provided	-
Torne waterbodies		
Ferry Drain	No imagery provided	-
Hatfield Waste Dr (trib of Torne/Three Rivs)[26]	 Fores Drain at Nutwell (SE63300 03100)  Woodhouse Sewer at confluence Hatfield Waste Drain (SE68527 08184)	Hatfield Waste Drain is a Heavily Modified Waterbody that has been channelised, re-sectioned and straightented. Gradient is shallow at 1-2m necessitating pumping at Brick Hill Carr and Goodcop to drain the upper section of the system. The lower section empties into the Three Rivers complex and then into the tidal River Trent downstream of Keadby pumping station. Realigned and pumped systems tend to have siltation problems due to the lack of gradient and flow velocities. High flow abstraction could exacerbate this because sediment could be delivered into the channel by rainfall runoff, but then flow abstraction further downstream could reduce the stream's capacity to transport sediment or deposit it to floodplains.

[25] Environment Agency (2017) GB104028058020 Meden from source to Sookholme Brook OPERATIONAL CATCHMENT: Idle River NGR: SK5054664487

[26] Environment Agency (2017) Hatfield Waste Drain Failure in Ammonia

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Mother Drain from Source to R Torne[27]	No imagery provided	Ecological review indicates species present are adapted to heavy sedimentation, suggesting of conditions in the river.-
North Soak Drain (trib of R Torne / Three Rivers)	No imagery provided	-
Ruddle (Paper Mill Dyke) from Source to R Torne	No imagery provided	-
S Lev Engine Dr / Upper Warping Drain Catch[28]	No imagery provided	The waterbody is a network of artificial drainage ditches, static flows, uniform laminar flow and lack of mixing, sedimentation is an issue (PSI scores), however the biological status has not been affected by this. Potential sewage inputs having localised effects on ammonia levels.
St Catherine's Well Stream from Source to R Torne	No imagery provided	-
Torne / Three Rivers from Mother Dr to R Trent	 Torne at Auckley (SE64653 01281)	Highly uniform reaches are unlikely to be significantly affected by high flow abstraction.

[27] Environment Agency (2017) GB104028058440 WATERBODY NAME: Mother Drain from Source to Torne OPERATIONAL CATCHMENT: Isle of Axholme NGR: SE6013200052

[28] Environment Agency (2018) GB104028058430 Waterbody Name: South Level Engine Drain catchment (trib of Trent) SE7256600598 (2018) – ammonia failure

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
	 Torne at Westgate Bridge (SE76250 07643)  Hatfield Waste Drain at Hirst Priory (SE78188 09850)	

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Torne from Ruddle to St Catherine's Well Stream[29]	 Torne at Wadworth Carr (NGR not provided)  Torne at Wadworth Carr showing limited flow and homogenous habitat (NGR not provided)	This waterbody is not designated as a Heavily modified waterbody although it considered to be homogenous in nature. It has been channelised and re-sectioned into long straight sections. Flow is predominantly slack with little habitat heterogeneity and heavy rates of sedimentation.
Torne from Source to Ruddle (Paper Mill Dyke)	No imagery provided	-

[29] Environment Agency (2017) River Torne from Ruddle to St Catherine's Well Stream dissolved oxygen failure

WFD Waterbody and Reasons for Failure reference	Imagery (presented from upstream to downstream in each waterbody for those with multiple images)	Description (based on imagery and Reason for Failure descriptions)
Torne from St Catherine's Well Strm to Mother Dr	 Torne at Rossington (SK62839 99499)	The Torne at Rossington has a uniform channel that is unlikely to be affected badly by peak flow abstraction, but wetland and floodplain habitats such as reeds could be detrimentally affected if peak flows are reduced. Bank erosion is unlikely to significantly reduce with peak flow abstraction.
Warping Drain Catch (trib of Trent)	No imagery provided	-

3.5.9 Overview

During the 2015 Feasibility Study, it was concluded that the most likely sensitive reaches would be those largely unmodified and those reaches susceptible to a reduction in out of bank flows (i.e. with lateral connectivity remaining in the absence of embankments). It was concluded at that time that further work should concentrate on flow and sediment dynamics.

Additional analyses have been undertaken through Phase 2a, as described above.

Extensive capital and maintenance works throughout the Torne and Idle have been documented. Activities such as dredging result in over wide and deep channels prone to excessive sedimentation. These include the main stem of the River Torne, lower (downstream) end of the Idle, River Ryton and Upper Idle and lower end of the River Meden. These works would likely have detrimentally altered the hydromorphology of the rivers at these points reducing their sensitivity to changes in flow as a result of high flow abstraction (i.e. if siltation levels increased noting that silt levels are already quite deep in the low lying and pumped areas).

1 in 2 year flood modelling was also reviewed and indicated that no out of bank flooding occurred in the central River Idle although was experienced in the lower Idle and upper Idle as well as in the lower part of the Torne catchment. These areas may be sensitive in this regard if the frequency of overtopping was reduced if abstractions were to occur at times of (winter) high flows.

It is noted that modelling of most of the River Idle catchment has not been undertaken with modelling efforts focussed on the main Idle stem itself (downstream of the River Maun which subsequently becomes the River Idle in Retford).

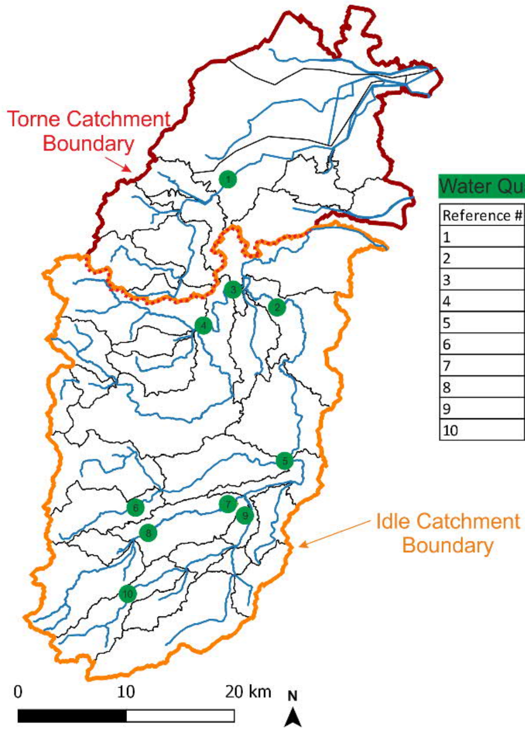
In both the Torne and Idle, silt beds dominate the lower lying parts of both catchments with good ecological habitat (pebbles/ gravel substrates) present in the upper parts of the catchments (in the Idle in particular).

Depending on the next steps in Phase 2b further consideration of deposition and erosion rate changes as a result of abstraction of high flows would be of value.

3.6 Water Quality

3.6.1 Monitoring Overview

Water quality has been monitored extensively through the Idle and Torne catchments over past few decades. We have selected a number of monitoring locations where data records are extended and sampling has occurred frequently (typically monthly) and where flow has also been recorded nearby, and reviewed water quality further. The sites are indicated in Figure 3.22 below and our review of the water quality at each follows. Our review examines water quality levels within various high flow bands, as these may be affected if the catchments are opened up to abstraction at high flows (above Q_{18} in the Idle and Q_{15} in the Torne).



Water Quality Sampling Points

Reference #	Sampling Point Name	Station #
1	RIVER TORNE AT AUCKLEY	MD-37421800
2	RIVER IDLE (MAUN) AT MATTERSEY	MD-38474920
3	RIVER RYTON AT SCROOBY	MD-38638380
4	OLD COATES DYKE AT BLYTHE OLD BRIDGE	MD-38688150
5	RIVER POULTER AT ELKESLEY	MD-39322060
6	RIVER POULTER AT CUCKNEY	MD-39324570
7	RIVER MEDEN AT THORESBY	MD-39480520
8	RIVER MEDEN AT WARSOP MILL	MD-38480380
9	RIVER MAUN AT WHITEWATER	MD-39481620
10	RIVER MAUN AT WHINNEY HILL	MD-38482980

Figure 3.22 Water quality monitoring points in the Idle and Torne catchments reviewed in this study

3.6.2 River Torne catchment

3.6.2.1 Torne at Auckley

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in the Torne at Auckley (see Figure 3.22) are indicated in Figures 3.23 to 3.25 respectively, below. Figure 3.23 indicates that dissolved oxygen levels are generally equivalent to at least Good WFD status concentrations though levels less than Good have been observed at times of high flow, albeit rarely. Total ammonia levels (Figure 3.24) are also generally equivalent to at least Good levels also. However, several exceedances of this level occurred between 2009 and 2012 including when levels were between the Q_{10} and Q_{25}. This implies some sensitivity at moderate to high flows.

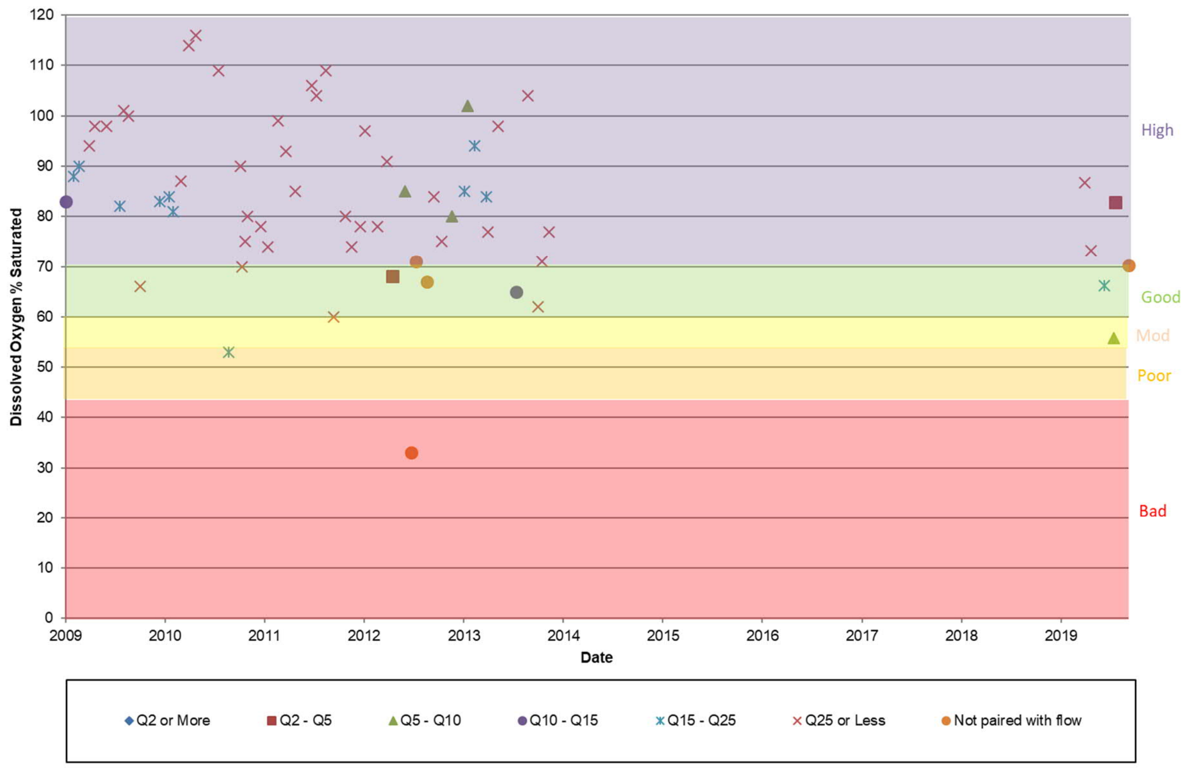


Figure 3.23 Dissolved oxygen (% saturation) in the Torne at Auckley (flow band on day of sampling from the same location) 2009 - 2019

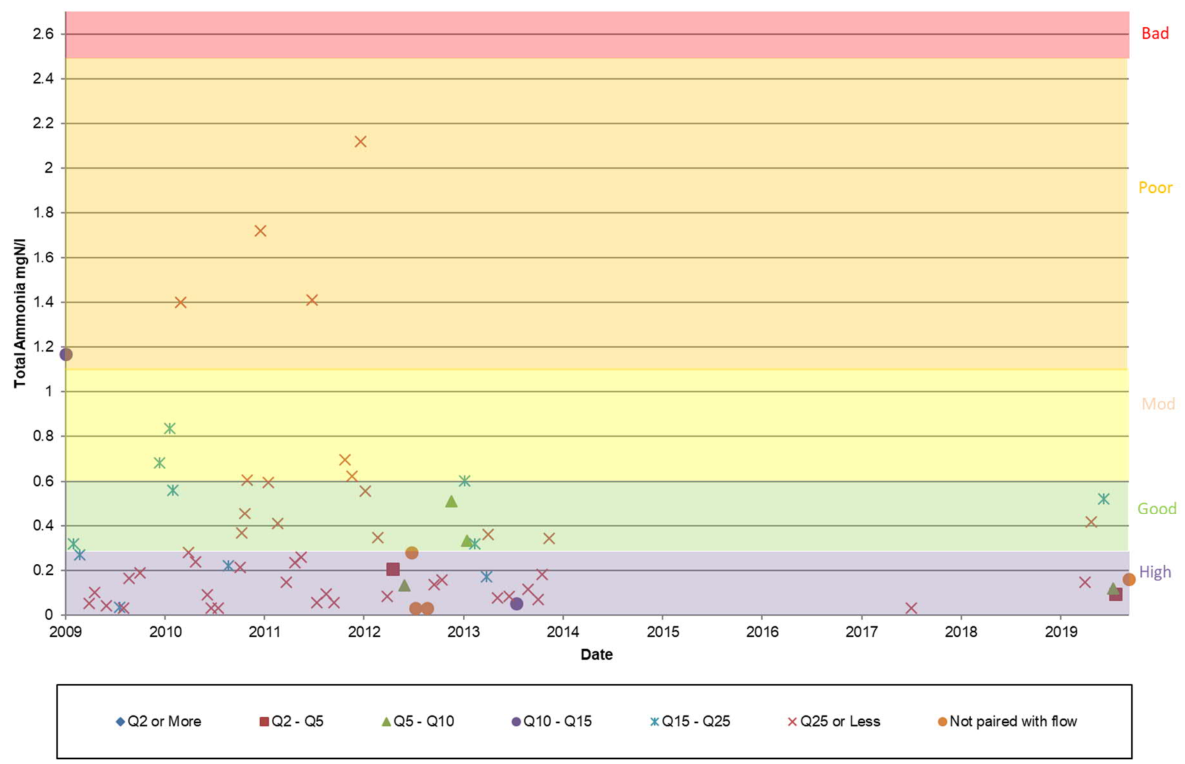


Figure 3.24 Total ammonia concentrations in the Torne at Auckley (flow band on day of sampling from the same location) 2009 - 2019

Orthophosphate concentrations at the Torne at Auckley (Figure 3.25) are equivalent to less than Good status. Levels in 2012 at flows greater than the Q_{10} were at levels equivalent to moderate status and better than at other times- implying they abstractions at high flows may result in more elevated concentrations.

Figure 3.25 Orthophosphate concentrations in the Torne at Auckley (flow band on day of sampling from the same location) 2009 - 2019

3.6.3 River Idle catchment

3.6.3.1 River Idle at Mattersey

The site lies in the lower stretch of the River Idle, close upstream of Bawtry (beyond which the system becomes level dependent) and the confluence with the River Ryton. Flow gauge Idle at Mattersey located roughly 80m downstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.26 to 3.28 respectively, below.

Figure 3.26 indicates that dissolved oxygen levels are generally equivalent to at least Good WFD status. Less than good status have been observed at times of high flow indicating that dissolved oxygen can be sensitive at times of high flow. Reduced dilution, as a result of high flow abstraction, may compound this.

All total ammonia level measurements (Figure 3.27) are generally equivalent to at least Good status levels. Abstraction at times of high flow would likely not increase concentrations (as water of same concentration would be abstracted).

Higher levels were recorded at higher flows suggesting that they may have due to diffuse pollution from agricultural areas (transported by runoff following significant rainfall events). Abstractions at times of high flow would likely have a neutral effect on these concentrations.

Orthophosphate concentrations (Figure 3.28) at the site are generally equivalent to less than Good status. Results at various flow levels are mixed although abstractions at high flows would reduce the dilution of orthophosphate.

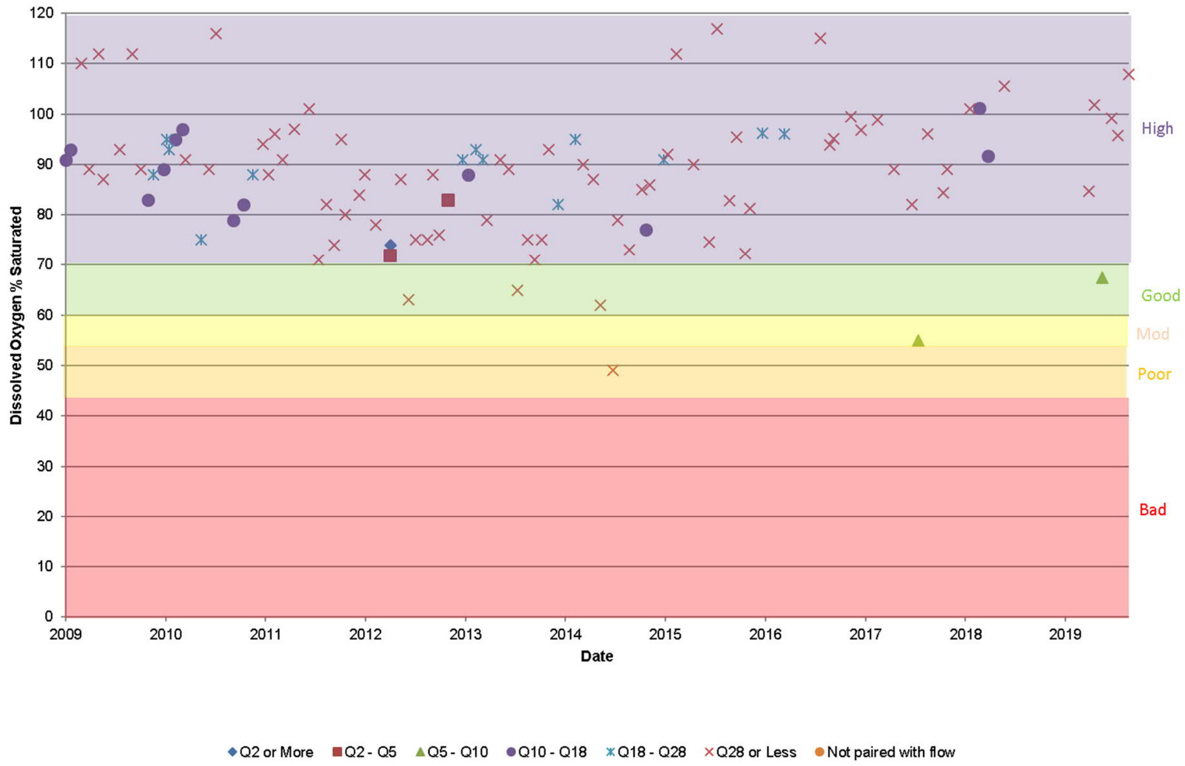


Figure 3.26 Dissolved oxygen (% saturation) in the River Idle at Mattersey (flow band on day of sampling from the same location) 2009 - 2019

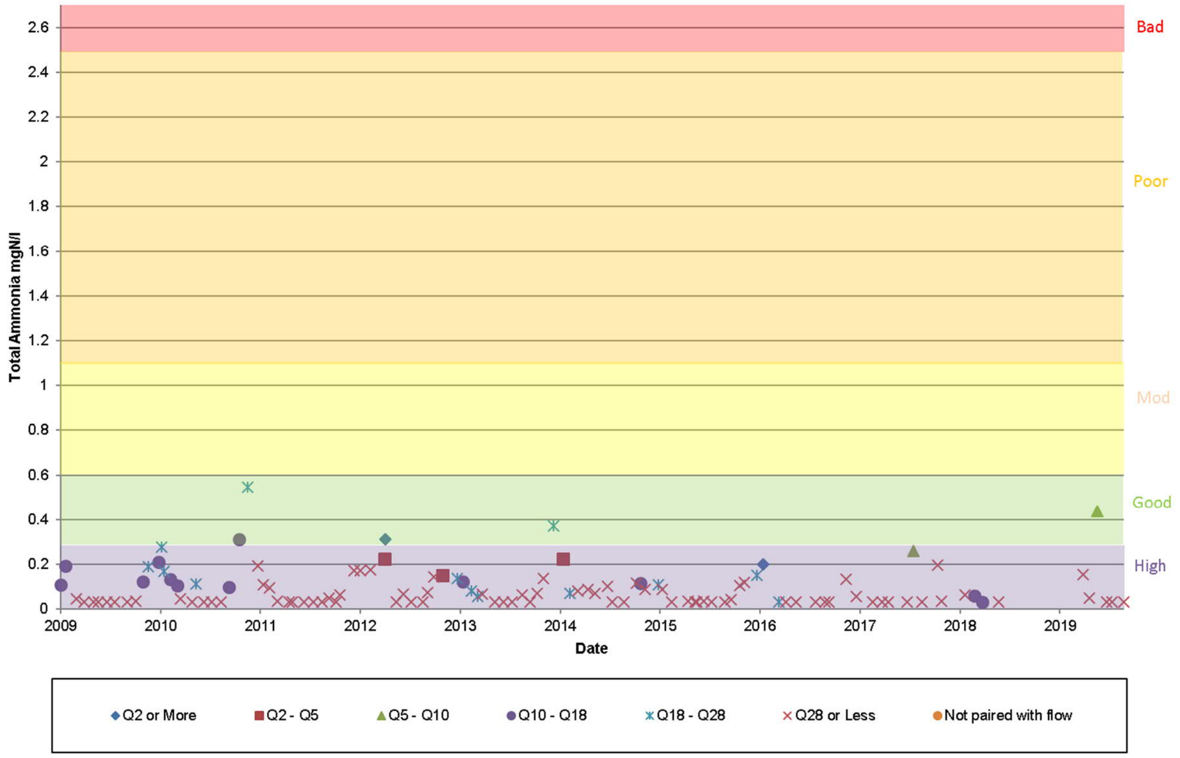


Figure 3.27 Total ammonia concentrations in the River Idle at Mattersey (flow band on day of sampling from the same location) 2009 – 2019

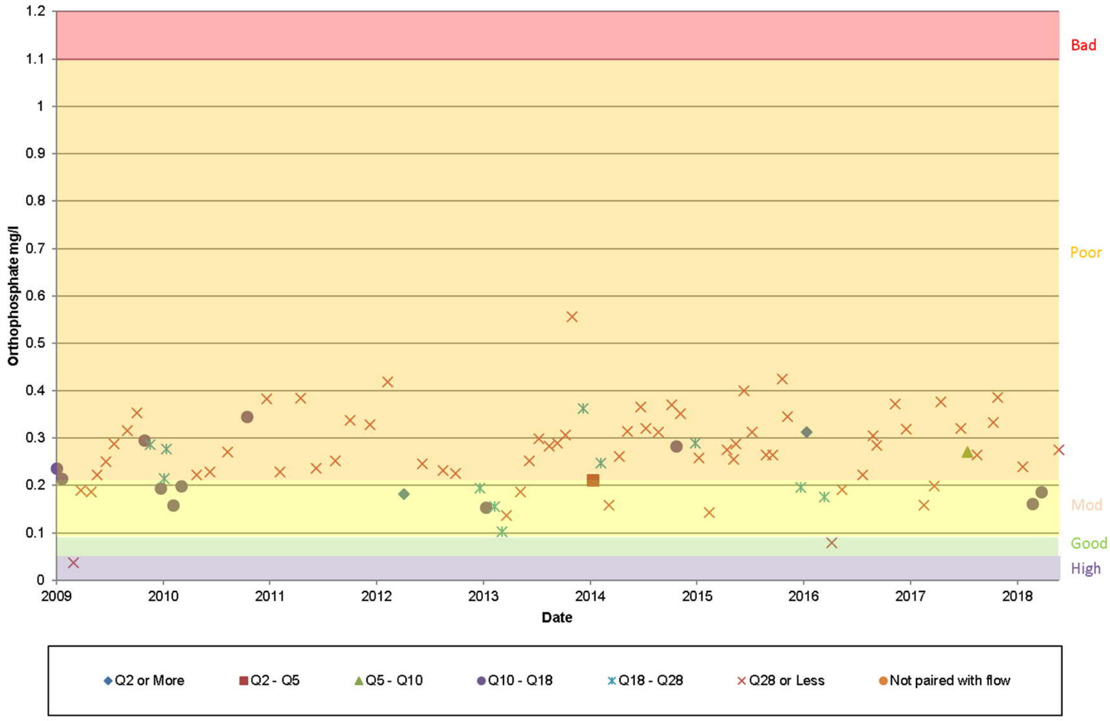


Figure 3.28 Orthophosphate concentrations in the River Idle at Mattersey (flow band on day of sampling from the same location) 2009 – 2019

3.6.3.2 River Ryton at Scrooby

The site lies in the lower stretch of the River Ryton, close upstream of Bawtry (beyond which the system becomes level dependent) and the confluence with the River Idle. Flow gauge Ryton at Blythe located roughly 7.12km upstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.29 to 3.31 respectively, below.

Figure 3.29 indicates that dissolved oxygen levels are generally equivalent to High WFD status concentrations though levels equivalent to Good status have been observed at times of high flow. This may be linked to intermittent events and suggests potentially sensitivity at times of high flows. Abstractions at times of high flow could compound this.

Total ammonia levels (Figure 3.30) are also generally equivalent to High status levels also. Two values equivalent to Good status and one equivalent to Moderate status are associated with higher flows. With a correspondent drop in dissolved oxygen and increase in orthophosphate these are likely associated with an intermittent event/ diffuse pollution. Abstraction at times of high flows would likely have a neutral effect on ammonia levels.

Orthophosphate concentrations (Figure 3.31) at the site are generally equivalent to less than Good status. Results tend to indicative that concentrations are lower at higher flows suggesting abstractions at high flows may further elevate concentrations (with less flow being available for dilution).

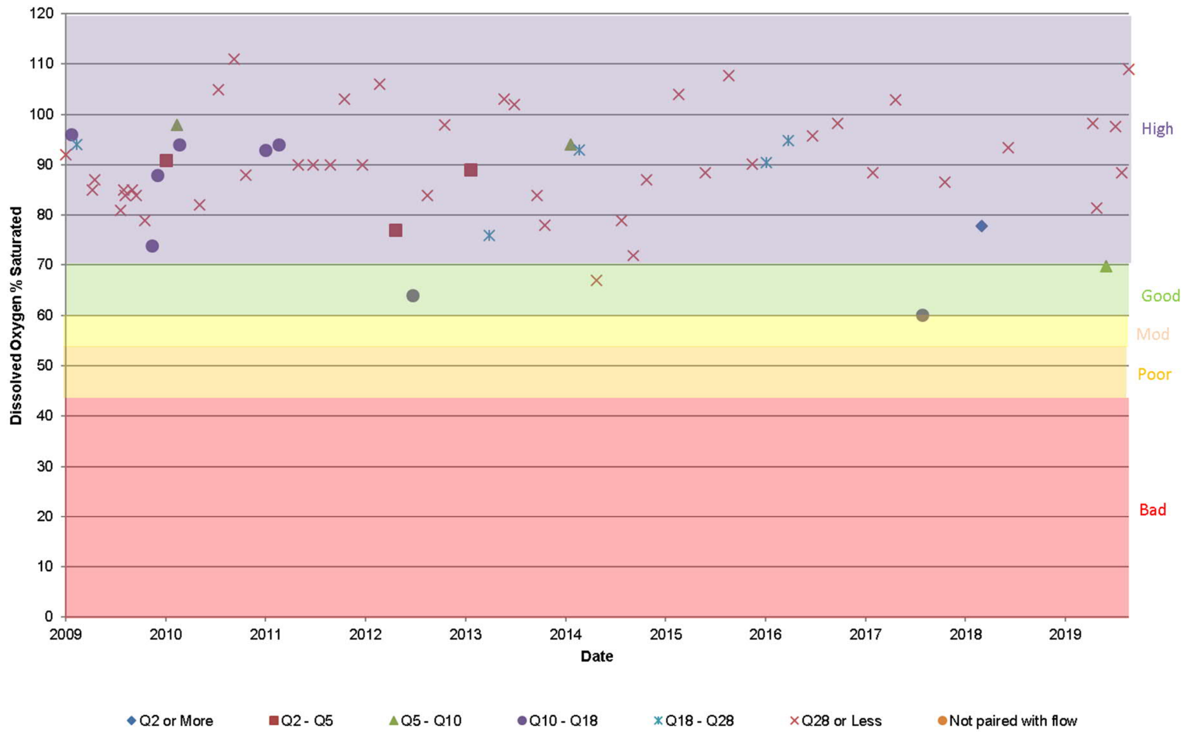


Figure 3.29 Dissolved oxygen (% saturation) in the River Ryton at Scrooby (flow band on day of sampling the Ryton at Blythe) 2009 - 2019

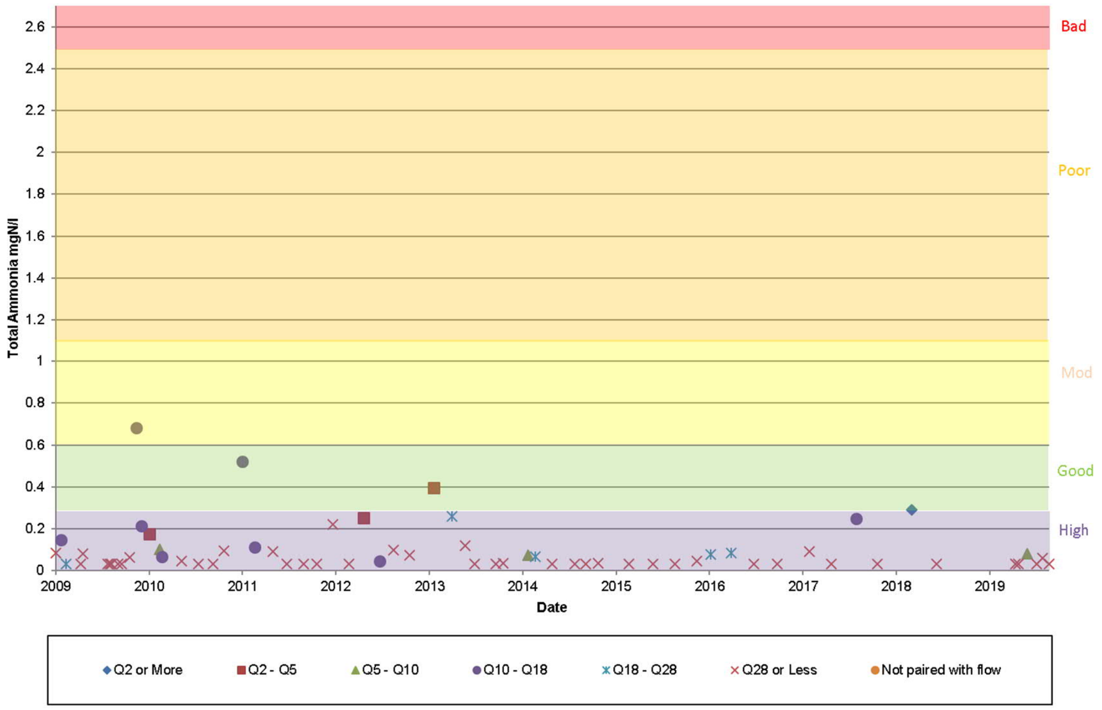


Figure 3.30 Total ammonia concentrations in the River Ryton at Scrooby (flow band on day of sampling from the Ryton at Blythe) 2009 – 2019

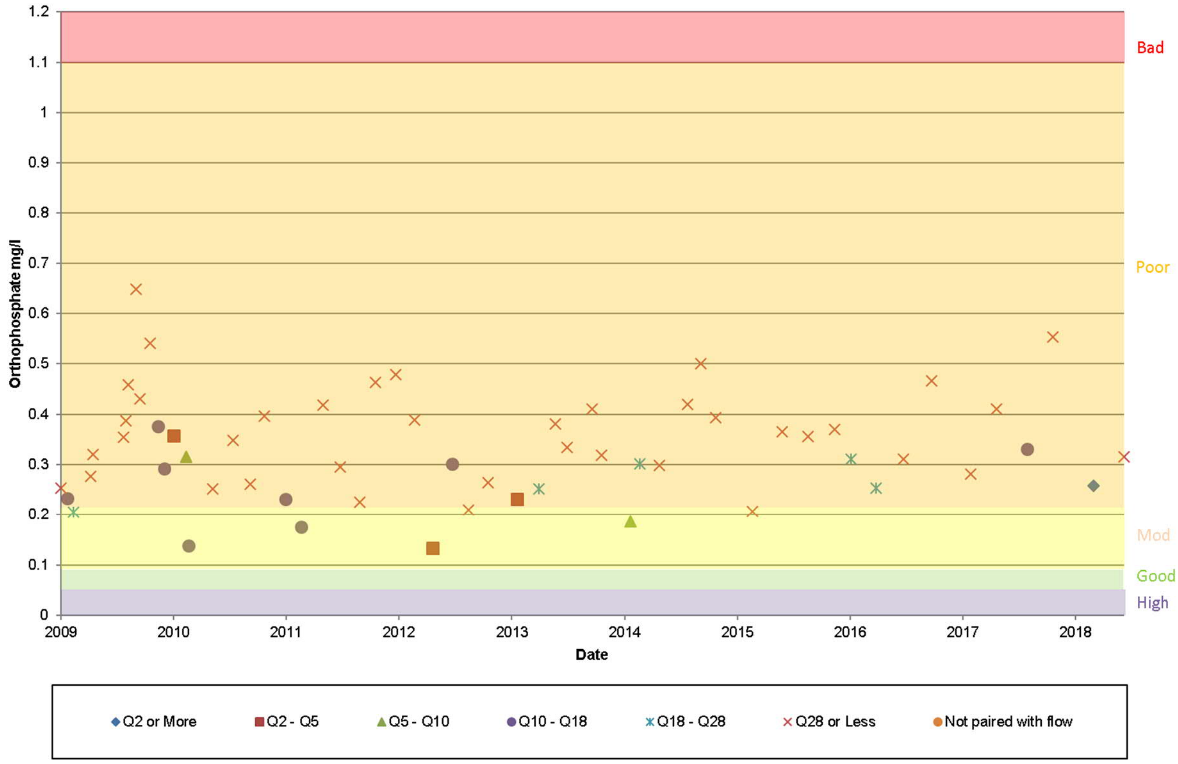


Figure 3.31 Orthophosphate concentrations in the River Ryton at Scrooby (flow band on day of sampling the Ryton at Blythe) 2009 - 2019

3.6.3.3 Old Coates Dyke at Blythe Old Bridge

The site lies in the lower stretch of Old Coates Dyke, close upstream of its confluence with the River Ryton. Flow gauge Old Coates Dyke at Blythe located roughly 1.2km upstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.32 to 3.34 respectively, below.

Figure 3.32 indicates that dissolved oxygen levels are generally equivalent to High WFD status concentrations under varied flow conditions, suggesting abstractions at high flow would have a limited effect.

Total ammonia levels (Figure 3.33) are also generally equivalent to High status with a few equivalent to Good status. Two values were equivalent to Good status and are associated with higher flows. These are likely due to an intermittent event/ diffuse pollution (with most high flows being associated with High status) being captured. Abstraction at times of high flows would likely have a neutral effect on ammonia levels.

Orthophosphate concentrations (Figure 3.34) at the site are generally equivalent to less than Good status. The early 2013 sample, when flow was between the Q10 and Q18 and ammonia levels were elevated also is associated with a lower orthophosphate (indicating the latter was diluted by a runoff event). A reduction in flow could hence result in higher orthophosphate concentrations downstream of an abstraction (noting that levels are less than Good status).

Figure 3.32 Dissolved oxygen (% saturation) in the Old Coates Dyke at Blyth (flow band on day of sampling from Old Coates Dyke at Blyth – 1.2km upstream) 2009 - 2019

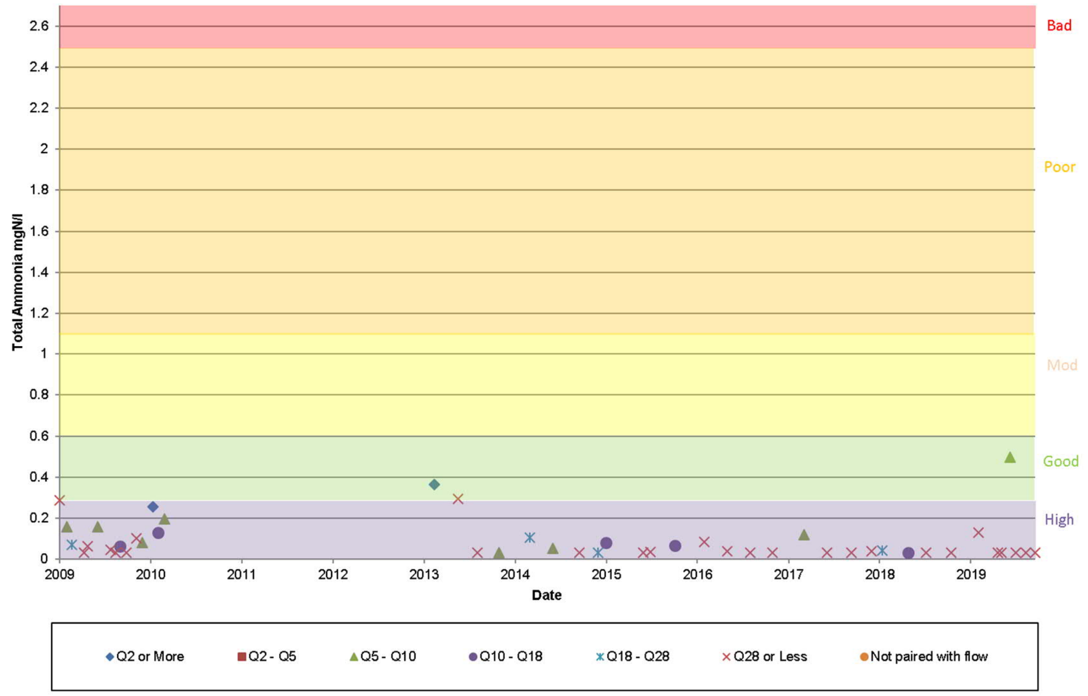


Figure 3.33 Total ammonia concentrations in the Old Coates Dyke at Blyth (flow band on day of sampling from Old Coates Dyke at Blyth – 1.2km upstream) 2009 - 2019

Figure 3.34 Orthophosphate concentrations in the Old Coates Dyke at Blyth (flow band on day of sampling from Old Coates Dyke at Blyth – 1.2km upstream) 2009 - 2019

3.6.3.4 River Poulter at Elkesley (downstream site)

The site lies in the lower stretch of the River Poulter, close upstream of where it joins the River Idle. Flow gauge Poulter at Twyford Bridge located roughly 100m downstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.35 to 3.37 respectively, below.

Figure 3.35 indicates that dissolved oxygen levels are generally equivalent to High WFD status concentrations though levels equivalent to Good status have been observed. An intermittent event was seemingly captured in early 2014 with dissolved oxygen levels dropping and ammonia levels increasing. This suggests the dissolved oxygen may be sensitive to a reduction in flow if abstractions at times of high flow were to occur (upstream of this site).

All total ammonia level measurements (Figure 3.36) are equivalent to High status levels also. This suggests that abstractions at high flows would have no discernible effect.

Orthophosphate concentrations (Figure 3.37) at the site are generally equivalent to less than Good status. As with dissolved oxygen a reduced flow would reduce dilution which may increase orthophosphate concentrations.

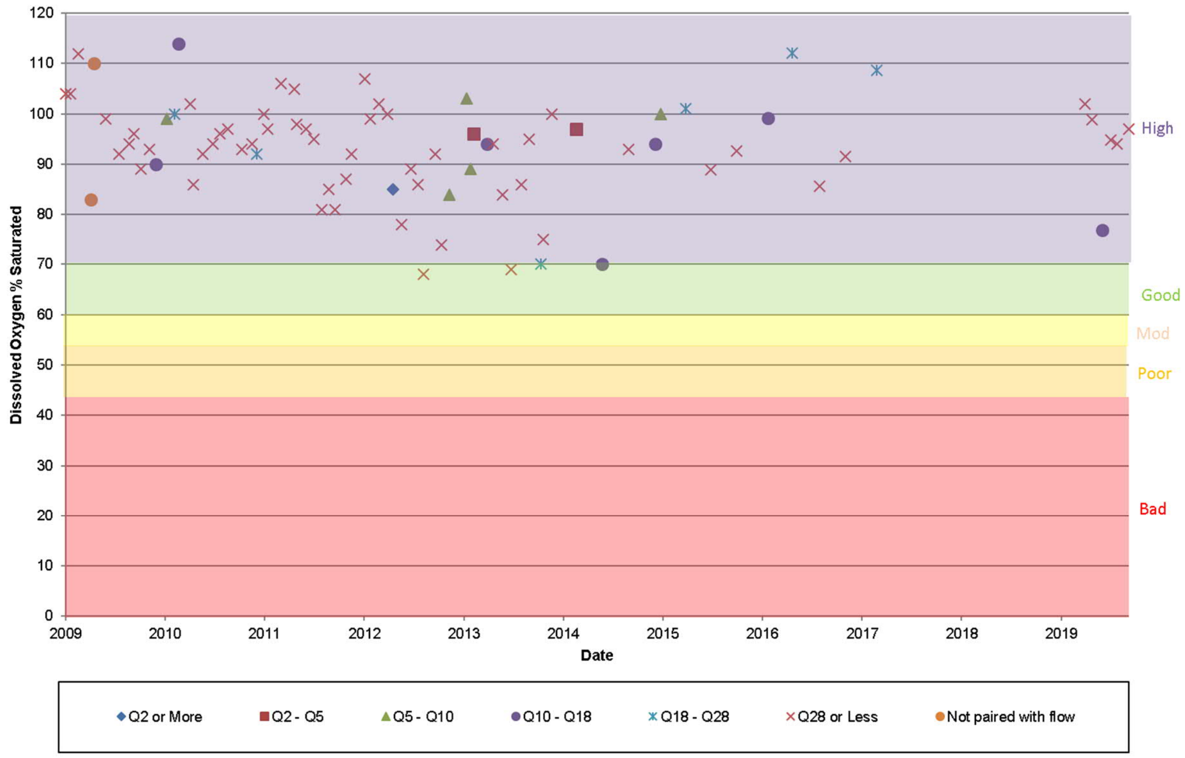


Figure 3.35 Dissolved oxygen (% saturation) in the River Poulter at Elkesley (downstream site) (flow band on day of sampling from the same location) 2009 - 2019

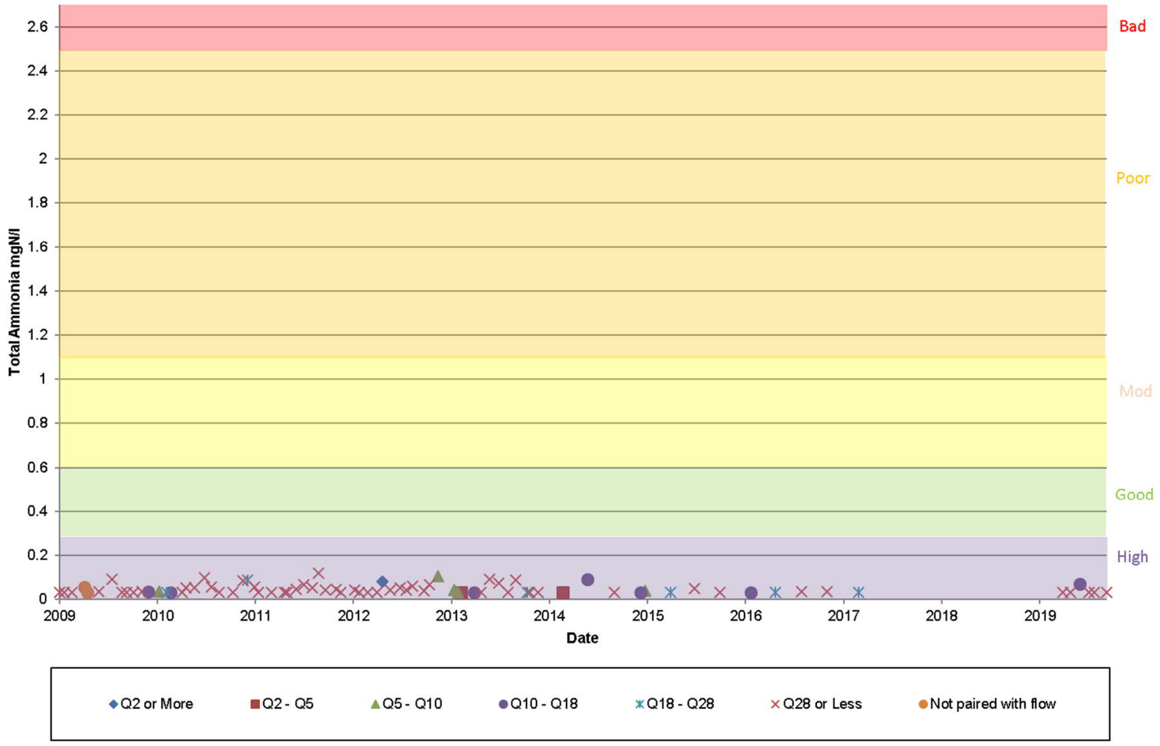


Figure 3.36 Total ammonia concentrations in the River Poulter at Elkesley (downstream site) (flow band on day of sampling from the same location) 2009 – 2019

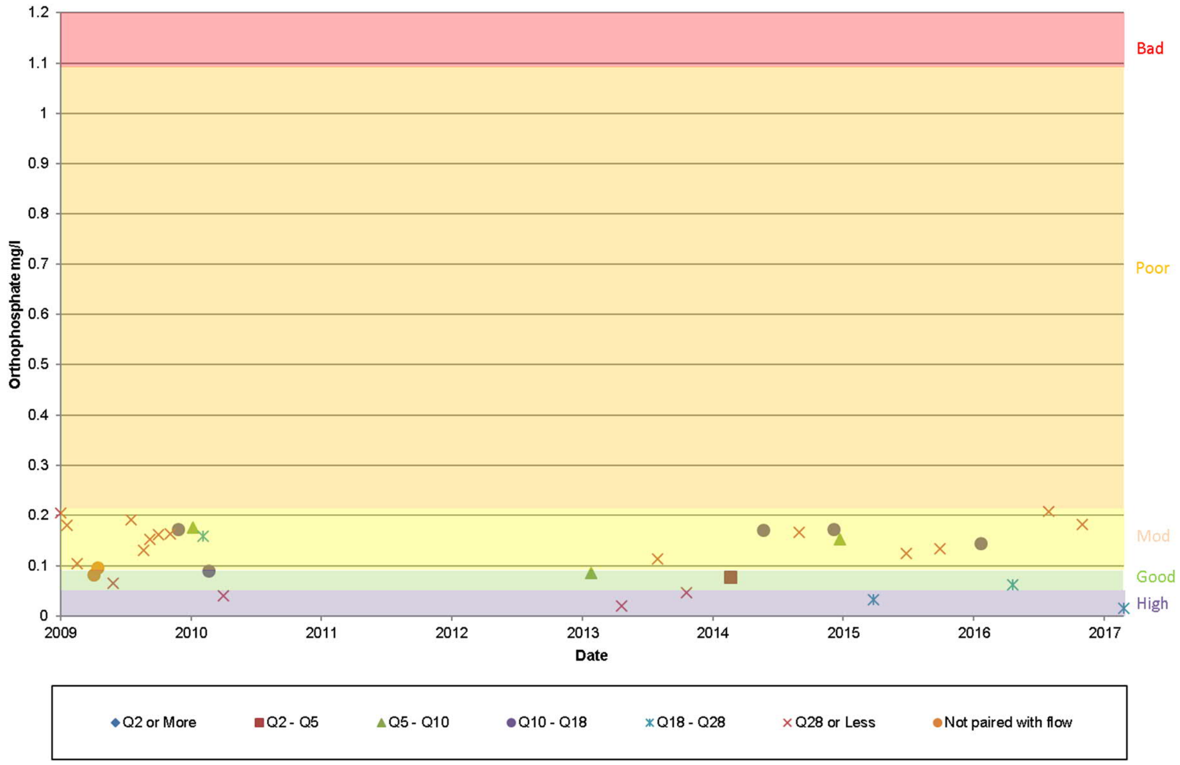


Figure 3.37 Orthophosphate concentrations in the River Poulter at Elkesley (downstream site) (flow band on day of sampling from the same location) 2009 - 2019

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3.6.3.5 River Poulter at Cuckney (upstream site)

The site lies in the upper reach of the River Poulter (located in the upper section at roughly 53.5mAOD of the overall Idle catchment). Flow gauge Poulter at Cuckney located roughly 1.3km downstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.38 to 3.40 respectively, below.

Figure 3.38 indicates that dissolved oxygen levels are generally equivalent to High WFD status and risk to these with high flow abstractions is considered to be negligible.

Total ammonia levels (Figure 3.39) are also generally equivalent to High status levels also. A few events were equivalent to Good status though these were at less than the Q_{28}/ flows not impacted by abstractions at high flows. Hence abstractions at high flows unlikely to have a notable effect on total ammonia levels.

Orthophosphate concentrations (Figure 3.40) at the site are generally equivalent to at least Good status though higher concentrations tend to occur at times of higher flow. Fitting a seasonal model to the orthophosphate data shows there is a trend for higher concentrations in the winter months. This suggests the inputs are coming from runoff which explains the higher concentrations at high flows. Abstracting at high flows may therefore exacerbate this.

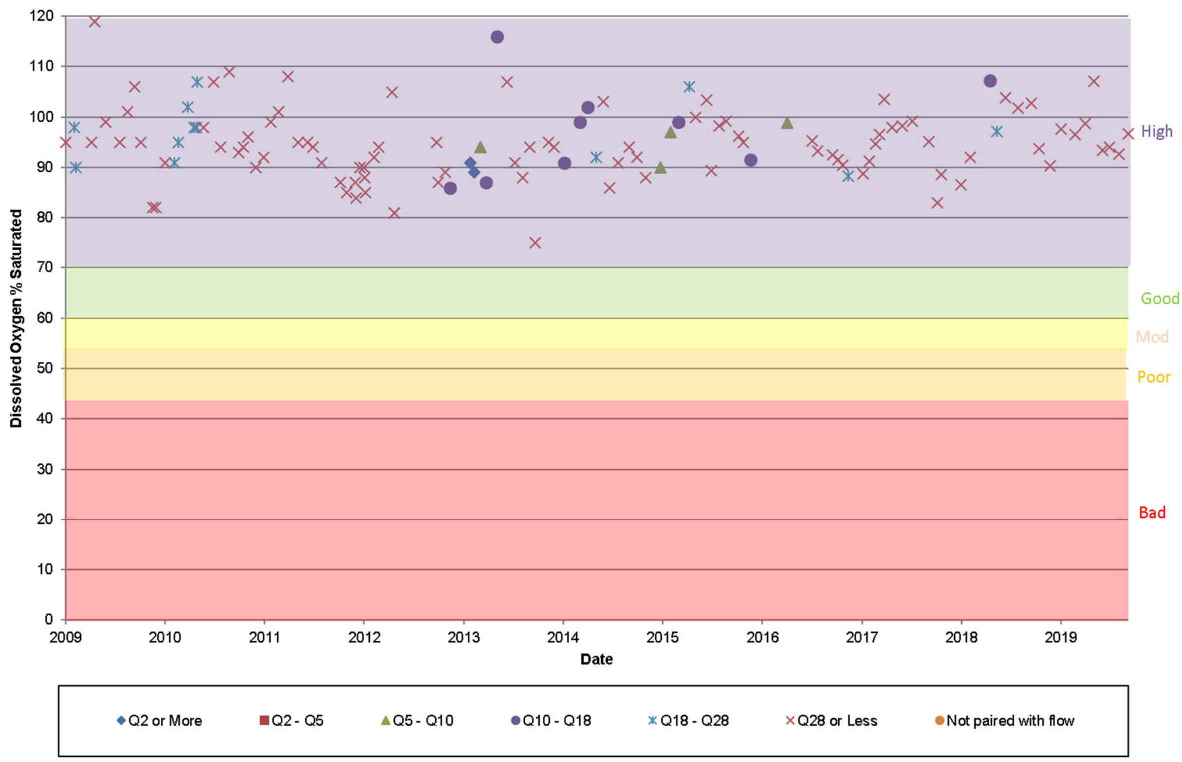

Figure 3.38 Dissolved oxygen (% saturation) in the River Poulter at Cuckney (upstream site) (flow band on day of sampling from the Poulter at Cuckney) 2009 - 2019

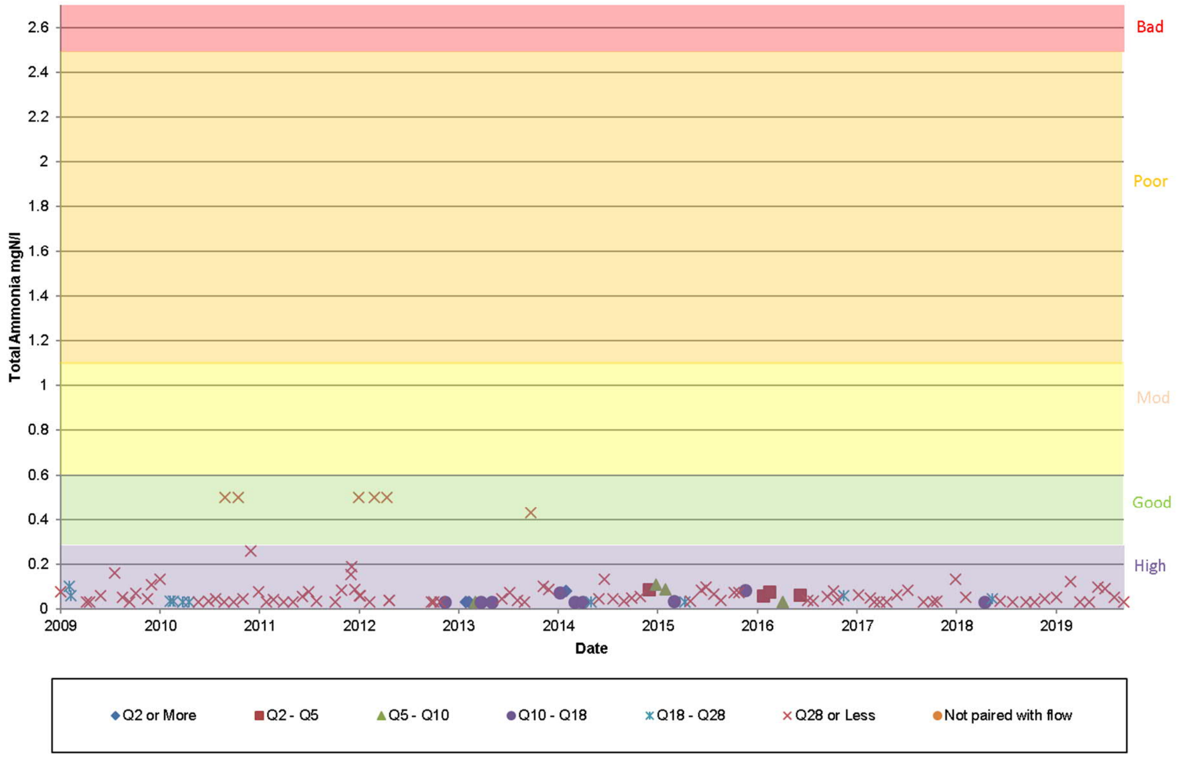

Figure 3.39 Total ammonia concentrations in the River Poulter at Cuckney (upstream site) (flow band on day of sampling from the Poulter at Cuckney) 2009 – 2019

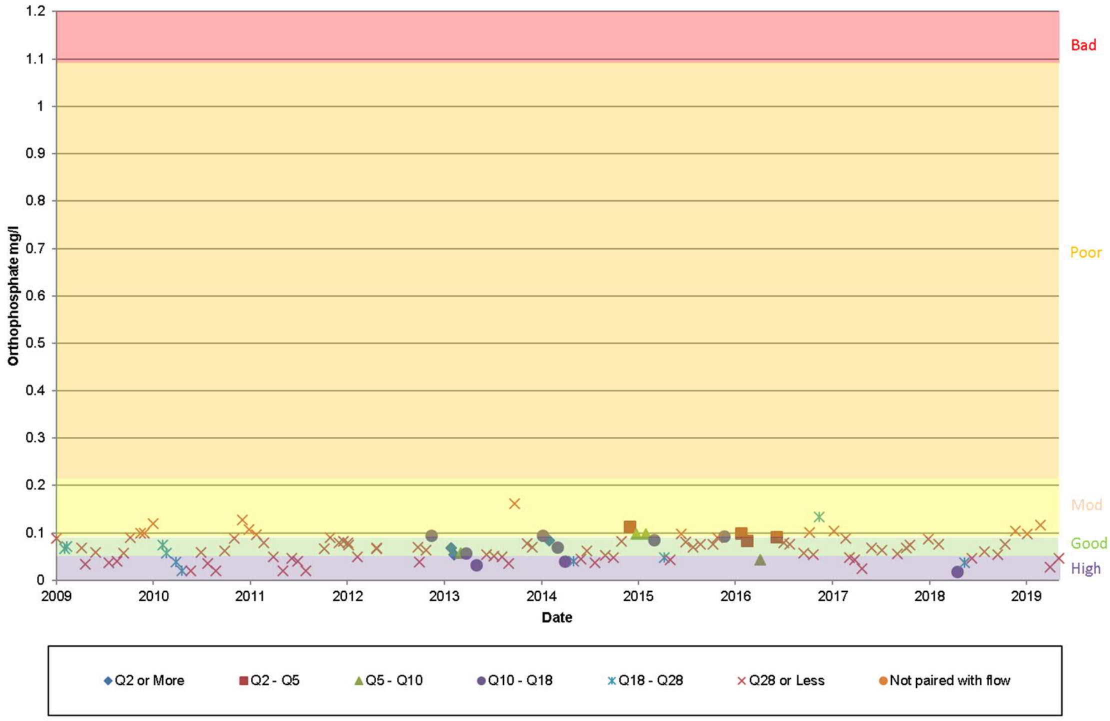

Figure 3.40 Orthophosphate concentrations in the River Poulter at Cuckney (upstream site) (flow band on day of sampling from the Poulter at Cuckney) 2009 - 2019

3.6.3.6 River Meden at Thoresby (downstream site)

The site lies in the lower stretch of the River Meden, close upstream of where it joins the River Maun. Flow gauge Meden at Perlethorpe located roughly 180m upstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.41 to 3.43 respectively, below.

Figure 3.41 indicates that dissolved oxygen levels are generally equivalent to High WFD status and risk to these with high flow abstractions is considered to be negligible.

All total ammonia level measurements (Figure 3.42) are generally equivalent to High status levels also. Two measurements at less than High (Good) were at times of high flow. These are likely due to an intermittent event/ diffuse pollution being captured. Abstraction at times of high flows would likely have a neutral effect on ammonia levels.

Orthophosphate concentrations (Figure 3.43) at the site are often equivalent to less than Good status. Results at various flow levels are mixed suggesting that the effect of abstractions at high flows would likely be neutral though.

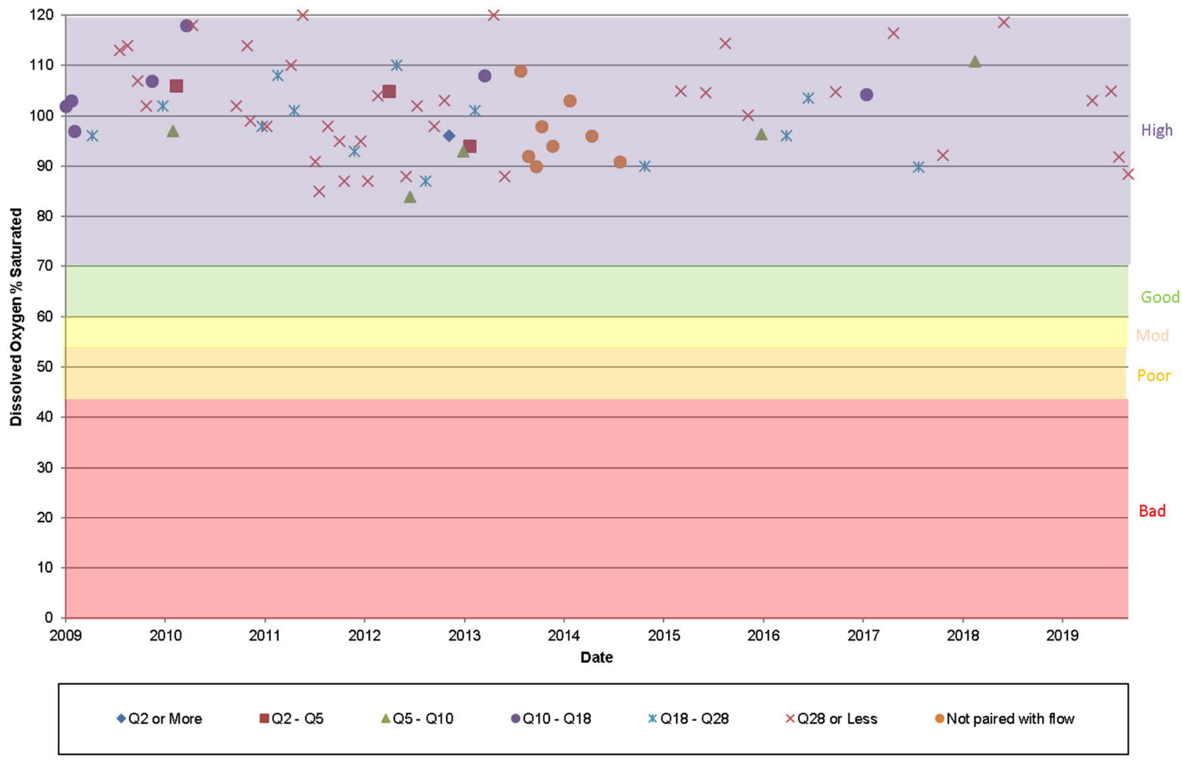

Figure 3.41 Dissolved oxygen (% saturation) in the River Meden at Thoresby (downstream site) (flow band on day of sampling from the Meden at Perlethorpe) 2009 - 2019

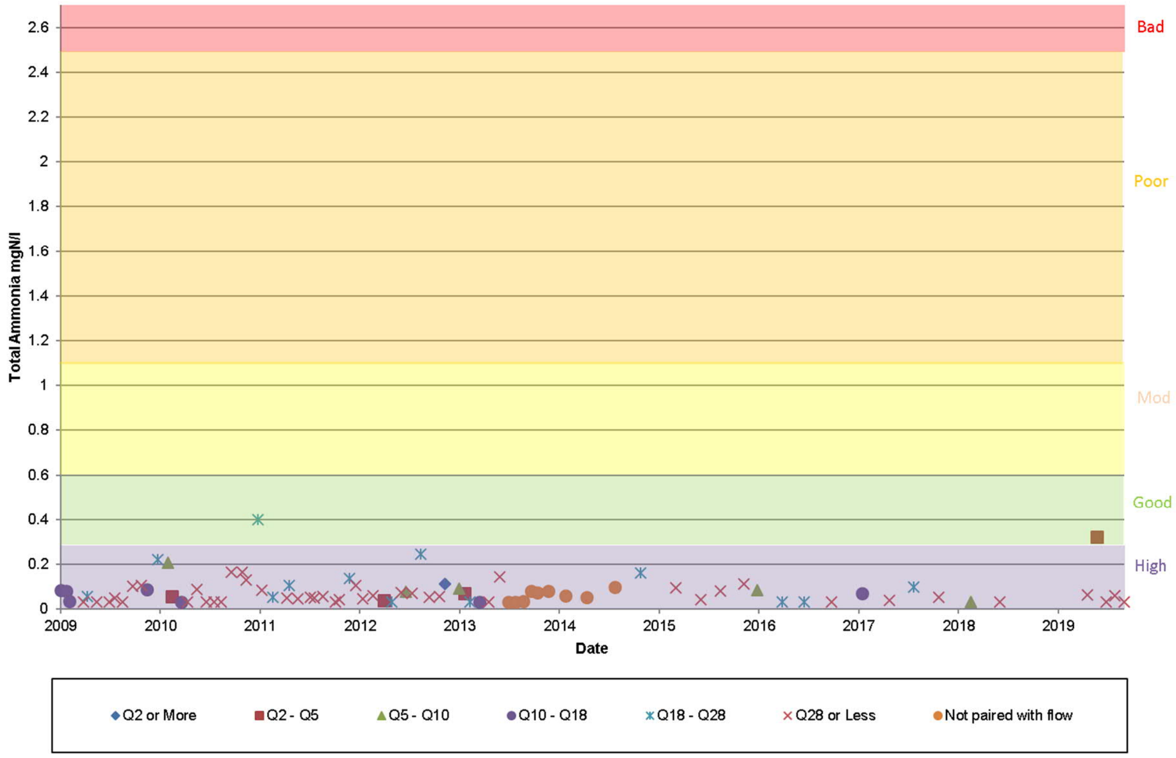

Figure 3.42 Total ammonia concentrations in the River Meden at Thoresby (downstream site) (flow band on day of sampling from the Meden at Perlethorpe) 2009 – 2019

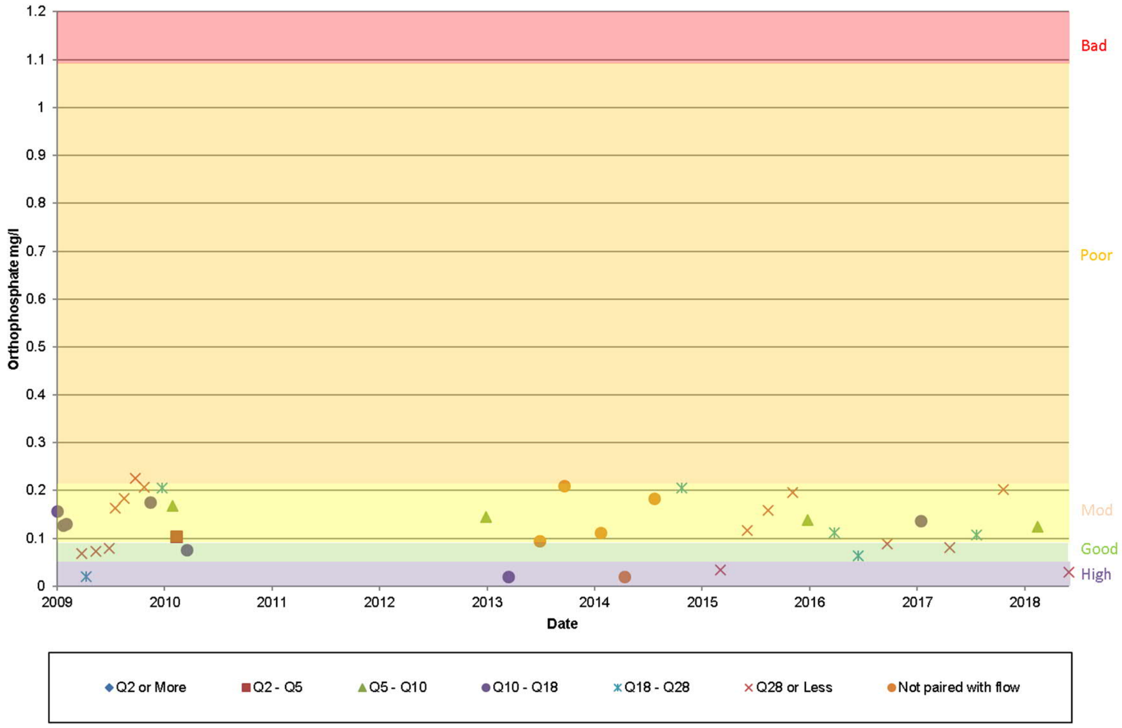

Figure 3.43 Orthophosphate concentrations in the River Meden at Thoresby (downstream site) (flow band on day of sampling from the Meden at Perlethorpe) 2009 - 2019

3.6.3.7 River Meden at Warsop Mill (upstream site)

The site lies in the middle length of the River Meden, and in the upland part at roughly 50.1mAOD of the River Idle catchment.

Flow gauge Meden at Church Warsop located roughly 1.3km upstream of the water quality site was used for this analysis. Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.44to 3.46 respectively, below.

Figure 3.44 indicates that dissolved oxygen levels are generally equivalent to High WFD status and risk to these with high flow abstractions is considered to be negligible.

All total ammonia level measurements (Figure 3.45) are equivalent to High status levels also. This suggests that abstractions at high flows would have no discernible effect.

Half of the indicated orthophosphate concentrations (Figure 3.46) at the site are generally equivalent to less than Good status/ while the other half are equivalent to at least Good. Results at various flow levels are mixed suggesting that the effect of abstractions at high flows may be neutral / potentially marginally adverse.

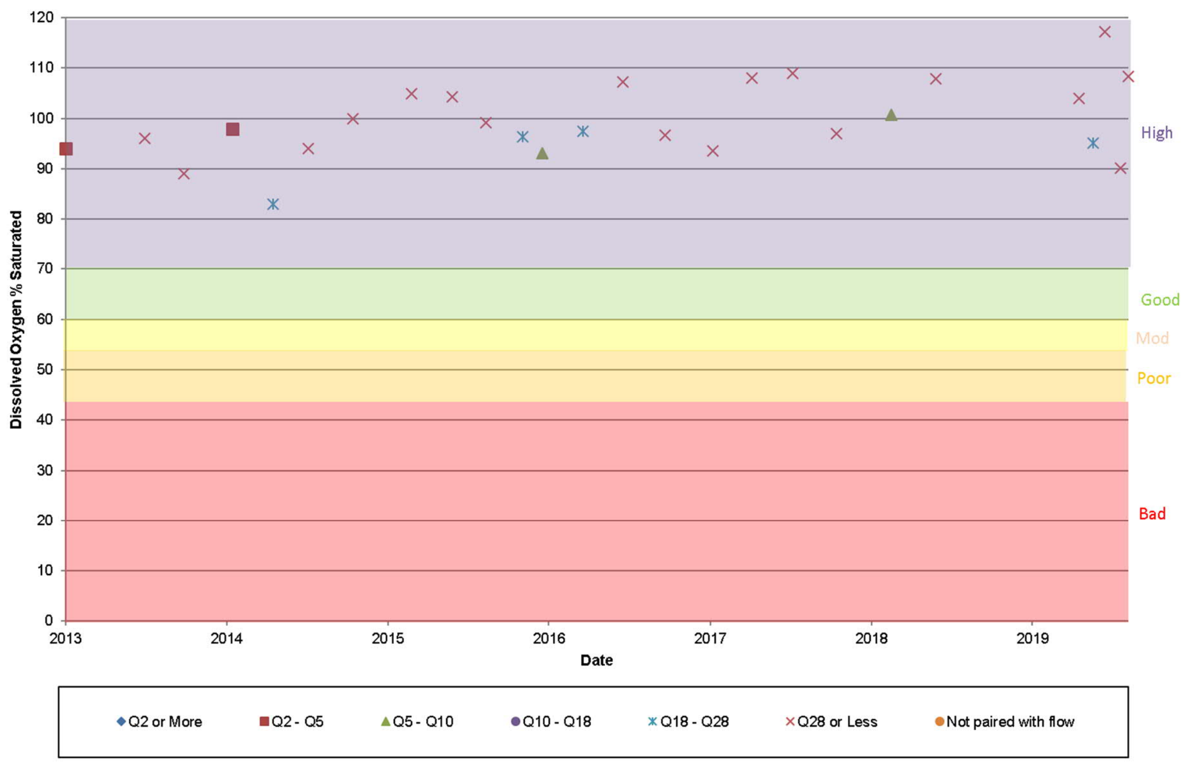

Figure 3.44 Dissolved oxygen (% saturation) in the River Meden at Warsop Mill (upstream site) (flow band on day of sampling from the Meden at Church Warsop) 2009 - 2019

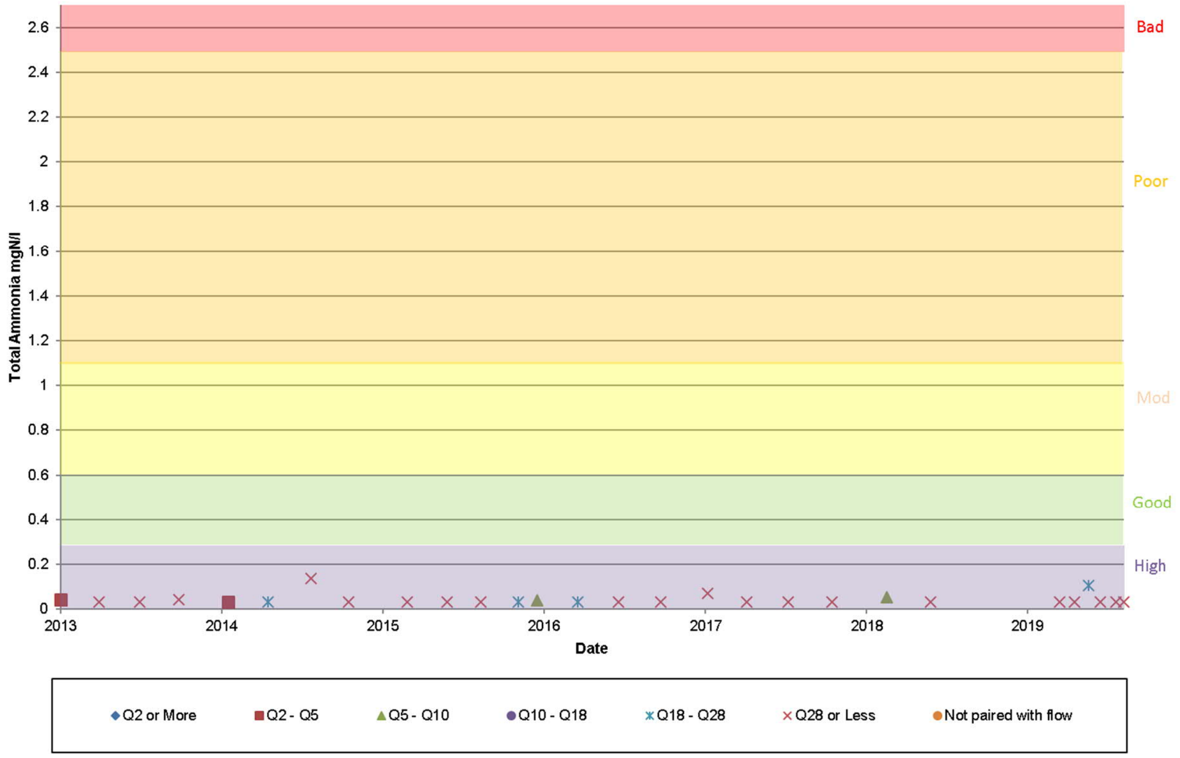

Figure 3.45 Total ammonia concentrations in the River Meden at Warsop Mill (upstream site) (flow band on day of sampling from the Meden at Church Warsop) 2009 – 2019

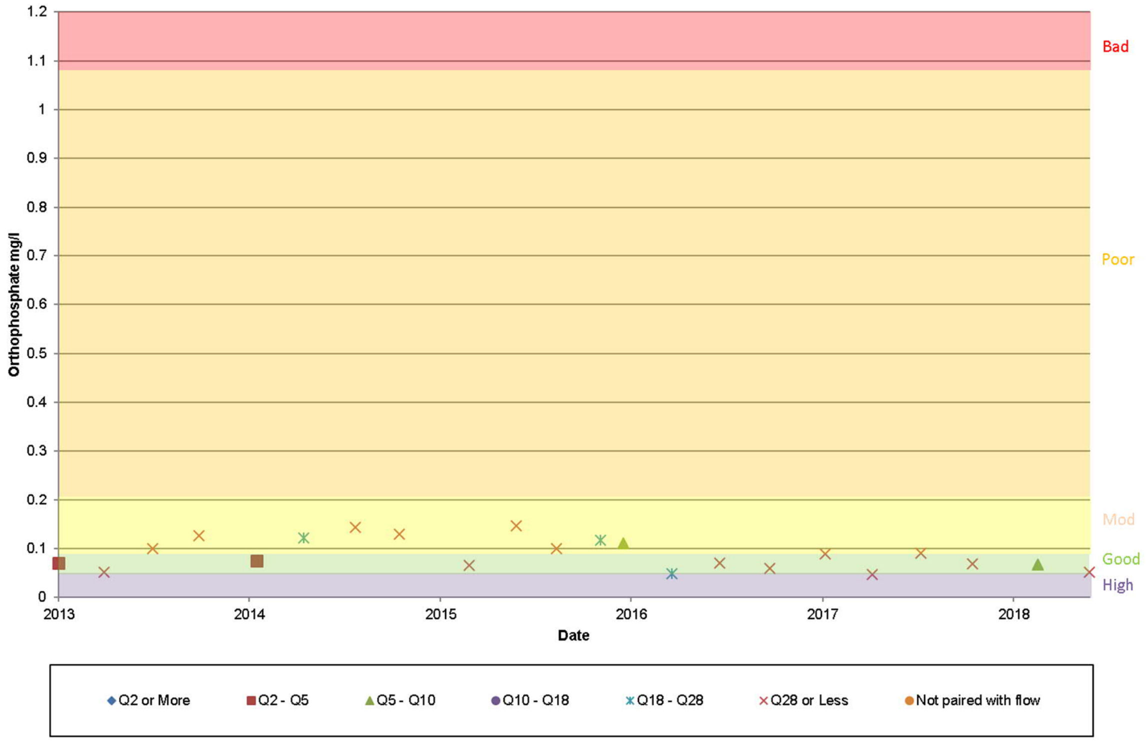

Figure 3.46 Orthophosphate concentrations in the River Meden at Warsop Mill (upstream site) (flow band on day of sampling from the Meden at Church Warsop) 2009 - 2019

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3.6.3.8 River Maun at Whitewater (downstream site)

The site lies in the middle stretch of the River Maun, close upstream of where it is joined by the River Meden. Flow gauge Maun at Whitewater Bridge located roughly 150m downstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.47 to 3.49 respectively, below.

Figure 3.47 indicates that dissolved oxygen levels are equivalent to High WFD status and risk to these with high flow abstractions is considered to be negligible.

Most total ammonia level measurements (Figure 3.48) are generally equivalent to High status levels also. One measurements at less at a Moderate level was observed at a time of high flow and is potentially linked with an intermittent event being captured. Abstraction at times of high flow would likely not increase concentrations (as water of same concentration would be abstracted).

Orthophosphate concentrations (Figure 3.49) at the site are each equivalent to less than Good status. Results at various flow levels are mixed though concentrations reduce with potential intermittent pollution events (runoff related). Abstractions at high flows would reduce the dilution of orthophosphate.

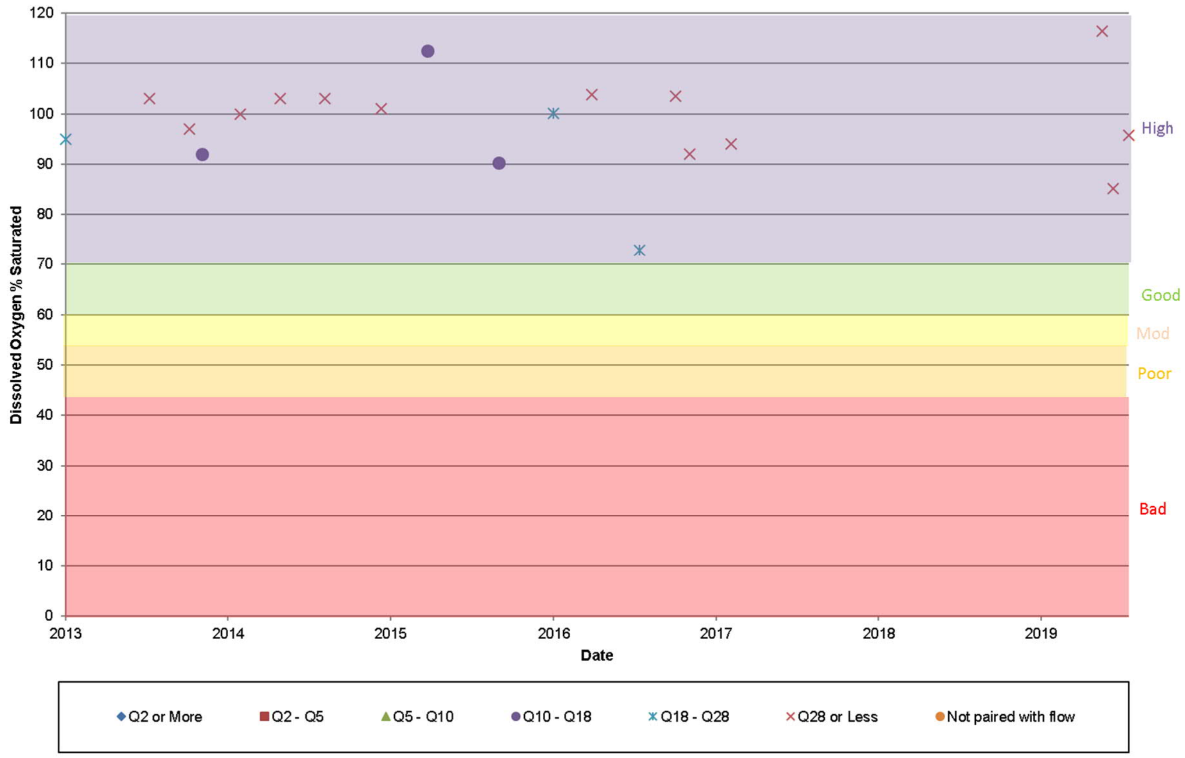

Figure 3.47 Dissolved oxygen (% saturation) in the River Maun at Whitewater (downstream site) (flow band on day of sampling from the same location) 2009 - 2019

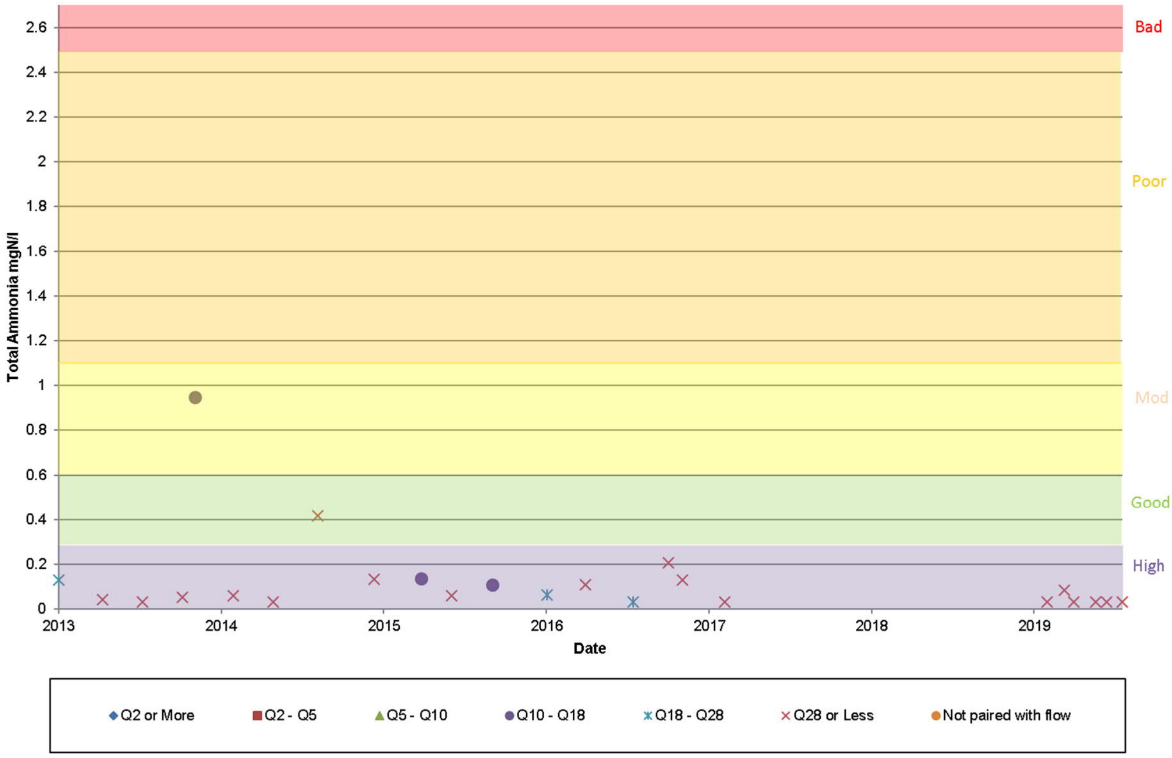

Figure 3.48 Total ammonia concentrations in the River Maun at Whitewater (downstream site) (flow band on day of sampling from the same location) 2009 – 2019

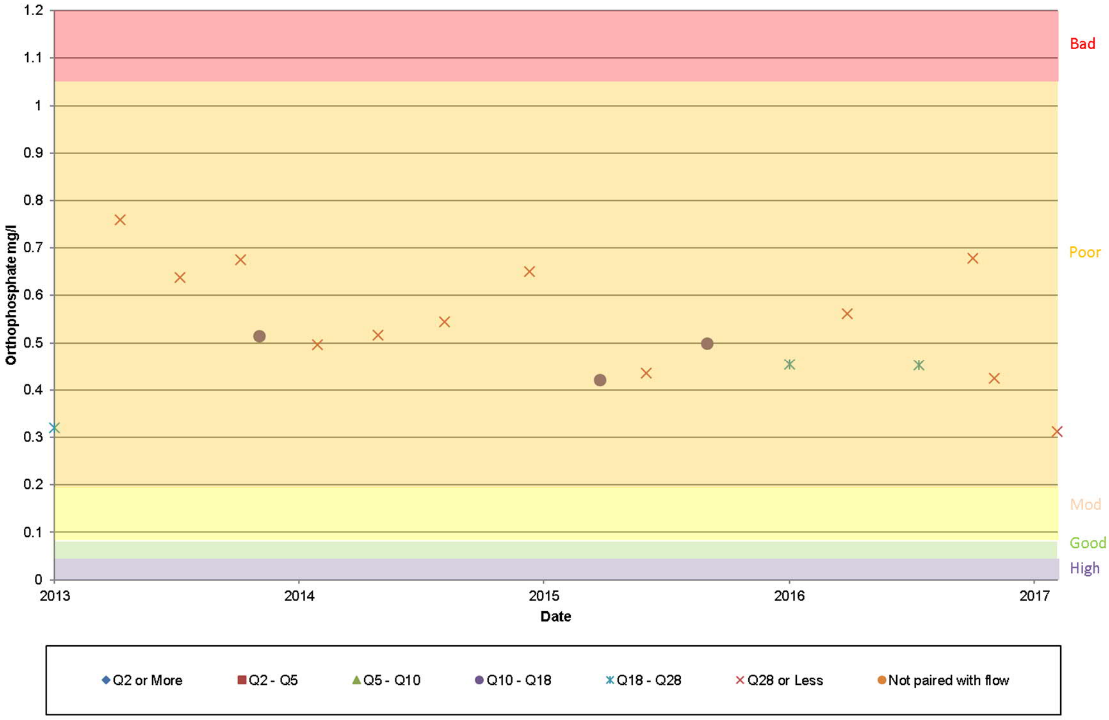

Figure 3.49 Orthophosphate concentrations in the River Maun at Whitewater (downstream site) (flow band on day of sampling from the same location) 2009 - 2019

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3.6.3.9 River Maun at Whinney Hill (upstream site)

The site lies in the upper reach of the River Maun (located in the upper section at roughly 71.6mAOD of the overall Idle catchment). Flow gauge Maun at Mansfield the Dykes located roughly 750m downstream of the water quality site was used for this analysis.

Dissolved oxygen, total ammonia, orthophosphate and suspended sediments in at this site (see Figure 3.22) are indicated in Figures 3.50 to 3.52 respectively, below.

Figure 3.50 indicates that dissolved oxygen levels are generally equivalent to High WFD status and risk to these with high flow abstractions is considered to be negligible.

All total ammonia level measurements (Figure 3.51) are generally equivalent to at least Good status. Two measurements at less than High (Good) were at times of high flow while another two were at lower flows. The former two appear to be due intermittent diffuse pollution events being captured. Abstraction at times of high flow would likely not increase concentrations (as water of same concentration would be abstracted).

Orthophosphate concentrations (Figure 3.52) at the site were less than Good at all times. Results at various flow levels are mixed although abstractions at high flows would reduce the dilution of orthophosphate.

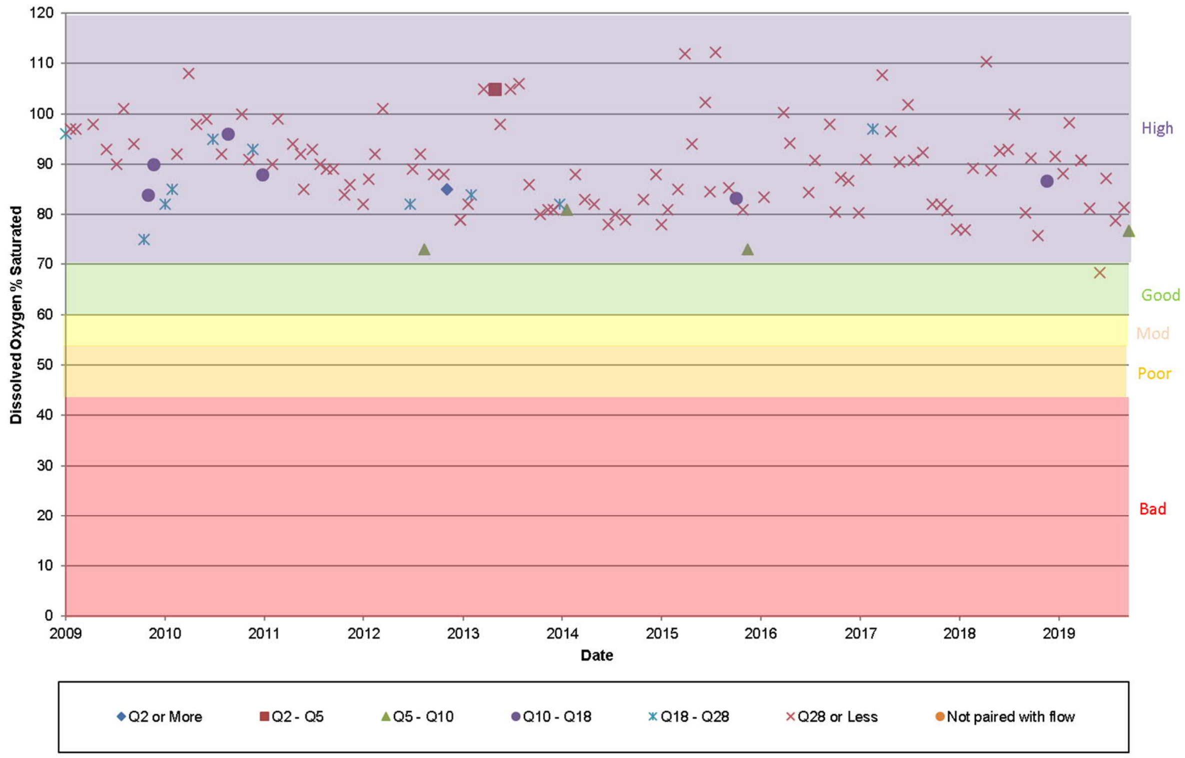

Figure 3.50 Dissolved oxygen (% saturation) in the River Maun at Whinney Hill (upstream site) (flow band on day of sampling from the Maun at Mansfield the Dykes) 2009 - 2019

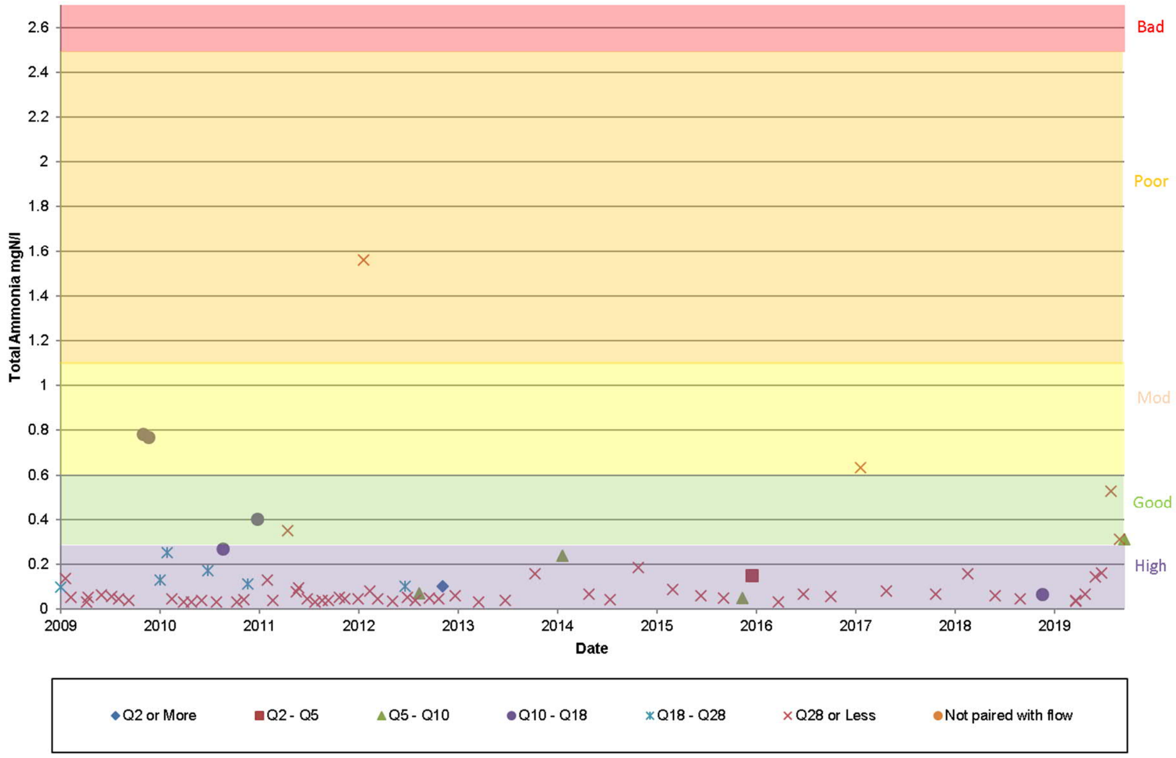

Figure 3.51 Total ammonia concentrations in the River Maun at Whinney Hill (upstream site) (flow band on day of sampling from the Maun at Mansfield the Dykes) 2009 – 2019

Figure 3.52 Orthophosphate concentrations in the River Maun at Whinney Hill (upstream site) (flow band on day of sampling from the Maun at Mansfield the Dykes) 2009 - 2019

3.6.4 Water Framework Directive

The 2016 WFD status for ammonia, phosphate and dissolved oxygen is indicated in Figure 3.53. Dissolved oxygen and ammonia status in waterbodies throughout the Idle is generally at least Good. Dissolved oxygen and ammonia are considered less than Good through much of the Torne, predominantly in the low lying pumped section. Phosphate status is less than Good for much of the Idle and Torne catchments.

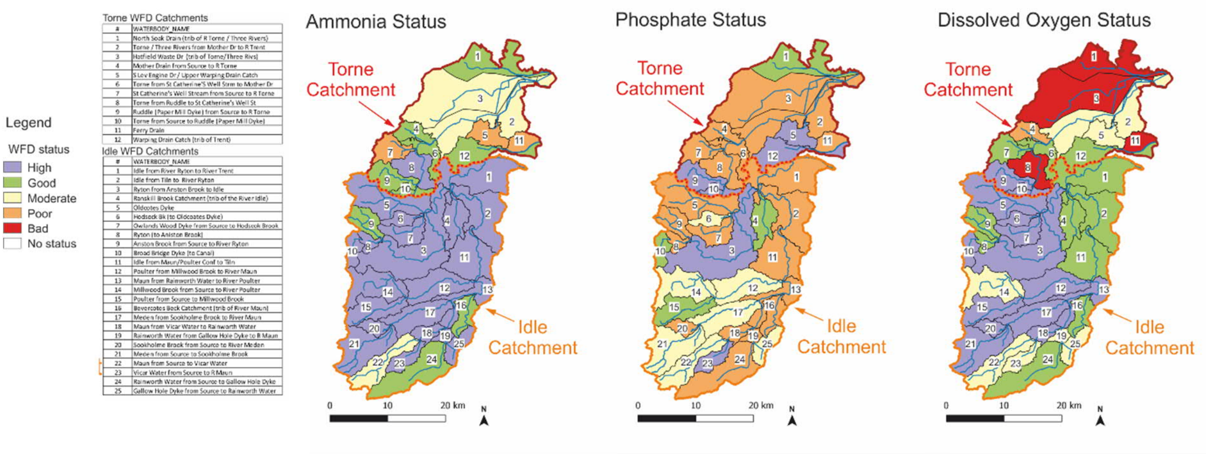

Figure 3.53 WFD waterbodies and physico-chemical status as of 2016 in the Idle and Torne catchments

3.7 Sensitivity Review

3.7.1 Overview and review

A review of the physical environment sensitivity of each WFD waterbody in the Idle and Torne catchments has been undertaken (focussing on the hydromorphology and water quality reviews in particular, see Sections 3.5 and 3.6 respectively). This is presented in Table 3.10 below. The results of the sensitivity review are presented in Figure 3.54.

Table 3.10 Review of Physical Environment Sensitivity

WFD Waterbody	Evidence of extensive in channel works	Predominant substrate	Review of Provided Imagery and RFF reports (- there was no information)	Extent of modification (RHS Review, noting data is limited)	2 year flood overtopping into the floodplain?	Presence of Flood Defences	Water quality Review	Sensitivity Review
Idle waterbodies								
Anston Brook from Source to River Ryton	No	No data, pebbles/ gravel expected to be present	-	Data indicates waterbody is significantly or severely modified.	Not known	No	Less than Good with regard to phosphate	Information indicates waterbody would be of low sensitivity to further abstraction.
Bevercotes Beck Catchment (trib of River Maun)	No	Pebble/ gravels	Information indicates beck is historically managed, straightened, and deepened, so likely to have poor lateral connectivity and that out-of-channel wetland areas are absent or depleted and sensitive to any further hydrological change. Similarly, in-channel fine sediment (and associated pollutant) loads may be excessive due to reduced capacity for floodplain deposition. Homogeneous nature of watercourse reported, resulting in lack of species diversity, Bank erosion in the steeper sections of the beck is reported in the RFF report.	No data	Not known	No	Less than Good with regard to phosphate	Information indicates waterbody would be of low sensitivity to further abstraction.
Broad Bridge Dyke (to Canal)	No	No data, pebbles/ gravel expected to be present	-	Data indicates waterbody is significantly or severely modified.	Not known	No	At least Good	Information indicates waterbody would be of low sensitivity to further abstraction (noting that data is generally lacking).
Gallow Hole Dyke from Source to Rainworth Water	No	Pebble/ gravels	-	No data	Not known	No	Less than Good with regard to phosphate and dissolved oxygen	Information indicates waterbody would be of low sensitivity to further abstraction.
Hodsock Bk (to Oldcoates Dyke)	No	No data, pebbles/ gravel expected to be present	-	Data indicates waterbody is significantly or severely modified.	Not known	No	Less than Good with regard to phosphate	Information indicates waterbody would be of low sensitivity to further abstraction (noting that data is generally lacking).
Idle from Maun/Poulter Conf to Tiln	Yes	Pebble/ gravels	-	No data	Yes	Yes	Less than Good with regard to phosphate	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction
Idle from River Ryton to River Trent	Yes	Silt dominated though pebble/ gravels present	Imagery indicated that the channel appears engineered (realigned and deepened) and embanked, which will have impacts on lateral connectivity and sediment loads. Flows in these images appear to be near bankfull though waterbody is low lying and level dependent (with levels generally controlled within a narrow level envelope). On one image marginal habitats appear inundated that would usually be dry. Some species and assemblages may be dependent on particular inundation regimes (depths and frequencies) which could be affected by high flow abstraction.	Data indicates waterbody is significantly or severely modified.	Yes	Yes	Less than Good with regard to phosphate	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction
Idle from Tiln to River Ryton	No	Silt dominated though pebble/ gravels present	Imagery indicated that the channel appears engineered (realigned and deepened) so existing degraded habitats may be sensitive to new hydrological changes. The Idle at Tiln is very uniform with a well defined baseflow channel and	No data	Yes (but only at downstream end)	Yes	Less than Good with regard to phosphate. Water quality and flow data available and review indicated potential sensitivity at times of high flow with	Information indicates the channel may be of moderate sensitivity to further abstraction

WFD Waterbody	Evidence of extensive in channel works	Predominant substrate	Review of Provided Imagery and RFF reports (- there was no information)	Extent of modification (RHS Review, noting data is limited)	2 year flood overtopping into the floodplain?	Presence of Flood Defences	Water quality Review	Sensitivity Review
			what appear to be managed grass banks (i.e. vegetation cut back to mitigate flood debris and blockage risks). This could mean high flow abstraction has relatively little impact, because there is little diversity of habitats to be affected. The Idle at Chain Bridge appears to have been photographed at low flow (as shown by the exposed bare silt margin) but there is a tier / berm of marginal macrophytes before the banktop / riparian tree line that could be sensitive to high flow abstraction.				regard to dissolved oxygen and orthophosphate.	
Maun from Rainworth Water to River Poulter	Yes	Pebble/ gravels	Imagery showed an engineered channel (realigned and deepened) which would be of reduced sensitivity to new hydrological changes. The Maun at Ollerton is physically very uniform with continuous and single species of macrophyte. This could mean high flow abstraction has relatively little impact, because there is little diversity of habitats to be affected. The Maun at Whitewater is also physically uniform, but at least has some low diversity of species, which appears to be layered according to height above water level.	No data	Not known	Yes	Less than Good with regard to phosphate. Water quality and flow data available and review indicated potential sensitivity at times of high flow with regard to orthophosphate.	Information indicates the channel may be of moderate sensitivity to further abstraction
Maun from Source to Vicar Water	No	No data, pebbles/ gravel expected to be present	-	Data indicates waterbody is obviously modified.	Not known	Yes	Less than Good with regard to phosphate and dissolved oxygen. Water quality and flow data available and review indicated potential sensitivity at times of high flow with regard to orthophosphate.	Data generally lacking to ascertain potential sensitivity
Maun from Vicar Water to Rainworth Water	No	No data, pebbles/ gravel expected to be present	-	Data indicates waterbody is obviously modified.	Not known	Yes	Less than Good with regard to phosphate. Water quality and flow data available (upstream and downstream waterbodies) and review indicated potential sensitivity at times of high flow with regard to orthophosphate.	Data generally lacking to ascertain potential sensitivity
Meden from Sookholme Brook to River Maun	No	Pebble/ gravels	Imagery of the Meden indicates that it looks to be high value habitat and much less impacted by historic management than other rivers in the catchment so it could be more sensitive to deterioration. Surface bed gravels were apparent, so bed habitats may be vulnerable to reduced fine sediment transport (less flushing / increased deposition) if high flows are abstracted. One site appeared physically very uniform with managed vegetation above bank side macrophytes opposite concrete and little diversity of habitats.	No data	Not known	Yes	Less than Good with regard to phosphate. Review with flow data indicated shouldn't be too sensitive to reductions in high flows.	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction
Meden from Source to Sookholme Brook	No	Pebble/ gravels	Imagery indicates that Meden from source to Sookholme brook has a diverse range of habitats including engineered reaches and what appear to	RHS information for three sites indicated pristine channel at one	Not known	Yes	Less than Good with regard to phosphate. Review with flow data	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction

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WFD Waterbody	Evidence of extensive in channel works	Predominant substrate	Review of Provided Imagery and RFF reports (- there was no information)	Extent of modification (RHS Review, noting data is limited)	2 year flood overtopping into the floodplain?	Presence of Flood Defences	Water quality Review	Sensitivity Review
			be natural and high quality habitats. Modified reaches such as at Pleasley and Newbound Mill and where there are culverts and concrete banks are generally uniform so high flow abstraction would have little impact. More natural reaches, with a diverse range of habitats, are also apparent and may be more sensitive to changes in peak flows, with marginal or riparian habitats likely to have some dependency on an inundation regime.	and semi-natural/ predominantly unmodified at the other two			indicated would probably not be sensitive to reductions in high flows.	
Millwood Brook from Source to River Poulter	No	No data, pebbles/ gravel expected to be present	-	No data	Not known	No	Less than Good with regard to phosphate and dissolved oxygen	Data generally lacking to ascertain potential sensitivity
Oldcotes Dyke	No	No data, pebbles/ gravel expected to be present	Hooton Dyke upstream to Riddings Close appears to have a well connected floodplain and wetlands, so high flow abstraction could be detrimental to water dependent habitats outside of the channel. Elsewhere, high silt loads may be associated with waste water discharges and other adjacent land uses, and a reduction in peak flows is likely to mean less flushing of pollutants, higher pollution retention time, and less pollutant dilution. Maltby Dyke and Oldcotes Dyke look to be diverse, high value habitats where channel – floodplain – wetland connections will serve important functions. High flow abstractions could be detrimental to both in-channel and out of channel habitats. Oldcotes Dyke at Blythe Old Bridge appears to be overdeep due to historic realignment, so may already have poor lateral connectivity that could be exacerbated by peak flow reductions.	RHS monitoring of one site on Maltby Dyke (upland location) indicated a semi-natural or predominantly unmodified channel	Not known	Yes	Less than Good with regard to phosphate (review with available flow data indicated this may worsen)	Information indicates the channel may be of moderate sensitivity to further abstraction
Owlands Wood Dyke from Source to Hodsock Brook	No	Pebble/ gravels	Owlands Wood Dyke is an incised channel that appears to have been historically straightened, but has a range of in-channel flow habitats at baseflow, which high flow abstraction should not impact to a large extent.	No data	Not known	Yes	Less than Good with regard to phosphate	Information indicates the channel may be of low to moderate sensitivity to further abstraction (noting data is lacking)
Poulter from Millwood Brook to River Maun	No	No data, pebbles/ gravel expected to be present	Imagery provided indicated a shallow channel, which suggests good floodplain connectivity. High flow abstraction may negatively affect out-of-channel habitat inundation.	Data indicates waterbody is obviously modified.	Not known	Yes	Less than Good with regard to phosphate. Water quality and flow data available and review indicated potential sensitivity at times of high flow with regard to dissolved oxygen and orthophosphate.	Information indicates the channel may be of moderate sensitivity to further abstraction (noting data is lacking)
Poulter from Source to Millwood Brook	No	Pebble/ gravels	The Poulter from source to Millwood Brook appears mainly natural and high quality habitat, with a diverse range of aquatic, marginal and riparian species that will have developed according to the existing flow regime.	Data indicates waterbody is significantly or severely modified.	Not known	No	At least Good. Water quality and flow data available and review indicated potential sensitivity at times of high flow with regard to orthophosphate.	Available information indicates waterbody (or parts of it) may be highly sensitive to effects of high flow abstraction
Rainworth Water from Gallow Hole Dyke to R Maun	No	Silt	Uniform reaches are unlikely to be significantly affected by high flow abstraction, but marginal	No data	Not known	No	Less than Good with regard to phosphate and dissolved oxygen	Information indicates waterbody would be of low sensitivity to further abstraction.

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WFD Waterbody	Evidence of extensive in channel works	Predominant substrate	Review of Provided Imagery and RFF reports (- there was no information)	Extent of modification (RHS Review, noting data is limited)	2 year flood overtopping into the floodplain?	Presence of Flood Defences	Water quality Review	Sensitivity Review
			vegetation could be negatively affected by decreased peak flows.					
Rainworth Water from Source to Gallow Hole Dyke	No	Pebble/ gravels	Uniform reaches are unlikely to be significantly affected by high flow abstraction, but marginal vegetation diversity could depend on the existing flow depth and inundation regime, and so could be negatively affected by decreased peak flows.	No data	Not known	No	Less than Good with regard to phosphate	Information indicates the channel may be of low to moderate sensitivity to further abstraction
Ranskill Brook Catchment (trib of the River Idle)	No	Silt/ clay but pebbles/ gravel present	Single image indicated potential for strong lateral connectivity, which could be depleted by high flow abstraction.	Data indicates waterbody is significantly or severely modified.	Not known	No	At least Good	Information indicates the channel may be of low to moderate sensitivity to further abstraction (noting data is contrasting and perhaps reflects different areas)
Ryton (to Anston Brook)	No	Pebble/ gravels	-	No data	Not known	Yes	Less than Good with regard to phosphate	Data generally lacking to ascertain potential sensitivity
Ryton from Anston Brook to Idle	Yes	No data, pebbles/ gravel expected to be present	-	RHS information for one site indicated pristine channel	Not known	No	At least Good. Water quality and flow data available and review indicated potential sensitivity at times of high flow with regard to dissolved oxygen and orthophosphate.	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction
Sookholme Brook from Source to River Meden	No	Pebble/ gravels	WFD investigations indicate a failure for fish in the upper Meden catchment with the reason for failure being associated with morphology (barriers) and sedimentation (from agricultural diffuse sources) however 'other' pressures, such as water quality are considered as likely to be contributing to the failure.	No data	Not known	No	Less than Good with regard to phosphate	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction (noting information is generally lacking in this reach)
Vicar Water from Source to R Maun	No	No data, pebbles/ gravel expected to be present	-	No data	Not known	No	Less than Good with regard to dissolved oxygen	Data generally lacking to ascertain potential sensitivity
Torne waterbodies								
Ferry Drain	No but considered likely	Silt	-	No data	Not known	No (though due to demaining/ still present but IDB maintained?)	Less than good	Information indicates waterbody would be of low sensitivity to further abstraction.
Hatfield Waste Dr (trib of Torne/Three Rivs)	No but considered likely	Silt	Hatfield Waste Drain is a Heavily Modified Waterbody that has been channelised, re-sectioned and straightented. Gradient is shallow at 1-2m necessitating pumping at Brick Hill Carr and Goodcop to drain the upper section of the system. The lower section empties into the Three Rivers complex and then into the tidal River Trent downstream of Keadby pumping station. Realigned and pumped systems tend to have siltation problems due to the lack of gradient and flow velocities. High flow abstraction could exacerbate this because sediment could be delivered into the channel by rainfall runoff, but then	Data indicates waterbody is severely modified.	Yes (downstream end mainly)	Yes	Less than good	Available information indicates waterbody may be moderately sensitive to effects of high flow abstraction (with regard to floodplain inundation)

WFD Waterbody	Evidence of extensive in channel works	Predominant substrate	Review of Provided Imagery and RFF reports (- there was no information)	Extent of modification (RHS Review, noting data is limited)	2 year flood overtopping into the floodplain?	Presence of Flood Defences	Water quality Review	Sensitivity Review
			flow abstraction further downstream could reduce the stream's capacity to transport sediment or deposit it to floodplains.					
Mother Drain from Source to R Torne	Not known	Pebbles/ gravel	Ecological review indicates species present are adapted to heavy sedimentation, suggesting of conditions in the river.-	No data	Not known	No	Less than good with regard to dissolved oxygen and phosphate	Information indicates the channel may be of low to moderate sensitivity to further abstraction
North Soak Drain (trib of R Torne / Three Rivers)	No but considered likely	No data, silt expected	-	No data	Yes	Yes	Less than good with regard to dissolved oxygen	Available information indicates waterbody may be moderately sensitive to effects of high flow abstraction (with regard to floodplain inundation)
Ruddle (Paper Mill Dyke) from Source to R Torne	Not known	No data, pebbles gravels expected to be present	-	Data indicates waterbody is severely modified.	Not known	No	At least Good	Information indicates waterbody would be of low sensitivity to further abstraction.
S Lev Engine Dr / Upper Warping Drain Catch	No but considered likely	No data, silt expected	The waterbody is a network of artificial drainage ditches, static flows, uniform laminar flow and lack of mixing, sedimentation is an issue (PSI scores), however the biological status has not been affected by this. Potential sewage inputs having localised effects on ammonia levels.	No data	Not known	Yes	Less than good with regard to dissolved oxygen and ammonia	Information indicates waterbody would be of low sensitivity to further abstraction.
St Catherine's Well Stream from Source to R Torne	Not known	No data, pebbles gravels expected to be present	-	No data	Not known	No	Less than good with regard to phosphate and ammonia	Data generally lacking to ascertain potential sensitivity
Torne / Three Rivers from Mother Dr to R Trent	Yes	Silt	Highly uniform reaches are unlikely to be significantly affected by high flow abstraction.	Data indicates waterbody is severely modified.	Yes (downstream end only)	Yes	Less than good	Available information indicates waterbody may be moderately sensitive to effects of high flow abstraction (with regard to floodplain inundation)
Torne from Ruddle to St Catherine's Well St	Yes	Silt though substantive pebbles/ gravel also present	This waterbody is not designated as a Heavily modified waterbody although it considered to be homogenous in nature. It has been channelised and re-sectioned into long straight sections. Flow is predominantly slack with little habitat heterogeneity and heavy rates of sedimentation.	No data	No	Yes	Less than good with regard to dissolved oxygen and phosphate	Information indicates waterbody would be of low sensitivity to further abstraction.
Torne from Source to Ruddle (Paper Mill Dyke)	Yes	No data, pebbles gravels expected to be present	-	No data	No	Yes	At least Good	Data generally lacking to ascertain potential sensitivity
Torne from St Catherine's Well Strm to Mother Dr	Yes	No data, pebbles gravels expected to be present	The Torne at Rossington has a uniform channel that is unlikely to be affected badly by peak flow abstraction, but wetland and floodplain habitats such as reeds could be detrimentally affected if peak flows are reduced. Bank erosion is unlikely to significantly reduce with peak flow abstraction.	Data indicates waterbody is severely modified.	No	Yes	Less than good with regard to phosphate. Water quality and flow data available and review indicated potential sensitivity at times of high flow with regard to dissolved oxygen and orthophosphate.	Information indicates the channel may be of low to moderate sensitivity to further abstraction
Warping Drain Catch (trib of Trent)	No but considered likely	No data, pebbles gravels expected to be present	-	No data	Not known	No (though due to demaining/ still present but IDB maintained?)	At least Good	Information indicates waterbody would be of low sensitivity to further abstraction.

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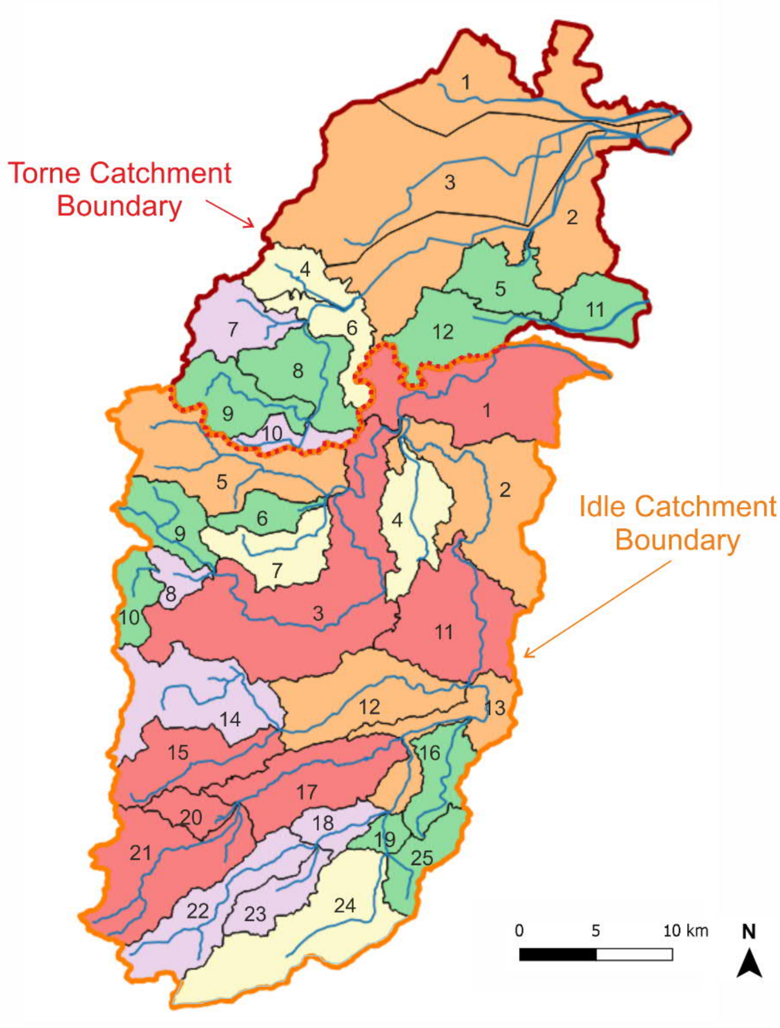
Figure 3.54 Physical Environment Sensitivity Review Summary



Legend

- Available information indicates waterbody would be of low sensitivity to further abstraction
- Available information indicates waterbody may be of low to moderate sensitivity to further abstraction
- Available information indicates waterbody may be of moderate sensitivity to further abstraction
- Available information indicates waterbody may be highly sensitive to further abstraction
- Data generally lacking to ascertain potential sensitivity

Torne WFD Catchments

#	Waterbody Name
1	North Soak Drain (trib of R Torne / Three Rivers)
2	Torne / Three Rivers from Mother Dr to R Trent
3	Hatfield Waste Dr (trib of Torne/Three Rivs)
4	Mother Drain from Source to R Torne
5	S Lev Engine Dr / Upper Warping Drain Catch
6	Torne from St Catherine'S Well Strm to Mother Dr
7	St Catherine's Well Stream from Source to R Torne
8	Torne from Ruddle to St Catherine's Well St
9	Ruddle (Paper Mill Dyke) from Source to R Torne
10	Torne from Source to Ruddle (Paper Mill Dyke)
11	Ferry Drain
12	Warping Drain Catch (trib of Trent)

Idle WFD Catchments

#	Waterbody Name
1	Idle from River Ryton to River Trent
2	Idle from Tiln to River Ryton
3	Ryton from Anston Brook to Idle
4	Ranskill Brook Catchment (trib of the River Idle)
5	Oldcotes Dyke
6	Hodsock Bk (to Oldcoates Dyke)
7	Owlands Wood Dyke from Source to Hodscok Brook
8	Ryton (to Aniston Brook)
9	Anston Brook from Source to River Ryton
10	Broad Bridge Dyke (to Canal)
11	Idle from Maun/Poulter Conf to Tiln
12	Poulter from Millwood Brook to River Maun
13	Maun from Rainworth Water to River Poulter
14	Millwood Brook from Source to River Poulter
15	Poulter from Source to Millwood Brook
16	Bevercotes Beck Catchment (trib of River Maun)
17	Meden from Sookholme Brook to River Maun
18	Maun from Vicar Water to Rainworth Water
19	Rainworth Water from Gallow Hole Dyke to R Maun
20	Sookholme Brook from Source to River Meden
21	Meden from Source to Sookholme Brook
22	Maun from Source to Vicar Water
23	Vicar Water from Source to R Maun
24	Rainworth Water from Source to Gallow Hole Dyke
25	Gallow Hole Dyke from Source to Rainworth Water

4. Environmental Features

4.1 Background

The Environmental Feature baseline has been developed and expanded from the Feasibility Study undertaken in 2015. This section of the report has been divided into the following sub-sections:

- Designated Sites;
- Protected and Invasive Non- Native Species;
- Water Framework Directive;
- Fish;
- Macroinvertebrates;
- Macrophytes and Phytobenthos; and
- Diatoms.

4.2 Designated Sites

4.2.1 Approach

Records of statutory sites for nature conservation, including Special Areas for Conservation (SACs), Special Protection Areas (SPA's), Sites of Special Scientific Interest (SSSI), and Local Nature Reserves (LNRs) within the Idle and Torne catchments were initially obtained from publicly available sources. The results from the initial screening highlighting water dependant sites were brought forward into this assessment.

The next stage of this process was to further investigate the nature conservation features of interest within each of the sites. This process was undertaken to try and identify sites where their 'water dependency' was reliant on watercourses within either the Idle or Torne catchments. It also allowed sites to be identified which specifically highlight winter flooding as an important component of their designation and therefore, may be very sensitive to changes in winter flows. This process also allowed further sites to be scoped out.

The data used in this assessment was collated from https://designatedsites.naturalengland.org.uk/.

4.2.2 Internationally and Nationally Designated Sites etc

Four internationally designated sites were brought forward from the phase 1 study for further analysis. These were Hatfield Moor SAC, Thorne Moor SAC, Thorne and Hatfield Moor SPA and the Humber Estuary SAC. A total of 20 nationally designated site were brought forward from the phase 1 study for further analysis. The location of the nationally and internationally designated sites is indicated on Figure 4.1.

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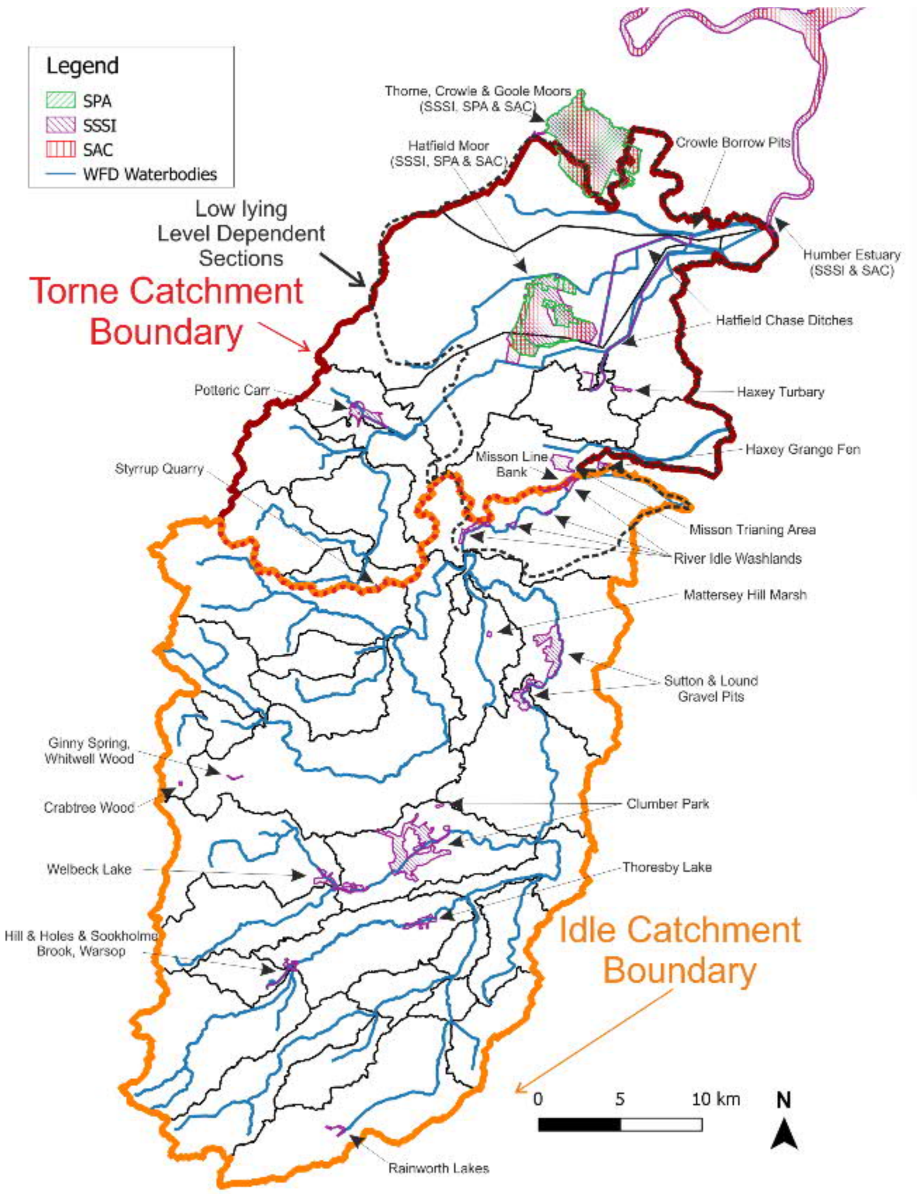

Figure 4.1 National and International Designated Sites in and downstream of the Idle and Torne

A high level qualitative review of the potential effects on these sites/ their sensitivity if abstractions at high flows were to occur is presented in Table 4.1.

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Table 4.1 International and national Sites and sensitivity appraisal

Name	Designation	Features of Interest	Appraisal of effects of high flow abstraction	Waterbody and Physical Environment Sensitivity	Screened in or out
Hatfield Moor (see Thorne and Hatfield Moors)	SAC and SSSI	Remnant raised and blanket mire, breeding birds including nightjar, important invertebrate assemblages,	The site is reliant on groundwater/ direct rainfall rather than surface waters, and so is not considered sensitive to surface water abstractions at times of high flow.	Hatfield Waste Drain (trib of Torne/ Three Rivers) - Moderately Sensitive	Screened out
Humber Estuary	SAC and SSSI	Aggregations of wide range of non-breeding birds, breeding wetland birds, Sea Lamprey (Petromyzon marinus), River Lamprey (Lampetra fluviatilis),Grey Seal (Halichoerus grypus), sand dune, saltmarsh and muddy/sandy shores, standing waters, estuary, saline coastal lagoons	Reductions in freshwater inflows to Humber Estuary likely to be small, given wider contributions e.g. from the Trent.	Downstream of catchments	Screened out
Thorne Moor	SAC	Remnant raised and blanket mire, breeding birds including nightjar, important invertebrate assemblages,	The site is reliant on groundwater/ direct rainfall rather than surface waters, and so is not considered sensitive to surface water abstractions at times of high flow.	North Soak Drain (trib of R Torne / Three Rivers) - Moderately Sensitive	Screened out
Thorne & Hatfield Moors	SPA	Remnant raised and blanket mire, breeding birds including nightjar, important invertebrate assemblages,	The sites are reliant on groundwater/ direct rainfall rather than surface waters, and so is not considered sensitive to surface water abstractions at times of high flow.	North Soak Drain (trib of R Torne / Three Rivers) - Moderately Sensitive	Screened out
Crabtree Wood	SSSI	Fen marsh and swamp	Site lies in the upland part of the catchment. Abstractions at times of high flow not expected to have an impact at this location.	Broad Bridge Dyke (to Canal) – Low sensitivity	Screened out
Crowle Borrow Pits	SSSI	Fen, marsh, swamp woodland	SSSI lies either side of the embankment of a disused railway line and include a variety of habitats including alder carr, scrub, fen and open water in which several locally uncommon plant species occur. Several small ponds exist within the fen and scrub and contain aquatic and marginal species. Reduction in floodplain inundation may impact upon this site. Environment Agency has advised that they believe that these may not be water dependent, however, as they are not aware of a WLMP for the site.	North Soak Drain (trib of R Torne / Three Rivers) and Hatfield Waste Drain (trib of R Torne / Three Rivers) - both Moderately Sensitive	**Screened in**
Clumber Park	SSSI	Standing open waters (OW), heath woodland	Environment Agency have advised that no formal WLMP for the site however there are habitats along the lake fringes and also notable colonies of water starwort in the lake which will be susceptible to lack of water but not excess water. Connectivity to river of waterbodies in the SSSI not known. If surface water reliant then impact of high flow abstraction may potentially be greater.	Poulter from Millwood Brook to River Maun – Moderately Sensitive	**Screened in**
Hatfield Chase Ditches	SSSI	Standing OW and canals, water voles	Physical environment review determined that reach not considered to be sensitive, other than with regard to a reduction in floodplain inundation at times of high flow. Site has a WLMP and levels in the ditch are controlled within these levels. A reduction in high flows may make management of these levels easier and a reduced inundation of the floodplain not considered to detrimentally impact upon the site.	Torne / Three Rivers from Mother Drain to R Trent and Hatfield Waste Drain (trib of Torne/ Three Rivers (with regard to floodplain inundation) - Moderately Sensitive	Screened out
Haxey Grange Fen SSSI	SSSI	Fen marsh and swamp	Site is reasonably distant from the Idle (200m) and citation indicates it is dependent on water table (groundwater) rather than surface water inundation.	Idle from River Ryton to River Trent- Highly sensitive	Screened out
Haxey Turbary	SSSI	Relic wet bog/open wet heathland	Site is reasonably distant from the Hatfield Chase Ditch (400m) and citation indicates it is a relict bog implying it is groundwater dependent. As such no effect predicted on this site.	Torne / Three Rivers from Mother Drain to R Trent	Screened out
Mattersey Hill Marsh	SSSI	Broad leaved woodland and bog	Site around 300m from Ranskill Brook and so likely more reliant on groundwater/ direct rainfall. As such no effects predicted.	Ranskill Brook Catchment (trib of the River Idle)- low to moderate sensitivity	Screened out
Misson Line Bank	SSSI	Standing OW and canals, fen marsh and swamp woodland	SSSI contains fine examples of wetland plant communities of unusual diversity and species richness developed in association with a series of old borrow pits. Environment Agency have advised that they have not been involved in or aware of any Natural England remedies or actions for this site and that it is open water (borrow pits), marsh and fen communities. They also don't think it is linked to the Idle which along with its designation suggests it is groundwater dependent. As such high abstraction not considered to have an effect.	Warping Drain Catchment (trib of Trent) – low sensitivity	Screened out

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Name	Designation	Features of Interest	Appraisal of effects of high flow abstraction	Waterbody and Physical Environment Sensitivity	Screened in or out
Misson Training Area	SSSI	Fen marsh and swamp, woodland, grassland	SSSI supports a diverse range of semi-natural habitats, including standing open water, tall-herb fen, unimproved neutral and acidic grassland, dry oak woodland and nationally restricted wet woodland types. Environment Agency have advised that they have not been involved in or aware of any Natural England remedies or actions for this site and that it is fen communities, open water and wet woodland.	Hatfield Waste Drain (trib of Torne/ Three Rivers) - Moderately Sensitive	Screened out
Rainworth Lakes	SSSI	Fen marsh swamp, standing open water and canals	Sites lies in the upland part of the catchment. Abstractions at times of high flow not expected to have a major impact at this location.	Rainworth Water from Source to Gallow Hole Dyke- low sensitivity	Screened out
Potteric Carr	SSSI	Variety of breeding bird, swamp, fen and marsh habitats,	The SSSI developed as the result of mining subsidence beginning in the early 1905's (but occurring particularly between 1960–67), which caused the flooding and severe waterlogging of former agricultural land and woodland. A mosaic of open water, reed bed, wet grassland and carr habitats was thus created which now represents the largest and most diverse wetland of its type in the county IDB reportedly have an IDB though this has not been reviewed. Given low sensitivity of the reach to high flow abstractions site has been screened out however.	Mother Drain from Source to R Torne- low sensitivity	Screened out
River Idle Washlands	SSSI	Wet grassland plant communities, large numbers of wintering and passage waterfowl.	The SSSI contained the remaining washland grasslands along the River Idle floodplain. Characteristically the grassland swards are dominated by marsh foxtail in a community which contains such wet meadow herbs as la smock and great burnet. In wetter areas the vegetation is dominated by stands of reed sweet-grass which has also colonised the internal drains although, locally, a more varied wetland plant community occurs which includes such plant species as meadow rue. The SSSI has a WLMP which implies it is sensitive to water level variation in the Idle. Similarly a reduction in floodplain inundation, as a result of additional high flow abstraction, could impact upon this site.	Idle from River Ryton to River Trent- Highly sensitive	**<u>Screened in</u>**
Styrrup Quarry	SSSI	Earth heritage	Site lies in the upland part of the catchment. Abstractions at times of high flow not expected to have an impact at this location.	Torne from Source to Ruddle (Paper Mill Dyke) – data lacking to assess sensitivity	Screened out
Thoresby Lake	SSSI	Standing OW and canals, fen marsh and swamp woodland	The site contains fine examples of dry acid grassland, acid-loam grassland, marsh and reedswamp plant communities which, together with an area of open water comprise one of the best mixed habitat assemblages on base-poor soils in Nottinghamshire. Lake is online (hydrologically) though likely and expected that levels in it would be partially controlled by a downstream structure. Likely that level controlled nature would buffer effects in the lake of high flow abstraction (noting that it would likely be around weir crest level when such abstractions would occur). Though a site visit is recommended to confirm outfall arrangements.	Meden from Sookholme Brook to River Maun - highly sensitive	Screened out although is recommended that the downstream dam is visited to confirm its importance to control levels in the lake.
Welbeck Lake	SSSI	Standing OW and canals, fen marsh and swamp woodland	The SSSI comprises a complex of habitats centred on the Great Lake and Carburton Dams, Welbeck and is notable for its breeding bird community, which includes a heronry, and for its wintering wildfowl. Lakes are online (hydrologically)though likely and expected that levels in it would be partially controlled by a downstream structure. Likely that level controlled nature would buffer effects in the lake of high flow abstraction (noting that it would likely be around weir crest level when such abstractions would occur and likely to be more sensitive at times of low flow). A site visit is recommended to confirm structural arrangements and their hydrological effects. The Environment Agency have indicated that there are no management actions or remedies at the site in which they are involved in.	Millwood Brook from Source to River Poulter – data lacking to assess sensitivity Poulter from Millwood Brook to River Maun – Moderately Sensitive	Screened out although is recommended that the site is visited to confirm the importance of structures.
Ginny Spring,Whitwell Wood	SSSI	Fen marsh and swamp	Site lies in the upland part of the catchment. Abstractions at times of high flow not expected to have an impact at this location.	Ryton from Anston Brook to Idle- highly sensitive	Screened out
Hills and Holes and Sookholme Brook, Warsop	SSSI	Grassland, rivers and streams, fen, marsh and swamp	Site does not have a formal WLMP however the brook is designated as a calcareous stream with plant species not commonly found within the East Midlands. These will affected by drying out in limited flow conditions (drought) rather than at times of high flows so site is screened out.	Sookholme Brook from Source to River Meden – highly sensitive	Screened out

Name	Designation	Features of Interest	Appraisal of effects of high flow abstraction	Waterbody and Physical Environment Sensitivity	Screened in or out
Sutton and Lound Gravel Pits	SSSI	Aggregations of non-breeding birds - Gadwall, Anas Strepera, ,Assemblages of breeding birds - Lowland open waters and their margins, Variety of passage bird species (150) (habitats standing waters and canals)	Idle in this area does not regularly inundate the floodplain. As such no significant effect predicted, based on information available.	Idle from Tiln to River Ryton – moderate sensitivity	Screened out
Thorne, Crowle and Goole Moors	SSSI	Remnant raised and blanket mire, breeding birds, including nightjar, and important invertebrate assemblages	The site is reliant on groundwater/ direct rainfall rather than surface waters, and so is not considered sensitive to surface water abstractions at times of high flow.	North Soak Drain (trib of r Thorne / Three Rivers) - moderate sensitivity	Screened out

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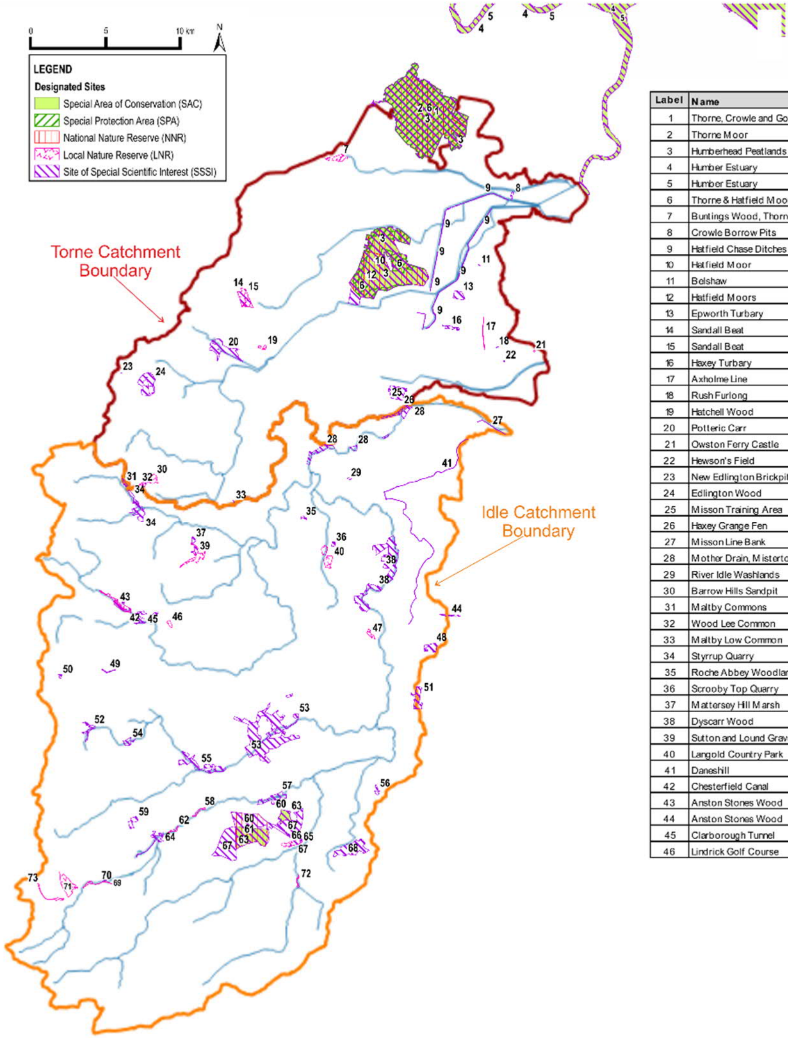


Label	Name	Designation
1	Thorne, Crowle and Goole Moors	SSSI
2	Thorne Moor	SAC
3	Humberhead Peatlands	NNR
4	Humber Estuary	SSSI
5	Humber Estuary	SAC
6	Thorne & Hatfield Moors	SPA
7	Buntings Wood, Thorne	LNR
8	Crowle Borrow Pits	SSSI
9	Hatfield Chase Ditches	SSSI
10	Hatfield Moor	SAC
11	Belshaw	SSSI
12	Hatfield Moors	SSSI
13	Epworth Turbary	SSSI
14	Sandall Beat	SSSI
15	Sandall Beat	LNR
16	Haxey Turbary	SSSI
17	Axholme Line	LNR
18	Rush Furlong	SSSI
19	Hatchell Wood	LNR
20	Potteric Carr	SSSI
21	Owston Ferry Castle	LNR
22	Hewson's Field	SSSI
23	New Edlington Brickpit	SSSI
24	Edlington Wood	SSSI
25	Misson Training Area	SSSI
26	Haxey Grange Fen	SSSI
27	Misson Line Bank	SSSI
28	Mother Drain, Misterton	SSSI
29	River Idle Washlands	SSSI
30	Barrow Hills Sandpit	SSSI
31	Maltby Commons	LNR
32	Wood Lee Common	SSSI
33	Maltby Low Common	SSSI
34	Styrrup Quarry	SSSI
35	Roche Abbey Woodlands	SSSI
36	Scrooby Top Quarry	SSSI
37	Mattersey Hill Marsh	SSSI
38	Dyscarr Wood	SSSI
39	Sutton and Lound Gravel Pits	SSSI
40	Langold Country Park	LNR
41	Daneshill	LNR
42	Chesterfield Canal	SSSI
43	Anston Stones Wood	SSSI
44	Anston Stones Wood	LNR
45	Clarborough Tunnel	SSSI
46	Lindrick Golf Course	SSSI

Label	Name	Designation
47	Woodsetts Pond	LNR
48	Retford Cemetery	LNR
49	Castle Hill Wood	SSSI
50	Ginny Spring,Whitwell Wood	SSSI
51	Crabtree Wood	SSSI
52	Gamston & Eaton Woods & Roadside Verges	SSSI
53	Hollinhill and Markland Grips	SSSI
54	Clumber Park	SSSI
55	Creswell Crags	SSSI
56	Welbeck Lake	SSSI
57	Bevercotes Park	SSSI
58	Thoresby Lake	SSSI
59	The Bottoms	LNR
60	Lord Stubbins Wood	SSSI
61	Birklands and Bilhaugh	SSSI
62	Sherwood Forest	NNR
63	The Carrs	LNR
64	Birklands & Bilhaugh	SAC
65	Hills and Holes and Sookholme Brook, Warsop	SSSI
66	Sherwood Heath	LNR
67	Cockglode and Rotary Wood	LNR
68	Birklands West and Ollerton Corner	SSSI
69	Wellow Park	SSSI
70	Pleasley Vale Railway	SSSI
71	Pleasley Vale	LNR
72	Pleasley	LNR
73	Rufford Country Park	LNR
74	Rowthorne Trail	LNR
75	Teversal to Pleasley Railway	SSSI
76	Vicar Water Nature Reserve	LNR
77	Clipstone Heath	SSSI
78	Ravensdale	LNR
79	Maun Valley Park	LNR
80	Teversal Pastures	SSSI
81	Sherwood Forest Golf Course	SSSI
82	Teversal/Pleasley Network	LNR
83	Oak Tree Heath	LNR
84	Strawberry Hill Heaths	SSSI
85	Quarry Lane	LNR
86	The Hermitage	LNR
87	Brierley Forest Park	LNR
88	Oakham	LNR
89	Rainworth Water	LNR
90	Rainworth Heath	SSSI
91	Rainworth Lakes	SSSI
92	Southwell Trail	LNR

Figure 4.2 Designated Sites in and downstream of the Idle and Torne catchments

4.2.3 Local Designated Sites

A number of other locally designated sites are present throughout the catchment and are indicated in Figure 4.2. Although the effect on each site has not been appraised their presence in a reach can indicate potential sensitivity (with their absence relatively indicating a lower sensitivity).

4.3 Protected and Invasive Non-Native Species

4.3.1 Approach

The available protected and notable species records were screened to identify water dependant species (species that require water or associated riverine habitats for all or a significant part of their lifecycle). The data used in this assessment is detailed below. The available data was restricted to records post 2000, to help characterise the recent (rather than historic) conditions of the catchments and included the following:

- otter, crayfish and water vole data (Nottinghamshire Biological and Geological Record Centre (NBGRC));
- otter, crayfish and water vole records from the Idle and Thorne catchments (Doncaster Local Records Centre (DLRC)); and
- notable and protected species records from within Local Wildlife Sites (LWS) in Doncaster.

The relevant protected and notable water dependant species records are provided below.

Fishery protected and invasive species are discussed in Section 4.4.

4.3.2 Protected Species

The desk study returned the following protected species records:

- water vole (*Arvicola amphibious*). There are approximately 1,000 records across both the Idle and Torne catchments;
- otter (*Lutra Lutra*), nine records within the Torne with four in the Idle catchment;
- white clawed crayfish (*Austropotamobius pallipes*), there are localised records at two locations in the Idle catchment.

The proposed high flow abstraction is only likely to reduce spate flows during the winter period and these changes are unlikely to directly affect these species. However, there could be indirect impacts (such as impacts on their food source), which are not currently understood. Therefore, potential effects on these species should still be considered in more detail in the next stage of the assessment.

In addition, species listed on the Doncaster LBAP were returned by DLRC, including various-leaved water-Starwort (*Callitriche* platycarpa). Further information is provided in Section 4.6 (macrophytes and phytobenthos section).

4.3.3 Invasive Non-Native Species

Review of the macrophyte WFD monitoring data also demonstrated that invasive non-native species (INNS) of macrophytes (*Elodea nutalii, Elodea canadensis, Impatiens glandulifera*) are present in several watercourses within the Idle and Torne catchments. These are presented in Table 4.2 below. There were no additional INNS records within the DLRC available data.

Table 4.2: Invasive non-native species records within the study area (from WFD monitoring data)

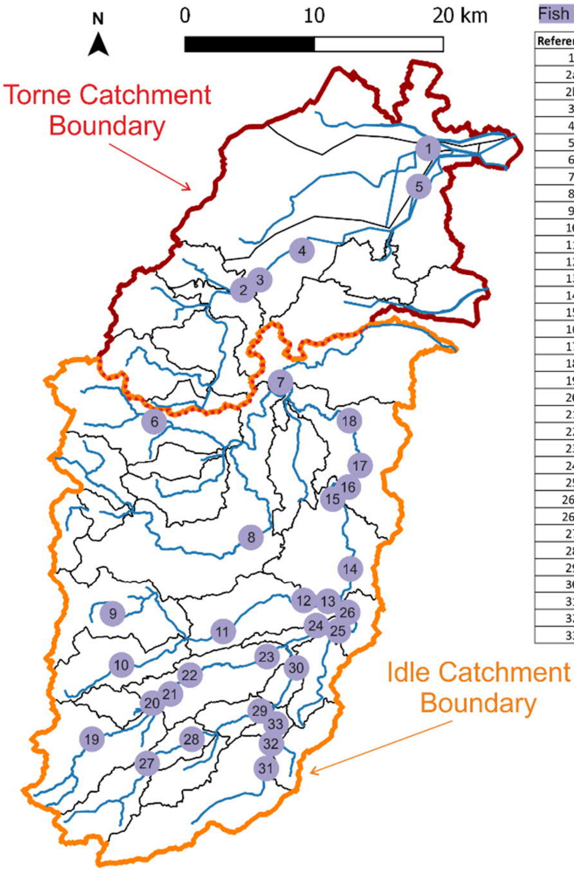
Species	Waterbody	Site	National Grid Reference
Nuttall's waterweed *(Elodea nutalii)*	Idle from River Ryton to River Trent (GB104028058110)	Misterton	SK-76466-96231
	Maun from Rainworth Water to River Poulter (GB104028058080)	Ollerton MTR Site	SK-65472-67804
	Meden from Sookholme Brook to River Maun (GB104028058060)	The Carrs Warsop (Welbeck) MTR Site	SK-58312-69695
	Meden from Source to Sookholme Brook (GB104028058020)	Littlewood	SK-53177-65282
	Torne / Three Rivers from Mother Dr to R Trent (GB104028064340)	Hammerwater Bridge MTR Site	SK-55600-67531
	Hatfield Waste Dr (trib of Torne/Three Rivs) (GB104028064330)	Goodcop Farm	SE-73550-08350
	Torne from St Catherine’s Well Strm to Mother Dr (GB104028058410)	Torne Bridge	SK-61944-98961
	Warping Drain Catch (trib of Trent) (GB104028058240)	Owston Ferry	SK-79900-98900
Himalayan balsam (*Impatiens glandulifera*)	Idle from River Ryton to River Trent (GB104028058110)	Bawtry	SK-65602-92740
	Maun from Rainworth Water to River Poulter (GB104028058080)	Ollerton MTR Site	SK-65472-67804
	Meden from Sookholme Brook to River Maun (GB104028058060)	The Carrs Warsop (Welbeck) MTR Site	SK-58312-69695
	Meden from Source to Sookholme Brook (GB104028058020)	Littlewood	SK-53177-65282
	Sookholme Brook from Source to River Meden (GB104028058050)	Spring Lane	SK-54980-67190
	Owlands Wood Dyke from Source to Hodscok Brook (GB104028058170)	Water Lane	SK-59625-84584
Canadian pondweed (Elodea canadensis)	Maun from Rainworth Water to River Poulter (GB104028058080)	Ollerton MTR Site	SK-65472-67804

Abstracting during high flows might change flow conditions and lead to a localised spread of the Nutall’s waterweed and Canadian pondweed. It should also be considered that reducing spate flows might limit the downstream spread of those species, which could constitute a beneficial impact from the abstraction.

4.4 Fish

4.4.1 Data

Since 1982, a combined total of 52 individual monitoring points have been surveyed by the Environment Agency across both catchments, providing a spatially and temporally rich dataset (Figure 4.3). Due to the size of the dataset, the data was filtered to include only the past ten years of data (01/01/2010 – 31/12/2019) as this will provide an accurate recent assessment of the resident fish populations.



Fish Monitoring Points

Reference #	Site Reference	Catchment
1	Hatfield Waste Drain at Dirtness Birdge	Torne
2a	Torne at Rossington	Torne
2b	Mother Drain at Rossington	Torne
3	Torne at Hayfield Lakes	Torne
4	Torne at Blaxton Banks	Torne
5	Torne et Westgate Bridge	Torne
6	Oldcotes Dyke Catchment (trib of Ryton)	Idle
7	Idle at Bawtry	Idle
8	Ryton at Scrofton	Idle
9	Millwood Brook Catchment (trib of Poulter)	Idle
10	Poulter at Nether Langwith	Idle
11	Poulter at Carburton	Idle
12	Poulter at Crookford	Idle
13	Poulter at Elkersley	Idle
14	Idle at Eaton	Idle
15	Idle at Idle Valley Nature Reserve	Idle
16	Idle at Tiln	Idle
17	Idle at Chain Bridge Lane	Idle
18	Idle at Mattersey Priory	Idle
19	Meden at US Pleasley Vale	Idle
20	Meden at Hammerwater Bridge	Idle
21	Meden at The Carrs	Idle
22	Meden at Meden Vale	Idle
23	Meden at Perlethorpe Gauging Weir	Idle
24	Maun at Bothamsall	Idle
25	Maun at Lound	Idle
26a	Maun at DS Bothamsall (DS Pre-barrage)	Idle
26b	Maun at US Pre-barrage (DS Bothamsall)	Idle
27	Maun at Valley Park	Idle
28	Maun at Cavendish Bridge	Idle
29	Maun at Carr Breck Farm	Idle
30	Maun at Whitewater Bridge	Idle
31	Rainworth at Cutts Wood	Idle
32	Rainworth at US Rufford Park	Idle
33	Rainworth Water from Gallow Hole Dyke to Maun	Idle

Figure 4.3 Locations of the Environment Agency fish monitoring points within the Idle and Torne catchment

In addition, detailed Environment Agency fish monitoring reports were analysed. They included an assessment of fish habitat quality and described the main pressures on fish communities, such as the presence of barriers to migration. This data was used in order to identify the presence of spawning habitat that may be impacted by increased sedimentation of gravel habitats due to high winter flow abstraction, and the presence of migratory fish species, for which flow reductions could limit passage through fish barriers already present in the catchment.

4.4.2 Water Framework Status

Within the Idle and Torne catchments, 37 water bodies have been identified by the Environment Agency for ecological assessment under the Water Framework Directive (WFD). Of these, 17 waterbodies are routinely monitored for fish populations with 11 and six waterbodies assessed within the Idle and Torne catchments respectively (Table 4.3 and Figure 4.4).

Table 4.3 WFD waterbodies within the Idle & Torne catchments and their 2016 WFD Fish status

Catchment	Waterbody name	Waterbody ID	WFD status (2016)
Idle	Idle from Maun/Poulter to Tiln	GB104028058091	High
Idle	Idle from Ryton to Trent	GB104028058110	High
Idle	Idle from Tiln to Ryton	GB104028058092	Good
Idle	Maun from Rainworth Water to Poulter	GB104028058080	Good
Idle	Maun from Source to Vicar Water	GB104028052960	Poor

Catchment	Waterbody name	Waterbody ID	WFD status (2016)
Idle	Maun from Vicar Water to Rainworth Water	GB104028058040	Moderate
Idle	Meden from Sookholme Brook to Maun	GB104028058060	High
Idle	Meden from Source to Sookholme Brook	GB104028058020	Moderate
Idle	Poulter from Millwood Brook to Maun	GB104028058140	Good
Idle	Poulter from Source to Millwood Brook	GB104028058130	Good
Idle	Rainworth Water from Source to Gallow Hole Dyke	GB104028052940	Moderate
Torne	Hatfield Waste Drain Catchment (trib of Torne/Three Rivers)	GB104028064330	Poor
Torne	Mother Drain from Source to Torne	GB104028058440	Poor
Torne	St Catherine's Well Stream from Source to Torne	GB104028058420	N/A
Torne	Torne from St Catherine's Well Stream to Mother Drain	GB104028058410	Poor
Torne	Torne/Three Rivers from Mother Drain to Trent	GB104028064340	Good
Torne	Warping Drain Catchment (trib of Trent)	GB104028058240	N/A

The WFD fish status for each of these water bodies is calculated by assessing multiple monitoring points along its course. Three of the four waterbodies in the Torne are failing to achieve Good status. The downstream Idle catchment waterbodies are reported to be achieving Good or High status while most of the upper waterbodies are failing to achieve Good status.

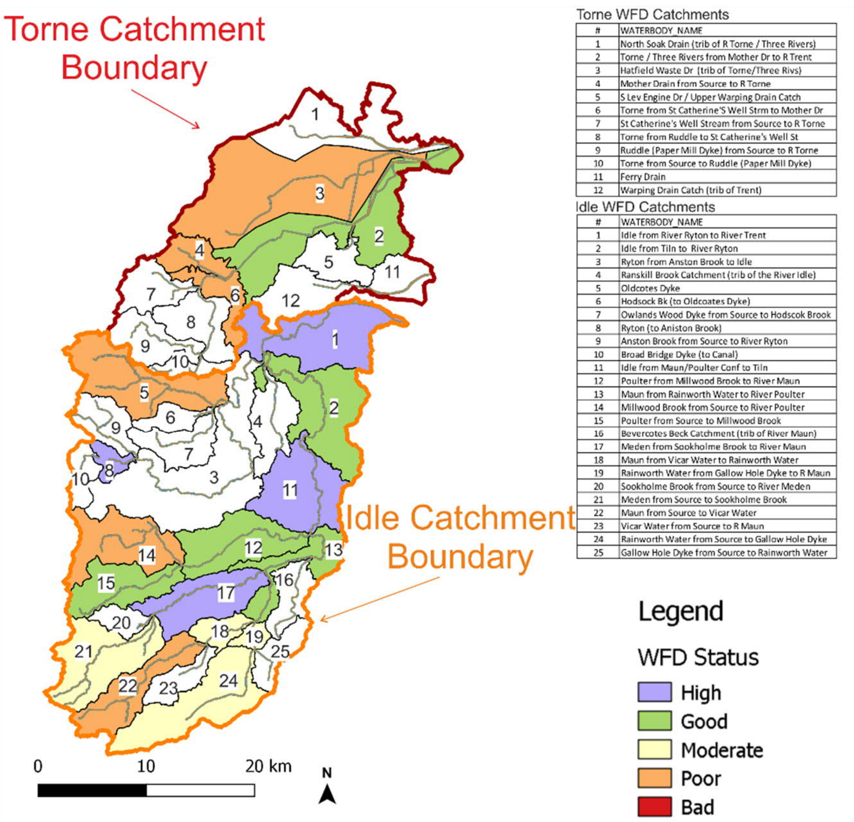


Figure 4.4 Fish WFD waterbodies and status as of 2016 in the Idle and Torne catchments

4.4.3 River Torne catchment

4.4.3.1 Fishery Baseline

The baseline assessment of the River Torne catchment has shown that since 2010, seven routine monitoring sites have been surveyed to assess the fish populations. These surveys have identified 20 different fish species with roach (*Rutilus rutilus*; n = 1007), gudgeon (*Gobio gobio;* n = 297), stone loach (*Barbatula barbatula*; n = 271) and bullhead (*Cottus gobio*; n = 208) being the most abundant (Figure 4.5). It should be noted that these abundances do not include the 'observed abundances' as these estimations are grouped into logarithmic bins and represent a potentially large source of error). The fish population is dominated by a predominately cyprinid assemblage. Of the cyprinids, many are benthivorous (i.e. tench (*Tinca tinca*) and bream (*Abramis brama*)) which are associated with slow flows and fine sediment environments.

It is noted that no fish monitoring information is available from a number of waterbodies in the Torne catchment. This is discussed further in Section 4.9.

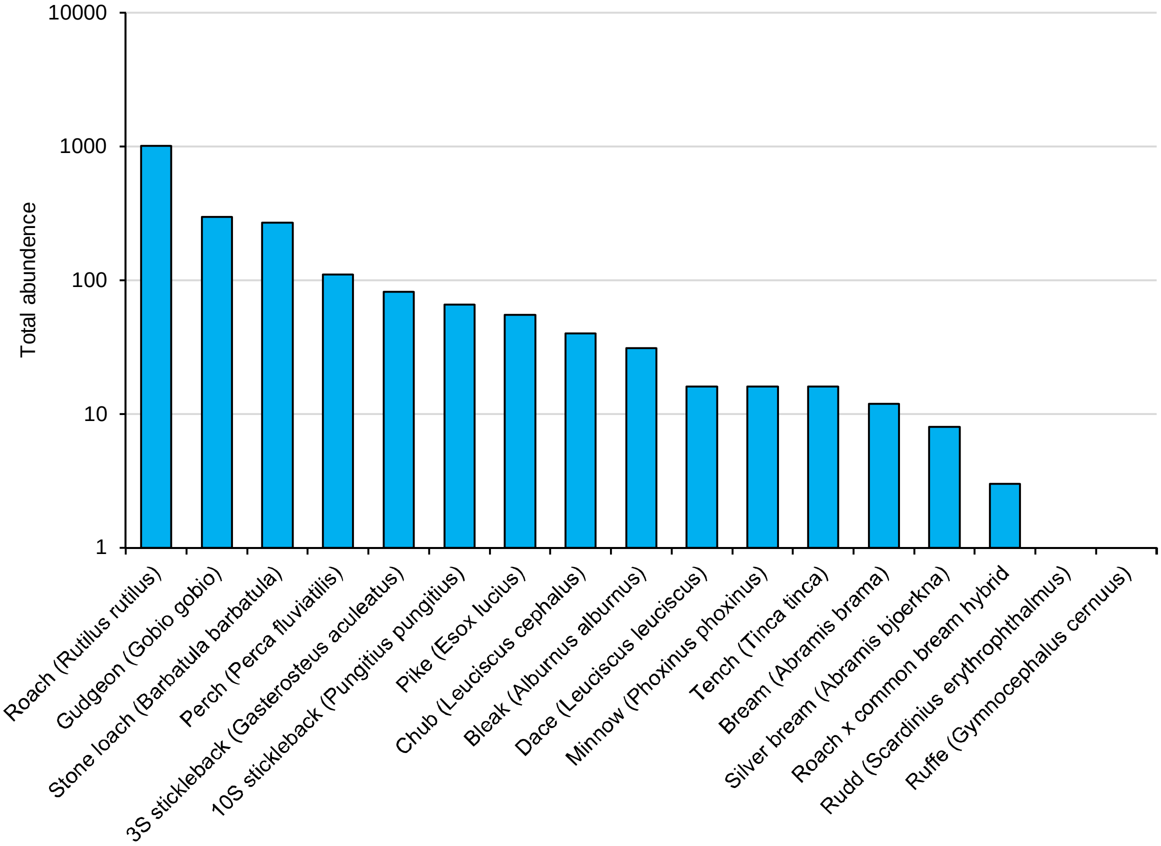


Figure 4.5 River Torne fish assemblage not including protected species (2010-2019)

4.4.3.2 Protected and invasive species

The following three protected species were recorded bullhead (n = 208), European eel (*Anguilla anguilla*; n = 32) and barbel (*barbus barbus*; n = 15) and no invasive species were recorded.

- Bullhead are protected under Annex II of the Habitats Directive (designation as qualifying feature within SACs).
- European eels are a critically endangered species protected under Appendix II of the Bonn Convention (migratory species that require international agreements for their conservation and management), a Section 41 (S41) species under the Natural Environment and Rural Communities (NERC) Act 2006, an Appendix II species under the Convention on

International Trade in Endangered Species (CITES) and a UK Biodiversity Action Plan (BAP) priority fish species. Additionally, Eels are protected by the Eels (England and Wales) Regulations (2009) which aims to act to halt and reverse the decline in the European eel stocks.

- Barbel are protected under Annex V of the Habitats Directive (exploitation may be subject to management) and a schedule 4 species under The Conservation of Habitats and Species Regulations 2010.

The protected species in the Torne catchment were recorded at six monitoring sites on five WFD waterbodies (Table 4.4). Of these, the European eel was the most ubiquitous having been identified at each of the six monitoring sites, followed by bullhead and barbel with 4 and 1 identifications at monitoring sites respectively.

Table 4.4 Spatial distribution of the protected and invasive species identified during the desktop study within the Torne catchment

Site information	Barbel	Bullhead	European eel
Hatfield Waste Drain Catchment (trib of Torne/Three Rivers) – (GB104028064330)			
Dirtness Bridge			✓
Mother Drain from Source to Torne – (GB104028058440)			
Rossington		✓	✓
St Catherine's Well Stream from Source to Torne – (GB104028058420)			
Below Sprotborough Weir	✓		✓
Torne from St Catherine's Well Stream to Mother Drain – (GB104028058410)			
Rossington		✓	✓
Torne/Three Rivers from Mother Drain to Trent – (GB104028064340)			
Blaxton Banks		✓	✓
Hayfield Lakes		✓	✓

4.4.3.3 Migratory species and barriers to migration

The catadromous European eel was the only migratory fish species that was identified within the Torne catchment. Their distribution is relatively wide spread within the catchment, but no individuals were recorded above Sprotbrough weir on the River Don, indicating that this weir is a potential barrier to their migration. Additional barriers to fish movement (weirs and impoundments) have been identified in the catchment by the Environment Agency. Both the River Torne at Westgate Bridge (GB104028064340) and at Rossington (GB104028058410) have been identified as barriers to fish migration, causing a deterioration in WFD status and thus a Reason For Failure (RFF).

4.4.3.4 Impacts on fish populations and the Torne catchment

Multiple RFF’s have been identified in the Torne catchment which are impacting the fish population. The Torne catchment appears to be suffering from high ammonia and sedimentation levels, these have been identified as RFF’s at GB104028058430 (South Level Engine Drain catchment (trib of Trent)), GB104028058400 (River Torne from Ruddle to St Catherine’s Well Stream) and GB104028064330 (Hatfield Waste Drain). It is believed that the high ammonia levels are the result of pollution (point source, sewage discharge and diffuse agricultural) and the natural peaty soils in the catchment. Whereas, sedimentation is believed to be the result of poor agricultural practises catchment wide.

The River Torne at Westgate Bridge (GB104028064340) WFD status has decreased due to low flows and sediment deposition. Whereas the River Torne at Rossington (GB104028058410) have been identified as poor water quality (specifically dissolved oxygen) and channel modification reducing habitat heterogeneity along its course. Abstraction at high flows at these locations has the potential to have a detrimental impact of fish populations.

Abstractions at times of high flow are not expected to result in impacts upon migration of species, as these generally occur during lower flows. Where siltation is expected to increase, or effects are not quantified, there may be impacts to fish (e.g. with good habitat or spawning grounds/ gravels potentially becoming smothered). Changes in macrophytes (see Section 4.6) may also have an effect on fish, e.g. if they are reduced there could be a loss in habitat or refuge.

4.4.4 River Idle catchment

4.4.4.1 Fishery Baseline

The baseline assessment of the River Idle catchment has shown that since 2010, 25 routine monitoring sites have been surveyed to assess the fish populations. These surveys have identified 25 different fish species with minnow (*Phoxinus phoxinus*; n = 16,624), stone loach (n = 2,568), gudgeon (n = 1,502), roach (n = 1,216) and bullhead (n = 1,046) being the most abundant (Figure 4.6). It should be noted that as before, the ‘observed abundances’ were not included in these abundances. The fish population is dominated by a predominately cyprinid assemblage which is expected given morphology of the Idle catchment. High numbers of the rheophilic species brown trout (*Salmo trutta*) and dace (*Leuciscus leuciscus*) where identified within the catchment suggesting that the water quality and the natural flow regime is higher than that in the Torne catchment. Interestingly, the presence of flounder (*Platichthys flesus*) at downstream monitoring sites displays their proximity to the brackish waters.

Three barrier to passage have been identified by the Environment Agency. Abstraction at times of high flow would be unlikely to cause further detriment to passage at these.

As for the Torne, there are a few waterbodies in the Idle catchment, in which no fish monitoring information is available. This is discussed further in Section 4.9.

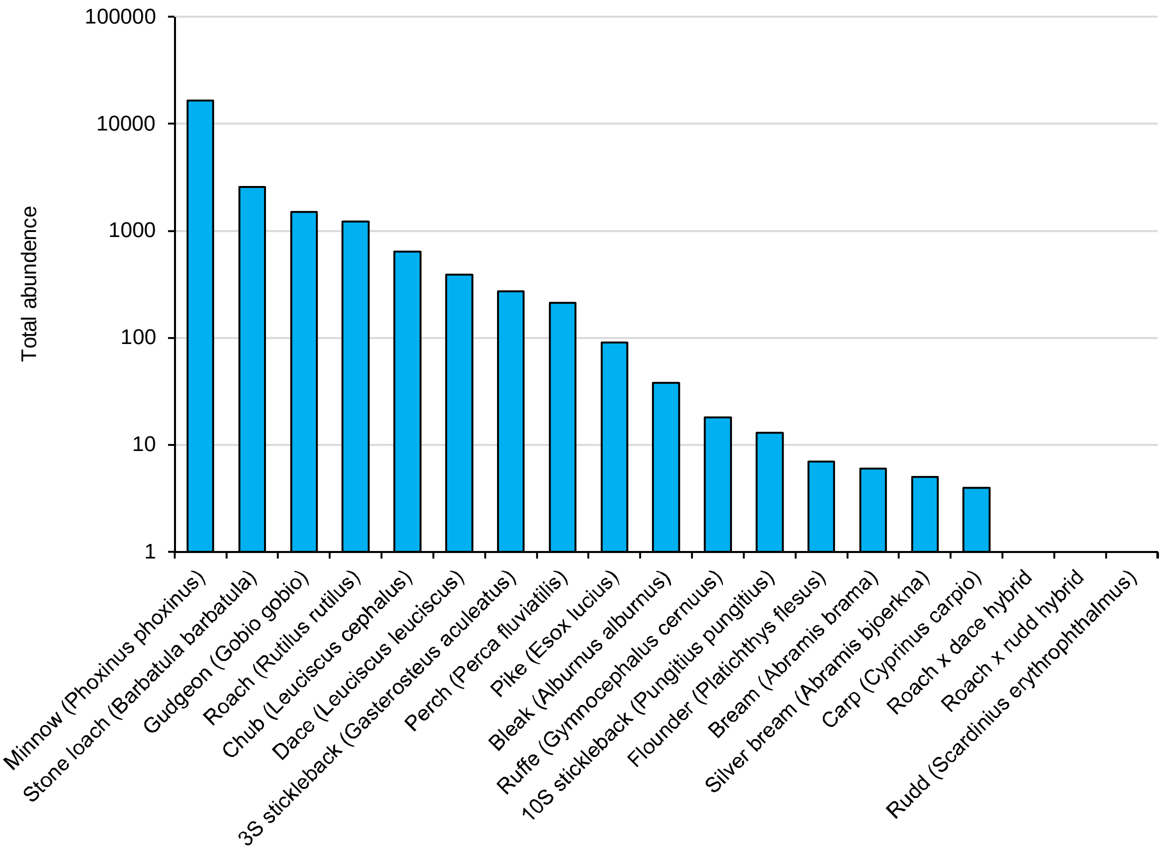


Figure 4.6 River Idle fish assemblage not including protected species (2010- 2019)

4.4.4.2 Protected and invasive species

Of these species, the following five protected species were recorded bullhead, European eel (n = 916), brown trout (n = 170), barbel (n = 15) and spined loach (*Cobitis taenia*; n = 5) and the invasive non-native species, feral goldfish (*Carassius auratus*; n = 1).

- Brown trout are a BAP UK priority species that are protected under the NERC Act 2006.
- Spined loach are a BAP UK priority species and a Section 41 (S41) species under the NERC Act 2006 that are additionally protected under Annex II of the Habitats Directive and Appendix III of the Bern Convention (regulation of the exploitation of species).
- The legislative status of the remaining three species are outlined in section 4.4.3.

There is also one historic record of Atlantic salmon recorded at Bawtry in 2003. However, no additional records have been recorded since. Several catchments in the River idle have a salmonid classification though it is considered this may be due to the presence and importance of brown trout (West Stcokwith pumping station is not believed to have a fish pass that would enable upstream salmon migration) .

The single record of the invasive non-native species goldfish is likely the result of a discard from a pet owner and is unlikely to have survived.

The protected species in the Idle catchment were recorded in 23 monitoring sites and ten WFD waterbodies (Table 4.5). Of these, the bullhead was the most spatial abundant having been identified at 17 monitoring sites, followed by European eel, barbel, brown trout and spined loach with 14, 10, seven and four identifications at monitoring sites respectfully.

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Table 4.5 The spatial distribution of the protected and invasive species identified during the desktop study within the Idle catchment

Site information	Bar-bel	Brown trout	Bull-head	European eel	Spined loach	Feral goldfish
Idle from Maun/Poulter to Tiln – (GB104028058091)						
Eaton	√		√	√	√	
Idle Valley Nature Reserve	√					
Tiln			√	√	√	
Idle from Ryton to Trent – (GB104028058110)						
Bawtry	√		√	√	√	
Idle from Tiln to Ryton – (GB104028058092)						
Chain Bridge Lane	√		√	√		
Mattersey Priory	√		√	√	√	
Maun from Rainworth Water to Poulter – (GB104028058080)						
Bothamsall	√		√	√		
DS Bothamsall (DS Pre-barrage)	√		√			
Lound				√		
US Pre-barrage (DS Bothamsall)	√					
Whitewater Bridge				√		
Maun from Source to Vicar Water – (GB104028052960)						
Cavendish Bridge			√			
Maun Valley Park			√			
Maun from Vicar Water to Rainworth Water – (GB104028058040)						
Carr Breck Farm				√		
Meden from Sookholme Brook to Maun – (GB104028058060)						
Meden Vale		√	√	√		
Perlethorpe Gauging Weir	√	√		√		√
The Carrs		√	√			
Meden from Source to Sookholme Brook – (GB104028058020)						
Hammerwater Bridge		√	√			
US Pleasley Vale		√	√			
Poulter from Millwood Brook to Maun – (GB104028058140)						
Carburton		√	√	√		
Crookford			√	√		
Elkersley	√		√	√		
Poulter from Source to Millwood Brook – (GB104028058130)						
Nether Langwith		√	√			

4.4.4.3 Migratory species and barriers to migration

The catadromous European eel and the anadromous brown trout were the only migratory fish species identified within the Idle catchment. The distribution of European eel wide spread within the catchment, whereas the brown trout are limited to the upper reaches of the Idle. The large spatial distribution of these species (in particular eels) suggest that potential barriers to their migration are passable but they could still be limiting their migratory range and thus overall success. Additionally, it must be noted that any future increase in abstraction could cause the currently passable structures to become impassable to fish passage. However, this impact will likely be negligible when abstracting during high flows when fish are less likely to be migrating and if they are passage issues/conditions unlike to vary from the existing situation.

On the Idle, three barriers to fish migration have been identified as RFF's due to causing ecological discontinuity, these are:

- GB104028058092 (Idle from Tiln to Ryton) at Mattersey Priory - physical modifications: both weir and flood protection structures in channel;
- GB104028058440 (Mother Drain from Source to Torne) - physical modification: weir structure in channel;
- GB104028058020 (Meden from source to Sookholme Brook) - physical modification: weir structure in channel of heritage value.

4.4.4.4 Impacts on fish populations and the Idle catchment

Additional fish RFF's have been identified in the Idle catchment which are impacting fish populations.

- GB104028058092 (Idle from Tiln to Ryton) groundwater abstraction reducing the natural flow regime (not stated in the RFF whether this was reducing the quantity or variability though former is presumed).
- GB104028058440 (Mother Drain from Source to Torne), high ammonia levels from industrial point sources, high sedimentation levels from agricultural and rural land management and dissolved oxygen (source unknown).
- GB104028058020 (Meden from source to Sookholme Brook) – high levels of sedimentation, source unknown and point source pollution from the urban transport and the water industry.

The Idle catchment has shown multiple RFF's to achieve overall good status resulting from catchment wide agriculture and rural land management increasing phosphorus level which are impacting other biological metrics, such as macrophytes. High phosphorus levels cause increased macrophyte abundance which can create daily changes in dissolved oxygen (DO) due to an increase in their overall photosynthetic cycle whereby increases and decreases are seen during day and night-time respectively. This sag in DO during the night can indirectly impact fish by creating areas of inhabitability or result in mortality if their movements are restricted. Increasing abstraction at high flows at the sites mentioned above, has the potential to have a detrimental impact on fish populations.

4.5 Macroinvertebrates

4.5.1 Screening

Macroinvertebrate communities are widely recognised as indicators of environmental quality, since they are largely static, and therefore reflect environmental conditions at a site-specific level and respond relatively rapidly to change.

During the first Phase of the study[30], WFD water bodies within the Idle and Torne catchments were screened in if they were at Good or High status for the macroinvertebrate quality element (based on

[30] AECOM (2015) - High Flow Abstraction for Multiple Environmental Benefits in the Idle and Torne Catchments – A Feasibility Study - Phase 1 Report

2013 WFD classification). Water bodies that were less than Good for macroinvertebrates were screened out of the assessment.

Although WFD macroinvertebrate status is calculated based on the tolerance of the macroinvertebrate community to a range of environmental variables including pollution as well as flow velocity, the screening approach based on the macroinvertebrate status being at least Good was considered to be reasonable. This is because it is able to identify flow sensitive river reaches.

A total of 18 water bodies were screened into the study during Phase 1 (for macroinvertebrates and macrophytes/ phytobenthos). These are shown in Table 4.6 below.

Table 4.6 WFD water bodies graded as High or Good (at least once) based on the WFD assessment of the macroinvertebrate community between 2010 and 2015

Water body identification	Water Body
GB104028058220	Ranskill Brook Catchment (tributary of the River Idle)
GB104028058130	Poulter from Source to Millwood Brook
GB104028058110	Idle from River Ryton to River Trent
GB104028058100	Ryton from Anston Brook to Idle
GB104028058050	Sookholme Brook from Source to River Meden
GB104028058190	Hodsock Brook (to Old Coates Dyke)
GB104028052980	Gallow Hole Dyke from Source to Rainworth Water
GB104028058092	Idle from Tiln to River Ryton
GB104028058080	Maun from Rainworth Water to River Poulter
GB104028058060	Meden from Sookholme Brook to River Maun
GB104028058091	Idle from Maun/Poulter Confluence to Tiln
GB104028058020	Meden from Source to Sookholme Brook
GB104028058170	Owlands Wood Dyke from Source to Hodscok Brook
GB104028058240	Warping Drain Catch (tributary of Trent)
GB104028058440	Mother Drain from Source to River Torne
GB104028064340	Torne / Three Rivers from Mother Drain to River Trent
GB104028064330	Hatfield Waste Dr (tributary of Torne/Three Rivers)
GB104028058410	Torne from St Catherine's Well Stream to Mother Drain

An additional seven WFD water bodies that were not screened into the assessment during the first phase of the study have since been identified as being of at least Good status for macroinvertebrates, (based on the 2016 classification). These have now been screened into the assessment are shown in Table 4.7 below.

Table 4.7 Additional WFD water bodies graded as High or Good based on the WFD assessment of the macroinvertebrate community in 2016

Water body identification	Water Body
GB104028058162	Ryton (to Anston Brook)
GB104028058140	Poulter from Millwood Brook to River Maun
GB104028058040	Maun from Vicar Water to Rainworth Water
GB104028064350	North Soak Drain (trib of R Torne / Three Rivers)
GB104028058430	S Lev Engine Dr / Upper Warping Drain Catch
GB104028058380	Ruddle (Paper Mill Dyke) from Source to R Torne
GB104028058370	Torne from Source to Ruddle (Paper Mill Dyke)

Investigation walkover reports from 2010 to 2019 were also reviewed for general comments on the state of the water bodies and observations on factors that may be affecting the biological state. These reports were compiled for WFD waterbodies where failures to achieve Good status for the biological elements were identified between 2009 and 2019.

Screened in waterbodies were also investigated for macrophytes and phytobenthos (see Section 4.6).

4.5.2 Data

WFD macroinvertebrate monitoring data was available between 2010 and 2019 for all of the 25 water bodies screened into the assessment.

The monitoring data was generally sparse, with usually a single monitoring site for each waterbody. Exceptions to this include the River 'Idle from River Ryton to River Trent' (GB104028058110), the River 'Meden from Sookholme Brook to River Maun' (GB104028058060) and 'Sookholme Brook from Source to River Meden' (GB104028058050) waterbodies.

4.5.3 Analysis

Sensitivity of the macroinvertebrate communities to flow reduction was assessed using LIFE (Lotic-invertebrate Index for Flow Evaluation) [31] scores at a species level. LIFE scores provide an assessment of the impact of variable flows on benthic macroinvertebrate communities. Where more than one sample per year was available, annual mean LIFE scores were calculated. As LIFE scores for a community generally vary from 5.5 to 8.5, categories for the LIFE scores index were defined as follows (where High indicates communities adapted to fast flowing conditions): Low = below 6.5; Moderate = 6.6 to 7.5; and High = above 7.6.

Sensitivity of the macroinvertebrate communities to fine sediments was also assessed using Proportion of Sediment-sensitive Invertebrates (PSI) scores[32], at a species level. The PSI index provides an assessment of the extent to which the river bed is composed of, or covered by, fine sediments. PSI scores were interpreted using the following thresholds and terminology: 81-100 = Minimally sedimented; 61-80 = Slightly sedimented; 41-60 = Moderately sedimented; 21-40 = Sedimented; and 0-20 = Heavily sedimented.

In addition to the interpretation scales described above, the River Invertebrate Classification Tool (RICT) was used to contextualise the scores. It deploys the RIVPACS (River Invertebrate Prediction And Classification System) model to predict site specific reference values (based on various physical parameters of the sample sites, including altitude, gradient, distance from source and substrate present and alkalinity) against which the scores can be evaluated. The model generates expected values for each metric so that observed/expected ratios can be derived (referred to as Environmental Quality Index (EQI)), which are then are then multiplied by a correcting factor to generate Environmental Quality Ratios (EQR). EQRs are then used for WFD classifications (High, Good, Moderate, Poor, Bad).

For LIFE scores, an EQI of 0.94 was used as a threshold for demonstrating impacts of low flows, following discussions with the Environment Agency, although similar thresholds of 0.93 are also given in the literature[33].

[31] Extence C., Balbi D. and Chadd R. (1999) River flow indexing using british benthic macroinvertebrates: a framework for setting hydroecological objectives. Regul. Rivers: Res. Mgmt. 15: 543–574

[32] Extence C., Chadd R., England J., Dunbar M.J., Wood P.J., Taylor E.D. (2013) The assessment of fine sediment accumulation in rivers using macro-invertebrate community response. River Res. Applic. 29: 17-55.

[33] Clarke R.T., Armitage P.D., Hornby D., Scarlett P. & Davy-Bowker J. (2003), Investigation of the relationship between the LIFE index and RIVPACS - Putting LIFE into RIVPACS. Environment Agency.

For PSI scores, following previous discussions with the Environment Agency an EQI of 0.70 has been used as a threshold for demonstrating the impact of fine sediments, although a threshold of 0.90 is also cited in the literature[34].

Other biotic indices, such as ASPT (Average Score Per Taxon), NTAXA (Number of taxa) and BMWP (Biological Monitoring Working Party) scores were also used in order to assess sensitivity of macroinvertebrate communities to pollution, which may be exacerbated through flow reductions. For ASPT and NTAXA the ratio between the value derived from a sample and the excepted value for a given water body in natural conditions, known as the Environmental Quality Index (EQI), was calculated. Where more than one sample per year was available, annual mean EQIs were calculated and assigned an ecological status class (ASPT EQI>0.97 = High, EQI > 0.86 = Good, EQI > 0.72 = Moderate, EQI > 0.53 = Poor, EQI < 0.53 = Bad; and NTAXA EQI>0.8 = High, EQI > 0.68 = Good, EQI > 0.56 = Moderate, EQI > 0.47 = Poor, EQI < 0.47 = Bad).

4.5.4 Water Framework Status

The 2016 (Cycle 2) WFD Macroinvertebrate status for both catchments is indicated in Figure 4.7.

Seven of the 12 Torne waterbodies (with Warping Drain) were reported as at least Good status in 2016. The other five were reported to be Moderate status.

Fourteen of the 25 Idle waterbodies were reported as at least Good status in 2016. The other eight were reported to be Moderate status.

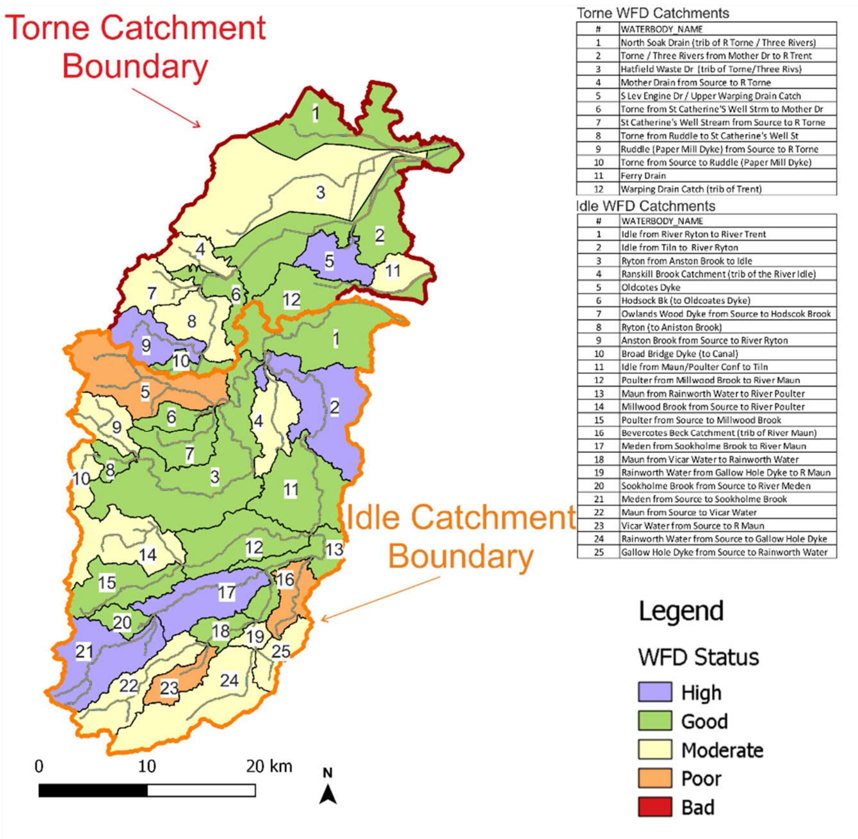

Figure 4.7 Macroinvertebrate WFD waterbodies and status as of 2016 (Cycle 2) in the Idle and Torne catchments

[34] JNCC (2014), Common Standards Monitoring Guidance for Rivers

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4.5.5 River Torne catchment

The nine River Torne WFD waterbodies screened in for detailed assessment have been considered further. A summary of the WFD macroinvertebrate data for these water bodies is presented in Table 4.8 below.

Table 4.8 Macroinvertebrate data summary for the WFD waterbodies in the River Torne catchment

Waterbody name (ID)	Data summary
Torne / Three Rivers from Mother Dr to R Trent (GB104028064340)	Auckley - data from 2010 to 2019 show moderate to high (ASPT 3.69 to 4.68 and NTAXA 13 to 26) quality, and communities adapted to slow flows and heavy sedimentation. EQIs for LIFE and PSI scores show an impact from flows and fine sediment Rossington Bridge - data from 2013 and 2015 show good to high (ASPT 4.09 to 5.04 and NTAXA 19 to 26) quality, and communities adapted to slow flows and heavy sedimentation. EQIs for LIFE and PSI scores show an impact from flows and fine sediment Hirst Priory, Anglers CP - data from 2010 to 2019 show moderate to good (ASPT 4.09 to 5.04 and NTAXA 19 to 26) quality, and communities adapted to slow flows
Hatfield Waste Dr (trib of Torne/Three Rivs) (GB104028064330)	Hirst Priory Above Golf Course - data from 2011 to 2019 show moderate to good (ASPT 3.58 to 4.67 and NTAXA 11 to 28) quality, and communities adapted to slow flows and heavy sedimentation. EQIs for LIFE and PSI scores show no impact from flows but an impact from fine sediment Diggin Dyke at Holmewood Farm - data from 2016 show moderate to good (ASPT 3.55 to 3.73 and NTAXA 11 to 15) quality, and communities adapted to slow flows. The EQI for the LIFE score shows an impact from flows. No PSI data available at this site. Fores Drain Nutwell - data from 2016 show poor to bad (ASPT 3.58 to 4.17 and NTAXA 12 to 18) quality, and communities adapted to slow flows and heavy sediment. The EQIs for LIFE and PSI scores show an impact from flows and sedimentation Hirst Priory (North Level Engine Drain) - data from 2016 show poor to high (APST 5.55 to 5.67 and NTAXA 11 to 21) quality, and communities adapted to slow flows. The EQI for the LIFE score shows no impact from flows. Confluence Hatfield Waste Drain - data from 2016 show poor to moderate (APST 3.63 to 3.64 and NTAXA 15 to 16) quality, and communities adapted to slow flows. The EQI for the LIFE score show some impacts from flows. PSI scores not available
Mother Drain from Source to R Torne (GB104028058440)	Rossington Bridge - data from 2013 and 2017 show moderate to high quality (NTAXA 24 to 26, ASPT 4.42 to 4.54), with communities adapted to slow to moderate flow velocities and heavily sedimented conditions. Analyses of the EQIs indicate communities impacted by flow pressure and sedimentation
Torne from St Catherine's Well Strm to Mother Dr (GB104028058410)	Torne Bridge - data from 2010 and 2015 show good quality (NTAXA 17 to 28, ASPT 4.76 to 5.07), with communities adapted to slow to moderate flow velocities.

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Waterbody name (ID)	Data summary
Warping Drain Catch (trib of Trent) (GB104028058240)	Owston Ferry (SK7990098900) - data from 2013 to 2015 show moderate to good (ASPT 34.63 to 4.89 and NTAXA 13 to 22) quality, and communities adapted to slow flows. EQIs do not show evidence of flow pressures. No PSI data available for this site
North Soak Drain (trib of R Torne / Three Rivers)(GB104028064350)	Keadby (SE 83562 12130) - data from 2013 and 2016 generally show moderate quality (ASPT 3.64 to 4.20 and NTAXA 14 to 18). Communities recorded are adapted to slow flows (LIFE 5.93 – 6.40) and heavily sedimented conditions (PSI 18.8) where data available. The EQIs for LIFE and PSI scores show an impact from flows and sedimentation. Crowle Station (SE 78099 11037) - data from 2011 to 2018 generally show moderate to high quality (ASPT 3.42 to 4.68 and NTAXA 12 to 21). Communities recorded are adapted to slow flows (LIFE 5.1 – 6.0) and heavily sedimented conditions (PSI 1.9 – 5.7). The EQIs for LIFE and PSI scores generally do not show an impact from flows and sedimentation.
S Lev Engine Dr / Upper Warping Drain Catch (GB104028058430)	Tunnel Pits (SE 74093 03939) - data from 2013 and 2014 generally show high quality (ASPT 4.5 – 4.7 and NTAXA 19 to 23), above expected values for this type of watercourse. Communities recorded are adapted to slow flows (LIFE 5.0 – 6.0) and heavily sedimented conditions (PSI 10.3 – 23.1) where data available. The EQIs for LIFE and PSI scores show some impacts from flows and sedimentation pressures on various occasions, indicating that the watercourse is already impacted by flow abstractions.
Ruddle (Paper Mill Dyke) from Source to R Torne (GB104028058380)	Tickhill (SK 58400 92780) - data from 2011 and 2015 show very variable quality, in terms of what would expected values for this type of watercourse and ranging from Bad to High quality (ASPT 4.3 – 5.6 and NTAXA 11 – 20). In 2015 communities recorded were adapted to high flow velocities (LIFE 8.0 – 8.2) and slightly sedimented conditions (PSI 64.5 – 75.0). The EQIs for LIFE and PSI scores for this year do not indicate impacts from flows and sedimentation pressures. However, in 2011, no LIFE scores or PSI scores were generated .
Torne from Source to Ruddle (Paper Mill Dyke) (GB104028058370)	Low Common (SK 60393 92390) - data from 2011, 2013 and 2015 generally show variable quality, ranging from Poor to High quality against expected values for this watercourse (ASPT 3.9 – 4.8 and NTAXA 10 to 16). Communities recorded are adapted to moderate to high flow velocities (LIFE 6.3 – 7.6) and sedimented to heavily sedimented conditions (PSI 7.0 – 33.3). The EQIs for LIFE scores show no impacts from flow pressures but do indicate that the communities are impacted by sedimentation pressures. Goole Bridge (SK 60712 93256) - data from 2011, 2013 and 2015 generally show variable quality, ranging from moderate to good quality (ASPT 3.9 – 4.3 and NTAXA 12 to 18) against expected values for this watercourse. Communities recorded are adapted to slow to moderate flow velocities (LIFE 6.0 – 7.4) and moderately sedimented to heavily sedimented conditions (PSI 12.5 – 50.0). The EQIs for LIFE scores indicate impacts of flow and sedimentation pressures, indicating that the watercourse is already impacted by flow abstractions.

Analysis of the species LIFE scores demonstrated that monitoring sites on two WFD water bodies are likely to support macroinvertebrate species and communities adapted to fast flows (LIFE scores > 7.5) on at least one of the sample sites for which data were available

- Ruddle (Paper Mill Dyke) from Source to R Torne (GB104028058380); and
- Torne from Source to Ruddle (Paper Mill Dyke) (GB104028058370)

Data from the Ruddle (Paper Mill Dyke) from Source to R Torne (GB104028058380) waterbody, the data from the single sample site available indicated communities adapted to high flow velocities and relatively sedimented conditions. They also showed that the communities are not currently impacted by flow or sedimentation pressures. Based on the available data, this waterbody is therefore considered as being sensitive to potential flow pressures.

Of the two sample sites on the Torne from Source to Ruddle (Paper Mill Dyke) (GB104028058370) waterbody, only one site, Low Common, indicate species adapted to moderate to fast flows. An analysis of the species LIFE scores EQIs indicated that the communities were not impacted by flow pressures. However, the data from the site indicated communities that are adapted to sedimented to heavily sedimented conditions, and also suggest that the watercourse is already impacted by sedimentation pressures. At Goole Bridge, the other sample site for which data were available on this waterbody, the samples were characterised by species adapted to slow to moderate flows and sedimented conditions, and the data indicates that at this location, the communities are already impacted by flow and sedimentation pressures.

The analyses of the LIFE and PSI scores for samples on the other waterbodies within this catchment indicated that they support macroinvertebrate communities generally adapted to slow to moderate flow velocities and heavy sedimentation. Analyses of the EQIs for both LIFE scores and PSI scores generally indicates that macroinvertebrate communities are likely to currently be impacted by flow pressures and fine sediments (EQIs > thresholds used to evaluate impact).

This is true for most monitoring sites for which baseline data was available, with the exception of Crowle Station (North Soak Drain (trib of R Torne / Three Rivers)(GB104028064350), 'Ferry Drain Owston' ('Warping Drain Catch (trib of Trent) (GB104028058240)') and 'Hirst Priory Above Golf Course' ('Hatfield Waste Dr (trib of Torne/Three Rivs') (GB104028064330)), for which macroinvertebrate communities do not appear to be impacted by flow pressures.

However, the ASPT indices indicated that all sites are generally of 'Good' to 'High' quality (on at least one occasion during the sampling period), indicating macroinvertebrate communities likely to be sensitive to changes in water quality. In terms of NTAXA, several of the waterbodies, notably the 'Torne / Three Rivers from Mother Dr to R Trent (GB104028064340)' (at 'Hirst Priory Anglers CP') and 'Hatfield Waste Dr (trib of Torne/Three Rivs) (GB104028064330)' (at 'Diggin Dyke at Holmewood Farm', 'Fores Drain Nutwell' and 'Hirst Priory North Level Engine Drain') indicate poor to moderate quality. As ASPT was Good to High at these sites, may indicate communities impacted by flows and / or fine sediments.

4.5.6 River Idle catchment

Sixteen of the WFD waterbodies screened in for detailed assessment were located in the River Idle catchment. A summary of the WFD macroinvertebrate data for these water bodies is presented in Table 4.9 below.

Table 4.9 Macroinvertebrate data summary for the WFD waterbodies in the River Idle catchment

Waterbody name (ID)	Data summary
Idle from River Ryton to River Trent (GB104028058110)	**Bawtry** - data show moderate to high (NTAXA 15 to 31 and ASPT 3.95 to 5.13) quality, and communities adapted to slow flows and heavy sedimentation. EQIs for LIFE and PSI scores show impact from flows and fine sediment. **Misterton** - data show moderate to high (NTAXA 13 to 32 and ASPT 3.85 to 5.33) quality, and communities adapted to slow flows and heavy sedimentation. EQIs for LIFE and PSI scores show impact from flows and fine sediment.
Idle from Tiln to River Ryton (GB104028058092)	**Mattersey** - data show good to high (NTAXA 19 to 27 and ASPT 4.75 to 5.19) quality, and communities adapted to moderate flows and heavy sedimentation. EQIs for LIFE and PSI scores show no impact from flows or fine sediment.

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Waterbody name (ID)	Data summary
	Chain Bridge Road - data show good to high (NTAXA 24 to 35 and ASPT 4.88 to 5.34) quality, and communities adapted to moderate flows and heavy sedimentation. EQIs for LIFE and PSI scores show no impact from flows or fine sediment.
Ryton from Anston Brook to Idle (GB104028058100)	**Scrooby** - data for 2013-2014 show good to high quality (NTAXA 18 to 32, ASPT 4.83 to 5.28), with communities adapted to moderate to fast flows. PSI scores not available and data insufficient to calculate EQIs. **Red Bridge Hodsock** - data for 2013-2014 show good to high quality (NTAXA 15 to 27, ASPT 4.42 to 5.11), with communities adapted to moderate to fast flows. PSI scores not available and data insufficient to calculate EQIs. **Ranby** - data for 2013-2014 show moderate to high quality (NTAXA 18 to 24, ASPT 4.29 to 5.00), with communities adapted to moderate flow velocities. PSI scores not available and data insufficient to calculate EQIs. **High Hoe Road** - data for 2013-2014 show good to high quality (NTAXA 19 to 27, ASPT 4.77 to 5.19), with communities adapted to moderate flow velocities. PSI scores not available and data insufficient to calculate EQIs.
Ranskill Brook Catchment (trib of the River Idle) (GB104028058220)	**Daneshill Road** - data from 2013 and 2015 show moderate to high (ASPT 4.43 to 5.14 and NTAXA 14 to 28) quality, and communities adapted to slow flows and sedimented to heavily sedimented conditions. **B6045** - data from 2010 to 2018 show moderate to good (ASPT 3.78 to 4.71 and NTAXA 16 to 29) quality, and communities adapted to slow to moderate flows and sedimentation. EQIs for LIFE and PSI scores show an impact from flows and fine sediment
Hodsock Bk (to Old Coates Dyke) (GB104028058190)	**A60 Costhorpe** - data indicative of moderate to good quality (ASPT 4.53 to 5.1, NTAXA 17 to 20), with communities adapted to fast flows
Owlands Wood Dyke from Source to Hodscok Brook (GB104028058170)	**Cornmill Farm** - data from 2013 and 2014 showed high quality (ASPT 4.9 to 5.1 and NTAXA 10 to 21) and communities adapted to fast flows. EQIs for LIFE and PSI scores show no impact from flows and or sedimentation.
Idle from Maun/Poulter Conf to Tiln (GB104028058091)	**Gamston -** data from 2013 and 2015 show high quality (NTAXA 26 to 29, ASPT 5.28 to 5.35), with communities adapted to moderate flow velocities and sedimented conditions. **Bolham Lane** - data from 2013 and 2015 show good to high quality (NTAXA 22 to 23, ASPT 4.87 to 4.91), with communities adapted to moderate flow velocities and sedimented conditions.
Maun from Rainworth Water to River Poulter (GB104028058080)	**Whitewater** - data from 2010 to 2019 show moderate to high (NTAXA 14 to 25 and ASPT 4.07 to 4.96) quality, and communities adapted to moderate flow velocities and sedimentation. EQIS for LIFE and PSI scores show communities impacted by flow pressures and potential impact from fine sediment **Markham Moor** - data from 2013 to 2014 show good to high (NTAXA 22 to 26 and ASPT 4.79 to 5.04) quality, and communities adapted to slow flows and sedimentation. EQIS for LIFE and PSI scores show potential impact from flows and fine sediment **West Drayton** - data for 2014 show good quality (NTAXA 19 to 23, ASPT 5.32 to 5.96), with communities adapted to moderate flows and sedimented conditions, with however no evidence of flow or sedimentation pressure.

Waterbody name (ID)	Data summary
Poulter from Source to Millwood Brook (GB104028058130)	**Nether Langwith -** data from 2010 to 2019 show good to high (NTAXA 19 to 27 and ASPT 4.74 to 5.96) quality, and communities adapted to fast flows and slight sediment. EQIs for LIFE and PSI scores show no impact from flows or fine sediment. **Cuckney** - data from 2010 to 2019 show moderate to good (NTAXA 16 to 25 and ASPT 3.64 to 4.96) quality, and communities adapted to moderate flows and sedimentation. EQIs for LIFE and PSI scores show an impact from flows and it is likely that there is an impact from fine sediment
Meden from Sookholme Brook to River Maun (GB104028058060)	**Warsop Mill** - data for 2013-2014 show good to high quality (NTAXA 20 to 24, ASPT 5.04 to 5.3), with communities adapted to fast flows and unsedimented conditions. LIFE scores and PSI EQIs do not show flow or sedimentation pressure **Thoresby** - data for 2012-2013 show good to high quality (NTAXA 24 to 27, ASPT 4.96 to 5.04), with communities adapted to moderate flows.
Sookholme Brook from Source to River Meden (GB104028058050)	**Sookholme** - data from 2012 and 2014 show good to high quality (NTAXA 21 to 24, ASPT 50.5 to 5.29), with communities adapted to moderate flow velocities and sedimented conditions, with however no evidence of potential flow pressure. **Shire Brook Confluence Sookholme Brook** - data from 2014 shows high quality (ASPT / NATXA), with communities adapted to moderate flow velocities and sedimented conditions, with evidence of potential flow and sediment pressure.
Meden from Source to Sookholme Brook (GB104028058020)	**Pleasley** - data from 2013-2014 show good to high (NTAXA 17 to 22 and ASPT 4.53 to 5.45) quality, and communities that are adapted to moderate to fast flows and slight sedimentation. EQIs for LIFE and PSI scores show no impact from flows or fine sediment **Littlewood** - data from 2010 to 2018 show good to high (NTAXA 17 to 23 and ASPT 5.27 to 5.95) quality, and communities that are adapted to fast flows and slight sedimentation. EQIs for LIFE and PSI scores show no impact from flows or fine sediment
Gallow Hole Dyke from Source to Rainworth Water (GB104028052980)	**Rufford Park** - data from 2010 and 2014 show moderate to good quality (NTAXA 12 to 22, ASPT 3.7 to 4.45), with communities adapted to moderate flow velocities.
Ryton (to Aniston Brook) (GB104028058162)	Aston Grange Footbridge (SK 5365082270) - data from 2013 and 2014 generally show good to high quality (ASPT 4.8 – 5.3 and NTAXA 16 to 24) and are in line with what would be expected for watercourse of this type. Communities recorded are adapted to moderate to high flow velocities (LIFE 7.3 – 7.8) and moderately sedimented to sedimented conditions (PSI 27.0 – 58.0). The EQIs for LIFE scores do not indicate impacts of flow pressures, while EQIs for sedimentation pressures indicate impacts from sedimentation.
Poulter from Millwood Brook to River Maun (GB104028058140)	Normanton Bridge (SK 64864 75745) – data from 2010 show moderate to good quality (ASPT 4.4 to 4.6 and NTAXA 23 to 24) in terms of what would be expected for a watercourse of this type. Communities recorded were adapted to high flow velocities in 2010 (LIFE 8.0), but low flow velocities in 2015 (LIFE 6.0). EQIs indicate flow impacts in 2015 but not in 2010. Communities also indicative of sedimented to highly sedimented conditions (PSI 6.1 – 25.0) and generally indicate impacts from sedimentation. Elksey (SK 69965 7245) - data from 2010 to 2019 show good to high quality (ASPT 3.9 – 5.6 and NTAXA 8 to 32) compared to what would be expected for this type of watercourse, with the exception of one survey in 2019. Communities recorded are generally adapted to low to moderate flow velocities (LIFE 6.2 – 7.1) and sedimented to heavily sedimented conditions (PSI 6.7 – 60.0), with evidence of flow and sedimentation pressures.

Waterbody name (ID)	Data summary
	Crookford (SK 67177 75202) - data from 2010 to 2019 show moderate to high quality (ASPT 4.1 – 5.6 and NTAXA 14 to 17) compared to what would be expected for this type of watercourse, with higher quality recorded in most recent surveys (since 2015). Communities recorded are generally adapted to moderate to high flow velocities (LIFE 6.7 – 7.8) and moderately sedimented to heavily sedimented conditions (PSI 16.7 –57.1), with evidence of flow and sedimentation pressures frequently recorded. Carburton (SK 60678 72745) - data from 2010 and 2015 show moderate quality (ASPT 3.9 – 4.1 and NTAXA 17 to 23) compared to what would be expected for this type of watercourse. Communities recorded are generally adapted to low flow velocities (LIFE 5.8 – 6.0) and heavily sedimented conditions (PSI 4.4 – 6.3), with evidence of flow and sedimentation pressures.
Maun from Vicar Water to Rainworth Water (GB104028058040)	Edwinstowe (SK 62701 66465) - data from 2012, 2013 and 2014 generally show moderate to good quality (ASPT 4.7 – 5.4 and NTAXA 14 to 19). Communities recorded are generally adapted to moderate to high flow velocities (LIFE 7.0 – 8.3) and slightly sedimented to moderately sedimented conditions (PSI 27.0 – 58.0). The EQIs for LIFE and PSIs scores generally do not indicate impacts of flow or sediments pressures, except on 1 and 2 occasions of the 6 sampling occasions (respectively).

Analysis of the species LIFE scores demonstrated that monitoring sites on the following WFD waterbodies are likely to support macroinvertebrate species and communities adapted to fast flows (LIFE scores > 7.5).

- Meden from Source to Sookholme Brook (GB104028058020);
- Meden from Sookholme Brook to River Maun (GB104028058060);
- Poulter from Source to Millwood Brook (GB104028058130) at 'Nether Langwith';
- Owlands Wood Dyke from Source to Hodscok Brook (GB104028058170) at 'Cornmill Farm';
- Hodsock Brook (to Old Coates Dyke) (GB104028058190);
- Ryton (to Aniston Brook) (GB104028058162);
- Poulter from Millwood Brook to River Maun (GB104028058140);and
- Maun from Vicar Water to Rainworth Water (GB104028058040).

Apart from Maun from Vicar Water to Rainworth Water (GB104028058040), Poulter from Millwood Brook to River Maun (GB104028058140)and 'Hodsock Brook (to Old Coates Dyke)' (GB104028058190), (for which data was insufficient to calculate LIFE score EQIs, analysis of the species LIFE scores) EQIs indicated that none of these sites are impacted by flow pressures.

Analysis of the PSI scores for these water bodies also indicates that the majority are 'slightly sedimented' to 'moderately sedimented', with no clear evidence of impacts from sedimentation (EQIs > 0.70 threshold for these sites). However, the Poulter from Millwood Brook to River Maun (GB104028058140);and Maun from Vicar Water to Rainworth Water (GB104028058040) recorded communities more typical of sedimented sites, and also indicated that the sites were also subject to sedimentation impacts.

The majority of the results indicate that the watercoursesare generally of 'Good' to 'High' WFD class in terms of ASPT and NTAXA, indicating macroinvertebrate communities likely to be sensitive of changes in water quality.

These watercourses are therefore likely to be the most sensitive to potential impacts (i.e. changes in flows, water quality and increased sedimentation) from high flow abstraction.

However, for the 'Poulter from Source to Millwood Brook' (GB104028058130) and 'Owlands Wood Dyke from Source to Hodscok Brook' (GB104028058170), data for other monitoring sites ('Cuckney' and 'Owlands Wood Dyke Confl. Oldcotes Dyke' respectively) indicate potential flow pressures (EQIs below threshold of 0.94), and also sedimentation issues for the River Poulter at 'Cuckney'). For both water bodies, the most sensitive sites appear to be in the most upstream stretches.

Review of the species present within these watercourses demonstrated the presence of several species of caddisfly, mayfly and stonefly that require fast flowing, well oxygenated waters with clean stony substrate (pebbles, cobbles). These include the caddisfly species *Silo nigricornis*, *Silo pallipes*, *Goera Pilosa*, *Rhyacophila dorsalis and Brachycentrus subnubilus*, the mayfly species *Seratella ignita* and *Heptagenia sulphurea* and stonefly species *Leuctra hippopus* and *Isoperla grammatica*.

For two other water bodies ('Idle from Tiln to River Ryton' (GB104028058092) and 'Ranskill Brook Catchment (trib of the River Idle)' (GB104028058220)), although the LIFE scores are indicative of communities and species adapted to slower flows, analyses of the LIFE scores EQIs show no evidence of flow pressure on macroinvertebrate communities (EQIs > 0.94 threshold). These water bodies however seem to be impacted by excess in fine sediments, as shown by the PSI scores EQIs (< threshold), but they are usually of 'Good' to 'High' WFD class in terms of ASPT and NTAXA, indicating macroinvertebrate communities likely to be sensitive of changes in water quality.

Three water bodies ('Idle from River Ryton to River Trent (GB104028058110)', 'Maun from Rainworth Water to River Poulter (GB104028058080)' and 'Sookholme Brook from Source to River Meden (GB104028058050)') however appear to support macroinvertebrate communities adapted to slower flowing conditions and 'sedimented' to 'heavily sedimented' conditions. EQIs for samples on these waterbodies demonstrate communities currently impacted by flow pressure and excess fine sediments. Nevertheless, analyses of the ASPT and NTAXA indices show that they support communities likely to be sensitive to changes in water quality.

For Gallow Hole Dyke from Source to Rainworth Water (GB104028052980), the Idle from Maun/Poulter Conf to Tiln (GB104028058091) and Ryton from Anston Brook to Idle (GB104028058100) data was insufficient to assess flow and sedimentation sensitivity.

4.5.7 Potential effects of abstractions at time of high flow

Potential reduction in flow velocities and potential habitat degradation through increased sedimentation in the long term could lead to the loss of macroinvertebrate species such as those listed above, which require fast flows and clean stony substrate. This could eventually lead to changes in the structure and composition of the macroinvertebrate communities.

Therefore, watercourses within the River Idle catchment, such as the River Maun, the River Ryton, the River Meden, the upper reach of the River Poulter and potentially the upper reach of Owlands Wood Dyke appear to be at a greater risk of impacts from high flow abstraction, which could lead to changes in flow conditions and impact the caddisfly, mayfly and stonefly species listed above.

In terms of increased sedimentation, the River Poulter and the River Maun appear to be at a greater risk, with the potential loss of species such as the caddisfly, mayfly and stonefly species listed above.

Most of the watercourses from the River Torne catchment are likely to be less sensitive, as they are currently impacted by flow pressures and / or increased sedimentation. However, the data do indicate that Ruddle and an upstream section of the River Torne (from its source to the confluence with the Ruddle) is more sensitive to flow pressures. In addition, with regards to increased sedimentation risk, the River Ruddle appears to be most sensitive.

Once more detailed reviews of potential changes in the physical environment are assessed during Phase 2b we anticipate that the potential effects on macroinvertebrates can be assessed in further detail (noting that each species has specific micro-habitat preferences so responses may vary and be difficult to predict for individual species).

4.6 Macrophytes and Phytobenthos

4.6.1 Screening

Sensitive WFD waterbodies were screened in Phase 1 with regard to macrophytes and phytobenthos were screened on the basis of invertebrate classifications, as outlined in Section 4.5.1. In total 18 waterbodies were screened in during Phase 1 plus an additional 7 during this Phase of the study, as presented in Section 4.5.1.

4.6.2 Data

Some WFD macrophyte monitoring data through 2010 – 2019 was available for 24 of the 25 water bodies screened as having > Good macroinvertebrate status. Data was not available for the River 'Idle from Tiln to River Ryton' (GB104028058092).

The monitoring data was sparse, with usually a single monitoring site for each waterbody, with the exception of the River 'Idle from River Ryton to River Trent' (GB104028058110), the River 'Meden from Sookholme Brook to River Maun' (GB104028058060) and 'Sookholme Brook from Source to River Meden' (GB104028058050).

4.6.3 Screening and Analysis

WFD macrophyte data was reviewed to update the sensitivity assessment carried out during the first phase of the study. The most recent data available (2015 – 2019) was provided by the Environment Agency for the 18 water bodies screened in for assessment in the Idle and Torne catchments.

An initial review for flow sensitive communities was carried out, based on two biotic indices: mean flow rank (MFR) and the river macrophyte hydraulic index (RMHI). MFR is a biotic index based on macrophyte community tolerance to flow conditions. Scores of 2 or below represent plant communities that have a preference for slower flows, with scores greater than 2 being recorded from plant communities with higher flow preferences. The MFR scoring system has now been superseded by the RMHI, but it is still included in the Environment Agency analysis.

The RMHI biotic index comprises part of the LEAFPACS suite of indices used to assess WFD monitoring data and describes plant community preferences for flow conditions based on a scale of 1 to 10. Scores of 10 indicate a plant community with a preference for very slow or non-existent flows while scores of 1 reflect plant communities with a preference for very fast powerful flows.

RMHI scores of 1 are reserved for very high energy systems such as seen in mountain headwaters. The Torne and Idle catchments are lowland systems with very little altitudinal gradient change across the catchment to boost velocity and flow levels.

Only sites or water bodies with MFR scores greater than 2 and / or RMHI scores less than 7 (approximately equivalent to MFR score 2) were selected for a more detailed assessment of species and communities sensitivity. For those sites or water bodies, a detailed review of the data was undertaken to identify the key species that might be affected by high flow abstraction.

4.6.4 Water Framework Status

The 2016 (Cycle 2) WFD Macrophyte and Phytobenthos status for both catchments is indicated in Figure 4.8.

Three of the 12 Torne waterbodies were reported as at least Good status in 2016. The other nine were reported to be Moderate or Poor status or not assessed for macrophytes.

Nine of the 25 Idle waterbodies were reported as at least Good status in 2016. The other 15 were reported to be Moderate or Poor status or not assessed for macrophytes.

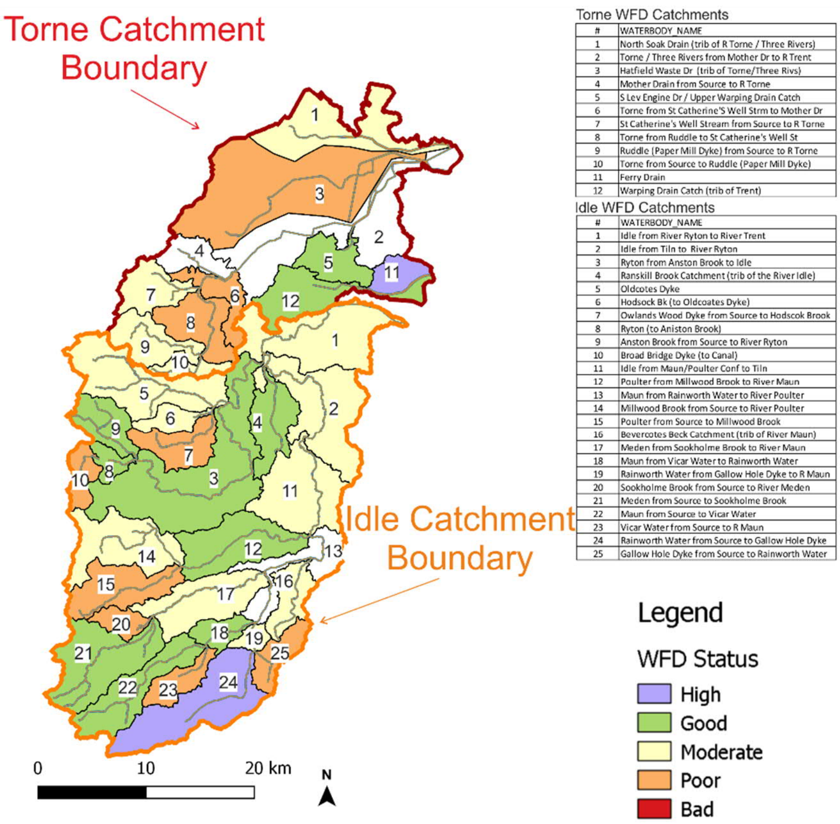

Figure 4.8 Macrophyte and Phytobenthos WFD waterbodies and status as of 2016 (Cycle 2) in the Idle and Torne catchments

4.6.5 River Torne Catchment

Review of the MFR and RMHI indices showed that monitoring sites on the nine waterbodies screened in within the River Torne catchment support macrophyte species and communities unlikely to be flow sensitive. However, the data was generally very limited for these waterbodies. A summary of the WFD macrophyte data is presented in Table 4.10 below.

Table 4.10 Macrophyte data summary data for the WFD waterbodies in the River Torne catchment

Waterbody name (ID)	Data summary
Torne / Three Rivers from Mother Dr to R Trent (GB104028064340)	Very limited data (1 sample only from 2013), suggesting species and communities unlikely to be flow sensitive (MFR score 1.5, RMHI score 8). 9 true aquatic species.
Hatfield Waste Dr (trib of Torne/Three Rivs) (GB104028064330)	Very limited data (1 sample only from 2013), suggesting species and communities unlikely to be flow sensitive (MFR score 1.6, RHMI score 8.12). 14 true aquatic species.
Mother Drain from Source to R Torne (GB104028058440)	Limited data (2 samples from 2012 and 2014), suggesting species and communities unlikely to be flow sensitive (MFR scores 1.75 to 1.77, RHMI scores 7.88 to 7.92). 8 to 9 true aquatic species.
Torne from St Catherine's Well Strm to Mother Dr (GB104028058240)	Very limited data (1 sample only from 2013), suggesting species and communities unlikely to be flow sensitive (MFR score 1.3, RMHI score 8.1). 9 true aquatic species.
Warping Drain Catch (trib of Trent) (GB104028058240)	Very limited data (1 sample only from 2012), suggesting species and communities unlikely to be flow sensitive (MFR score 1.29, RMHI score 7.99). 8 true aquatic species.

Waterbody name (ID)	Data summary
North Soak Drain (trib of R Torne / Three Rivers)(GB104028064350)	Limited data (2 samples from 2013 and 2016), suggesting species and communities unlikely to be flow sensitive (MFR scores 1.10 to 1.38, RHMI scores 8.17 to 8.37). 6 – 9 true aquatic species.
S Lev Engine Dr / Upper Warping Drain Catch (GB104028058430)	Limited data (2 samples for 2013 and 2014), suggesting species and communities unlikely to be flow sensitive (MFR score 1.50 to 1.67, RMHI score 7.69 to 7.82). 5 true aquatic species recorded, including water starwort (Callitriche sp. and Callitriche stagnalis), relatively flow sensitive.
Ruddle (Paper Mill Dyke) from Source to R Torne (GB104028058380)	Limited data (2 samples for 2013 and 2015), suggesting species and communities likely to be flow sensitive based on the RMHI score from 2015 only (6.78), with 2013 RMHI score indicating that the community is less sensitive (7.38). MFR scores (1.67 to 1.80) are not indicative of a flow sensitive community, however, as the RMHI supersedes MFR, these scores are considered less important and overall the communities are considered to be potentially flow sensitive, 5 - 6 true aquatic species, including *Fissidens* sp. (bryophytes) and floating sweet grass (*Glyceria fluitans* agg.), considered to be flow sensitive.
Torne from Source to Ruddle (Paper Mill Dyke) (GB104028058370)	Limited data (2 samples for 2013 and 2015). While the MFR score from 2013 (2) indicates that the community is flow sensitive, the 2015 MFR score (1.82) and RMHI scores from both surveys (7.85 to 7.95) suggest species and communities are unlikely to be flow sensitive. 5 – 9 true aquatic species recorded. The MFR score for 2013 (2.0) would be indicative of a flow sensitive community, however, as the RMHI supersedes MFR, this score are considered less important and overall the communities are considered not to be potentially flow sensitive.

4.6.6 River Idle Catchment

WFD monitoring macrophyte data was available for fifteen of the sixteen WFD waterbodies in the River Idle catchment that have been screened. A summary of the WFD macrophyte data is presented in Table 4.11 below.

Table 4.11 Macrophyte data summary data for the WFD waterbodies in the River Idle catchment

Waterbody name (ID)	Data summary
Idle from River Ryton to River Trent (GB104028058110)	Data (8 samples between 2010 and 2018) indicate species and communities unlikely to be flow sensitive (MFR scores 1.33 to 1.79, RHMI scores 8.05 to 8.46). 9 to 14 true aquatic species.
Idle from Tiln to River Ryton (GB104028058092)	No data
Ryton from Anston Brook to Idle (GB104028058100)	Limited data (2 samples in 2011 and 2014), indicate potentially flow sensitive species and communities (MFR scores 1.86 to 2.36, RMHI scores 2.42 to 7.28). 9 to 13 true aquatic species, including high cover in water crowfort (*Ranunculus sp.*) and presence of water starwort (*Callitriche truncata*)
Ranskill Brook Catchment (trib of the River Idle) (GB104028058220)	Very limited data (1 sample for 2013), suggesting potentially flow sensitive species and communities (MFR score 2.00, RMHI score 7.09). 8 true aquatic species, including bryophyte species that might be sensitive to reduced flows (*Amblystegium riparium*) and water starwort (*Callitriche* sp.)
Hodsock Bk (to Old Coates Dyke) (GB104028058190)	Data (4 samples for 2010 and 2014), suggesting potentially flow sensitive species and communities (MFR scores 2.00 and RMHI scores 6.79 to 6.84). 5 to 6 true aquatic species, including low cover of bryophytes species adapted to fast flows

Waterbody name (ID)	Data summary
Owlands Wood Dyke from Source to Hodscok Brook (GB104028058170)	Limited data (2 samples from 2013 and 2014), suggesting species and communities unlikely to be flow sensitive (MFR scores 1.50 to 1.70, RHMI scores 7.84 to 7.96). 5 to 8 true aquatic species.
Idle from Maun/Poulter Conf to Tiln (GB104028058091)	Very limited data (1 sample for 2013), suggesting species and communities unlikely to be flow sensitive (MFR score 1.87, RHMI score 7.6). 14 true aquatic species).
Maun from Rainworth Water to River Poulter (GB104028058080)	Limited data (3 samples from 2012 to 2014), suggesting potentially flow sensitive species and communities (MFR scores 2.00 to 2.1, RMHI scores 7.1 to 7.51). 9 true aquatic species, including water starwort (*Callitriche truncata*) and water crowfoot (*Ranunculus (Batrachian) spp., Ranunculus penicillatus subsp. pseudofluitans* and *Ranunculus fluitans*) species in high cover
Poulter from Source to Millwood Brook (GB104028058130)	Data (6 samples between 2010 and 2018) indicate potentially flow sensitive species and communities (MFR score 2.22 to 2.38, RMHI score 6.7 to 7.09). 8 to 11 true aquatic species, including high covers of water crowfoot (*Ranunculus (Batrachian) spp.*)
Meden from Sookholme Brook to River Maun (GB104028058060)	Limited data (2 samples from 2011) indicate potentially flow sensitive species and communities (MFR scores 2.11 to 2.67, RMHI scores 7.0 to 7.09). 6 to 9 true aquatic species, including high cover of water starwort (*Callitriche* sp.) and water crowfoot (*Ranunculus penicillatus subsp. pseudofluitans* and *Ranunculus sp*.) species at The Carrs Mtr site
Sookholme Brook from Source to River Meden (GB104028058050)	Limited data (3 samples from 2011 and 2014), suggesting potentially flow sensitive species and communities at Sookholme Moor and Spring Lane (MFR scores 2.00 and 2.25, RMHI scores 7.24 and 7.46). 3 to 6 true aquatic species, with however high starwort (*Callitriche sp.*) cover at Spring Lane. Other sites (Daneshill Road and Sookholme Moor) appear less sensitive
Meden from Source to Sookholme Brook (GB104028058020)	Limited data (3 samples from 2012 and 2014), indicate potentially flow sensitive species and communities (MFR scores 2.00, RMHI scores 7.2 to 7.41) 6 to 8 true aquatic species, including water starwort (*Callitriche stagnalis, Callitriche obstusangula*) and water crowfoot (*Ranunculus sceleratus*) species however in low cover of the channel
Gallow Hole Dyke from Source to Rainworth Water (GB104028052980)	Limited data (2 samples from 2011 and 2014) indicate potentially flow sensitive species and communities (MFR score 1.6 to 2.00, RMHI score 7.6 to 7.92). 4 to 5 true aquatic species, including water starwort (*Callitriche stagnalis*). High algal cover *(Enteromorpha sp., Cladophora sp.*)
Ryton (to Aniston Brook) (GB104028058162)	Limited data (2 samples from 2013 and 2014) indicate potentially flow sensitive species and communities (MFR score 6.74 to 6.61, RMHI scores 2.0 on both occasions). 8 true aquatic species recorded, including liverworts (*Pellia endiviifolia*) and bryophytes (*Fissidens* sp.), considered as being flow sensitive.
Poulter from Millwood Brook to River Maun (GB104028058140)	Limited data (2 samples for 2011 and 2015), suggesting species and communities unlikely to be flow sensitive (MFR score 1.2 0 to 1.54, RHMI score 7.81 to 8.03). 6 – 10 true aquatic species. High cover of algae (*Cladophora, Enteromorpha* spp.) recorded.
Maun from Vicar Water to Rainworth Water (GB104028058040)	Limited data (2 samples for 2012 and 2014), indicate potentially flow sensitive species and communities (MFR score 2.74 to 1.83, RMHI score 6.79 to 7.09) 7 - 8 true aquatic species including bryophytes (*Fissidens* sp. and *Fontinalis antipyretica*) and water starwort (*Callitriche truncata*) that are considered to be flow sensitive.

Analyses of the MFR and RMHI indices showed that monitoring sites on nine of the WFD water bodies are likely to support macrophyte communities and species adapted to fast flowing conditions (RMHI <7, MFR >2). These are as follows:

- Ranskill Brook Catchment (trib of the River Idle) (GB104028058220) – 'High' for macrophytes;
- Meden from Sookholme Brook to River Maun (Meden from Sookholme Brook to River Maun) – 'Good' for macrophytes;
- Poulter from Source to Millwood Brook (GB104028058130) – 'Good' for macrophytes;
- Ryton from Anston Brook to Idle (GB104028058100) – 'Good' for macrophytes;
- Maun from Rainworth Water to River Poulter (GB104028058080) – 'Moderate' for macrophytes
- Meden from Source to Sookholme Brook (GB104028058020) – 'Moderate' for macrophytes;
- Hodsock Bk (to Old Coates Dyke) (GB104028058190) – 'Moderate' for macrophytes;
- Gallow Hole Dyke from Source to Rainworth Water (GB104028052980) – 'Poor' for macrophytes; and
- Sookholme Brook from Source to River Meden (GB104028058050) – no WFD status for macrophytes.
- Ruddle (Paper Mill Dyke) from Source to R Torne (GB104028058380) – 'Good' status for macrophytes
- Ryton (to Aniston Brook) (GB104028058162) – 'Good' status for macrophytes
- Maun from Vicar Water to Rainworth Water (GB104028058040) – 'Good' status for macrophytes

The seven remaining water bodies ('Idle from River Ryton to River Trent' (GB104028058110), 'Owlands Wood Dyke from Source to Hodscok Brook' (GB104028058170) and 'Idle from Maun/Poulter Conf to Tiln' (GB104028058091), Poulter from Millwood Brook to River Maun (GB104028058140), Torne from Source to Ruddle (Paper Mill Dyke) (GB104028058370), North Soak Drain (trib of R Torne / Three Rivers)(GB104028064350) S Lev Engine Dr / Upper Warping Drain Catch (GB104028058430)) appear to support species and communities adapted to slower flowing conditions.

Detailed review of the macrophyte data for the 12 WFD water bodies identified above, which support macrophyte species and communities adapted to faster flows demonstrated that monitoring sites on the following watercourses are the ones supporting the most diverse macrophyte communities (with number of true aquatic species (i.e. not helophytes) between 7 and 11):

- the River Maun ('Maun from Rainworth Water to River Poulter' (GB104028058080));
- the River Meden ('Meden from Sookholme Brook to River Maun' (GB104028058050) and 'Meden from Source to Sookholme Brook' (GB104028058020)); and
- the River Poulter ('Poulter from Source to Millwood Brook' (GB104028058130))

In particular, they support several species of water starwort (*Callitriche* sp.) and water crowfoot (*Ranunculus* sp.), which are usually adapted to fast flowing and oxygenated waters, with clean gravel beds. Other species adapted to fast flows generally included several bryophyte species, such as *Fissidens crassipes, Fontinalis antipyretica* or *Amblystegium tenax*. Notably, high percentage cover of the channel by water crowfoot and water starwort was recorded in:

- the 'Maun from Rainworth Water to River Poulter' (GB104028058080) at 'Ollerton Mtr site': *Ranunculus fluitans, Ranunculus penicillatus subsp. penicillatus* and *Callitriche truncata*;
- the 'Meden from Source to Sookholme Brook' (GB104028058020) at 'The Carrs Warsop': *Ranunculus sp.* and *Ranunculus penicillatus subsp. pseudofluitans*;
- the 'Poulter from Source to Millwood Brook (GB104028058130)' at 'Nether Langwith': *Ranunculus (Batrachian) spp.* and *Ranunculus penicillatus subsp. pseudofluitans*.

Other WFD water bodies such as 'Ranskill Brook Catchment (trib of the River Idle)' (GB104028058220), the 'Ryton from Anston Brook to Idle' (GB104028058100) and 'Sookholme Brook from Source to River Meden (GB104028058050)' the 'Maun from Vicar Water to Rainworth Water' (GB104028058040) also support water starwort or water crowfoot species, such as *Callitriche obtusangula, Callitriche stagnalis, Callitriche truncata* and *Glyceria fluitans agg.,* but in low cover.

Therefore, communities on these water bodies might be less typical of fast flows and oxygenated rivers, however, this would need to be confirmed by collecting further data.

Review of the data also showed that water bodies such as 'Gallow Hole Dyke from Source to Rainworth Water' (GB104028052980), 'Poulter from Millwood Brook to River Maun' (GB104028058140) and 'Hodsock Bk (to Old Coates Dyke)' (GB104028058190) generally have high algal cover (*Enteromorpha sp., Cladophera sp.*), which could indicate issues such as flows and excessive nutrients.

4.6.7 Potential effects of abstractions at time of high flow

It is important to bear in mind that high flow abstraction is only likely to reduce spate flows during the winter period, a season when macrophytes generally die back and are largely dormant, hence having a potentially less pronounced impact on macrophyte communities and species than if summer flows were abstracted.

The potential impacts on macrophyte communities and species of abstracting during high (spate) flows are more likely to be through increased sedimentation in the long term (i.e. if spate flows are reduced, they might not be flushing sediments), which could impact on macrophyte habitats and species that require clean gravel beds for example.

Ranunculus fluitans communities generally occur in large rivers with moderate-to-fast flows and variable flow regime. They are considered vulnerable to impacts at a catchment scale, especially those modifying the flow regime. Diffuse pollution is also likely to be an issue, resulting in invasion by species such as *Potamogeton pectinatus* and *Elodea spp.*

Ranunculus penicillatus ssp. pseudofluitans-Callitriche obtusangula communities are typical of small, lowland rivers, with stable flows are stable and substrates dominated by sand, gravels and pebbles. Such communities are at risk from human impacts including flow regulation, abstraction, and introduced species.

In general, the physical habitat preferred by Callitricho-Batrachion communities is clean substrate and swift to moderate flow. Except for the channel margins (and localised deposits associated with macrophytes) the substrate should be predominantly free of silt[35].

These could lead to a decrease in abundances and distribution of species of water crowfoot and water starwort, such as Ranunculus fluitans, Ranunculus penicillatus subsp. penicillatus, Ranunculus sceleratus and Ranunculus (Batrachian) spp., Callitriche stagnalis, Callitriche obstusangula and Callitriche truncata, especially in reaches where they are dominant and extend across the channel.

Therefore, large watercourses within the River Idle catchment, the River Maun, the River Meden and the River Poulter appear to be at a greater risk of impacts from high flow abstraction, which could lead to changes in the macrophyte communities of those watercourses.

Watercourses from the River Torne catchment are likely to be less sensitive, as they are currently impacted by flow pressures and / or increased sedimentation.

4.7 Diatoms

4.7.1 Data and Analysis

WFD diatom data was collected by the Environment Agency from nine locations between 2005 and 2015. Diatoms are a less reliable indicator of high alkalinities (occurring in both catchments) than macrophytes and so the latter has increasingly been favoured for WFD classifications by the

[35] Hatton-Ellis TW & Grieve N (2003). Ecology of Watercourses Characterised by Ranunculion fluitantis and Callitricho-Batrachion Vegetation. Conserving Natura 2000 Rivers Ecology Series No. 11. English Nature, Peterborough.

Environment Agency. This explains why diatom sampling in both catchments has reduced in recent years.

Neverthless available data has been used to assess the nutrient status of the Idle and Torne catchment, using DARLEQ2 (Diatom for Assessing River and Lake Ecological Quality) and is based on a biotic metric called the trophic diatom index (TDI)[36]. DARLEQ2 forms one element of WFD assessment for ecological quality in “macrophytes and phytobenthos” analysis, which are evaluated separately and then combined to produce an overall classification for ecological quality, using the worst of either sub-element. TDI4 is the most recent version of the metric and is based on diatom community sensitivity to eutrophication, specifically sensitivity to phosphorous concentrations, where each taxon is assigned a score of 1 (nutrient sensitive) to 5 (nutrient tolerant).

From assessing the community assemblage and computing the overall TDI4 score (0 – 100: very low to very high nutrients), an Ecological Quality Ratio (EQR) can be calculated. Although TDI4 is primarily used to understand and identify nutrient enrichment of water bodies, other factors such as invertebrate grazing and hydromorphology can also influence the diatom assemblage and should be considered in tandem with trophic status. Ideally, two samples per year should be collected, one in the spring (March to May) and one in the autumn (September to November), although one sample in the summer (June to September) is also suitable if seasonal sampling is not possible. The resulting EQR (where 0 is Bad ecological status and 1 is High ecological status) is calculated based on a predicted reference value, which enables WFD classification of High, Good, Moderate, Poor or Bad.

Diatom assemblage data was only available for four of the sample sites. Four of the survey data points (two at Bawtry, one at Bolham Lane and one at Rossington Bridge) only report a TDI3 score, an earlier version of the TDI metric which uses different nutrient sensitivity scores for some taxa. Furthermore, on four occasions, diatom samples were collected during the spring period, without a corresponding summer or autumn sample. TDI scores calculated from surveying only once in spring/autumn, or which report TDI3 scores, should be interpreted with caution.

EQR data was also only available for two sites (A614 at Rainworth Water and Poulter and Nether Langwith), which both fell within the Idle catchment, therefore assigning a TDI class was only possible for the Idle at these sites. A summary of diatom data is presented in Table 4.12 below.

Table 4.12 Summary of Environment Agency Diatom data from 2005 - 2019

Site Name	Catchment	NGR	Date	TDI4	Taxa Data	TDI3	EQR	TDI4 Class
A614 at Rainworth Water	Idle	SK6472566713	30/04/2014	81	Y		0.35	Poor
A614 at Rainworth Water	Idle	SK6472566713	25/09/2014	79	Y		0.37	Poor
Bawtry	Idle	SK6560092700	06/07/2005	67	N	62		
Bawtry	Idle	SK6560092700	17/04/2007	65	N	66		
Bawtry	Idle	SK6560092700	08/10/2007	65	N	71		
Bawtry	Idle	SK6560292740	12/04/2010	63	N	65		
Bawtry	Idle	SK6560292740	25/10/2010	62	N	63		
Bawtry	Idle	SK6560292740	02/05/2013		N	59		
Bawtry	Idle	SK6560292740	16/10/2013		N	62		
Bolham Lane	Idle	SK7050082450	28/06/2005	64	N	68		

[36] Water Framework Directive - United Kingdom Advisory Group (UK-TAG), 2008. UK-TAG Lake Assessment Methods - Macrophytes and Phytobenthos: Phytobenthos - Diatom Assessment of Lake Ecological Quality (DARLEQ). SNIFFER, Edinburgh

AECOM

Site Name	Catchment	NGR	Date	TDI4	Taxa Data	TDI3	EQR	TDI4 Class
Bolham Lane	Idle	SK7050082450	16/08/2006	70	N	61		
Bolham Lane	Idle	SK7044082582	27/04/2015		Y	70		
Goole Bridge Tickhill	Torne	SK6060093200	08/04/2008	56	N	19		
Goole Bridge Tickhill	Torne	SK6060093200	24/09/2008	72	N	71		
Misterton	Idle	SK7660096200	01/07/2005	69	N	65		
Misterton	Idle	SK7660096200	20/07/2006	72	N	72		
Misterton	Idle	SK7660096200	17/04/2007	68	N	70		
Misterton	Idle	SK7660096200	08/10/2007	68	N	75		
Misterton	Idle	SK7646696231	27/04/2015	60	Y			
Poulter at Nether Langwith	Idle	SK5303470407	06/05/2010	64	N		1.16	High
Poulter at Nether Langwith	Idle	SK5303470407	07/10/2010	68	N		1.04	High
Poulter at Nether Langwith	Idle	SK5303470407	24/04/2013	44	N		1	High
Poulter at Nether Langwith	Idle	SK5303470407	05/05/2015	49	Y		1	High
Rossington Bridge	Torne	SK6280099600	11/05/2007	73	N	75		
Rossington Bridge	Torne	SK6280099600	24/10/2007	73	N	75		
Rossington Bridge	Torne	SK6290799638	20/04/2015		N	69		
Tiln Mtr Site	Idle	SK7030084200	28/06/2005	67	N	62		
Tiln Mtr Site	Idle	SK7030084200	16/08/2006	65	N	63		
Torne Bridge	Torne	SK6194498961	12/04/2010	65	N	71		
Torne Bridge	Torne	SK6194498961	25/10/2010	67	N	67		

Source: Environment Agency at https://data.gov.uk/dataset/94a92f06-4c2c-49c2-a64e-267332713c17/freshwater-and-marine-biological-surveys-for-diatoms-england

4.7.2 River Torne Catchment

4.7.2.1 Diatom assemblage data

No diatom assemblage data was available for sites in the Torne catchment, and so assessment beyond the TDI metric scores was not possible.

4.7.2.2 TDI4

Three sites (Goole Bridge Tickhill, Rossington Bridge and Torne Bridge) in the Torne catchment were sampled for diatoms between 2007 and 2015. All three sites were sampled seasonally, with TDI4 scores ranging from 56 to 73 in the spring, and 67 to 73 in the autumn. Rossington bridge had one additional diatom survey in the summer of 2015, however, TDI4 data was not available. The TDI3 score for this survey was 69, lower than the previous TDI3 scores of 75 recorded in the seasonal surveys in 2007.

4.7.2.3 EQR and water body classification

No EQR data was available for the Torne catchment, therefore an EQR classification could not be calculated. Desk study was completed for the WFD classifications based on macrophyte and phytobenthos for the water bodies at each sample site. Goole Bridge Tickhill was classified as Poor in 2015 and Moderate 2016, while Torne Bridge was classified as Poor from 2015 – 2017. Given that the assemblage is already primarily nutrient-tolerant, it is unlikely that future hydromorphological changes will impact the diatom assemblages, however, further data from a range of seasons and locations in the Torne catchment is required to confirm this.

4.7.2.4 Summary for River Torne catchment

Given the paucity of data from the River Torne catchment, it is not possible to fully assess the impact that changes to the hydromorphology will bring to the diatom assemblage. Existing data suggests that the River Torne catchment exhibits poor to moderate ecological quality, and it is therefore unlikely that additional changes to nutrient enrichment as a result of flow abstraction will significantly alter the diatom community, however further seasonal surveys across a longer temporal study period would be required to assess this.

4.7.3 River Idle Catchment

4.7.3.1 Diatom assemblage data

Four sites (A416 at Rainworth Water, Bolham Lane, Misterton and Poulter at Nether Langwith) had diatom assemblage data available and are presented in Figure 4.9. Species diversity can also be assessed by the Shannon-Wiener diversity index (H'), which considers both number of species and spread of abundance between species; a higher H' value indicates a higher level of species diversity, as demonstrated in Figure 4.10.

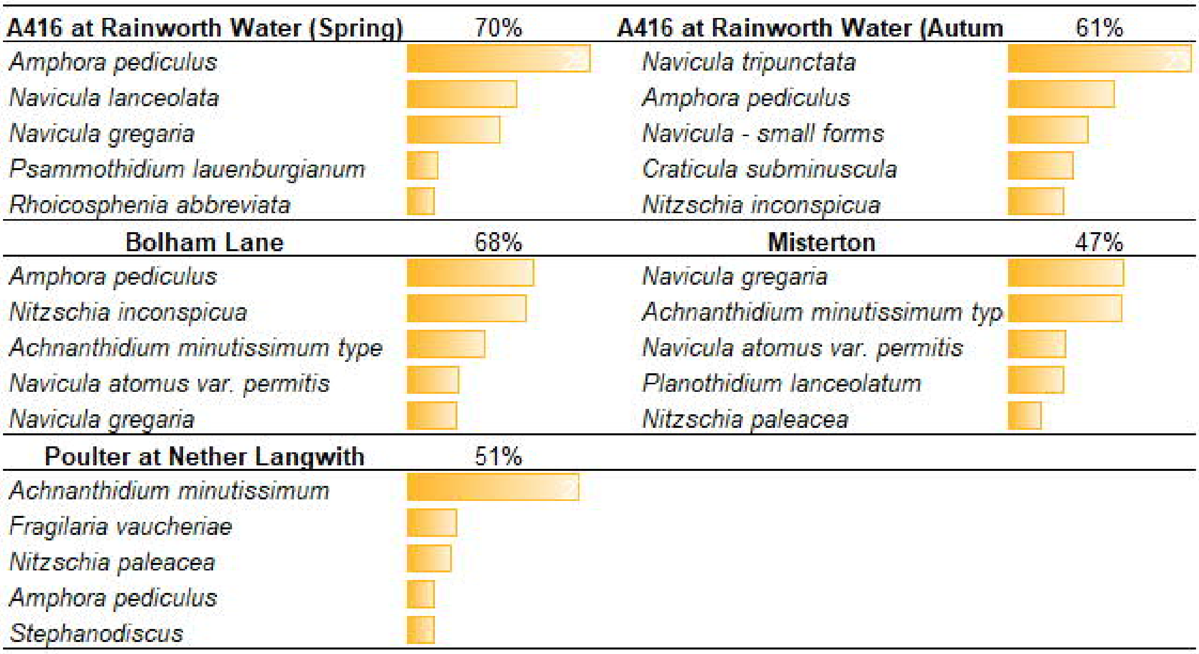

Figure 4.9 The five most abundant diatom taxa and their contribution to total abundance in the Idle catchment (2014 – 2015)

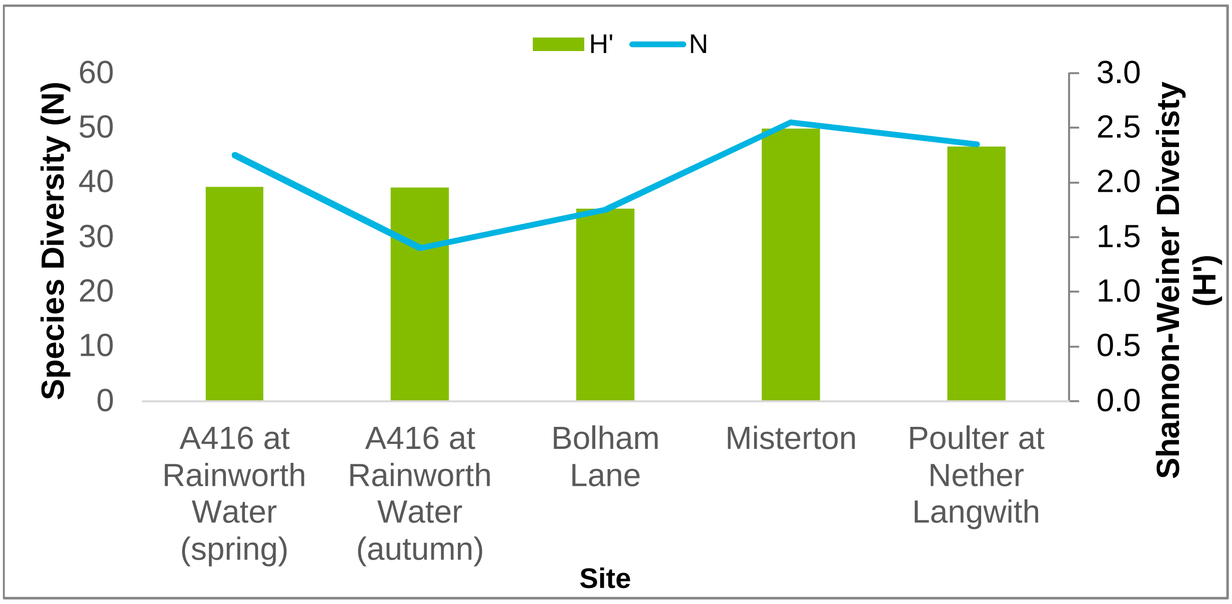

Figure 4.10 Species richness (N) and Shannon-Weiner diversity indices (H') for diatom assemblage data in the Idle catchment 2014-2015

4.7.3.2 A416 at Rainworth Water

A total of forty-five taxa were identified in the spring and 28 were identified in the autumn, with high abundance of nutrient-tolerant species including *Amphora pediculus* and *Navicula tripunctata.* Shannon-Weiner analysis produced a H' of 1.96 in the spring and 1.95 in the autumn, suggesting seasonal changes in nutrient enrichment on diversity is minimal.

4.7.3.3 Bolham Lane

A total of thirty-five taxa were identified in the spring with no corresponding survey in the autumn. The assemblage was dominated by *Amphora pediculus, Nitzschia inconspicua* and other nutrient-tolerant species. Shannon-Weiner analysis produced a H' of 1.8, the lowest of the sites analysed in the Idle catchment. Lower diversity and dominance of *A. pediculus* suggests nutrient enrichment in this area is likely inorganic. Given that this sample was analysed from the spring, and that phosphorous concentrations are generally higher in lowland rivers during the summer/autumn, a change to the hydromorphological regime is unlikely to impact the diatom assemblage, although further seasonal surveys and information are required to confirm this. Misterton

A total of fifty-one taxa were identified in the spring, with no corresponding survey in the autumn. The assemblage was dominated by *Navicula gregaria,* with high abundance of other nutrient-tolerant species *Planothidium lanceolatum* and *Nitzschia palaecea.* High abundance of *Achnanthidium minutissimum type*, which has a lower nutrient sensitivity score of 2, suggests variable levels of nutrient enrichment. This is confirmed by the Shannon-Weiner analysis which produced a H' of 2.5, which suggests Misterton exhibits the highest species diversity of the sites analysed in the Idle catchment. This is possibly due to high abundance of motile species *Navicula gregaria* which is able to utilise nutrient resources in the water column that are unavailable to those living in a fixed/thicker biofilm. Therefore, changes to the hydromorphological regime may compromise this diversity. Having said this, as phosphorous concentrations tend to be higher in the summer/autumn particularly in lowland rivers, and as motile species are more commonly epiphytic rather than epilithic, additional seasonal surveys and further information about the substrate type (whether the sample was collected from macrophyte of rock substrate) would be required to confirm this.

4.7.3.4 Poulter at Nether Langwith

A total of forty-seven taxa were identified in the summer. The assemblage was dominated by *Achnanthidium minutissimum type* and *Fragilaria vaucheriae* which show relatively high sensitivity to nutrient loading. Moderate abundances of nutrient-tolerant species such as *Nitzschia palaecea* and *Amphora pediculus* suggests variable levels of nutrient enrichment. This is confirmed by the Shannon-Weiner diversity index H' of 2.3, similar to Misterton. Changes to the hydromorphological regime that would alter the nutrient enrichment cycling in the Idle Catchment at Misterton would therefore likely affect the diatom community assemblage, where species which are nutrient generalists (rather than nutrient specialists) and are sensitive to eutrophication and would likely decrease. Further seasonal surveys across a larger temporal study period are required to confirm this.

4.7.3.5 TDI4

Six sites (A614 at Rainworth Water, Bawtry, Bolham Lane, Misterton, Poulter at Nether Langwith and Tiln Mtr Site) in the Idle catchment were sampled for diatoms between 2005 and 2015. Four of the sites were sampled seasonally (A614 at Rainworth Water, Bawtry, Misterton and Poulter at Nether Langwith) with one sample in spring and one in the autumn within the same year. Two sites (Bolham Lane and Tiln Mitr site) were only sampled during the summer. Additionally, four data points (one during 2013 at Poulter at Nether Langwith, and three during 2015 at Bolham Lane, Misterton and Poulter at Nether Langwith) were collected in the spring, without a corresponding autumn sample.

TDI4 scores ranged from 44 to 79 in the spring, and 62 to 81 in the autumn. TDI4 scores in the summer ranged from 64 to 72. The 2013 seasonal surveys at Bawtry did not have TDI4 data available, however the TDI3 scores were lower than the TDI3 scores recorded in the seasonal surveys in 2007 and 2010. Furthermore, TDI4 data was not available for the 2015 spring survey at Bolham, with no comparative spring sampling occurring at this site. Diatom DNA analysis was also undertaken on the 2015 A416 at Rainworth Water sample, which provided at TDI4 score of 69, although this methodology is not currently accepted for routine monitoring and assessment.

4.7.3.6 EQR and water body classification

EQR data was available for two sites in the Idle catchment. Samples taken at A416 at Rainworth Water indicated Poor ecological quality in 2014, with EQR scores from 0.35 to 0.37. Samples analysed from Poulter at Nether Langwith indicated high ecological quality between 2010 and 2015, however, samples in 2013 and 2015 occurred in the spring, without a corresponding summer/autumn survey. EQR scores for Poulter at Nether Langwith ranged from 1 – 1.16.

4.7.3.7 Summary for River Idle catchment

Overall, the available diatom data suggests that the impact of nutrient enrichment is highly variable across the Idle catchment, suggesting further hydromorphological changes could further impact ecological quality, particularly in more ecologically sensitive rivers such as the River Poulter. Desk study of WFD classifications based on macrophytes and phytobenthos for other sites along Rainworth Water confirm an ecological quality classification of Poor to Moderate from 2013 – 2016, while other sites along the River Poulter are classed as Poor to High. Additional survey data spanning a range of years and seasons at a larger range of sites is required to fully assess the impact of hydromorphological changes on a catchment scale. In particular, the impact of flow on the nutrient enrichment cycle (e.g. concentration of phosphorous in the summer) must be evaluated to assess the potential sensitivity of nutrient-generalist species to flow abstraction. It is recommended that monthly or seasonal water quality and diatom surveys are undertaken for at least one year (ideally three years) to establish baseline conditions.

4.8 Water Framework Directive

4.8.1 Overall Designations

A summary map of the overall 2016 WFD status is provided in Figure 4.11.

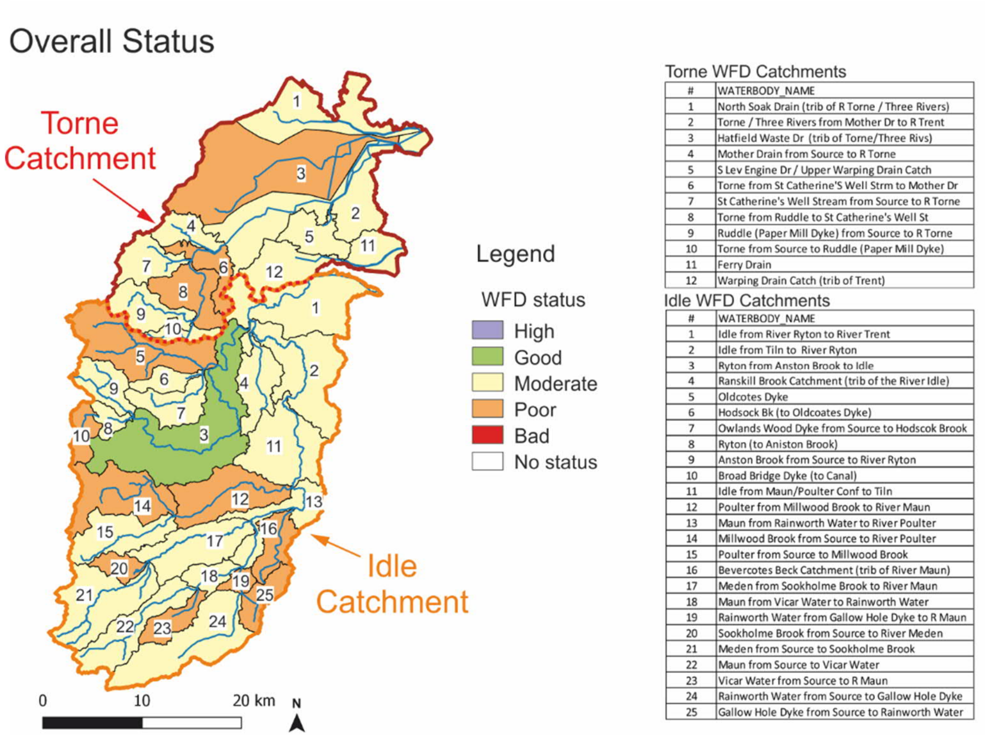

Figure 4.11 WFD Overall Status (2016) for Idle and Torne waterbodies

4.9 Data Gaps

4.9.1 Overview

Through our review some data gaps have been determined and our discussed below. Potentially some of these could be filled as part of Phase 2b, although project timing may make this unfeasible.

4.9.2 Protected Species and Invasive Species

Some of the key ecological data gaps are provided below:

- Up-to-date biological species records from the relevant biological records centres; and
- Up-to-date Local Wildlife Site citations and further details on the conservation value of the Local Nature Reserves.

4.9.3 Fisheries

Although the Environment Agency dataset is vast, there are numerous WFD waterbodies which are yet to be assessed for fish. The reason for this is it is not feasible to assess every waterbody and the Environment Agency have had to prioritise those which have a fisheries interest. To allow for a greater understanding of the fish assemblage within the Idle and Torne catchments, it is recommended that these are surveyed (Table 4.13).

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Table 4.13 The outstanding Idle and Torne WFD waterbodies which are yet to have fish surveys completed and a subsequent WFD fish status assigned

Catchment	Waterbody name	Waterbody ID
Torne	Ferry Drain Catchment (trib of Trent)	GB104028058241
Torne	North Soak Drain Catchment (trib of Torne/Three Rivers)	GB104028064350
Torne	Ruddle (Paper Mill Dyke) from Source to Torne	GB104028058380
Torne	S Lev Engine Drain Catchment (trib of Trent)	GB104028058430
Torne	Torne from Ruddle to St Catherine's Well Stream	GB104028058400
Torne	Torne from Source to Ruddle (Paper Mill Dyke)	GB104028058370
Idle	Anston Brook from Source to Ryton	GB104028058210
Idle	Bevercotes Beck Catchment (trib of Maun)	GB104028058070
Idle	Broad Bridge Dyke Catchment (trib of Chesterfield Canal)	GB104028058161
Idle	Gallow Hole Dyke Catchment (trib of Rainworth Water)	GB104028052980
Idle	Hodsock Bk (to Old Coates Dyke)	GB104028058190
Idle	Owlands Wood Dyke from Source to Hodscok Brook	GB104028058170
Idle	Rainworth Water from Gallow Hole Dyke to Maun	GB104028052970
Idle	Ranskill Brook Catchment (trib of Idle)	GB104028058220
Idle	Ryton from Chesterfield Canal to Anston Brook	GB104028058162
Idle	Sookholme Brook Catchment (trib of Meden)	GB104028058050
Idle	Vicar Water from Source to Maun	GB104028052950

4.9.4 Macroinvertebrates

Macroinvertebrate data was available for the 18 water bodies screened in the assessment. Data was not available for 2010 – 2019 for Hodsock Bk (to Old Coates Dyke) (GB104028058190). However, for six water bodies, the data was relatively sparse, with data being available from only one monitoring site.

For other water bodies, data pre-2015 was available. Additional post-2015 data was only available for the following water bodies:

- Idle from River Ryton to River Trent (GB104028058110);
- Idle from Tiln to River Ryton (GB104028058092)
- Ranskill Brook Catchment (trib of the River Idle) (GB104028058220)
- Owlands Wood Dyke from Source to Hodscok Brook (GB104028058170)
- Maun from Rainworth Water to River Poulter (GB104028058080)
- Poulter from Source to Millwood Brook (GB104028058130)
- Meden from Source to Sookholme Brook (GB104028058020)
- Torne / Three Rivers from Mother Dr to R Trent (GB104028064340)
- Hatfield Waste Dr (trib of Torne/Three Rivs) (GB104028064330)
- Warping Drain Catch (trib of Trent) (GB104028058240

4.9.5 Macrophytes

Additional macrophyte WFD monitoring data from 2015 – 2019 was only available for a limited number of WFD water bodies and sites, as follows:

- Idle from River Ryton to River Trent (GB104028058110);

- Maun from Rainworth Water to River Poulter (GB104028058080);
- Poulter from Source to Millwood Brook (GB104028058130); and
- Meden from Source to Sookholme Brook (GB104028058020).

For other water bodies, no additional data was available and therefore, the baseline will remain the same as presented in the report for the Phase 1 of the study.

4.10 Environmental Features Summary

4.10.1 Overview and review

A review of the sensitivity environmental features of each WFD waterbody in the Idle and Torne catchments has been undertaken. This is presented in Table 4.14 below.

Through our review it is recommended that the following waterbodies are examined through Phase 2b (due to potential effects on designated sites and/ or macroinvertebrates/ macrophytes / fish):

- Idle from River Ryton to River Trent
- Meden from Sookholme Brook to River Maun
- Millwood Brook from Source to River Poulter
- Poulter from Millwood Brook to River Maun
- Sookholme Brook from Source to River Meden
- Mother Drain from Source to R Torne
- Hatfield Waste Drain
- Torne / Three Rivers from Mother Dr to R Trent

In addition further studies on the Meden from Source to Sookholme Brook may be of value (though potentially less of a priority).

Diatom monitoring is recommended through the Idle catchment while data for Hodsock Brook is also notably lacking.

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Table 4.14 Review of Sensitivity of Environmental Features

WFD Waterbody	Physical Environment Sensitivity Review (see Section 3.8)	Nationally Designated Sites Warrant Further Attention?	Density of other important sites (e.g. LWS) / initial review	Macroinvertebrates	Macrophytes	Fish	Next Steps Review
Idle waterbodies							
Anston Brook from Source to River Ryton	Information indicates waterbody would be of low sensitivity to further abstraction.	No	Yes	Screened out	Screened out (based on macroinvertebrate status), however Good WFD status for macrophytes in 2016.	Potentially effects by increased siltation. No other significant effects predicted however.	No further studies recommended
Bevercotes Beck Catchment (trib of River Maun)	Information indicates waterbody would be of low sensitivity to further abstraction.	No	One site. Upland area so potentially limited effects?	Screened out	Screened out	Potentially effects by increased siltation. No other significant effects predicted however.	No further studies recommended
Broad Bridge Dyke (to Canal)	Information indicates waterbody would be of low sensitivity to further abstraction (noting that data is generally lacking).	No	No	Screened out	Screened out	Potentially effects by increased siltation. No other significant effects predicted however.	No further studies recommended
Gallow Hole Dyke from Source to Rainworth Water	Information indicates waterbody would be of low sensitivity to further abstraction.	No	No	Screened in though insufficient data to assess flow and sedimentation sensitivity	Screened in. Data indicates presence of species that may be sensitive to flow changes. Smaller watercourse though, so effects likely to be less significant than if in a larger watercourse.	Potentially effects by increased siltation. Macrophytes not considered to be significantly affected given timing of abstractions, so no knock on effect on fish.	No further studies recommended (with finite resources focussed elsewhere)
Hodsock Bk (to Oldcoates Dyke)	Information indicates waterbody would be of low sensitivity to further abstraction (noting that data is generally lacking).	No	Sites present though seemingly distant from river itself	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in. Data indicates presence of species that may be sensitive to flow changes. Smaller watercourse though, so effects likely to be less significant than if in a larger watercourse.	Potentially effects by increased siltation. Macrophytes not considered to be significantly affected given timing of abstractions, so no knock on effect on fish.	No further studies recommended (with finite resources focussed elsewhere)
Idle from Maun/ Poulter Conf to Tiln	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction	No	No	Screened in though insufficient data to assess flow and sedimentation sensitivity.	Screened in. Limited data indicates not sensitive to flow changes.	Limited impacts. Potential for floodplain habitat at times of high flows to be reduced.	No further studies recommended (with finite resources focussed elsewhere)
Idle from River Ryton to River Trent	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction	Yes- River Idle Washlands SSSI	Sites present, potential effects similar to those identified for National sites	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened in. Data indicates not sensitive to flow changes however.	No effects predicted.	**Further investigations recommended**
Idle from Tiln to River Ryton	Information indicates the channel may be of moderate sensitivity to further abstraction	No	Sites not in sensitive area	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened in although insufficient data to complete a review.	Potentially effects by increased siltation. Macrophytes not considered to be significantly affected given timing of abstractions, so no knock on effect on fish. Additional effects if macrophytes are affected.	No further studies recommended (with finite resources focussed elsewhere)
Maun from Rainworth Water to River Poulter	Information indicates the channel may be of moderate sensitivity to further abstraction	No	At upstream end though potentially not influenced by river	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened out	Potential for increased siltation and floodplain habitat at times of high flows to be reduced (both potentially affecting fish).	No further studies recommended (with finite resources focussed elsewhere)

WFD Waterbody	Physical Environment Sensitivity Review (see Section 3.8)	Nationally Designated Sites Warrant Further Attention?	Density of other important sites (e.g. LWS) / initial review	Macroinvertebrates	Macrophytes	Fish	Next Steps Review
Maun from Source to Vicar Water	Data generally lacking to ascertain potential sensitivity	No	Yes, several	Screened out	Screened out (based on macroinvertebrate status), however Good WFD status for macrophytes in 2016.	Hydromorphological effects unknown- may be associated effects on fish.	No further studies recommended
Maun from Vicar Water to Rainworth Water	Data generally lacking to ascertain potential sensitivity	No	At upstream end though potentially not influenced by river	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in. Review indicates species that may be sensitive to flow changes.	Hydromorphological effects unknown- may be associated effects on fish.	**Further investigations recommended**
Meden from Sookholme Brook to River Maun	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction	No	Yes, several	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in. Data indicates presence of species that may be sensitive to flow changes. Larger watercourse than others considered sensitive, which may compound any effects.	Potential siltation, reduced floodplain connection and knock on effects on macrophytes (each of which may impact upon fish)	**Further investigations recommended**
Meden from Source to Sookholme Brook	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction	No	Yes, several	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in. Data indicates presence of species that may be sensitive to flow changes. Smaller watercourse though (as from source), so effects likely to be less significant than if in a larger watercourse/ downstream.	Potential for increased siltation and floodplain habitat at times of high flows to be reduced (both potentially affecting fish).	**Further investigations recommended (Tier 2)**
Millwood Brook from Source to River Poulter	Data generally lacking to ascertain potential sensitivity	No	Yes, several	Screened out	Screened out (based on macroinvertebrate status), however Good WFD status for macrophytes in 2016.	Hydromorphological effects unknown- may be associated effects on fish.	No further studies recommended
Oldcotes Dyke	Information indicates the channel may be of moderate sensitivity to further abstraction	No	Sites present	Screened out	Screened out (based on macroinvertebrate status), however Good WFD status for macrophytes in 2016.	Hydromorphological effects unknown- may be associated effects on fish.	No further studies recommended (with finite resources focussed elsewhere)
Owlands Wood Dyke from Source to Hodscok Brook	Information indicates the channel may be of low to moderate sensitivity to further abstraction (noting data is lacking)	No	No	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in. Limited data indicates not sensitive to flow changes.	Potential for increased siltation and floodplain habitat at times of high flows to be reduced (both potentially affecting fish).	No further studies recommended (with finite resources focussed elsewhere)
Poulter from Millwood Brook to River Maun	Information indicates the channel may be of moderate sensitivity to further abstraction (noting data is lacking)	Yes - Clumber Park SSSI	Yes, several	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in. Review indicates species that macrophytes not sensitive to flow changes.	Hydromorphological effects unknown- may be associated effects on fish.	**Further investigations recommended**
Poulter from Source to Millwood Brook	Available information indicates waterbody (or parts of it) may be highly sensitive to effects of high flow abstraction	No	No	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in. Data indicates presence of species that may be sensitive to flow changes. Smaller watercourse though (as from source), so effects likely to be less significant than if in a larger watercourse/ downstream.	Potential for increased siltation and floodplain habitat at times of high flows to be reduced (both potentially affecting fish).	**Further investigations recommended**

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WFD Waterbody	Physical Environment Sensitivity Review (see Section 3.8)	Nationally Designated Sites Warrant Further Attention?	Density of other important sites (e.g. LWS) / initial review	Macroinvertebrates	Macrophytes	Fish	Next Steps Review
Rainworth Water from Gallow Hole Dyke to R Maun	Information indicates waterbody would be of low sensitivity to further abstraction.	No	One	Screened out	Screened out	Hydromorphological effects unknown- may be associated effects on fish.	No further studies recommended
Rainworth Water from Source to Gallow Hole Dyke	Information indicates the channel may be of low to moderate sensitivity to further abstraction	No	Yes, several at its upstream end	Screened out	Screened out (based on macroinvertebrate status), however Good WFD status for macrophytes and phyto benthos in 2016.	Potential for increased siltation and floodplain habitat at times of high flows to be reduced (both potentially affecting fish).	No further studies recommended
Ranskill Brook Catchment (trib of the River Idle)	Information indicates the channel may be of low to moderate sensitivity to further abstraction (noting data is contrasting and perhaps reflects different areas)	No	Yes	Screened in and considered to be sensitive to water quality changes.	Screened in. Very limited data indicates may be sensitive to flow changes.	Connection with floodplain at times of high flow unknown (and associated effect on fish habitat similarly unknown).	No further studies recommended
Ryton (to Anston Brook)	Data generally lacking to ascertain potential sensitivity	No	No	Screened in and considered to be most sensitive to sedimentation/ flow changes	Screened in – review indicates waterbody and macrophytes may be flow sensitive. Smaller watercourse though (as from source), so effects likely to be less significant than if in a larger watercourse/ downstream.	Potential for increased siltation and floodplain habitat at times of high flows to be reduced (both potentially affecting fish).	**Further investigations recommended (Tier 2)**
Ryton from Anston Brook to Idle	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction	No	Sites at upstream end	Screened in though insufficient data to assess flow and sedimentation sensitivity	Screened in. Limited data indicates presence of species that may be sensitive to flow changes. Larger watercourse than others considered sensitive, which may compound any effects.	Hydromorphological effects unknown- may be associated effects on fish. Potential effect on macrophytes which may in turn affect fish.	**Further investigations recommended**
Sookholme Brook from Source to River Meden	Available information indicates waterbody may be highly sensitive to effects of high flow abstraction (noting information is generally lacking in this reach)	No	No	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened in. Data indicates presence of species that may be sensitive to flow changes. Smaller watercourse though, so effects likely to be less significant than if in a larger watercourse.	Potentially effects by increased siltation. Macrophytes not considered to be significantly affected given timing of abstractions, so no knock on effect on fish.	**Further investigations recommended (Tier 2)**
Vicar Water from Source to R Maun	Data generally lacking to ascertain potential sensitivity	No	Yes, several	Screened out	Screened out	Hydromorphological effects unknown- may be associated effects on fish.	No further studies recommended
Torne waterbodies							
Ferry Drain	Information indicates waterbody would be of low sensitivity to further abstraction.	No	None	Screened out	Screened out (based on macroinvertebrate status), however Good WFD status for macrophytes and phyto benthos in 2016.	No significant effects predicted	No further studies recommended
Hatfield Waste Dr (trib of Torne/Three Rivs)	Available information indicates waterbody may be moderately sensitive to effects of high flow	Crowle Borrow Pits SSSI (see also North Soak Drain)	High but not additional to National sites already considered	Screened in. Community adapted to slow to moderate velocities and	Screened in. Limited data indicates not sensitive to flow changes however.	No significant effects predicted	**Further investigations recommended (Tier 2/**

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WFD Waterbody	Physical Environment Sensitivity Review (see Section 3.8)	Nationally Designated Sites Warrant Further Attention?	Density of other important sites (e.g. LWS) / initial review	Macroinvertebrates	Macrophytes	Fish	Next Steps Review
	abstraction (with regard to floodplain inundation)			heavy sedimentation. Sensitive to water quality.			**focussed on Nationally designated site)**
Mother Drain from Source to R Torne	Information indicates the channel may be of low to moderate sensitivity to further abstraction	No	Site considered under National sites	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened in. Limited data indicates not sensitive to flow changes however.	Hydromorphological effects unknown- may be associated effects on fish.	No further studies recommended
North Soak Drain (trib of R Torne / Three Rivers)	Available information indicates waterbody may be moderately sensitive to effects of high flow abstraction (with regard to floodplain inundation)	Crowle Borrow Pits SSSI (see also Hatfield Waste Drain)	Low	Screened in. Waterbody not considered sensitive to flow or sedimentation.	Screened in though data indicates not flow sensitive	No significant effects predicted other than potential reduction in downstream floodplain connection (habitat)	**Further investigations recommended (Tier 2/ focussed on Nationally designated site)**
Ruddle (Paper Mill Dyke) from Source to R Torne	Information indicates waterbody would be of low sensitivity to further abstraction.	No	Upland sites unlikely to be impacted	Screened in and considered to be sensitive to sedimentation/ flow changes	Screened in though data indicates flow sensitive	No significant effects predicted	No further studies recommended (given low physical environment sensitivity/ with finite resources focussed elsewhere)
S Lev Engine Dr / Upper Warping Drain Catch	Information indicates waterbody would be of low sensitivity to further abstraction.	No	Site not close to the river/ other site already screened out	Screened in. Waterbody not considered sensitive to flow or sedimentation.	Screened in though data indicates relatively flow sensitive	No significant effects predicted though data is lacking with regard to certain considerations.	No further studies recommended
St Catherine's Well Stream from Source to R Torne	Data generally lacking to ascertain potential sensitivity	No	Upland sites unlikely to be impacted	Screened out	Screened out	Hydromorphological effects unknown- may be associated effects on fish.	No further studies recommended
Torne / Three Rivers from Mother Dr to R Trent	Available information indicates waterbody may be moderately sensitive to effects of high flow abstraction (with regard to floodplain inundation)	No	High but not additional to National sites already considered or sites likely to be impacted	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened in. Limited data indicates not sensitive to flow changes however.	No significant effects predicted other than potential reduction in downstream floodplain connection (habitat)	No further studies recommended
Torne from Ruddle to St Catherine's Well St	Information indicates waterbody would be of low sensitivity to further abstraction.	No	None	Screened out	Screened out	No significant effects predicted	No further studies recommended
Torne from Source to Ruddle (Paper Mill Dyke)	Data generally lacking to ascertain potential sensitivity	No	None	Screened in and considered to be sensitive to sedimentation/ flow changes (at one of two sites/ the other indicated river is not sensitive)	Screened in though data indicates not flow sensitive	No significant effects predicted	No further studies recommended (with finite resources focussed elsewhere)
Torne from St Catherine's Well Strm to Mother Dr	Information indicates the channel may be of low to moderate sensitivity to further abstraction	No	None	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened in. Limited data indicates not sensitive to flow changes however.	No significant effects predicted	No further studies recommended
Warping Drain Catch (trib of Trent)	Information indicates waterbody would be of low sensitivity to further abstraction.	No	Site not close to the river/ unlikely to be impacted	Screened in. Community adapted to slow to moderate velocities and heavy sedimentation. Sensitive to water quality.	Screened in. Limited data indicates not sensitive to flow changes however.	No significant effects predicted	No further studies recommended

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5. Model Reviews

5.1 Background

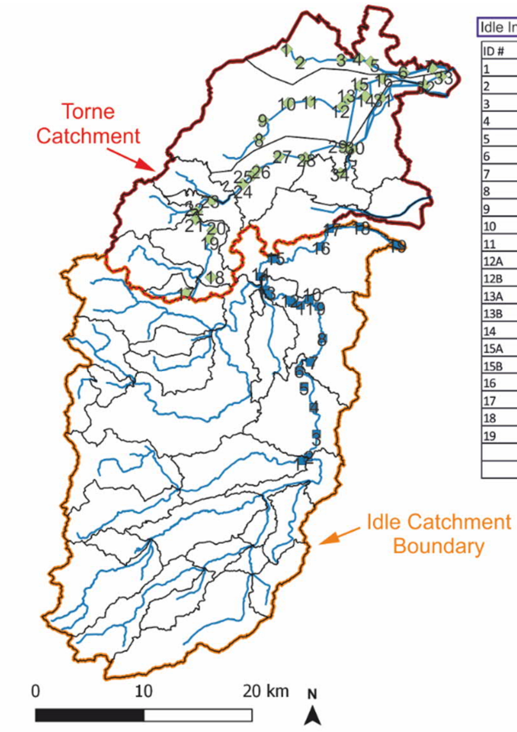
Our review of the Idle and Torne hydraulic models and of the East Midlands Yorkshire Sherwood Sandstone groundwater model, with regard to their potential use in Phase 2b, are presented in his section.

5.2 Hydraulic Models

Reviews of the latest Environment Agency River Idle and Torne strategic scale linked 1D/2D hydraulic FMP-TUFLOW flood models have been undertaken. These are included in Appendix A.

The reviews have been undertaken using a modified version of our standard review proforma which we have employed previously on numerous Environment Agency projects. This proforma includes a traffic light comments system and will be adapted to include key criteria necessary for modelling the impacts of high flow abstraction on floodplain connectivity, and in-stream hydraulic parameters required for geomorphological and eco-hydrological assessment.

A summary of the model inflows is provided in Figure 5.1 below. This indicates that the Torne model covers a reasonable amount of that catchment although the Idle model is limited to the main stem of the Idle itself (downstream of the River Maun/ from Retford). This limited extent reduces the value of the Idle model as a tool if other parts of the catchment require further investigations.



Idle Inflow Locations

ID #	Inflow Name
1	Poulter
2	MaunMed
3	Eaton
4	Eaton
5	Eaton
6	Babworth
7	Tiln
8	Lound
9	Wiseton
10	Drakeholes
11	Mattersey
12A	Mattersey
12B	Bawtry
13A	Bawtry
13B	Bawtry
14	Ryton
15A	Newington
15B	Scaftworth
16	Gringley
17	Idlestop
18	Langholme
19	WestStock
	Eaton
	Eaton

Torne Inflow Locations

ID #	Inflow Name
1	Wikewell
2	Wikewell
3	NewZealand
4	MedgeHall
5	Crowle
6	Ealand
7	Keadby Grange
8	WatertonF 1
9	Waterton F 2
10	Goodcop1
11	Goodcop2
12	Goodcop3
13	LowBank
14	WoodCarrN
15	Dirtness
16	BeltonGrange
17	Auckley US 1
18	Auckley US 2
19	Auckcley 1
20	Auckley 2
21	Auckley 3
22	Auckley 4
23	Auckley 5
24	Auckley 6
25	Kilham Farm 2
26	Kilham Farm 1
27	TorBridgeN
28A	CandyFN
28B	CandyFS
29A	TunnelPitsS
29B	TunnelPitsN
30	Greenholme
31	WoodCarrS
32	FollyDrain
33	Althorpe
34	BullHassocks

Figure 5.1 Hydraulic Model Inflows (Idle and Torne)

In addition, the Idle review found the following:

- Glass-walling during the 50% AEP /1 in 2 year flow event. Glasswalling in the 1D domain results in increased depth and flow within the 1D channel and the 2D domain. This produces increased depths and inaccurate representation of floodplain flow paths and flood extents. Glasswalling within the 2D domain occurs during the 20% AEP event, so this may not be an issue during smaller flow events. Glasswalling within the 1D domain occurs during the 2% AEP event, so again may be less of an issue at lesser flows (which are focus of the current study). This may not be an issue at lower flows (such as high flows where abstraction may occur);

- Significant oscillation of flows across the 1D/2D link files and fluctuations in flow and stage occurred during the reviewed model runs, which would impact results. Changes in the model structure and setup, such as introduction of FLC values at the 1D/2D boundaries and the reduction of 1D and 2D timesteps may help to improve model stability.
- There are a number of uncertainties regarding dimensions of the 1D reservoir units within the model. Whilst there is survey data, the polygons used to generate the reservoir units are not provided, thus any overlap between surveyed sections and reservoir units cannot be identified. Without the shapefiles used to generate the reservoir units within Flood Modeller, dimensions cannot be checked for accuracy or possible double counting of floodplain volume.
- Discrepancies occur between 1D spill widths and associated bank lengths, where 1D spills have been used to model out of bank flow from the channel. 1D spill widths should match the chainage between nodes they are attached to.
- The downstream boundary conditions do not run for the whole simulation; the model run time is 200 hours, and the downstream boundary runs for 140 hours. The boundary should be extended to run for the whole simulation as, under the current setup, a single level is applied for the final 60 hours.
- Abstractions and logical rules have been used to represent pumps rather than pump units. Correctly implemented the use of abstraction units will not impact results, however it means pump curves were not discretely simulated.
- The 1D and 2D model timesteps will have to be lowered if the grid size is reduced. Reducing the grid size will also improve the representation of the 1D channel, 2D channels and floodplain flow paths. There are 2D inflows within the model connected by pumps to the 1D domain, and as such a reduction of the grid size will improve the linkage between the 1D and 2D domains even when flows are in bank within the 1D domain.
- Whilst the save interval specified within the model does not impact results, file sizes are prohibitively large. Increasing the model output save interval would allow generation of easily manageable ,model outputs.

The Torne review found the following:

- The model was previously run with the same timestep for the 1D and 2D domains. The 1D model timestep should be ½ or ¼ of the 2D model timestep. Reducing the 1D timestep will aid both 1D model convergence and reduce flow oscillations across the 1D/2D boundaries. The 1D timestep would also have to be reduced further in line with any reduction in grid size.
- Reducing the grid size will improve model representation of smaller channels within the 2D domain. However, stability issues within the 2D model may occur as result, as variations in topography will be represented in greater detail. The current pumping arrangement, where the pumps are linked to the 2D domain, will be improved with a reduced grid size, as the pumps could be represented with a single cell covering the drainage channel, rather than a 15m grid cell.
- There is poor convergence throughout the model, which is exacerbated by long chainages between 1D model nodes and the relatively large timestep. Without the survey for the full model domain, schematisation of structures within the full 1D model cannot be verified, and neither can structure dimensions or bank levels.
- Flow transfer between the 1D and 2D model domains operates poorly, as highlighted by the high Form Loss Coefficient values within the HX link files and the use of Boundary Viscosity values. Reduction in timestep and grid size is likely to improve flow transfer between domains, however the model may still struggle when out of bank flow occurs.
- Glasswalling occurs upstream of model node DGND_23073, located to the west of Armthorpe. The 2D domain needs to be extended to prevent this. However, glasswalling only occurs during events greater than the 3.33% AEP (1 in 33 year flood) event and therefore will not impact model performance during lower order events.

- Discrepancies occur between the 1D and 2D cross-section widths throughout the model, which should be corrected for future model runs. Either the 2D sections should be updated to match the 1D sections, or the 1D cross-sections should be extended via LiDAR to tie in with the channel extent within the 2D domain.
- Abstractions and logical rules have been used to represent pumps, rather than specific FMP pump units. If implemented correctly, the use of abstraction units will not impact model results. However, as a result of the current model setup, discrete representation of pump curves is not utilised.
- There are a number of missing structures within the model with no explanation for their exclusion; these structures should be added to the model, however further survey would then be required to capture structure dimensions. Missing structures, that were not included in the supplied survey data, could impact results even at low flows.
- Spill units are not present at all structures within the 1D model. These should be added either in 1D or spills to the 2D with a smaller grid size.

The above indicates a number of issues that would need to improved were the models to be used for this project. In addition a 1D in channel part of the model would provide limited in channel information, e.g. with averaged velocities across the channel cross section.

Given the above it is recommended that the hydraulic models are not developed further during or used in Phase 2b of the project.

5.3 East Midlands Yorkshire Sherwood Sandstone Groundwater Model Review

5.3.1 Overview

The Environment Agency developed a groundwater model encompassing the Idle and Torne study area, the ‘East Midlands Yorkshire Sherwood Sandstone Groundwater Model’. The model is a time variant distributed model with a uniform model grid with cell size of 200m and 4 layers. Aquifer properties and recharge are distributed across the model grid with abstractions and discharges assigned to the appropriate grid cell. The model runs from 1963 to 2004 with a ‘warm up’ period from 1839 to simulate the slow changes in the Sherwood Sandstone.

Further details can be found in the model report (noting that the figures in Section 5.3 are also obtained and sourced from this report)[37]:

The following sections review the calibration of the model based on information contained within the model report. Figures have been reproduced where appropriate.

Flow gauges available in the Idle and Torne catchments to calibrate river flows are shown in Figure 5.2.

[37] M.G Shepley, & R Soley, East Midlands Yorkshire Sherwood Sandstone Groundwater Modelling Project Task 3. April 2009

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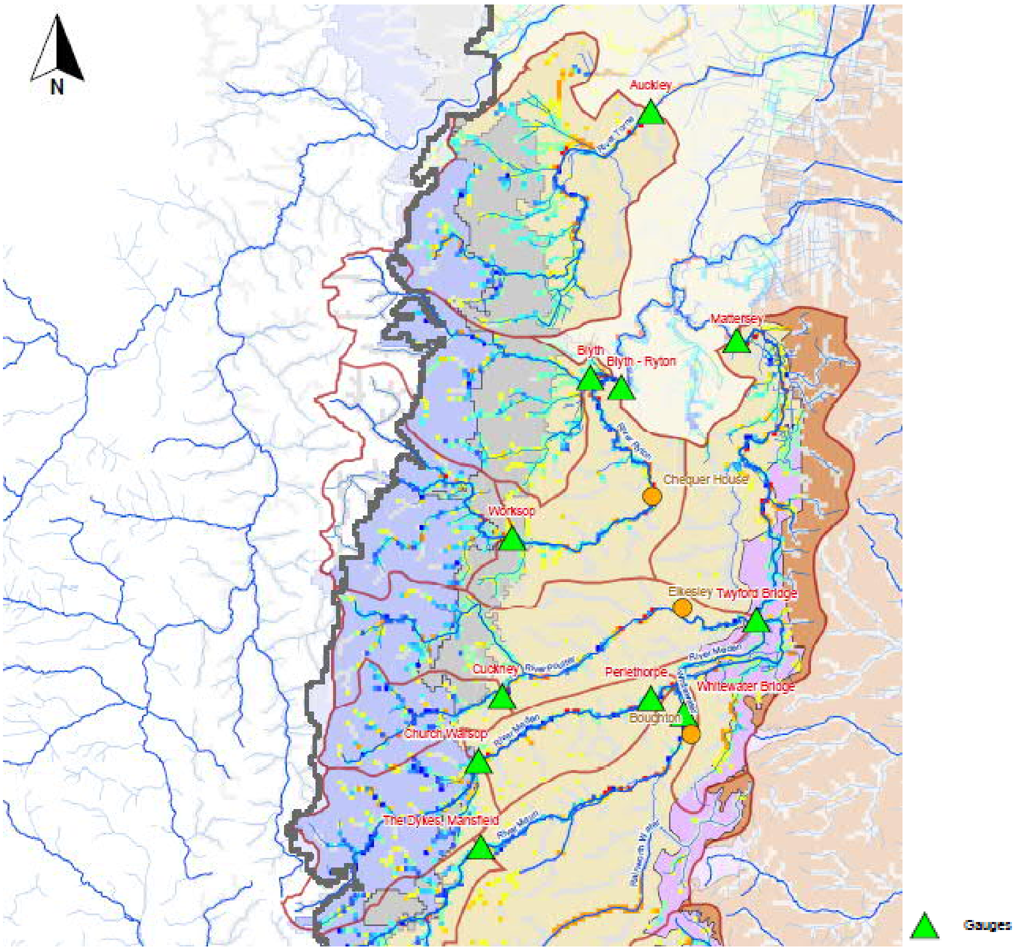

Figure 5.2 River flow gauges utilised in the groundwater model

Groundwater monitoring boreholes in the study area contained within the groundwater model are shown in Figure 5.3. The boreholes of interest are the unconfined Cadeby and Sherwood Sandstone Formations which provide baseflow to the rivers in the study area.

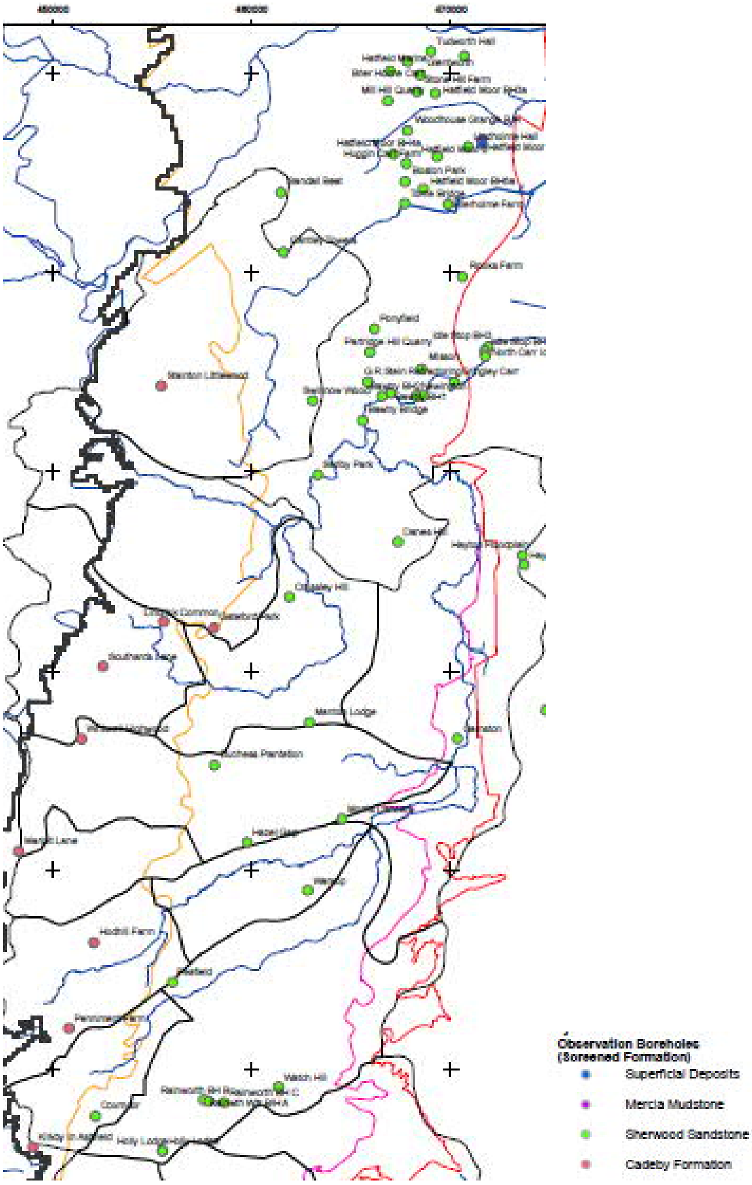

Figure 5.3 Groundwater monitoring boreholes utilised in the groundwater model

The model produces output for stream flows and groundwater levels on a monthly basis and are compared with monthly averaged gauge flows (the average of a month's daily gauge data). Groundwater observed data are generally collected once a month.

5.3.2 Torne Catchment

5.3.2.1 Torne

The bottom of the Torne catchment is represented at the Auckley gauge (Figure 5.4). The River Torne at Auckley is moderately-well calibrated when comparing simulated flows to gauged flows; overall seasonality is represented but in most years flow recessions and low flows are under-estimated by model, the recession curve falls more rapidly than observed and to a lower flow volume. Some components of flow are missing where in some years gauged flow rises but simulated flows do not show a response or any response is subdued.

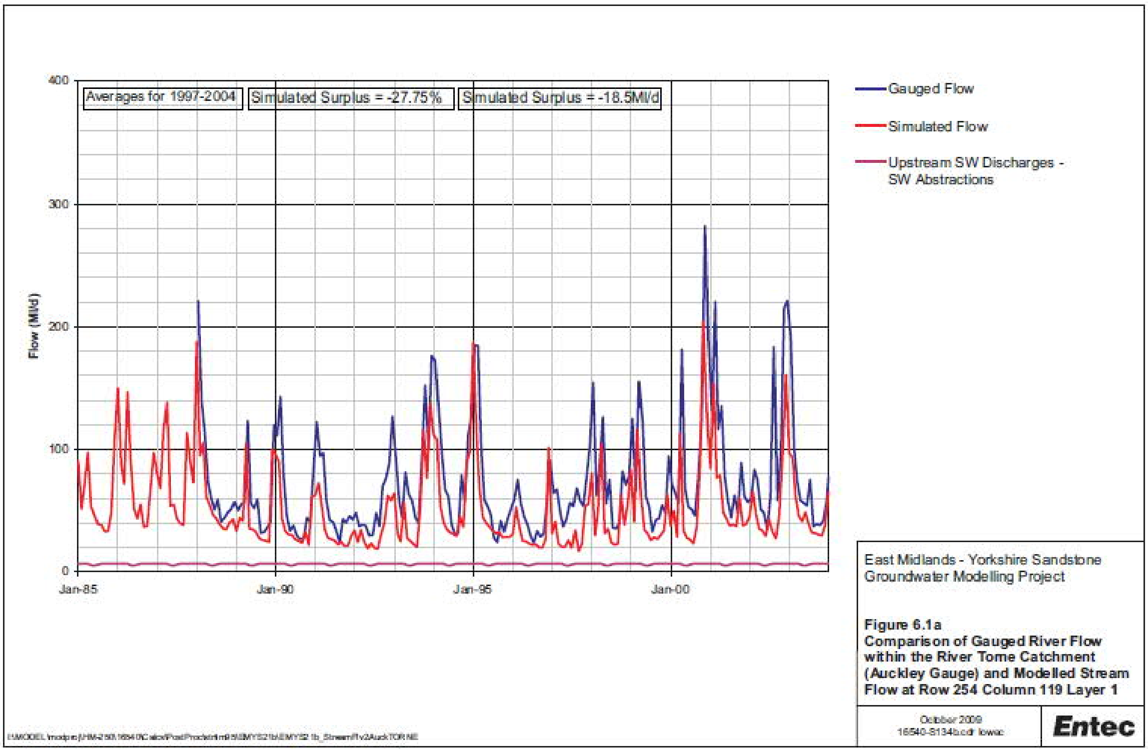

Figure 5.4 River Torne flows at Auckley

The flow duration curve based on data from 1997-2004, shows how simulated flow is too low at all percentiles, however the gauge is noted to over-estimate flows by approximately 10%. The rate of change in flow in reasonably good at high and middle flows (Figure 5.5).

The model summary statistics for flows at Auckley between 1997-2004 are given in Table 5.1.

Table 5.1 Auckley river flow statistics

Gauge	Mean Gauge Flow (Ml/d[38])	Simulated Mean Flow (Ml/d)	Surplus/deficit (-)	Observations
Auckley	66.5	48.1	-18.4	Under predicts flows exiting Torne catchment Timing and relative size of high flow events comparable to gauged flow

[38] 1 cumec or 1 m^3/s is equivalent to 86.4 Ml/d. Ml/d used more commonly with regard to Water Resources studies.

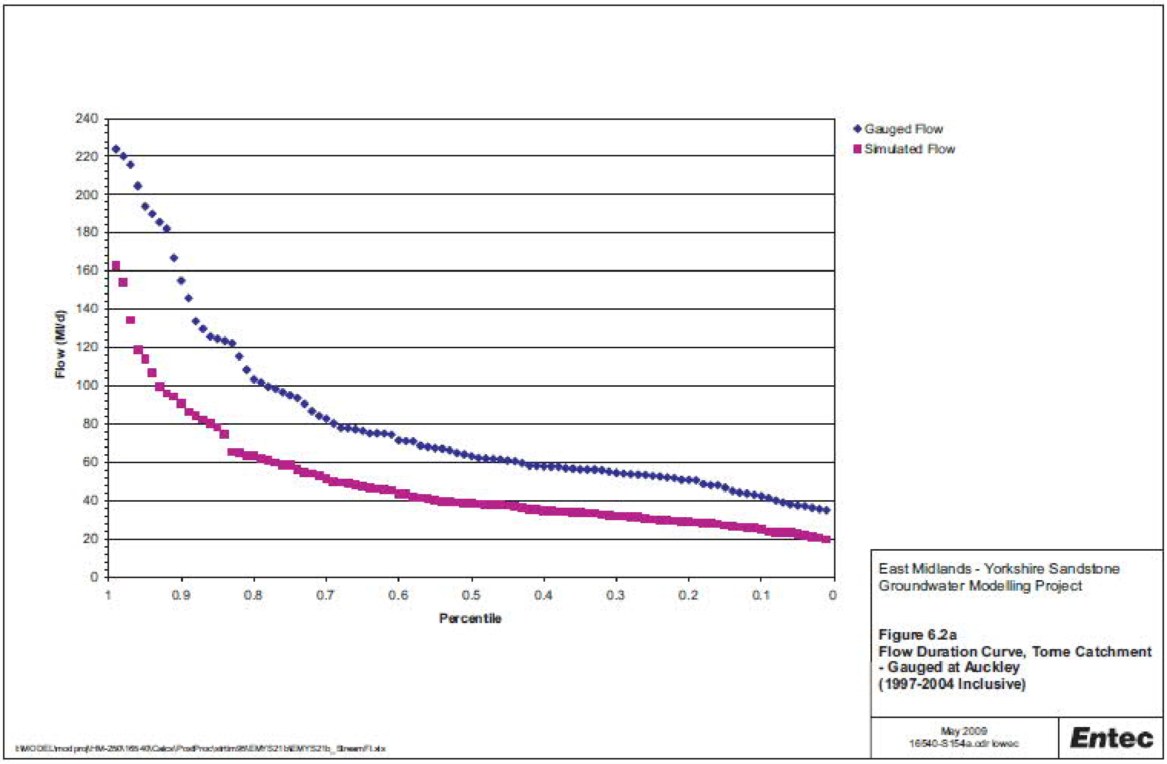

Figure 5.5 Flow Duration Curve for River Torne at Auckley

Groundwater level calibration has been compared at Sandall Beat (Figure 5.6) and Cantley Towers (Figure 5.7) in the Sherwood Sandstone aquifer. Simulated groundwater levels are lower than observed in both boreholes with the long term temporal pattern reasonably well represented. Lower groundwater levels will lead to lower simulated baseflows in rivers, hence the flow calibration under estimates flow.

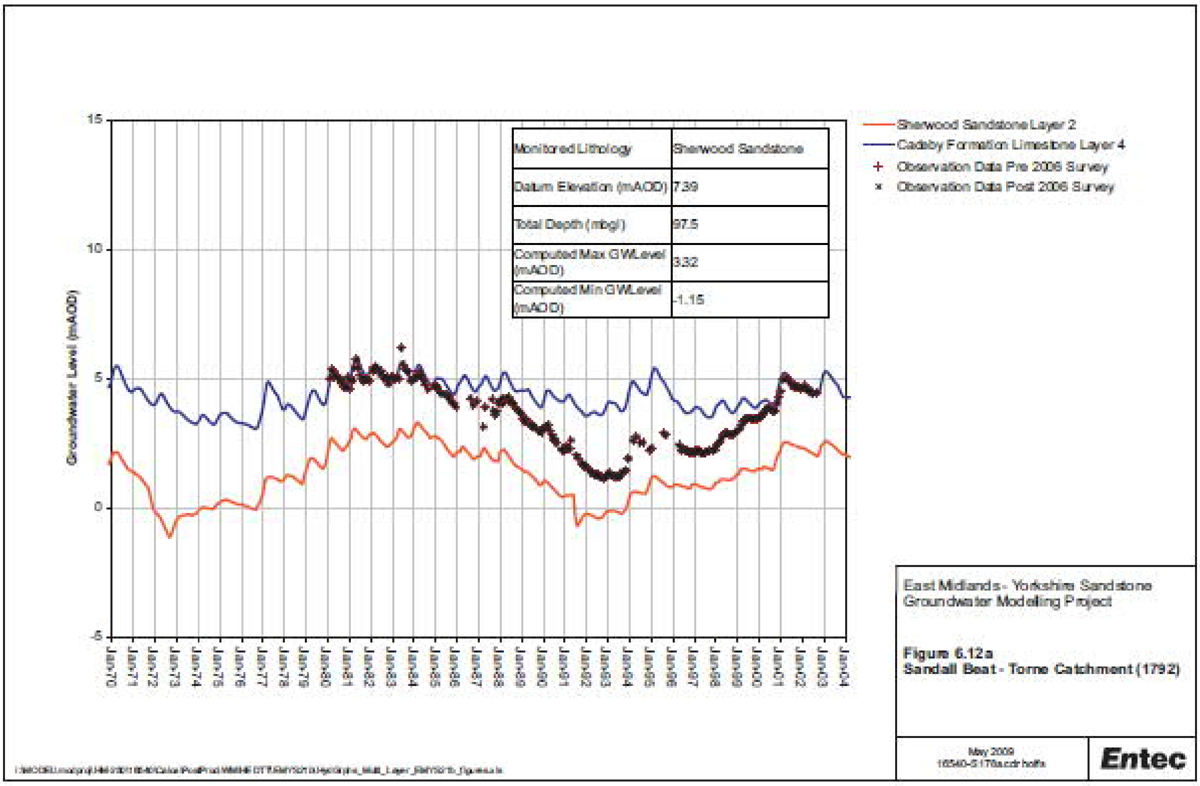

Figure 5.6 Groundwater Levels in Sherwood Sandstone at Sandall Beat

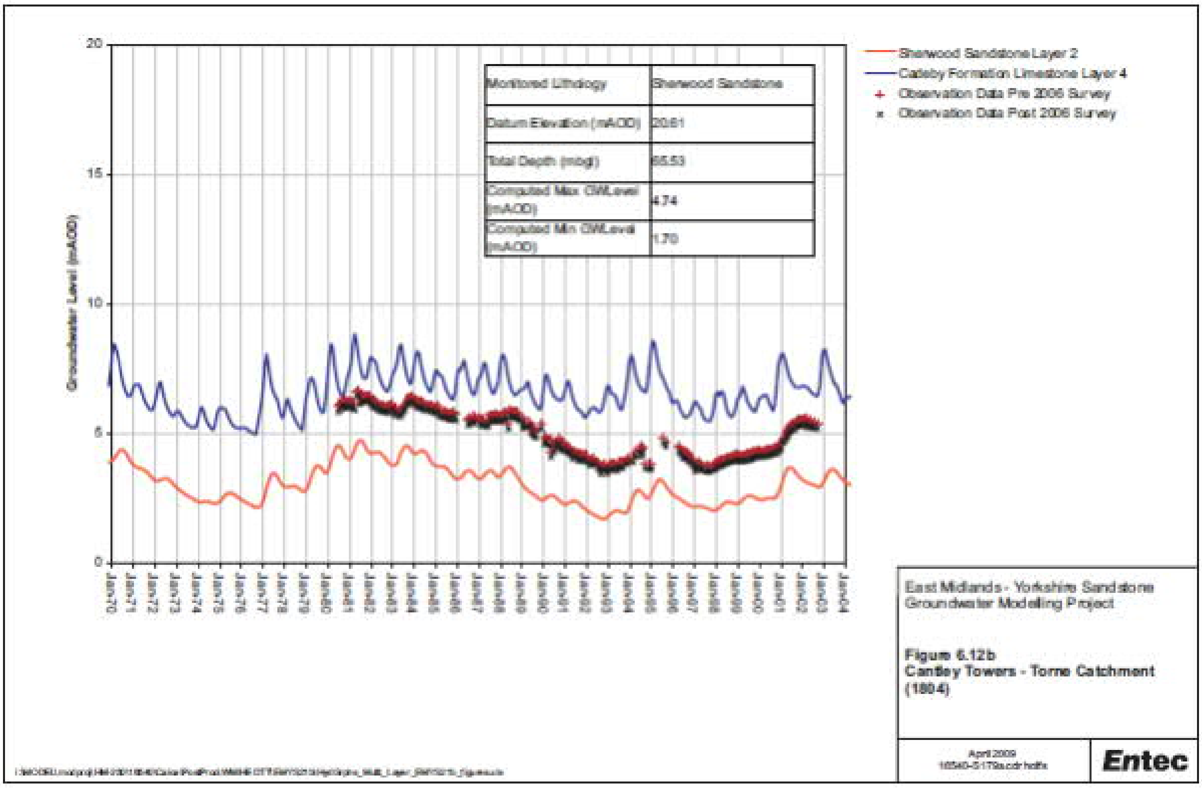

Figure 5.7 Groundwater Levels in Sherwood Sandstone at Cantley Towers

5.3.3 Idle catchment

5.3.3.1 Idle

The bottom of the River Idle is represented at the Mattersey flow gauge.

The River Idle at Mattersey is well calibrated particularly at higher flows, though the peaks are not well simulated in very wet years. Moderately high flows tend to be better predicted by the model as well as the rate of recession from peak to trough/ high to low flows, and low flows in many years. The lowest flows show a sudden fall below a typical low which is not represented by the model (Figure 5.8).

The model summary statistics for flows at Mattersey between 1997-2004 are given in Table 5.2.

Table 5.2 Mattersey river flow statistics (1997 – 2004)

Gauge	Mean Gauge Flow (Ml/d)	Simulated Mean Flow (Ml/d)	Surplus/deficit (-)	Observations
Mattersey	207.9	182.5	-25.4	Simulation closely follows gauge flows in hydrograph and flow duration curve for the later time series. Early to mid-90s simulated summer low flows are too high.

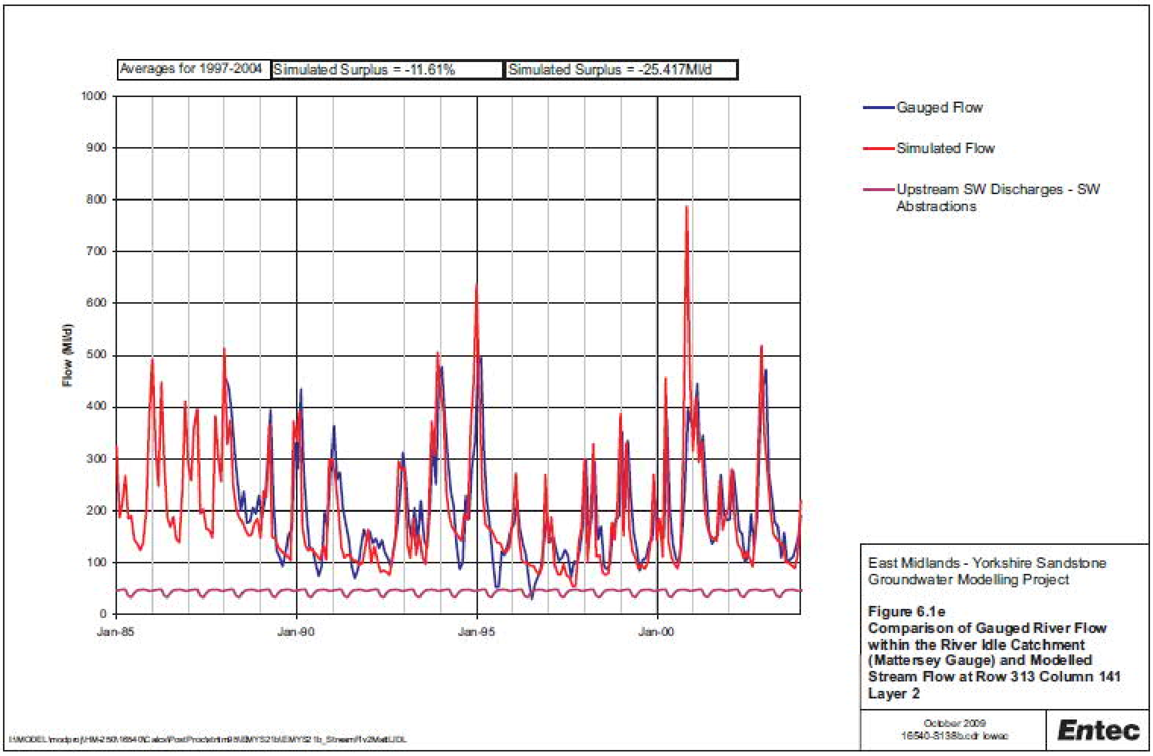

Figure 5.8 River Idle flows at Mattersey

This can be seen in the flow duration curves based on data from 1997-2004 (Figure 5.9). The River Idle at Mattersey is a good calibration particularly at higher flows with a good representation of the rate of change across the flow percentiles.

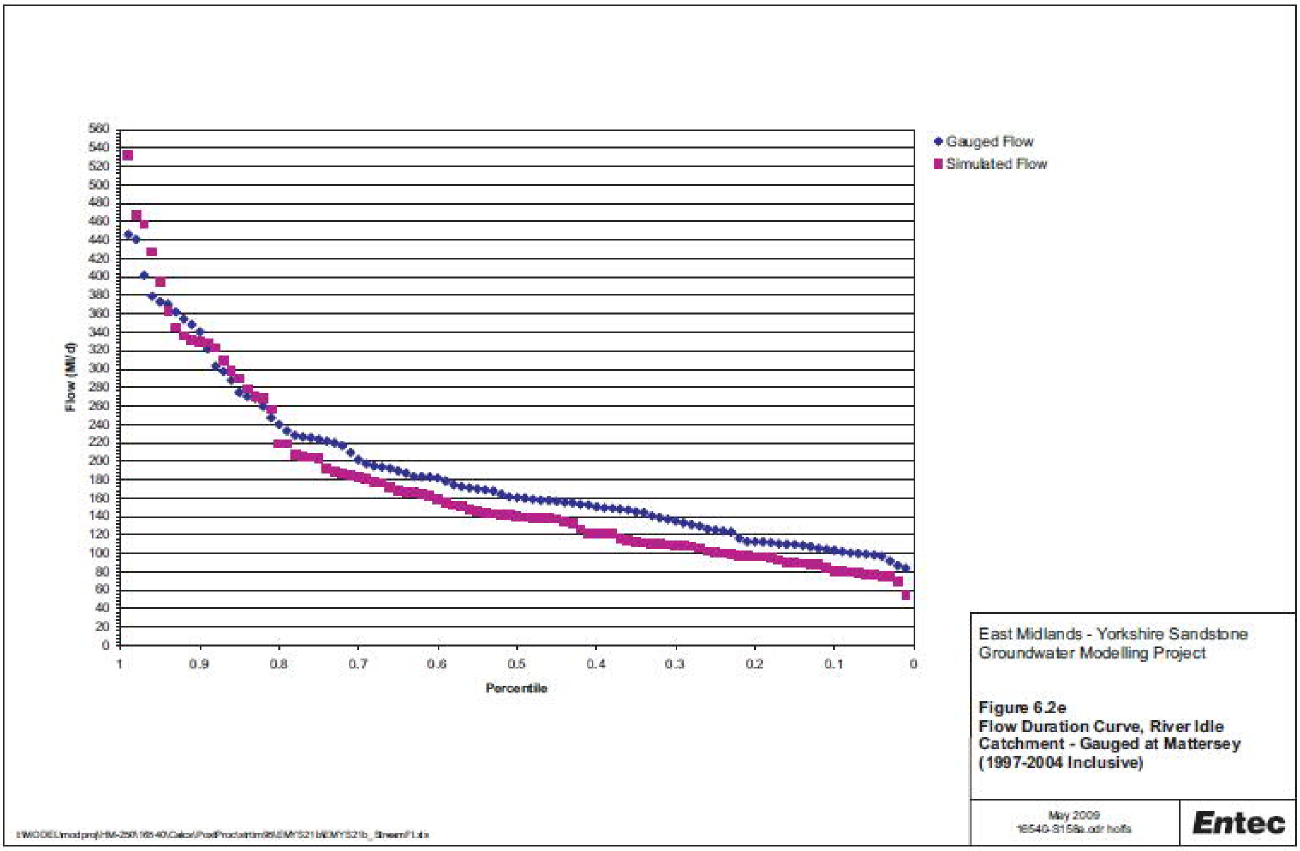

Figure 5.9 Flow Duration Curve for River Idle at Mattersey

Therefore the model simulates the flow for the total Idle catchment reasonably well.

5.3.3.2 Other tributaries

The River Idle is formed of several inflowing streams which also are gauged. Model performance in the following main tributaries are discussed further below:

- The Poulter (upper and lower);
- The Meden; and
- The Maun.

5.3.3.3 Poulter

The lower Poulter catchment (Twyford Bridge gauge) shown in Figure 5.10 is not well calibrated with too much flow at high flows and too little and middle and low flows.

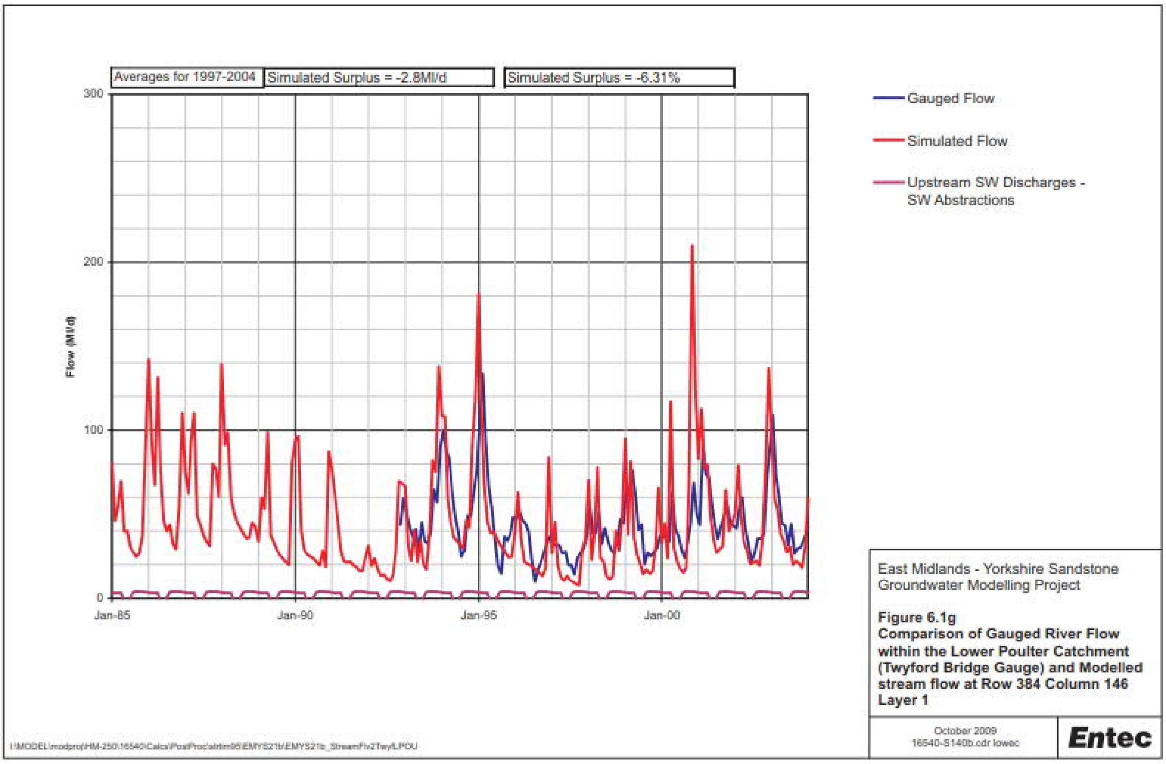

Figure 5.10 River Poulter flows at Twyford Bridge

The model summary statistics for flows at Twyford Bridge between 1997-2004 are given in Table 5.3.

Table 5.3 Twyford Bridge river flow statistics

Gauge	Mean Gauge Flow (Ml/d)	Simulated Mean Flow (Ml/d)	Surplus/deficit (-)	Observations
Twyford Bridge	45.0	42.2	-2.8	Partially inherited from the Upper Poulter catchment, simulated flows show increased peak flows and under predicted summer flows.

The stepped high flows calibration in the upper Poulter has followed through to the flow duration curve for the lower Poulter, based on data from 1997-2004 (Figure 5.11), which has become more extreme as flow volume increases. Meanwhile the gauged flow duration curve is flatter, leading to a deterioration in the calibration.

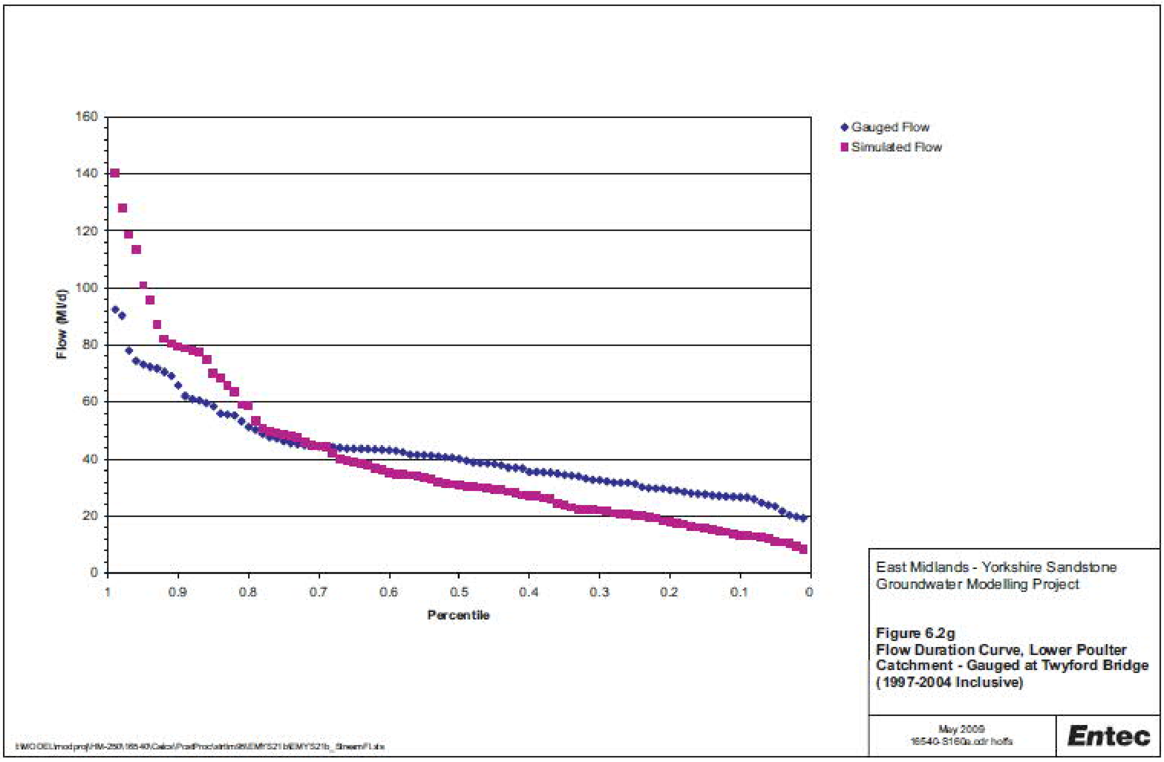

Figure 5.11 Flow Duration Curve for River Poulter at Twyford Bridge

Whitwell Lane groundwater monitoring borehole is located in the Lower Poulter catchment and monitors the Cadeby Formation aquifer. Simulated levels are too low and have much larger fluctuations than observed (Figure 5.12).

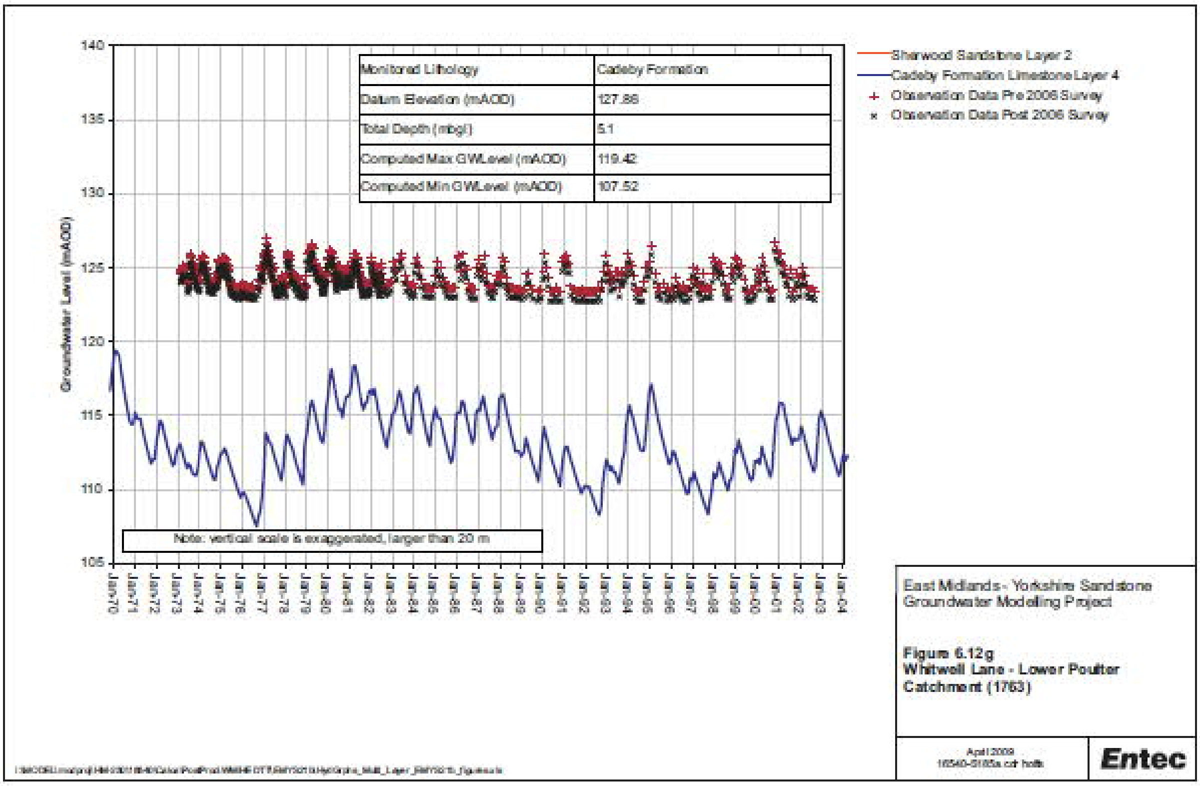

Figure 5.12 Groundwater Levels in Cadeby Formation at Whitwell Lane

Duchess groundwater monitoring borehole is located in the Lower Poulter catchment and monitors the Sherwood Sandstone aquifer. Simulates levels are too high while the seasonal pattern is well represented Figure 5.13).

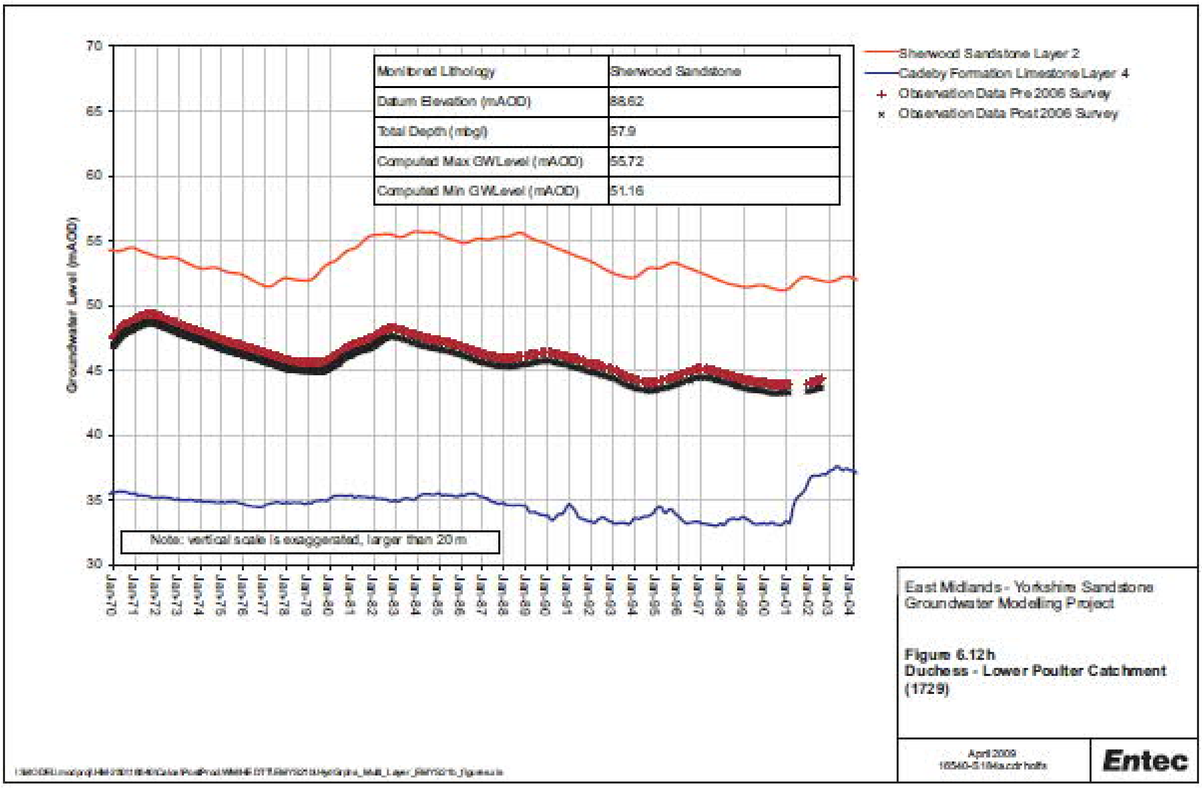

Figure 5.13 Groundwater Levels in Sherwood Sandstone at Duchess

The River Poulter flows are moderately-well calibrated in its upper reaches (Cuckney gauge) at higher flows, though over-estimates the high flows. The rate of recession from high flow to low flow is generally too steep compared to the observed, and low flows are not as low as observed (Figure 5.14).

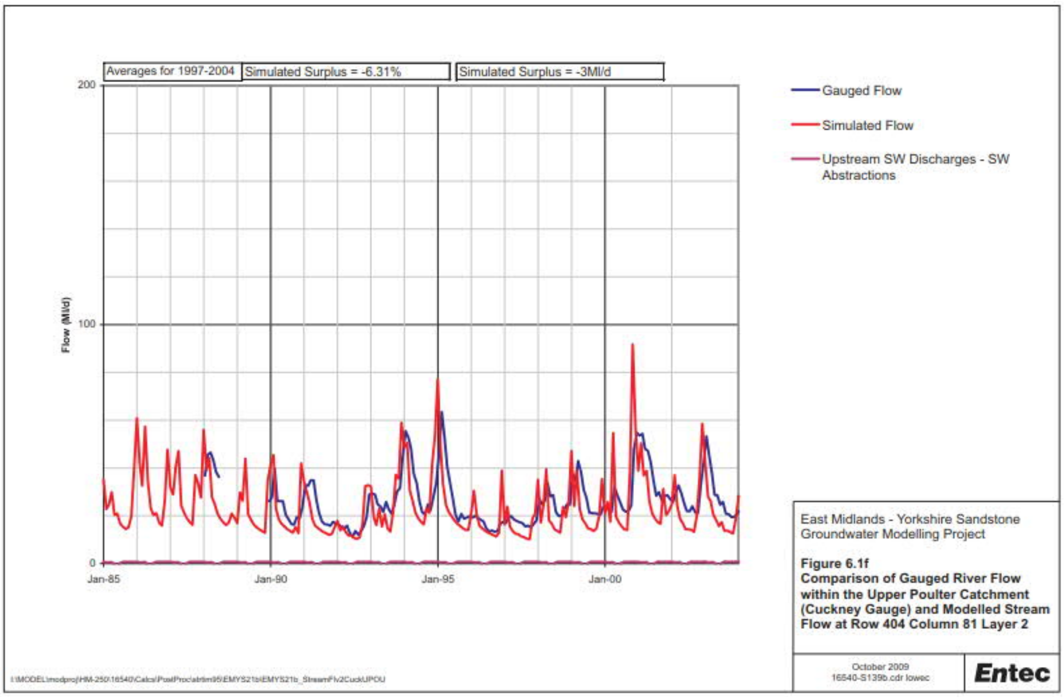

Figure 5.14 River Poulter flows at Cuckney

The model summary statistics for flows at Cuckney between 1997-2004 are given in Table 5.4.

Table 5.4 Cuckney river flow statistics

Gauge	Mean Gauge Flow (Ml/d)	Simulated Mean Flow (Ml/d)	Surplus/deficit (-)	Observations
Cuckney	26.1	23.1	-3.0	Modelled flows are too early and portray a more flashy response than gauged record.

The flow duration curve based on data from 1997-2004 (Figure 5.15), is steeper and flatter (stepped) than observed at high flows between Q_5 and Q_{20}, while middle and lower flows represent the observed curve reasonably well but under estimate the flow volume.

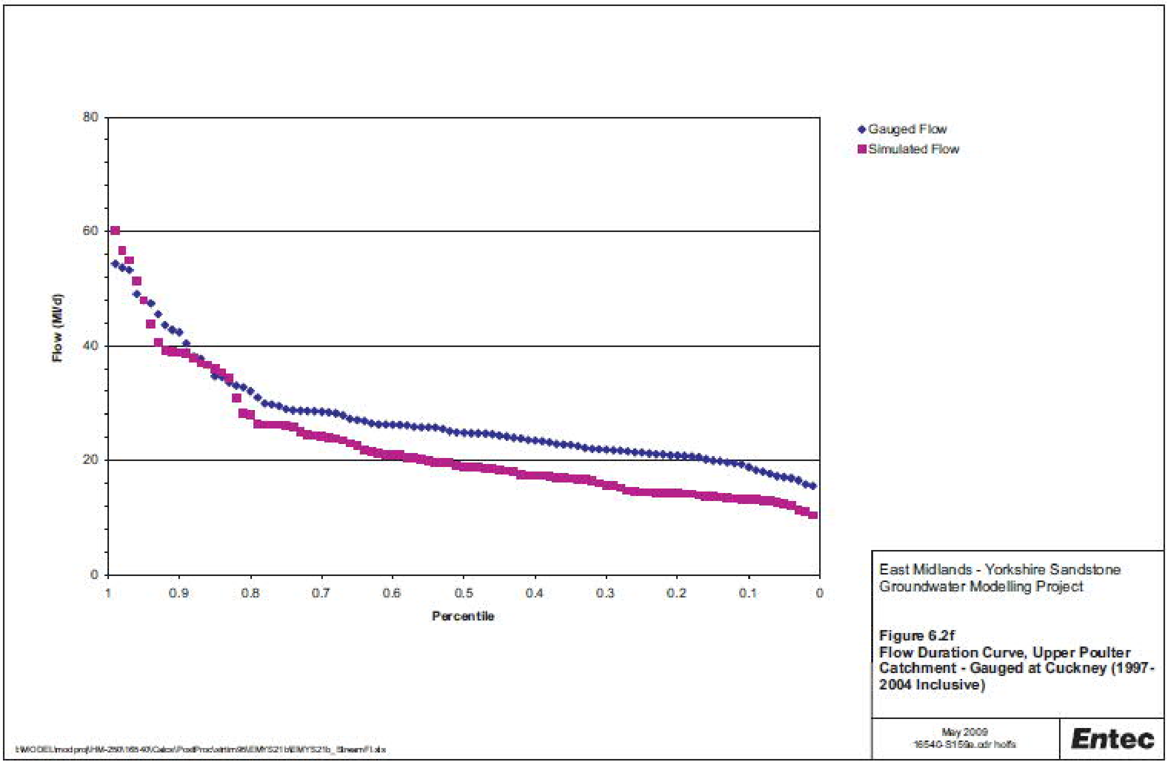

Figure 5.15 Flow Duration Curve for River Poulter at Cuckney

Marlpit Lane groundwater monitoring borehole is located in the Upper Poulter catchment, and monitors the Cadeby Formation. Groundwater levels fluctuate more than observed and levels are too low in most years (Figure 5.16), resulting in lower than observed baseflow to rivers.

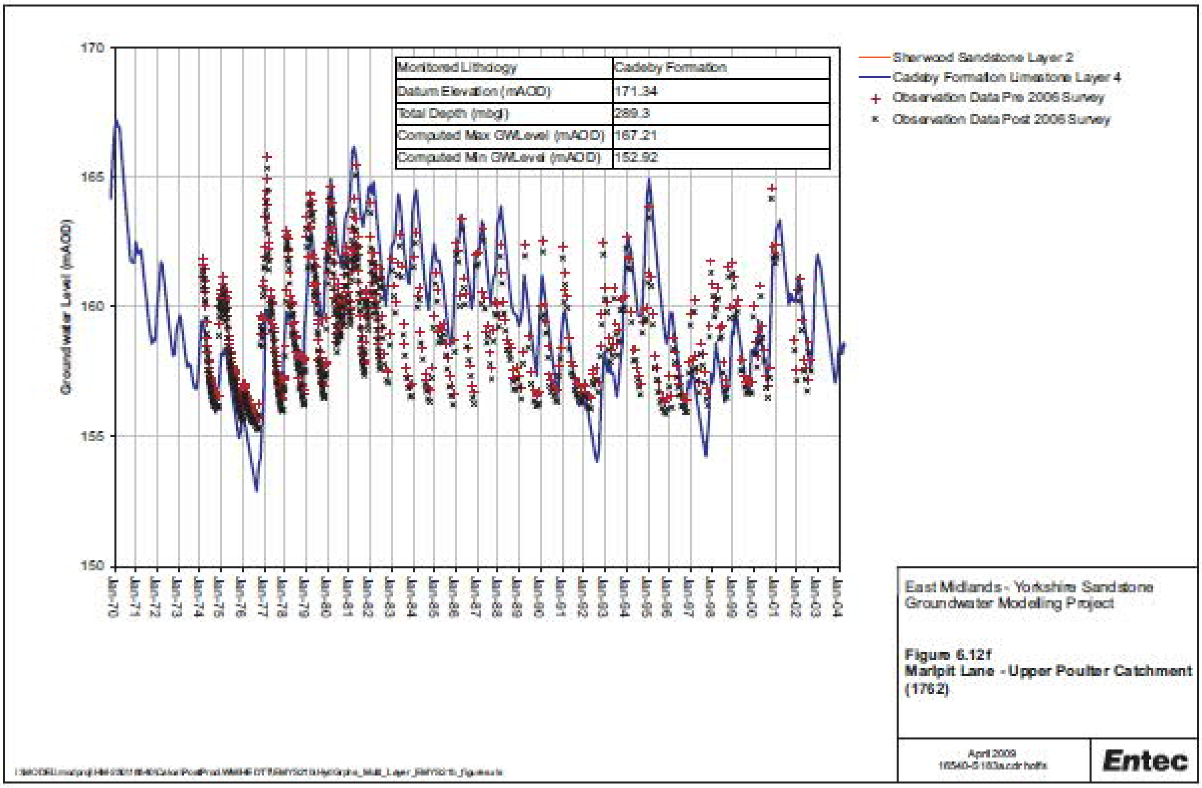

Figure 5.16 Groundwater Levels in Cadeby Formation at Marlpit Lane

5.3.3.4 Meden

The River Meden is another tributary of the River Idle (via the River Maun discussed next). The River Meden catchment is located south of the Poulter catchment.

The Lower Meden is gauged at Perlethorpe (Figure 5.17). The model generally simulates the seasonality well with typical winter high flows peaks reasonably well calibrated although duration of peaks often under represented. Low flows appear to be too low too.

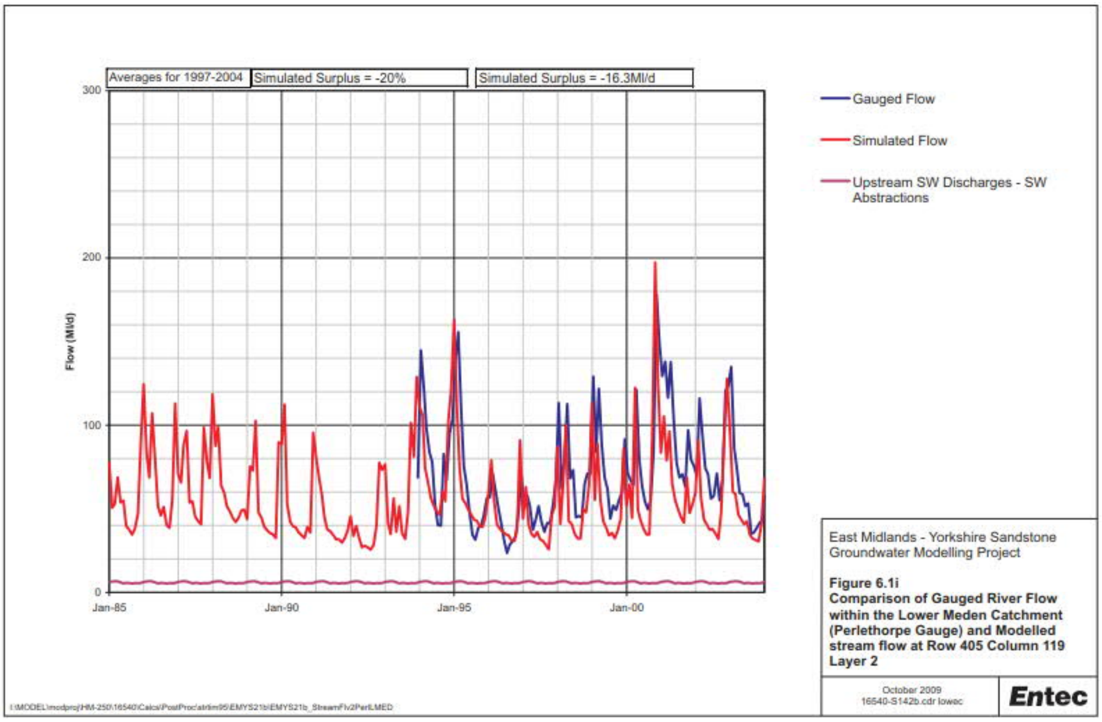

Figure 5.17 River Meden flows at Perlethorpe

The model summary statistics for flows at Perlethorpe between 1997-2004 are given in Table 5.5.

Table 5.5 Perlethorpe river flow statistics

Gauge	Mean Gauge Flow (Ml/d)	Simulated Mean Flow (Ml/d)	Surplus/ deficit (-)	Observations
Perlethorpe	71.7	55.4	-16.3	Behaviour of the catchment is captured in the [hydrograph] and flow duration curves are comparable. Flows are consistently under predicted by approximately 10 Ml/d.

The flow duration curve based on data from 1997-2004 (Figure 5.18) confirms this understanding (i.e. the overall shape of the curve is similar to the observed but insufficient flow being estimated).

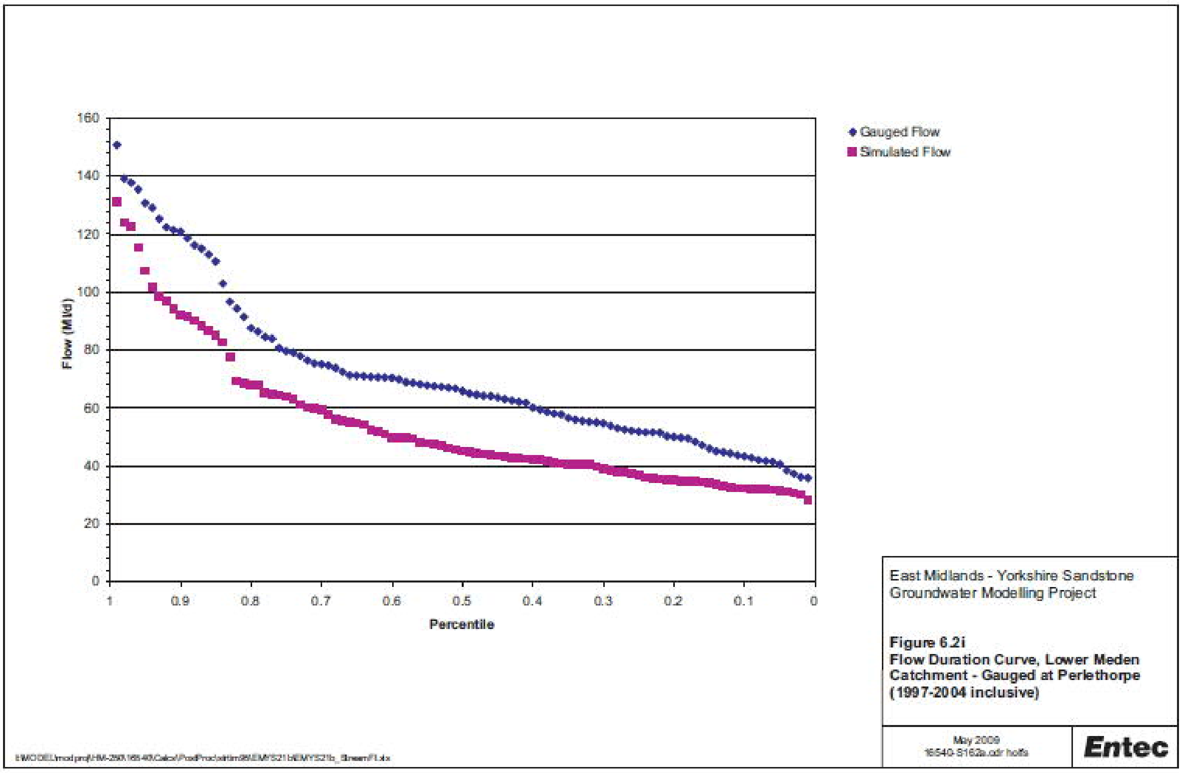

Figure 5.18 Flow Duration Curve for River Meden at Perlethorpe

Warsop groundwater monitoring borehole is located in the Lower Meden catchment and monitors the Sherwood Sandstone aquifer. Simulated levels are approximately the correct elevation while the seasonal pattern fluctuates over a larger range than observed (Figure 5.19).

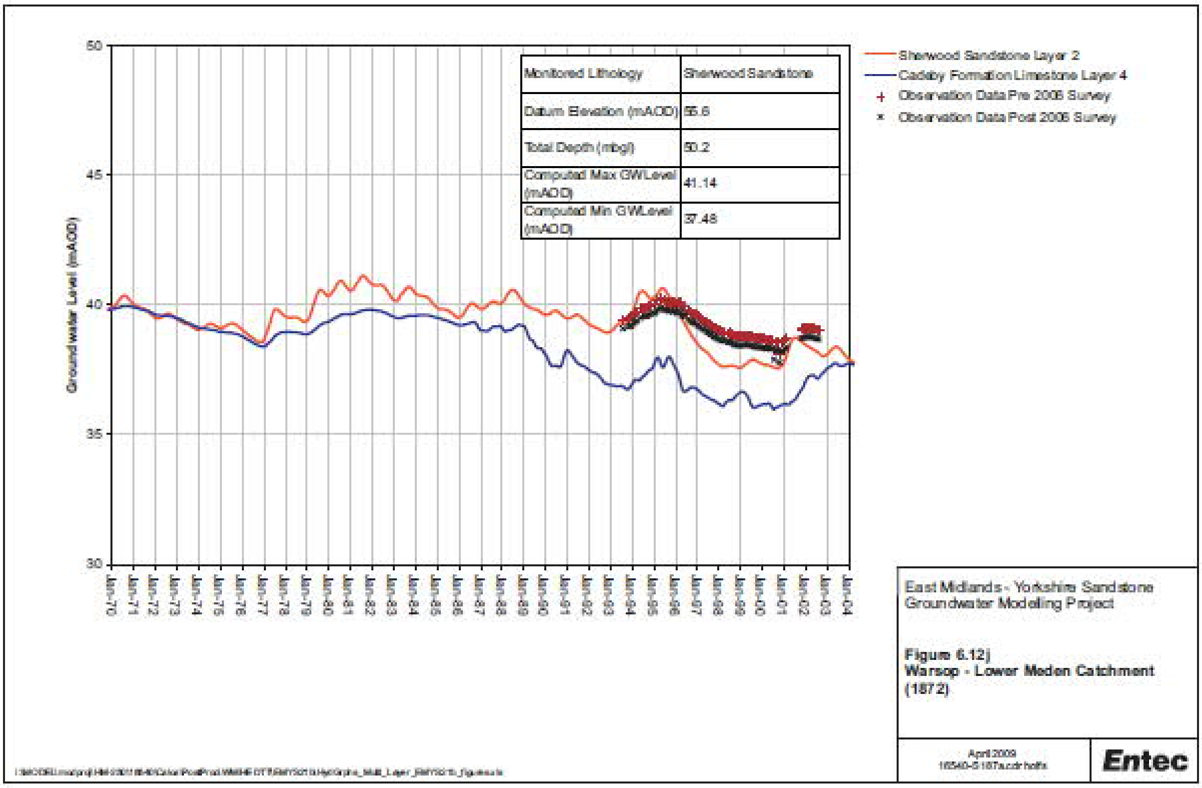

Figure 5.19 Groundwater Levels in Sherwood Sandstone at Warsop

Holly Lodge groundwater monitoring borehole is also located in the Lower Meden catchment and monitors the Sherwood Sandstone aquifer. Simulated levels significantly lower than observed elevation while the seasonal pattern is reasonably accurate (Figure 5.20).

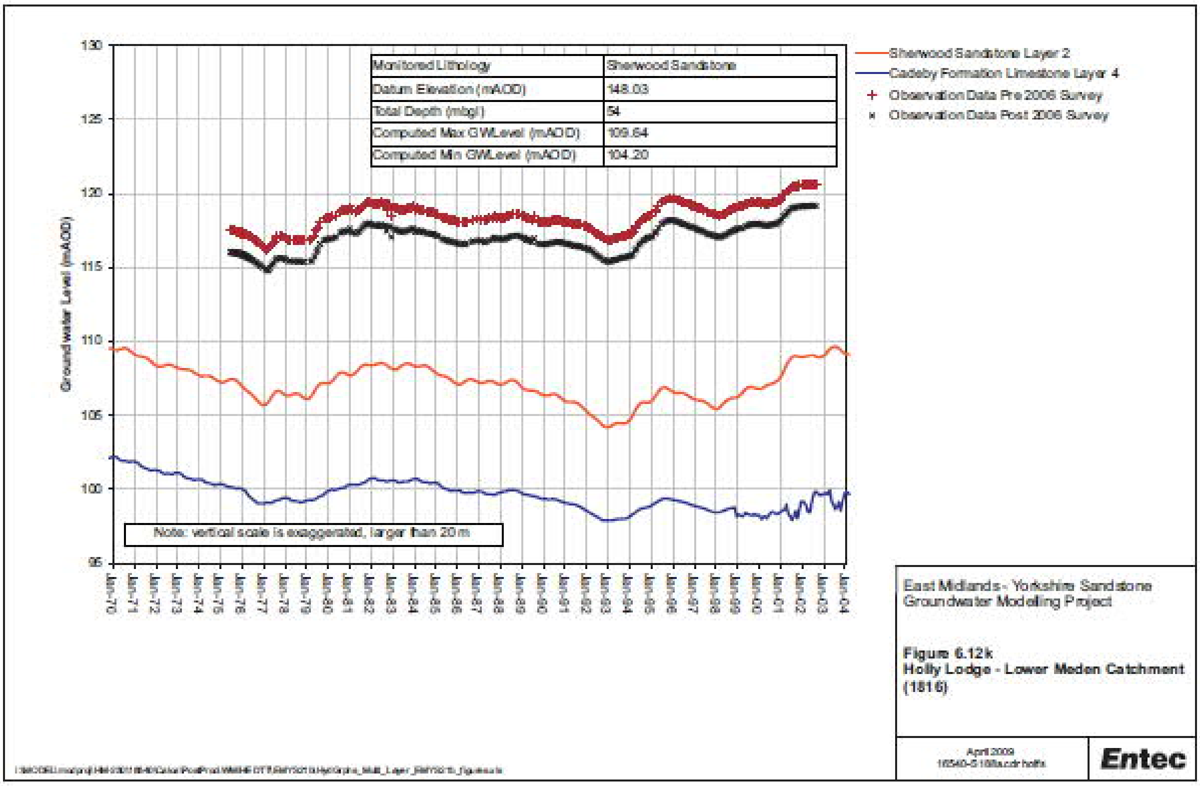

Figure 5.20 Groundwater Levels in Sherwood Sandstone at Holly Lodge

The upper Meden has gauged flows recorded at Church Warsop. Compared to the downstream site, flows appear to be better calibrated temporally (see Figure 5.21) and across the flow duration curve (with regard to magnitude, see Figure 5.22) based on data from 1997-2004.

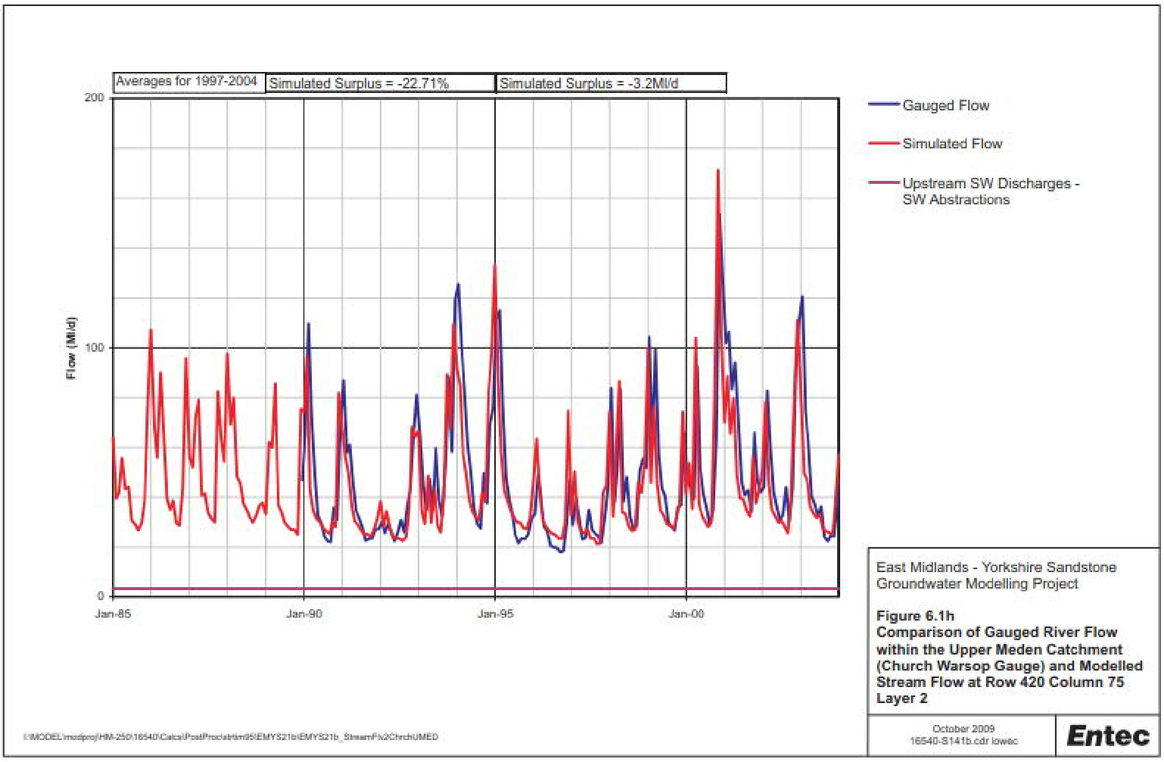

Figure 5.21 River Meden flows at Church Warsop

The model summary statistics for flows at Church Worksop between 1997-2004 are given in Table 5.5.

Table 5.5 Church Worksop river flow statistics

Gauge	Mean Gauge Flow (Ml/d)	Simulated Mean Flow (Ml/d)	Surplus/ deficit (-)	Observations
Church Worksop	48.3	45.1	-3.2	Simulation closely follows the catchment hydrograph and flow duration curves. Simulated summer flows in the mid-90s are too low.

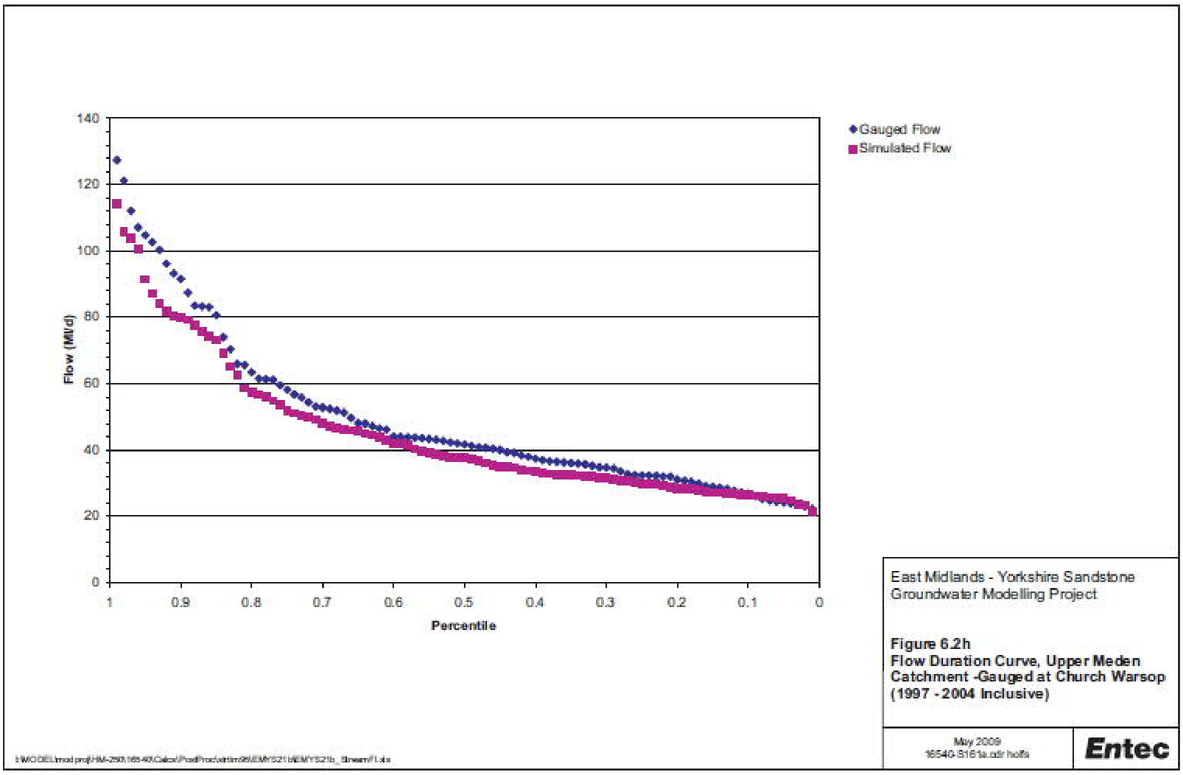

Figure 5.22 Flow Duration Curve for River Meden at Church Warsop

Penniment Farm groundwater monitoring borehole is located in the Upper Meden catchment, and monitors the Cadeby Formation. Groundwater levels fluctuate more than observed and levels are too low (Figure 5.23), resulting in lower than observed baseflow to rivers.

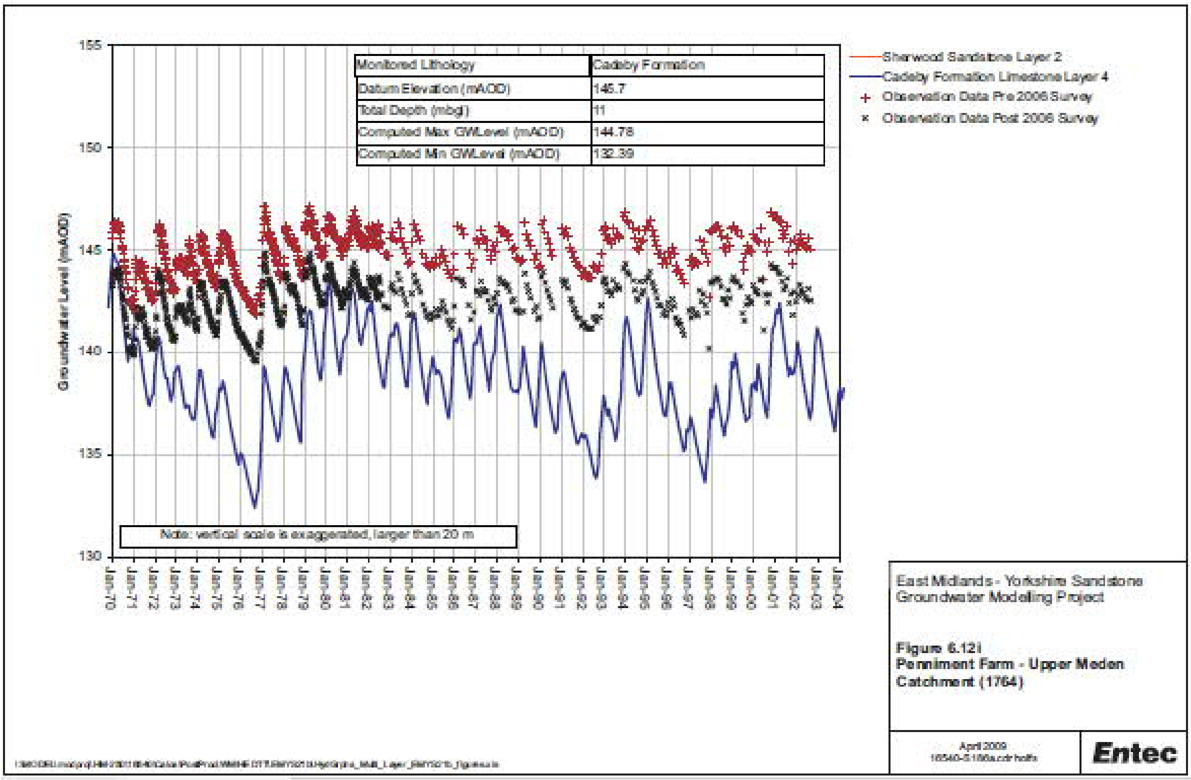

Figure 5.23 Groundwater Levels in Cadeby Formation at Penniment Farm

5.3.3.5 Maun

The River Maun is another tributary of the River Idle. It is generally to the south of the Meden catchment, though continues in a northward direction once that river joins it.

Flow in the lower Maun is recorded at Whitewater Bridge (Figure 5.24). Modelled flows represent seasonal variations poorly and flow is under estimated in most years.

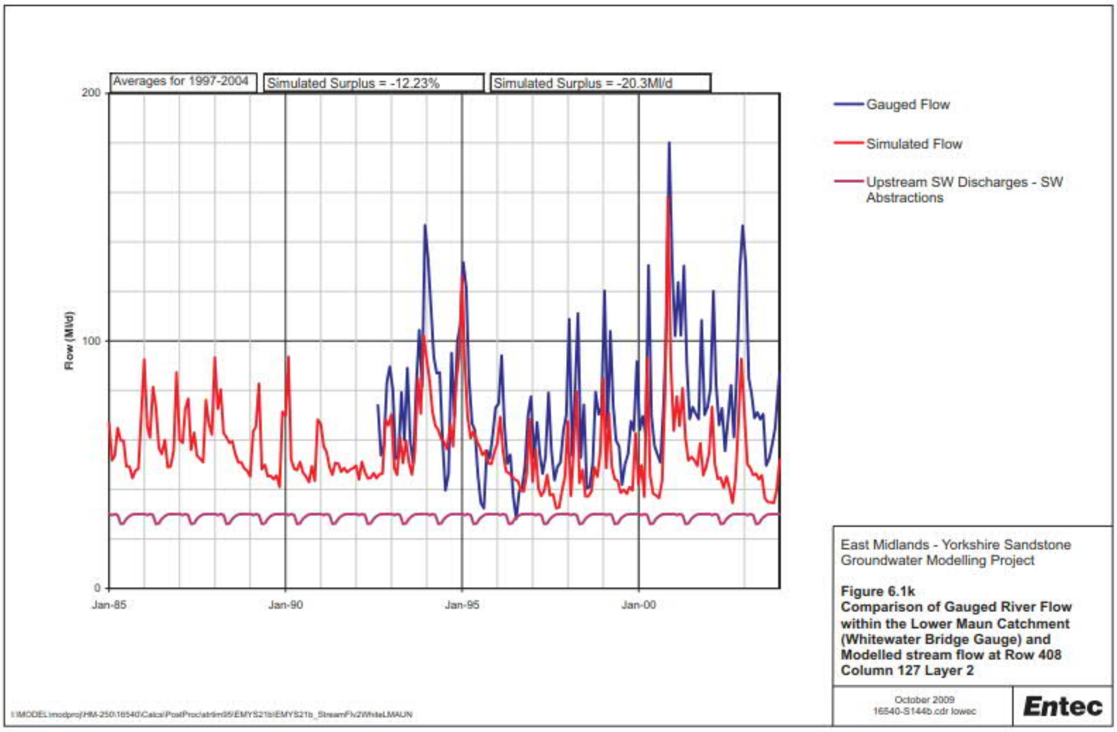

Figure 5.24 River Maun flows at Whitewater

The model summary statistics for flows at Whitewater Bridge between 1997-2004 are given in Table 5.6.

Table 5.6 Whitewater Bridge river flow statistics

Gauge	Mean Gauge Flow (Ml/d)	Simulated Mean Flow (Ml/d)	Surplus/ deficit (-)	Observations
Whitewater Bridge	74.9	54.6	-20.3	As the Upper Maun catchment flow is under predicted, the loss is superimposed in this downstream catchment. If the difference between the Upper Maun simulated and gauged flow duration curves are added to the Lower Maun curves, there is a good fit to gauged flow.

The flow duration curve based on data from 1997 to 2004 (Figure 5.25) shows a similar pattern to the gauged flow across the percentiles from high flows to Q_{65}, but with a flatter curve for mid and lower flows than observed. However overall the flow volume is under estimated across the curve.

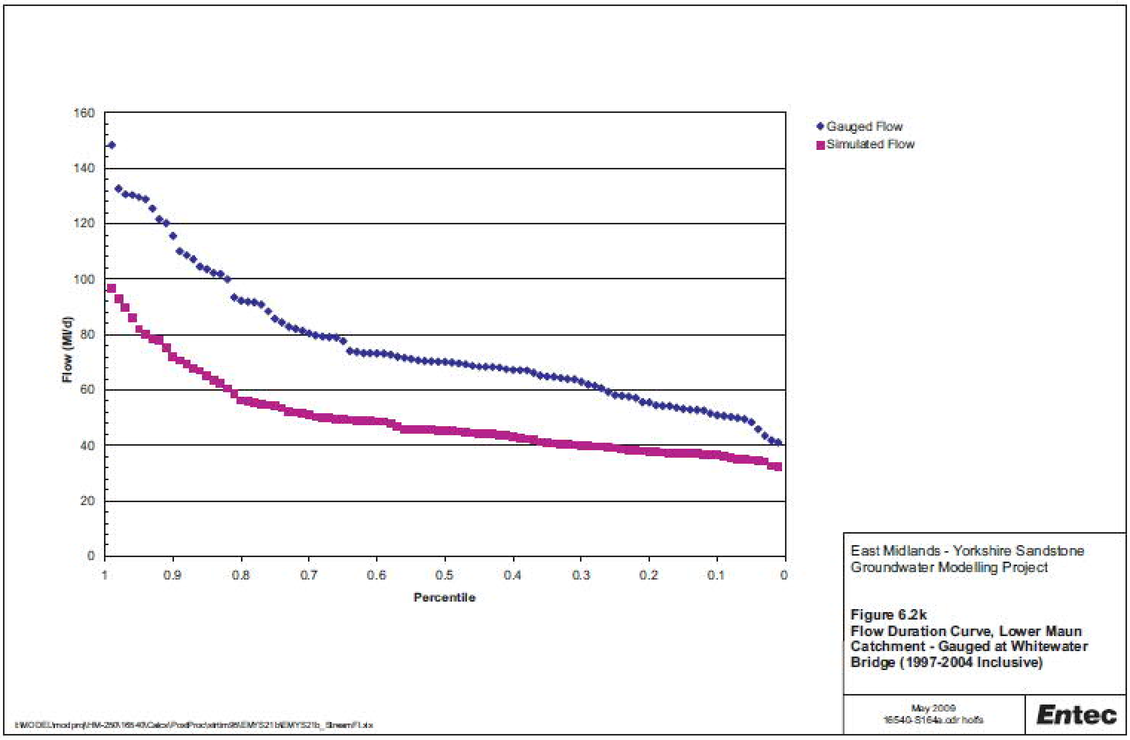

Figure 5.25 Flow Duration Curve for River Maun at Whitewater

Watch Hill groundwater monitoring borehole is located in the Lower Maun catchment, and monitors the Sherwood Sandstone (Figure 5.26). Groundwater levels in a similar patter to the observed levels but the simulated levels show a more prominent declining trend. Simulated levels are lower than observed, resulting in lower than observed baseflow to rivers.

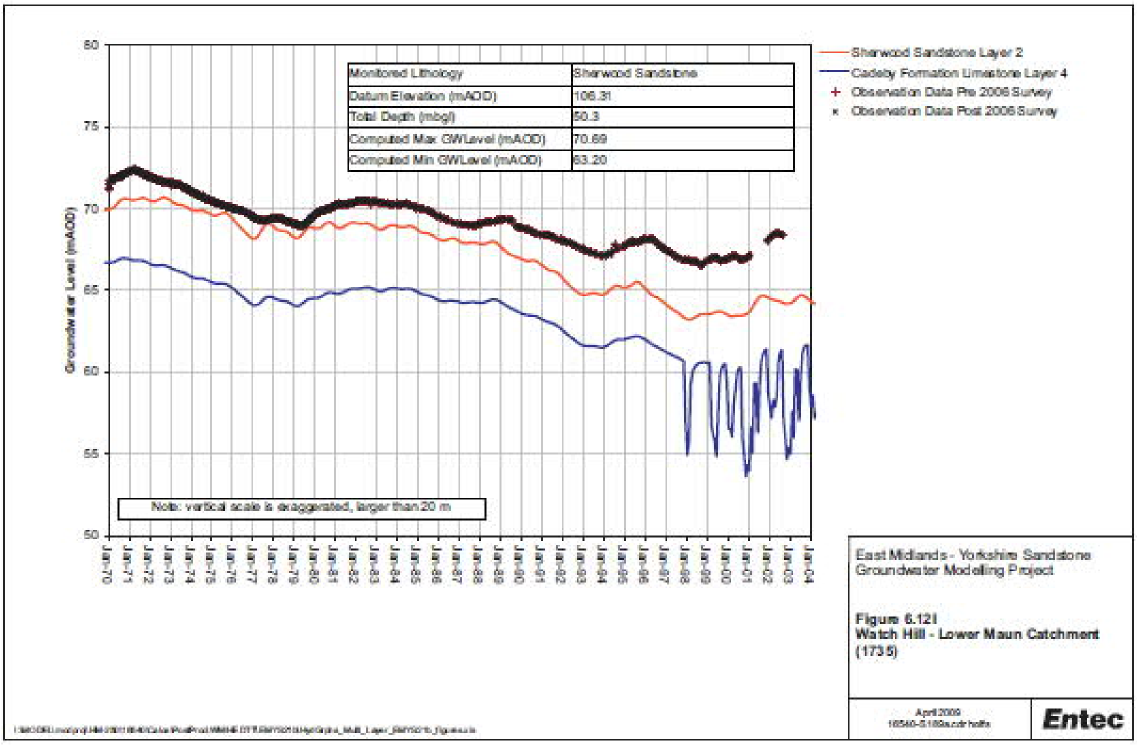

Figure 5.26 Groundwater Levels in Sherwood Sandstone at Watch Hill

The upper Maun flows are recorded at Mansfield gauge (Figure 5.27). The model under estimates flows at high and low flows while the temporal variations are reasonably well calibrated.

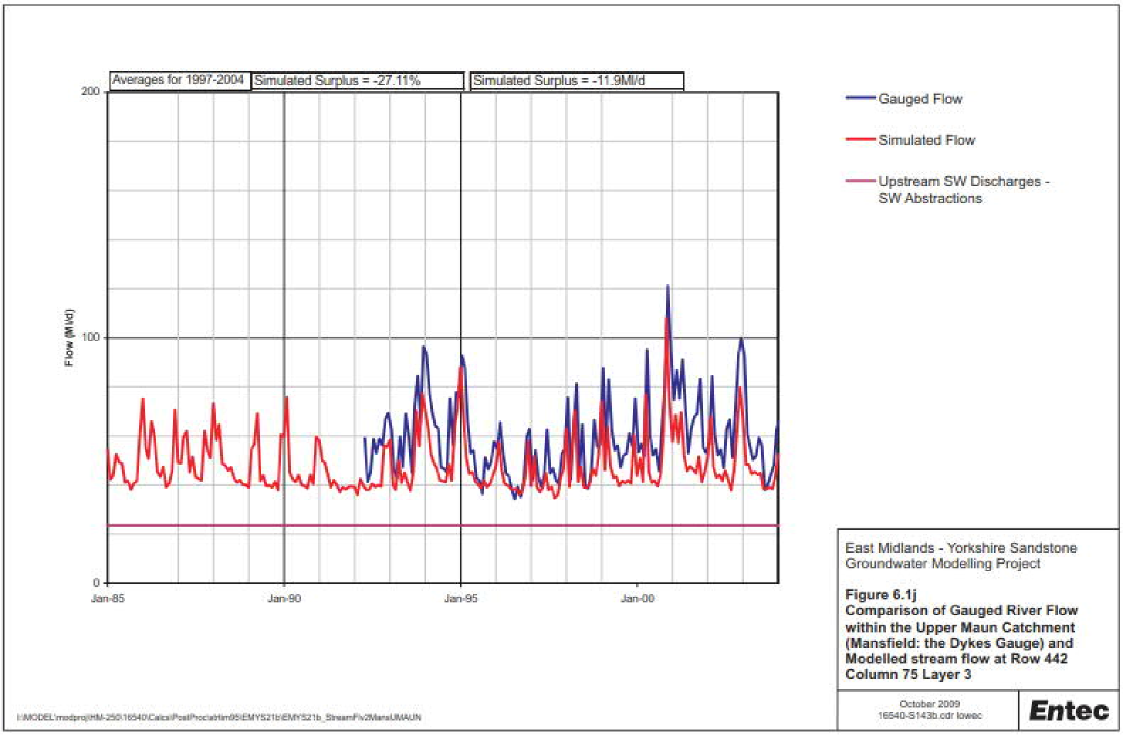

Figure 5.27 River Maun flows at Mansfield

The model summary statistics for flows at Mansfield between 1997-2004 are given in Table 5.7.

Table 5.7 Mansfield river flow statistics

Gauge	Mean Gauge Flow (Ml/d)	Simulated Mean Flow (Ml/d)	Surplus/deficit (-)	Observations
Mansfield	59.7	48.1	-11.9	The overall flow is under predicted across the majority of the flow duration curve. Uncertainty exists with respect to net surface water anthropogenic in/output which are a large component of total flow in this catchment.

The flow duration curve based on data from 1997 to 2004 (Figure 5.28), shows that the rate of change from high flows to Q_{70} is reasonably well simulated but under estimating flow. The curve is flatter than observed from mid to low flows.

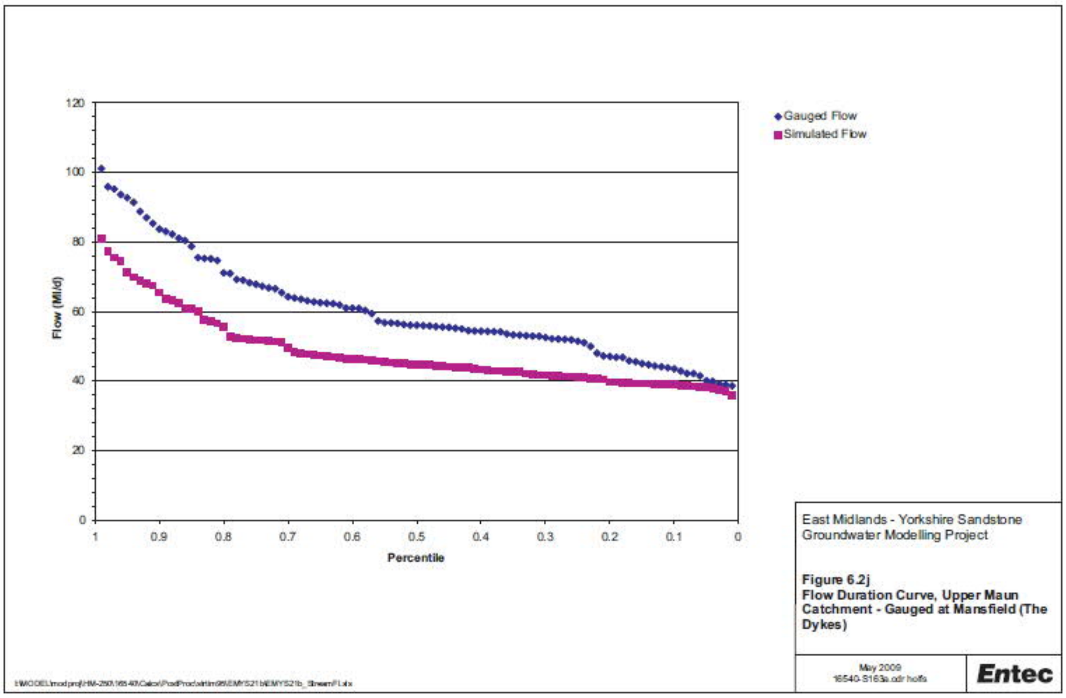

Figure 5.28 Flow Duration Curve for River Maun at Mansfield

5.3.4 Conclusions

The model does not simulate enough flow in each of the rivers in the Idle and Torne catchments, including at high flows which are the focus of this project. The pattern of flow is generally well represented suggesting that while there is not enough flow being simulated, the catchment flow processes are generally represented in most areas. The Upper Meden and Idle to Mattersey are the best calibrated catchments.

Given this, and that surface water abstractions are mooted, we recommend that groundwater model is not used through Phase 2b of the project.

6. Phase 2a Summary and Phase 2b Recommendations

6.1 Summary of 2a

Through a more detailed review of the potential effects of abstractions at time of high flow (above the EFI in both catchments/ the EFI for the Torne is equivalent to the Q_{15} while the EFI for the Idle is equivalent to the Q_{18}) on the physical environment. During Phase 2a AECOM (we) have in turn refined our assessment of the potential effects on the physical environment in the Idle and Torne catchments (focussing on hydrology, water quality and hydromorphology). Potential effects are on the following receptors, amongst others; nationally designated sites, fish, macroinvertebrates and/ or macrophytes.

There are 37 WFD waterbodies, in total, across both catchments. Through our review on the sensitivity of the receptors described above and accounting for potential changes in the physical environment as result of additional high flow abstractions, we recommend that the following are examined more closely during Phase 2b of the project:

- Idle from River Ryton to River Trent (including River Idle Washlands SSSI);
- Maun from Vicar Water to Rainworth Water;
- Meden from Sookholme Brook to River Maun;
- Poulter from Source to Millwood Brook;
- Poulter from Millwood Brook to River Maun (including Clumber Park SSSI); and
- Ryton from Anston Brook to Idle.

Future studies on the following may also be useful (which may be considered to be moderate sensitivity to changes):

- Hatfield Waste Dr (trib of Torne/Three Rivs) and North Soak Drain (trib of Torne/ Three Rivs) (focussed on Crowle Borrow Pits SSSI);
- Meden from Source to Sookholme Brook;
- Ryton (to Anston Brook); and
- Sookholme Brook.

In addition we have undertaken reviews of the Environment Agency River Idle and Torne strategic scale linked 1D/2D hydraulic FMP-TUFLOW flood models and the East Midlands Yorkshire Sherwood Sandstone groundwater models. Our reviews have found that these are not well suited for extended use in Phase 2b of this project.

6.2 Phase 2b recommendations

The existing Environment Agency River Idle and Torne strategic scale linked 1D/2D hydraulic FMP-TUFLOW models are not considered suitable for use in this project for the purposes of exploring potential in channel and inundation floodplain effects as a result of high flow abstraction.

However, we can investigate the potential effects through constructing CAESAR-LisFlood models of discrete reaches/ areas. The tool can be used to determine flow conditions at which out of bank flows and inundation of riparian floodplain areas occurs and examine in channel effects (such as changes in velocities/ shear stresses). Similarly potential differences, as a result of changes in flow as a result of high flow abstraction can be used, can be investigated through scenario analysis using the CAESAR-LisFlood model.

An example of some of the outputs from previous study[39] of ours in which the approach was tested, are provided below (Figure 6.1).

[39] AECOM (2017) Modelling management decisions on WLMP sites. On behalf of the Environment Agency

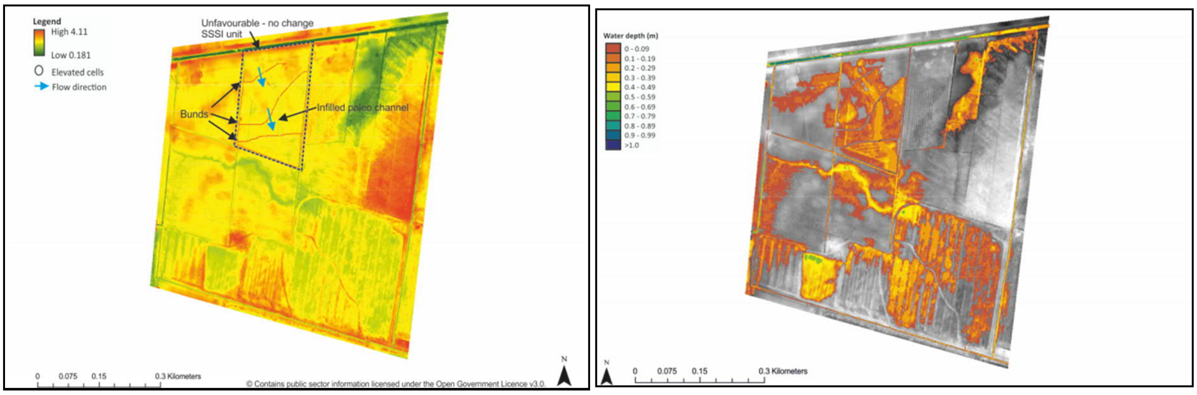

Figure 6.1 Restoration scenario and CAESAR Lis-Flood modelled water depth values for the Hatfield Moors (Isle of Axholme) model

During 2016 AECOM undertake an evaluation of the model for environmental purposes such as those described above (in channel hydromorpological and floodplain inundation effects). The study found that the relative merits of the modelling approach included:

- The model is constructed using freely available LiDAR data, available for most of the UK, and hydrological data that is often available or estimates can be derived;
- The model is able to simulate the environmental effects of a range of relevant management actions (including many that will help those who manage designated sites);
- The models can be constructed relatively quickly;
- Representation of structures such as weirs and embankments are well represented in CAESAR-LisFlood. Culverts can be simulated well up until the point where the structures surcharge during extreme flooding;
- The tool is best applied at simpler fluvial systems, such as river floodplain systems with few drainage ditches and distributaries;
- Up to eight inflows can be included within the model so that a reasonably complicated system can be simulated. A connected groundwater/ surface water system can be simulated by spreading the inflows throughout the study area;
- It can be used to appraise the effects of management decisions and actions at sites including on the ecology that is found there.

The study has found that the relative dismerits of the approach include:

- Large areas (>0.5 km^2) are not simulated easily (with model runs times being slow).
- Large areas can be investigated by splitting them into smaller discrete models whilst the study areas of hydrologically complex sites could be focussed on areas of greater interest (e.g. area surrounding a weir that may be decommissioned); and
- The effects of water management structures such as sluices and pumping stations is simulated better through other models, such as FMP-TUFLOW.

The model requires flow and topographical data.

One of the five waterbodies identified as highly sensitive and recommended for further investigations is situated in the level dependent area of the River Torne. As such it may be harder to simulate conditions at this site using the CAESAR Lis-Flood model. As such we would recommend that it is undertaken in the other 4 waterbodies (subject to there being sufficient resources to do so). Suitable hydrological information for the modelling of parts of these waterbodies is available.

The relative dismerits of the approach can be accounted for through the design of our model and suitable selection and agreement on reaches within a waterbodies that could be simulated. It is expected that the Environment Agency officers may be best placed to where such areas may be (e.g. through local knowledge of particularly sensitive areas).

Such modelling would benefit from a site visit while multiple sites could be visited within the same day to reduce assuming they are easily accessible and in the vicinity of one another. Subject to access being available, we would also be able important designated sites during our site visits and examine presence and importance of in channel structures (e.g. sluices at the end of designated lake systems).

Walkovers (fluvial audits or similar) of the waterbodies identified, or parts of them, would also be beneficial to Phase 2b. Previously the Environment Agency indicated that they may be able to undertake this.

A number of data gaps have been flagged in Section 4.9 of this report, though many of these relate to general gaps that may not be filled during Phase 2b.

Appendix A Hydraulic Model Audits

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A.1 River Idle Model Review

	ACTION LEVELS
RED	Unacceptable: Remedial action required
AMBER	Useful: Improvements recommended
GREEN	Satisfactory: Compliant with best-practice guidance

Explanation:

- **Comments in the 'Action' column are colour coded to indicate how important it is that the proposed changes are addressed.**
- **Any elements not applicable to the audited model are marked with "N/A".**
- **Any improvements made based on the recommended actions should be logged in the 'Issue addressed comment (if applicable)' column.**

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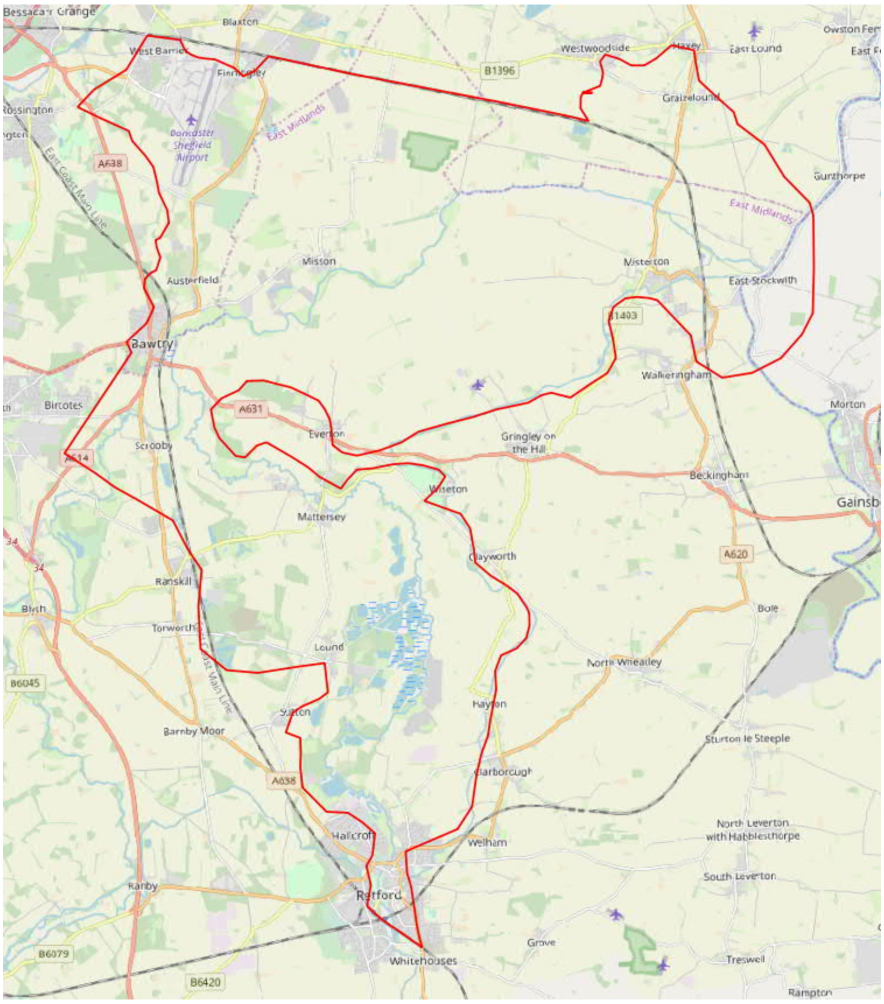
1. Model Overview

1.1 Model extent & description

The River Idle model produced by Capita covers the River Idle from the A1 at Twyford Junction (NGR 469966, 375243) to its confluence with the River Trent (NGR 478991, 394654) at West Stockwith pumping station. The model also included several drains within the 2D domain, and the 2D extent is shown below. The model was built as part of the Water and Environment Management Framework
Lot 1 – Modelling, Mapping and Data Services, to assess fluvial flood risk and West Stockwith Pumping Station, and other catchment management options, for the Isle of Axholme,

The model is a linked 1D-2D Flood Modeller Pro – TUFLOW model.



1.2 Model originator and date created

The model was built by Capita in January 2019.

1.3 Software used

TUFLOW version: 2018-03-AB-iDP-w64 Flood Modeller version: 4.4.0.5162

1.4 Model version reviewed

IDLE_1000F_190 and IDLE_0002F_189

1.5 AEP design events provided for review
IDLE_1000F_190 and IDLE_0002F_189
1.6 Model files reviewed
IDLE_1000F_190.dat IDLE_0002F_189.dat
1.7 Guidance used to inform the review
List any guidance documents used to inform the review. For example: Fluvial Design Guide – Chapter 7 Hydraulic analysis and design (FDG2, 2009) Flood modeller online manual (CH2M HILL, 2015) TUFLOW manual (version 2016-03) CES Manning's Roughness Advisor

2. Survey Review				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Has topographic survey been provided?	Pass	WEM_Lot1_Package1_Report_IDLE_FINALv1 reporting outlines 4 sets of survey dated 2002 to 2012. Survey provided is dated as 2015. X-PH-IOA-01-32 1 (Lower Reach) covers IDLW_0d to IDLW_18118bu. X-PH-IOA-33-54 2 (Middle Reach) covers IDLW_18118bu to IDUP_38522sp. X-PH-IOA-55-59 3 (Upper Reach) covers IDUP_38522sp to IDUP_49194. Unknown where sections upstream of IDUP_49194 are from. Survey can be found at: \\Ukmcr1fp002\ukmcr1fp002-v1ie\Proposal\3512\EA Idle and Torne 2019\4. Analysis\Hydromorph\Idle Survey	The survey provided differs from the survey outlined in the reporting. However, as the 2015 survey data matches the model geometry, it is assumed this survey has been used in the model build.	
Is the topographic survey of an acceptable age?	Pass	Survey referenced in the reporting summarised below, oldest of which is from 2000. Eaton to Retford Survey from 2000, A1 down to North of Retford survey and Bawrty to West Stockwith survey from 2002.	All survey referenced in the reporting is more than 18 years old. Difficult to undertake checks to ascertain areas that might need to be updated without original survey. The survey provided differs from the survey outlined in the reporting. However, as	

		However, survey provided is dated as 2015, which would be of an acceptable age.	the 2015 survey data matches the model geometry, it is assumed this survey has been used in the model build.	
Does the survey comply with current EA National Survey Specification?	Pass	Survey provided complies with EA National Survey Specification.		
Does the cross-section spacing of the survey provided seem reasonable?	Pass	Cross-section survey spacing seems reasonable.		
Does the survey include information on channel structures (including trash screens) and channel roughness?	Fail	Survey provided but contains no information on channel roughness.		
Has LiDAR of appropriate resolution been provided?	Pass	Model 2D domain predominantly covered by 1m LiDAR, with missing areas filled in with 2m LiDAR. However, 1m LiDAR flown in 2011 and 2m LiDAR in 2008.	The use of newer or composite LiDAR could improve model accuracy.	

3. In-Channel Representation				
3.1 Cross-section schematisation				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Is georeferencing information (e.g. a gxy or ixy) available?	Pass	GXY file supplied. Some sections between IDUP_45100 and IDUP_43451 not fully georeferenced.	Fill in missing georeferencing data for all sections and structures.	
Is the node naming convention logical and include chainage information?	Pass	Naming logical and based on chainage. However, 1D cross-sections do not always contain a comment referencing the surveyed section that they are based on.		
Does the model chainage seem reasonable for the channel length/sinuosity?	Pass	Generally appropriate throughout model – some instances where sinuosity not captured. See comment below.		
Does the model chainage match with the cross-section survey?	Pass			
Is the cross-section spacing appropriate; i.e. is it erratic or reasonably consistent?	Pass	Cross-section spacing generally appropriate, although 200m+ intervals are present between three sections: IDUP_45100 IDUP_47560 IDUP_38494ds. All three sections are located within rural areas, however there is a meander between IDUP_38494ds and IDUP_38318. See Figure 1.	Interpolated sections could be used where chainages are large and where channel meanders between surveyed sections.	
Does the channel width match the cross-section survey?	Pass	Survey not provided.		
Have hard or softbed levels been used in the model?	Pass	Hard bed levels have been used.		

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Have cross-sections been deactivated appropriately; i.e. near the highest elevation points in the cross-section survey?	Pass	Good correlation between 1D cross-section widths and 2D channel extent throughout model, except for sections IDLW_135999 and IDLW_6868. See Figure 1.	Cross-sections IDLW_135999 and IDLW_6868 should be updated to ensure a match between the 1D and 2D domains.	
Have top of bank markers been used correctly?	Pass			
Have panel markers been used appropriately? Is channel conveyance smooth?	Pass	Panel markers used throughout. There is a Jump in conveyance at IDUP_41785bu IDUP_41658bu.	Embankment markers should be added at bridge units to ensure smooth conveyance.	
3.2 Channel roughness				
Do the roughness values seem to fall within an appropriate range?	Pass	Roughness values between 0.03 and 0.05.		
Do the roughness values show reasonable consistency? If not, have changes been justified?	Pass			
Has evidence been provided to justify variation in Manning's roughness values?	Fail	Roughness taken from survey, however no information on channel roughness is included with the survey provided. Reporting states roughness values have been checked and amended in line with Chow et all but no evidence provided.	Provide evidence of how roughness values were adjusted in line with Chow should be provided.	
3.3 Structure representation				
Has a list of modelled structures been provided, and any exclusions justified?	Fail		Provide list of structures included within model as part of supporting documentation	
Do there appear to be any key structures not modelled?	Pass	All key structures appear to be modelled.		
Does a sample check of the structure dimensions	Pass			

match with the survey drawings?				
Have bridge and culvert units been used appropriately; i.e. culvert schematised for bridges where the length:width ratio is greater than 2:1?	Pass			
Are spills over bridge and culvert parapets included?	Pass			
Have inlet and exit losses been represented with appropriate units?	N/A	No culverts present within model extent.		
Do head losses across structures appear reasonable for a high-magnitude event?	Pass			
Are appropriate losses for changes in culvert geometry and direction included?	N/A	No culverts present within model extent.		
Do structure coefficients and modular limits appear reasonable?	Pass	Modular limits at Spills, Sluice units and orifice units all default values.		
If applicable, are any control rules appropriate?	Pass	West Stockwith Gate Operation rules provided by EA and incorporated. Gates represented by sluice units Gate_A_us and Gate_B_us. Sluice gates NCD_A, MISSUS_A and MISSION_A closed throughout simulation.		

4. 1D Out-of-Bank Representation

4.1 Extended cross-sections

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
Is the discretisation of extended cross-sections too sparse or too detailed?	Pass			
Have extended cross-sections been used where depth of flooding is excessive?	Fail	Glass-walling occurs at IDUP_43714bu during the 2% AEP event and at IDUP_45993bu during the 1% AEP event.	Extend cross-sections so that glass-walling does not occur. This may not be an issue at lower return periods (focus of current study).	
Do extended cross-sections intersect with one another?	Pass			
Are the extended cross-sections approximately perpendicular to flow?	Pass			
Is the cross-section spacing appropriate; i.e. is it erratic or reasonably consistent?	Pass			
Have the sections been sufficiently extended to avoid glass-walling?	Fail	As above, glass-walling occurs at IDUP_43714bu and IDUP_45993bu	As above, extend cross-sections so that glass-walling does not occur.	
Have defences and any scheme options been appropriately represented?	N/A	Figure 2-2 in the WEM_Lot1_Package1_Report_IDLE_FINALv1 reporting suggests all defences are within the linked 1D/2D domain.		

4.2 Floodplain reservoirs

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
Do 1D reservoirs glass-wall?	Fail	Reservoirs do not glass-wall in the 1D domain, but there is glass-walling between the 1D reservoir and 2D boundary.	See below comment.	
Are there a sufficient number of spills from the channel into the reservoirs?	Fail	Spill units connected to surveyed sections adjacent to reservoir units, however spills	Spill lengths connecting 1D sections to reservoirs should match the chainage	

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		lengths differ from bank lengths between the surveyed sections. E.g. chainage between IDUP_43219 to IDUP_43129 is 90m, and the length of the spill unit attached to SP_43219 spill is 192m. Similarly, The chainage between IDUP_43129 and IDUP_43034u is 96m, whereas the SP_43129 spill unit length is 140m. This disparity also occurs at reservoir RE_42600a.	between associated sections, to ensure realistic representation of over bank flows. The spills should be remodelled accordingly where necessary.	
Have reservoirs been used where there is a steep channel gradient?	Pass	Channel gradient is not steep where reservoirs have been used.		
Do reservoir boundaries appear to be consistent with ground topography?	Fail	RE_43129a reservoir area well defined by East Cost Main Line and the Sheffield to Lincoln Line. The RE_42600a reservoir area is also well defined by the East Coast Mainline and Victoria Road. The RE_42479a reservoir is used to model the right bank floodplain between the Sheffield to Lincoln Line and Albert Road. However, there is interaction between this area of floodplain and the floodplain further downstream. No interaction can occur as the reservoir unit is not connected to the 2D domain, therefore glass-walling against the 1D domain boundary occurs. The glass-walling at the 1D domain boundary first	The area modelled in 1D through the RE_42479a reservoir unit should be modelled as part of the 2D domain or connected to the 2D domain through a spill unit and SX connection to ensure that the transfer of flow and interaction between different areas of the floodplain is fully captured. Whilst this will impact the modelling results, it has no impact on flows below the 2% AEP event (which are the focus of current study).	

		occurs during the 2% AEP event. See Figure 2.		
Does there appear to be any overlap between extended cross-sections and reservoirs (which would result in double-counting)?	N/A	Cannot check without shapefile used to generate reservoir unit.		

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5. 2D Out-of-Bank Representation				
5.1 2D domain schematisation				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Is the number of domains appropriate?	Pass			
Is the 2D horizontal cell size suitable for the study objectives?	Fail	Grid size of 20m throughout 2D domain cannot effectively capture smaller watercourses/drains. Furthermore, in some locations the banks are represented by a single HX cell. See below comment regarding 1D/2D spacing.	Reduction in grid size would improve model accuracy; especially in relation to small watercourses/drains within the 2D domain. Reducing grid size would also adversely affect model run times.	
Is the grid orientation suitable?	Pass			
Is the domain extent sufficient so that glass-walling doesn't occur?	Fail	Glass walling occurs adjacent to the left bank at node IDUP_42168. Glasswalling occurs during the 20% AEP event and above. See Figure 3.	2D domain should be extended in this area to prevent glasswalling noting that a 20% AEP event is significantly larger than the flow threshold above which abstractions may occur (Q18) (18% of flows above the value of Q18, rather than a 1 in 18year event).	
Is the connectivity to the 1D domain (e.g. HX or SX links) appropriate?	Fail	Appropriate throughout the model except for at RE_42479a where an SX connection to the 2D domain should be included.	See comments on reservoirs representing floodplain and Figure 2.	
Is the spacing between 1D-2D connection appropriate?	Fail	In several locations just one active HX cell links the 1D domain to 2D domain. Separate HX cells to represent each bank are not activated, due to the coarse grid resolution.	See grid cell size comment above.	

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		Coarse grid resolution also precludes deactivation of the 1D channel area at several locations. HX cells representing the right and left banks are therefore adjoining which can reduce accuracy of 1D/2D link. Examples include, but not limited to, watercourse reaches at nodes IDUP_41905i. IDUP_40994, IDUP_40566i1, IDUP_35284, IDLW_23259. See Figure 4.		
Is the 1D-2D connectivity at structures suitable?	N/A	Spills at all structures modelled in 1D.		
Has the channel area been deactivated so that double-counting does not occur?	Pass	Channel deactivated throughout model, however cross-sections IDLW_135999 and IDLW_6868 both extend into the 2D domain. Shapefiles used to generate reservoir unit geometry not supplied, consequently it is not possible to check if double counting of storage volume occurs where reservoir units used to represent floodplain. See Figures 1 and 2.	Channel should be updated so 1D and 2D cross-section widths match. Supply data used to generate reservoir unit geometry.	
Has the floodplain been adequately represented between the 1D and 2D domains; i.e. extended cross-sections not extending into the 2D domain?	Pass	There is generally a good match 1D and 2D cross-sections, however IDLW_13599 and IDLW_6868 both include sections of the floodplain also present within the 2D domain.	Channel geometry should be updated so 1D and 2D cross-section widths match. Truncate sections IDLW_13599 and IDLW_6868 to match deactivated channel	

			extent within the 2D model.	
Is LiDAR used to represent the 2D topography; i.e. has a zpt layer been used of indeterminate age?	Pass	Model 2D domain predominantly covered by 1m LiDAR, with missing areas filled in with 2m LiDAR. However, 1m LiDAR flown in 2011 and 2m LiDAR in 2008.		
Have floodplain features and obstructions been represented appropriately?	Pass	Zshape and Zline have been used to represent floodplain features including drainage channels and defences.		
Have buildings been represented in the 2D domain appropriately?	Pass	Building's represented through increased Manning's value (0.5). this is relatively high in comparison to specifications used in other AECOM built WEM models.		
5.2 Top-of-bank schematisation				
Have top-of-bank elevations been schematised in the model at the 1D-2D boundary?	Pass	Zpoint GIS features read into model as part of 2d_bc input using the 'ZP' flag. 1D and 2D bank levels correspond.		
Is there any evidence that the best available data (e.g. AIMS or topographic survey) has been used to define the bank top crests?	N/A	Levels stated as being taken from survey, but as no survey provided this cannot be verified.		
Is there any evidence that checks have been undertaken between the bank top levels and LiDAR?	Fail	No evidence provided.	Comparison between surveyed bank levels and LiDAR should be undertaken to establish locations where bank levels are being over/underestimated.	
5.3 Out-of-bank roughness				
Are the 2D roughness values within a suitable range?	Fail	Manning's value of 0.5 used for roughness patches throughout model domain.	0.5 roughness is excessive. Alternative methods of improving stability around 1D/2D boundaries should be	

			considered, such as specification of Form Loss Coefficient value within HX boundaries.	
Have any sensitivity tests been undertaken involving altering floodplain roughness?	Pass	Undertaken but reporting does not state if satisfactory.		

6. Model Boundaries

6.1 Inflow boundaries

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
Have appropriate inflow boundary types been used?	Pass	FEH boundaries used throughout and pumping station catchments applied directly at pumping station location.		
Does inflow boundary distribution seem reasonable; e.g. lateral inflows distributed logically?	Pass			
Do initial conditions within the 1D domain seem appropriate?	Pass	All 1D initial conditions are within channel for the defended scenarios, however the same initial conditions would be out of bank for the undefended scenario model. Initial conditions were reduced to in bank for the undefended scenario, thus the defended and undefended scenarios have differing initial conditions.	The lower, undefended initial conditions should be used within the model for future runs.	
If applicable, are any sweetening flows appropriate, and been removed from the model?	N/A	No sweetening flows.		
Do the upstream & downstream inflows correspond to the FEH/Hydrology report, if available?	N/A	Hydrology not included in reporting.		
Are any inflows located close to structure justified?	Fail	Missus_INF located at Missus_A sluice. No justification provided.		
If applicable, are any pump/abstraction units appropriate?	Pass	Drain pumps connected to the 2D domain via SX connection. Rules applied via abstraction		

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		units match those in report appendix. West Stockwith pump rules applied via 8 Abstraction units. Rules similar for each abstraction unit with activation levels changing. Pumping rates derived from this sheet. FMP Pump units not used to represent pumps, which would allow discrete specification of pump characteristics.		
Has an appropriate storm duration been used, and any other storm durations assessed?	Fail	42.5 hours used for all inflows. No evidence that other durations were tested or explanation which 42.5 hours was used.	Other critical durations could be tested. This is only necessary for assessing flood flows, and thus may not be required for this study.	
6.2 Downstream boundary				
Is the location and schematisation of the downstream boundary appropriate?	Fail	Boundary based on the Tidal Trent Model levels at West Stockwith. The HTBDY unit was specified for a duration of 140 hours, however the model simulation was 200 hours in length, meaning the last 60 hours of simulation time featured constant level (the final value within the tidal curve) applied as the downstream boundary. See Figure 5.	Downstream boundary needs to be extended to cover the entire length of the simulation. Pumping rules/rates are influenced by tidal levels and, as such, this could impact all results within the influence of the West Stockwith pumps.	
Is there any evidence that the sensitivity to downstream conditions has been assessed?	Pass	Model Report indicates that sensitivity testing of downstream boundary conditions was undertaken as part of modelling exercise.		

7. Calibration, Verification, and Sensitivity Analysis

7.1 Calibration and verification

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
Has the selection of events been appropriately justified?	Pass	Three events selected (November 2012, January 2008, December 2012) but no justification provided within Model Report.		
Does the best available data appear to have been used?	Pass	Reporting states that available pump records and gauge record datasets, were incomplete and/or unreliable.		
Is there any evidence of the model replicating historical events satisfactorily?	Pass	Within 150mm tolerance at all but one gauge, the North Carr Farm gauge (Model node: IDLW_8831). Gauge discrepancy attributed to manual override of pumps.		
Has calibration knowledge been transferred to design events?	Pass			

7.2 Sensitivity analysis

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
Has sensitivity analysis been undertaken to test model sensitivity to e.g. roughness, the downstream boundary, flow changes.	Pass	Roughness and downstream boundary.		
Has model uncertainty been quantified?	Pass			
Have the major model assumptions been detailed?	Pass	Report states a cell size of 10m has been used, however 20m has been used.		

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8. Model Run Parameters & Performance

8.1 Model run parameters

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
What is the time step? Is it appropriate?	Pass	2D timestep for 20m grid size: 10 seconds 1D timestep for 20m grid size: 5 seconds.	Specification of a 2D timestep of ¼ of the 2D grid size (5 seconds) and a 1D timestep of half this revised 2D timestep could aid model convergence and stability across 1D/2D boundaries.	
Have any simulation parameters been edited? If so, are they within acceptable limits?	Fail	All default run parameters used within Flood Modeller. However, the output save interval has been specified as 5 seconds which produces very large results files. These take considerable time to open and process.	Output save interval should be increased (e.g. to 300 seconds) as this will have no impact on the model performance and allow results to be easily managed.	
If applicable, have any changes in simulation parameters for different events been justified?	N/A			
Are run times reasonable?	Pass	Run time 18 hours for 0.1% AEP event.	Note – halving the grid size (see earlier comments) would approx. double the run time but would still be acceptable. Increase of the output save interval (see above comment) may reduce model run time	

8.2 Performance

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
Is model convergence good?	Fail	Poor convergence throughout model for 0.1% AEP event. Most notably at: IDLW_18118 IDLW_19924 IDUP_43333 See Figure 6.	The bridges at IDLW_18118 and IDLW_19924 should be replaced with Orifice units to aid convergence. Poor convergence is prevalent throughout all simulations, as is a degree of noise	

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		Poor convergence is also present throughout the 50% AEP simulation. Notably at IDLW_dsby_U. (the downstream boundary). In addition, oscillation of flows occurred between the 1D and 2D domains at several locations throughout the model, notably at IDLW_18586. See Figure 7.	(fluctuations of flow/stage within the 1D domain). This could likely impact results and the sources of poor convergence should be addressed. See previous comments regarding using FLC values on HX lines.	
Are there any negative depths?	Fail	No model log provided.		
Is mass balance reasonable (target ± 1%)?	Fail	No model log provided.		
Are there any warnings or errors within the 1D domain?	Fail			
Are there any warnings or errors within the 2D domain?	Fail	No model log provided.		

9. Audit Trail				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Has a model report/interim handover report been provided?	Pass	Report provided.		
Has a model log been provided?	Pass	Log provided		
Is the file naming and structure clear and logical?	Pass	Yes		
Have check files been provided?	Pass	Yes		
Have sufficient comments been provided within the 1D model?	Pass	Yes		

10. Concluding Remarks

10.1 Suitability of modelling approach

A linked Flood Modeller-TUFLOW was suitable for use in the original study, however changes may be required in order to utilise the model for the high flow study. The grid size should be reduced along with other recommendations below.

10.2 Key findings and recommendations

For the purpose of the High Flow study, the Idle model will need to be run with inflows below the 50% AEP event. However, as the 50% AEP event is the lowest AEP provided, the performance of the model during this event has been assessed.

Whilst there are a number of issues within the model which need to be updated, those that apply specially to the 50% AEP event are glass-walling and fluctuations in flow at the 1D/2D domain boundary. Figures 8 and 9 demonstrate how much out of bank flow occurs, even at lower order events, and fluctuations which occur across the domain boundary. Both of these factors are likely impact model results. Whilst glass-walling occurs even at the 50% AEP event, this can be rectified by extending the cross-sections based upon LIDAR or by interpolating from wider cross-section upstream and downstream.

Figure 10 shows the Flood Modeller 1D convergence plot. There is poor convergence throughout the simulation, however oscillations in water level are not as large as those shown in Figure 7. The model may not include enough detail to accurately represent flows below the 50% AEP event; this is especially true of channels within the 2D domain, where shallow flows are unlikely to be captured by the coarse grid size.

In addition to the above, a number of performance issues with the model should be addressed before it is used for the High Flow Study.

Instances of glasswalling occur at the edge of the 2D domain and at the RE_42479a reservoir boundary, which need to be addressed. Glasswalling in the 1D domain results in increased depth and flow within the 1D channel and the 2D domain. This produces increased depths and inaccurate representation of floodplain flow paths and flood extents. Glasswalling within the 2D domain occurs during the 20% AEP event, so this may not be an issue during smaller flow events. Glasswalling within the 1D domain occurs during the 2% AEP event, so again may be less of an issue at lesser flows (which are focus of the current study).

Significant oscillation of flows across the 1D/2D link files and fluctuations in flow and stage occurred during the reviewed model runs, which would impact results. Changes in the model structure and setup, such as introduction of FLC values at the 1D/2D boundaries and the reduction of 1D and 2D timesteps may help to improve model stability.

There are a number of uncertainties regarding dimensions of the 1D reservoir units within the model. Whilst there is survey data, the polygons used to generate the reservoir units are not provided, thus any overlap between surveyed sections and reservoir units cannot be identified. Without the shapefiles used to generate the reservoir units within Flood Modeller, dimensions cannot be checked for accuracy or possible double counting of floodplain volume.

Discrepancies occur between 1D spill widths and associated bank lengths, where 1D spills have been used to model out of bank flow from the channel. 1D spill widths should match the chainage between nodes they are attached to.

The 1D and 2D model timesteps will have to be lowered if the grid size is reduced. Reducing the grid size will also improve the representation of the 1D channel, 2D channels and floodplain flow paths. There are 2D inflows within *the model connected by pumps to the 1D domain, and as such a reduction of the grid size will improve the linkage between the 1D and 2D domains even when flows are in bank within the 1D domain.*

The downstream boundary conditions do not run for the whole simulation; the model run time is 200 hours, and the downstream boundary runs for 140 hours. The boundary should be extended to run for the whole simulation as, under the current setup, a single level is applied for the final 60 hours.

Abstractions and logical rules have been used to represent pumps rather than pump units. Correctly implemented the use of abstraction units will not impact results, however it means pump curves were not discretely simulated.

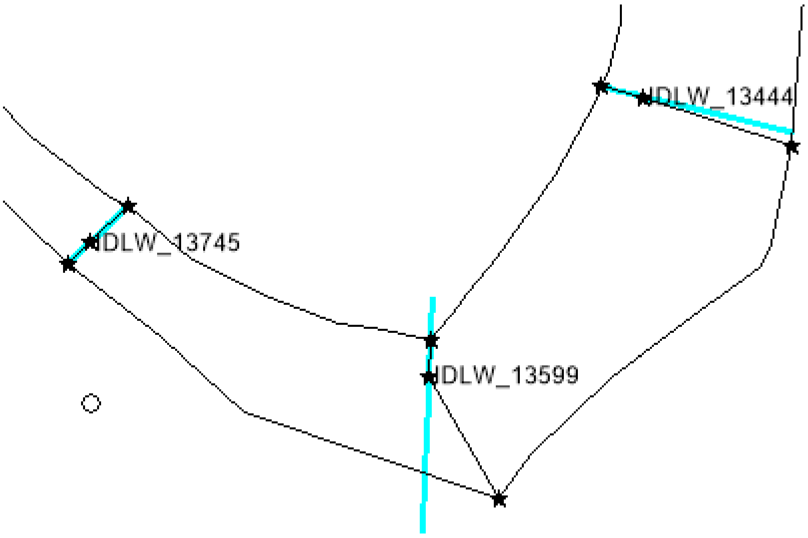
Whilst the save interval specified within the model does not impact results, file sizes are prohibitively large. Increasing the model output save interval would allow generation of easily manageable ,model outputs.

11. Model audit signoff

Model audit signed off by	Sam Burrows
Model audit approved for issue by	Richard Karooni

12. Figures

Figure 1: Discrepancy between 1D and 2D cross-section widths.



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See Figure 2: Glass-walling at reservoir boundary.

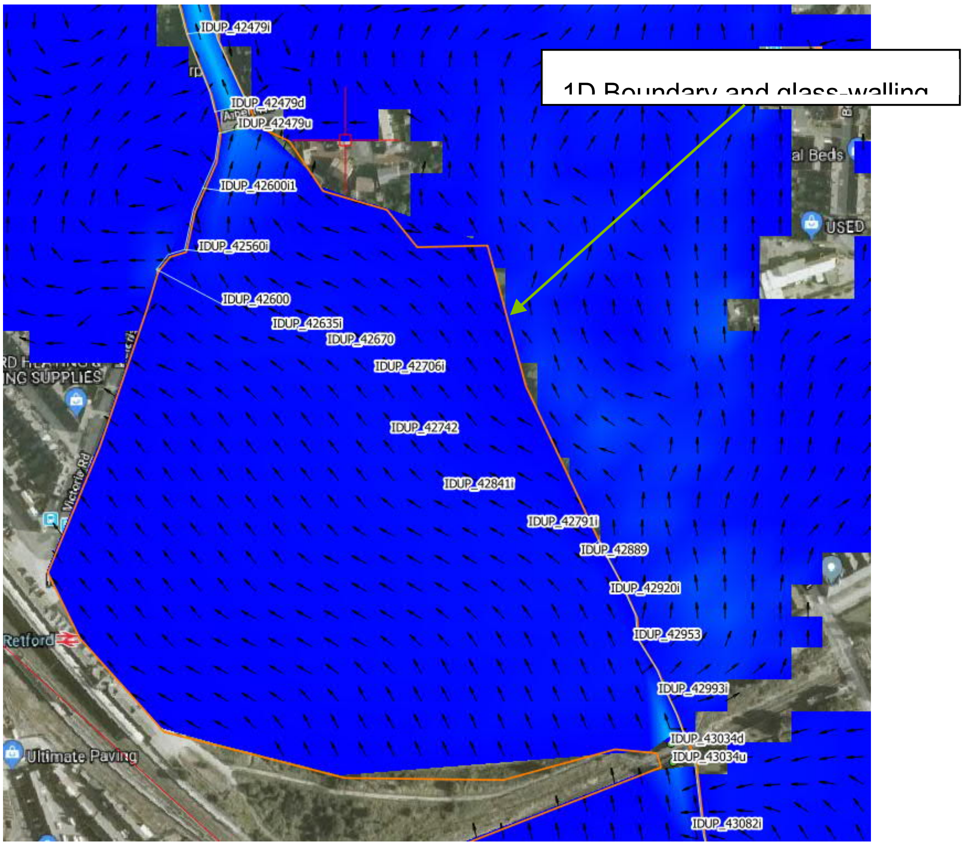


Figure 3: Glass-walling.

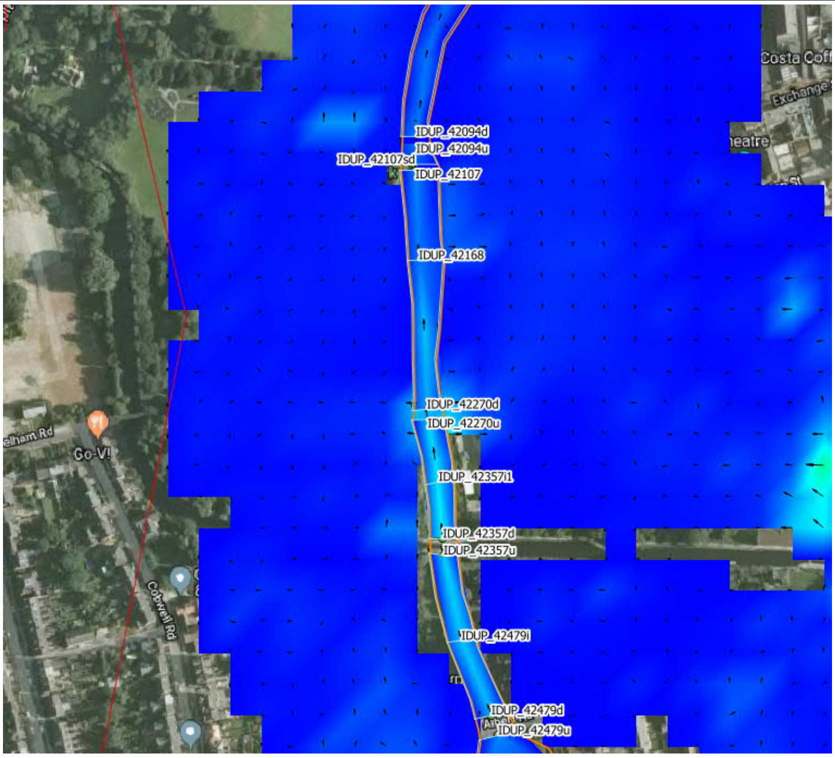

IDUP_42094d
IDUP_42094u
IDUP_42107sd
IDUP_42107
IDUP_42168
IDUP_42270d
IDUP_42270u
IDUP_42357i
IDUP_42357d
IDUP_42357u
IDUP_42479i
IDUP_42479d
IDUP_42479u
Costa Cof
Exchange
Cobwell Rd
Go-V!

Figure 4: Example of both one HX cell representing both banks and no inactive cell between active HX cells.

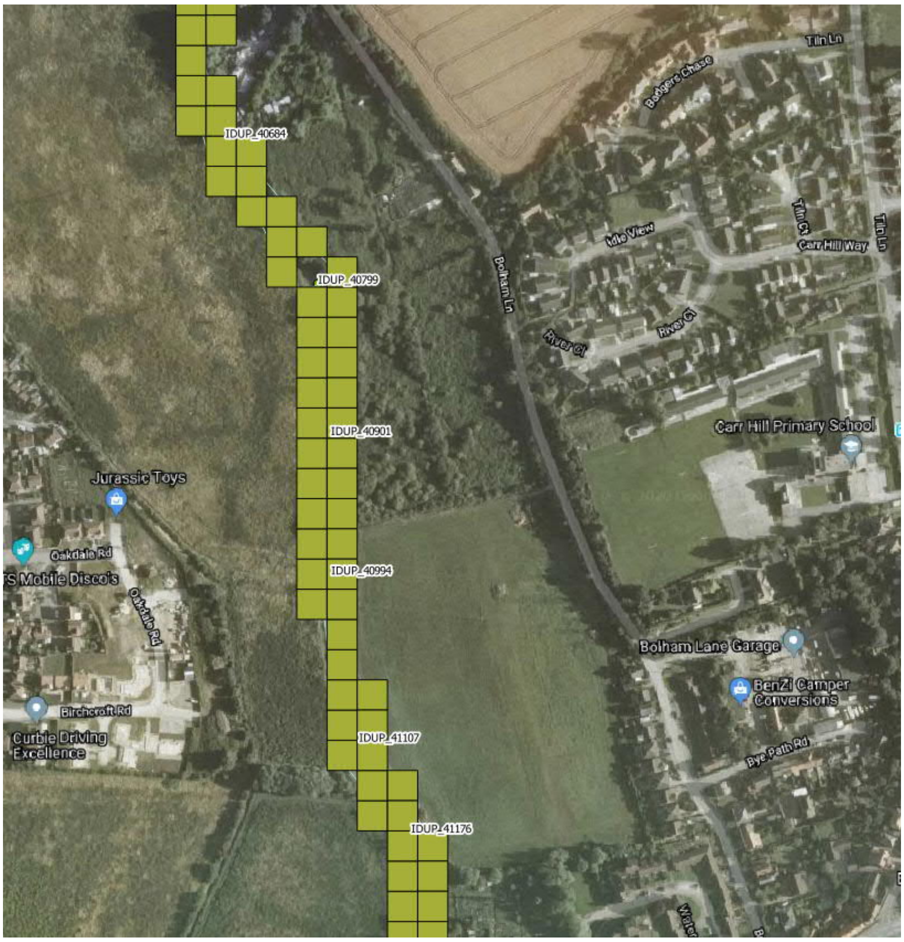


Figure 5: Downstream boundary stage

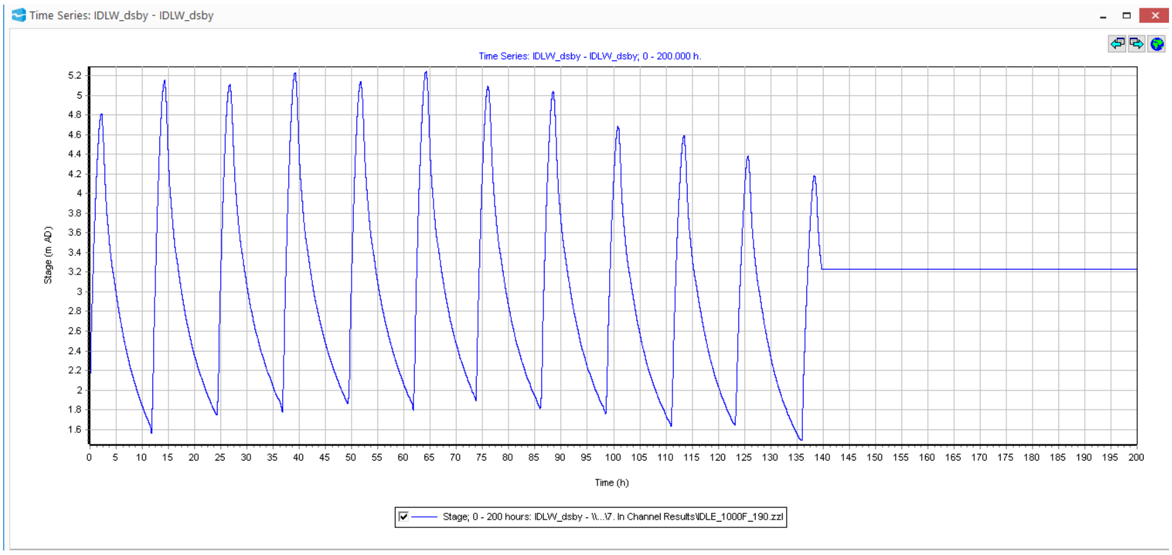


Figure 6: Oscillation of water levels during poor convergence at IDLW_18118u for the 0.1% AEP event.

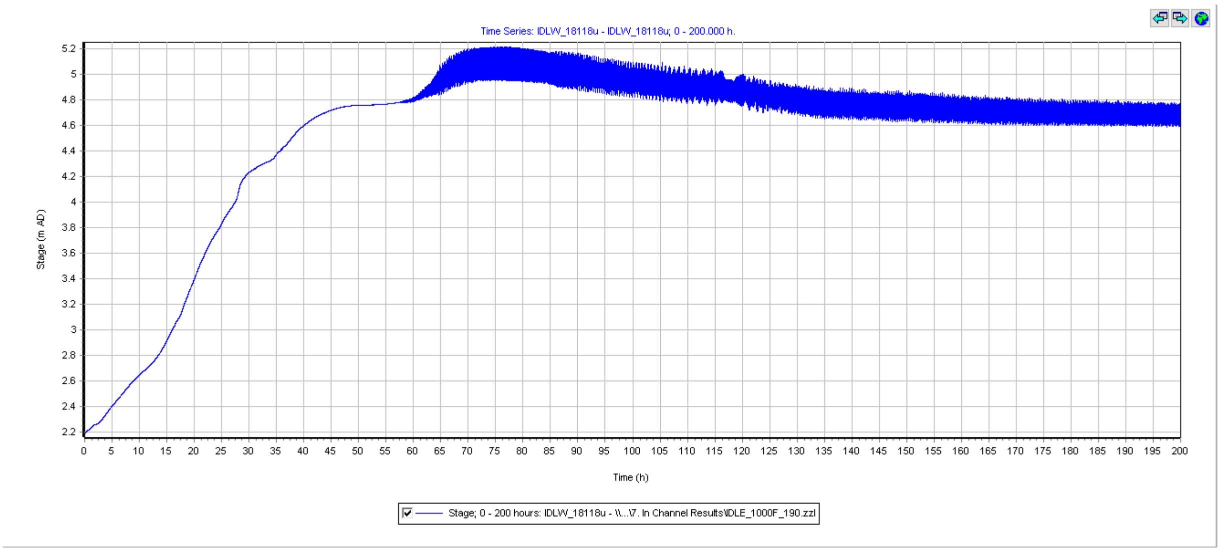


Figure 7: Sample of 2D inflows for the 0.1% AEP event.

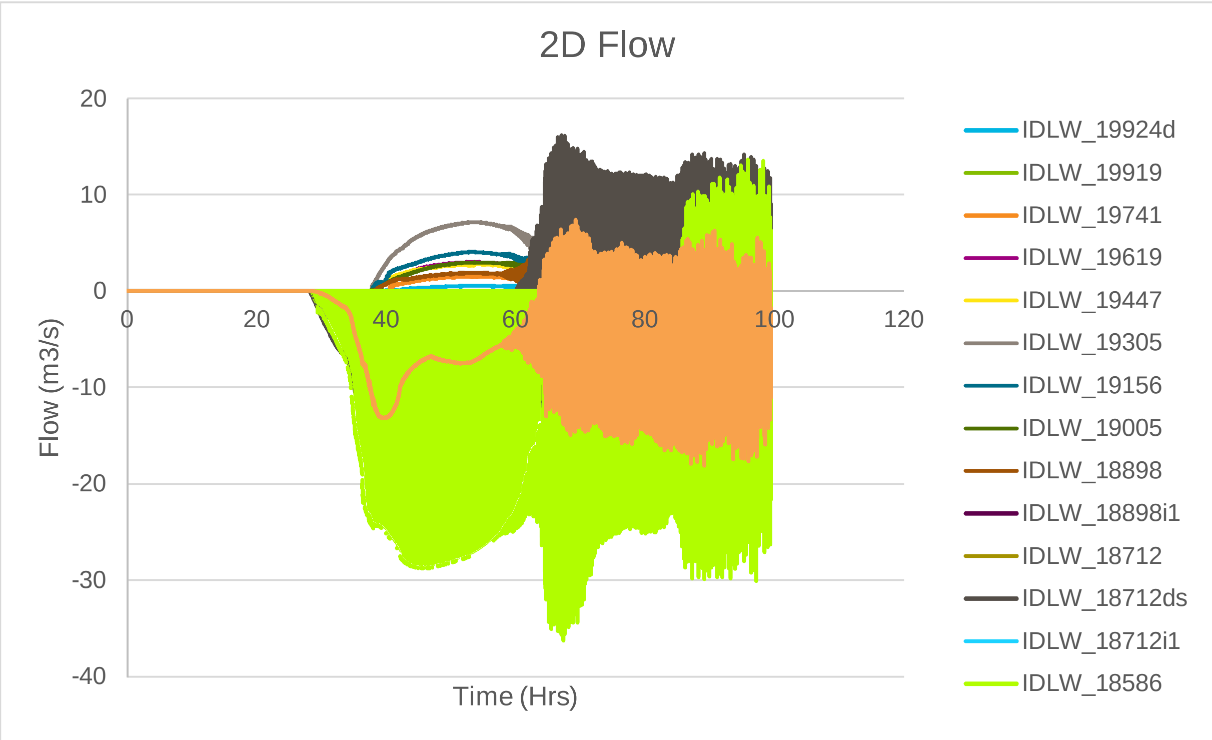


Figure 8: Lower Idle: 50% AEP flood extent and bank lines demonstrating areas where out of bank flooding occurs.

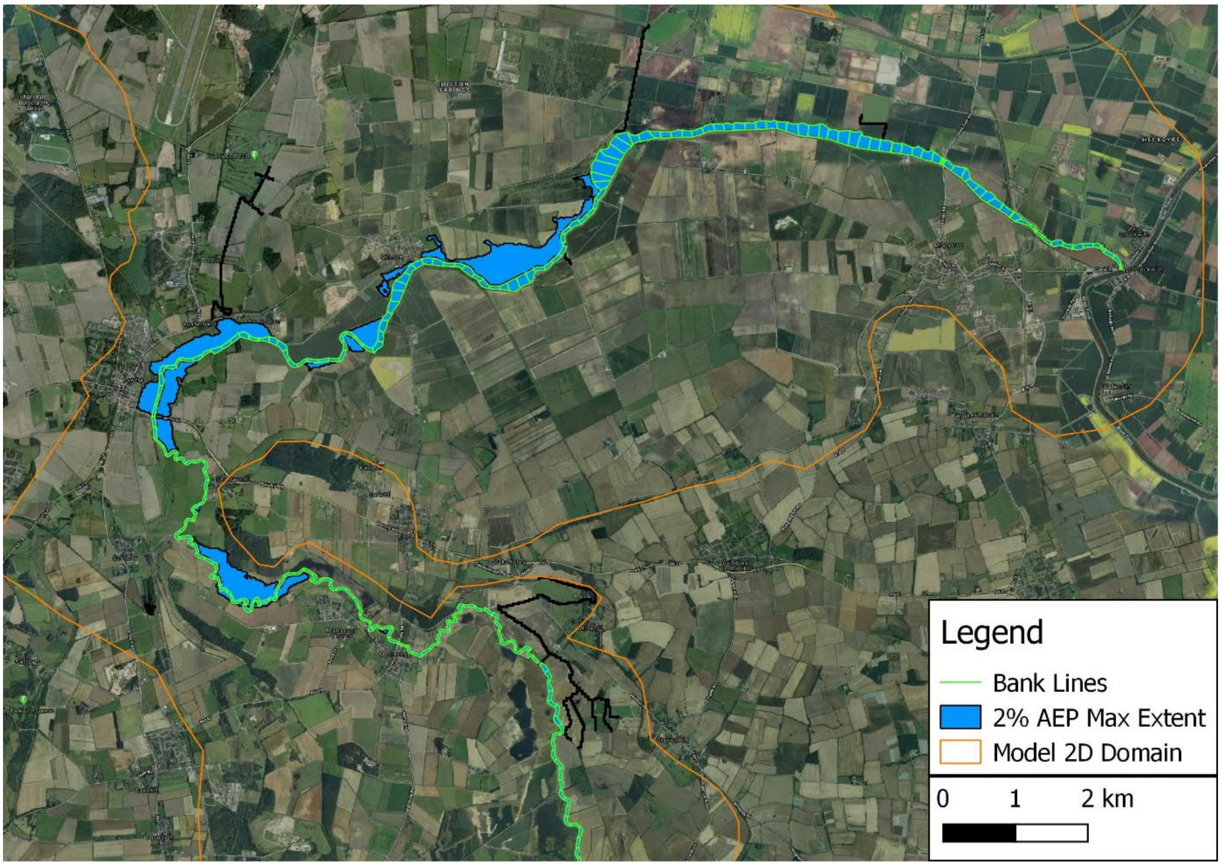


Figure 9: Upper Idle: 50% AEP flood extent and bank lines demonstrating areas where out of bank flooding occurs.

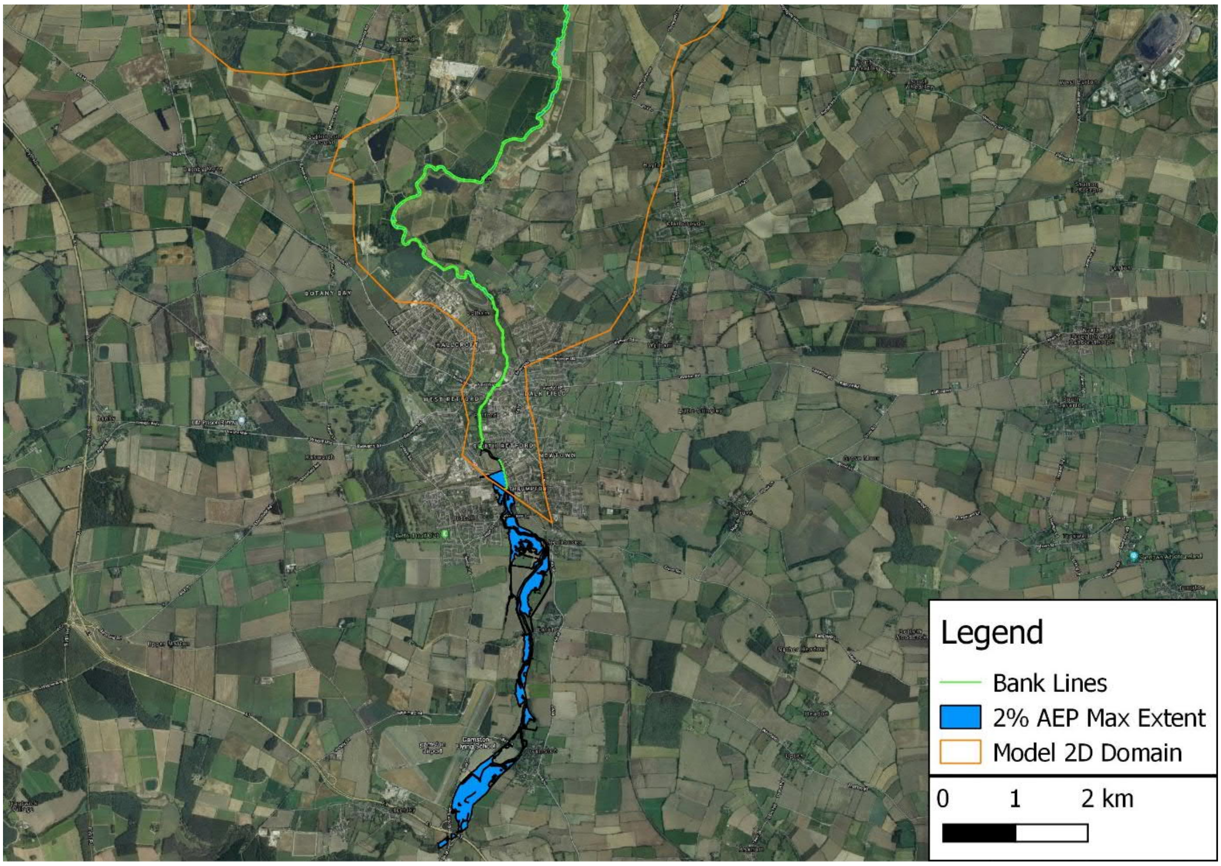
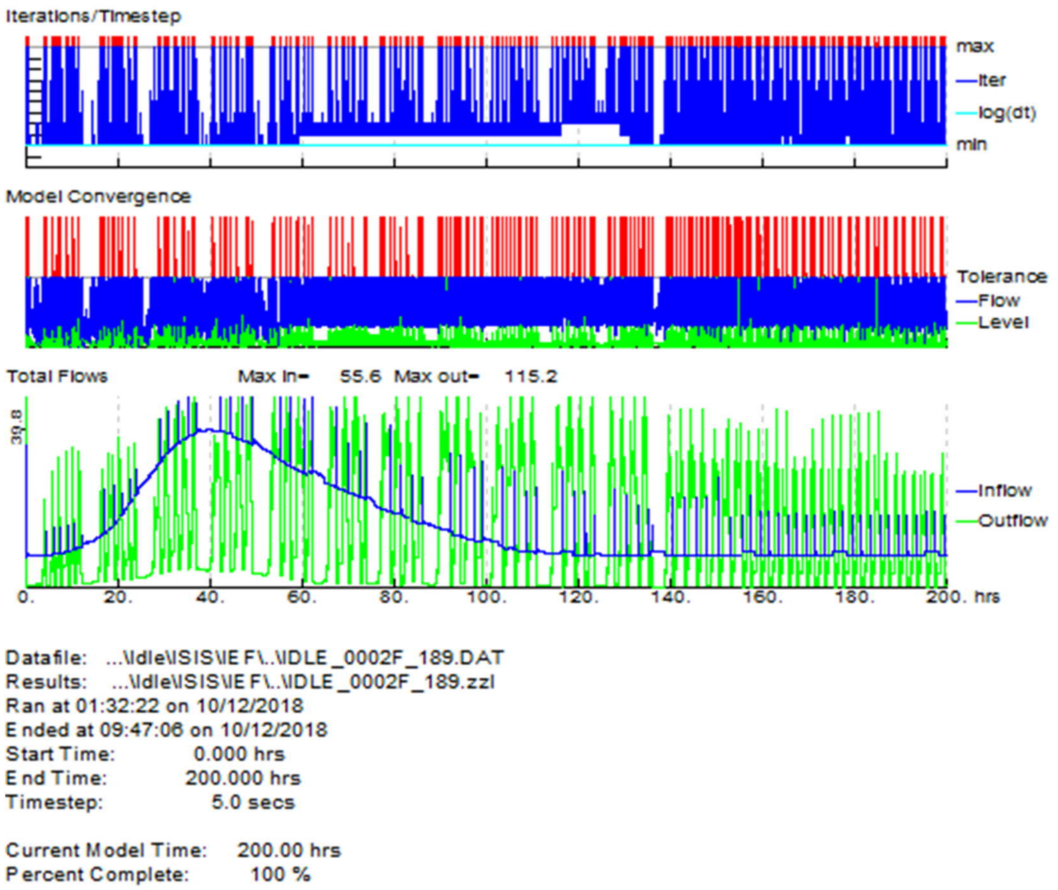


Figure 10: 50% AEP Flood Modeller convergence plot.



A.2 River Torne Model Review

	ACTION LEVELS
RED	Unacceptable: Remedial action required
AMBER	Useful: Improvements recommended
GREEN	Satisfactory: Compliant with best-practice guidance

Explanation:

- **Comments in the 'Action' column are colour coded to indicate how important it is that the proposed changes are addressed.**
- **Any elements not applicable to the audited model are marked with "N/A".**
- **Any improvements made based on the recommended actions should be logged in the 'Issue addressed comment (if applicable)' column.**

1. Model Overview

1.1 Model extent & description

The River Torne model produced by Capita covers the River Torne from the A60 at Styrrup Lane (NGR 458864, 390574) to its confluence with the River Trent at Keadby (NGR 483526, 411310). The model also includes several drains within the 2D domain, and the 2D extent is shown below. The model was built as part of the Water and Environment Management Framework Lot 1 – Modelling, Mapping and Data Services, to assess fluvial flood risk and Keadby Pumping Station, as well as other catchment management options for the Isle of Axholme,

The model is a linked 1D-2D Flood Modeller Pro – TUFLOW model.

1.2 Model originator and date created

The model was built by Capita in August 2017.

1.3 Software used

TUFLOW version: 2016-12-AE-*iSP-w64 Flood Modeller version: 4.3/4.2*

1.4 Model version reviewed

TOR_BSC_317

1.5 AEP design events provided for review

Torne_BSC2_0002A_FBFTMST_317

Torne_BSC2_1000A_FBFTMST_317
1.6 Model files reviewed
TOR_BSC_317.dat *TOR_38hr_1000yr_draft_inflows_ftp_v3.IED* *TOR_BSC2_GravityOutfallsClosed_312.ied* *TOR_dsbdy_FBF_TMST_001.ied* *TOR_Winter_Pumps_316.IED* *TOR_38hr_2yr_draft_inflows_ftp_v2* *TOR_~s1~_~s2~_~e1~_~e2~_317.tcf* *TOR_317.tbc* *TOR_317.tgc* *bc_dbase_TOR_306.csv*
1.7 Guidance used to inform the review
List any guidance documents used to inform the review. For example: Fluvial Design Guide – Chapter 7 Hydraulic analysis and design (FDG2, 2009) Flood modeller online manual (CH2M HILL, 2015) TUFLOW manual (version 2016-03) CES Manning’s Roughness Advisor

2. Survey Review				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Has topographic survey been provided?	Fail	The 2013 Maltby Land Survey was provided in PDF form. Only cross-sections were included in the PDF, with no long sections or overview map. WEM_Lot_1_Package 1_Report_Torne_FINAL_Nov_2017, Appendix C is attached as Figure 1. This does not list the 2013 Maltby survey, however a 2014 Maltby survey covering North Soak Drain and South Soak Drain is referenced. The 2013 Maltby survey provided appears to cover the main River Torne. Only the 1D model structures include a comment outlining which survey section they relate to no comment is given for open channel sections. The 2013 Maltby Lane Survey appears to cover from model node TORN_7501 to TORN_2848. The footbridge at survey section 5.001 within the 2013 Maltby Land Survey is not included within the 1D model. 2013 survey1D cross-sections match survey sections. Survey data is saved here: \\Ukmcr1fp002\ukmcr1fp002-v1ie\Proposal\3512\EA	Provision of survey would allow for the model to be checked against survey and for evaluation of the quality of the survey. Only one reach of the model is covered by the survey provided, whilst this section does match the survey, the above comment still applies for the remainder of the model.	

		Idle and Torne 2019\3. Data\From EA\06-01-20		
Is the topographic survey of an acceptable age?	Pass	Whilst survey not provided so cannot checked, the survey referenced in the reporting (Appendix C) is all of a suitable age, ranging from 2012 to 2016. The 2015 South Staffs survey is flagged as being poor quality. 2013 Maltby survey provided of suitable age.	Area covered by South Staffs survey could be a location where resurvey is required, however the area covered by the South Staff survey is unknown.	
Does the survey comply with current EA National Survey Specification?	Pass	The survey provided does comply with EA survey specifications, However this survey only covers one reach of the model.		
Does the cross-section spacing of the survey provided seem reasonable?	Pass	Cross-section spacing for reach of Torne where survey provided is acceptable. No survey provided for remainder of model.		
Does the survey include information on channel structures (including trash screens) and channel roughness?	Fail	No roughness information provided within survey data.		
Has LiDAR of appropriate resolution been provided?	Pass	Model 2D domain covered by 1m and 2m LiDAR. However, 1m LiDAR flown in 2011 and 2m LiDAR in 2008. Query in model log as to why 2015 LiDAR hasn't been used.	New composite LiDAR is available; updating the LiDAR would give more accurate results but may also cause modelling instabilities.	

3. In-Channel Representation				
3.1 Cross-section schematisation				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Is georeferencing information (e.g. a gxy or ixy) available?	Pass	GXY file supplied. However, some sections are not fully georeferenced.	Fill in missing georeference data.	
Is the node naming convention logical and include chainage information?	Pass	Naming logical and based on chainage. As survey not provided cannot be compared to survey.		
Does the model chainage seem reasonable for the channel length/sinuosity?	Fail	Whilst watercourses are predominantly straight, but several chainages in excess of 300m (up to 659m) where sinuosity not captured. See Figure 2.	Interpolates should be added to reduce chainages and capture sinuosity.	
Does the model chainage match with the cross-section survey?	Pass	Cross-section chainage within the model matches the survey for reach of Torne where survey provided. No survey provided for remainder of the 1D model.		
Is the cross-section spacing appropriate; i.e. is it erratic or reasonably consistent?	Fail	Three Rivers chainages around 25m, upstream on the Torne chainages in excess of 300m. Chainages largest at: RT-14517: 659m RT-15064: 547m RT-10196: 523m. See Figure 2.	See above comment.	
Does the channel width match the cross-section survey?	Pass	Cross-section width within the 1D model matches the survey for reach of Torne where survey is provided.		

		No survey provided for remainder of 1D model.		
Have hard or soft bed levels been used in the model?	Pass	Hard bed has been used where survey has been provided.		
Have cross-sections been deactivated appropriately; i.e. near the highest elevation points in the cross-section survey?	Fail	Cross-sections not always deactivated at highest point in the cross-section. Discrepancies apparent between the 1D and 2D cross-section widths throughout model. See Figure 3.	Cross-sections should be deactivated at high points within the cross-section. 1D/2D cross-sections widths should match – 2D width should be updated to match 1D with or vice versa.	
Have top of bank markers been used correctly?	Pass	Bank markers not used consistently throughout the model.	Banks marks could be added throughout model; however, these do not impact results.	
Have panel markers been used appropriately? Is channel conveyance smooth?	Pass	Panel markers appear to be used throughout on River Sections, however jumps in conveyance occur at Bridge Units.	Add embankment markers at bridge units.	
3.2 Channel roughness				
Do the roughness values seem to fall within an appropriate range?	Pass	Roughness values between 0.03 and 0.05.		
Do the roughness values show reasonable consistency? If not, have changes been justified?	Pass			
Has evidence been provided to justify variation in Manning's roughness values?	Pass	No roughness values were present in survey provided which covers a reach of the Torne. Reporting states roughness values taken from survey, however survey data covering the whole model was not provided, so this cannot be verified.		

3.3 Structure representation				
Has a list of modelled structures been provided, and any exclusions justified?	Fail	Provide structure list.		
Do there appear to be any key structures not modelled?	Fail	Features that appear to not have been modelled: Rail crossing at 4010_01615, Footbridge at 4010_02862, Footbridge downstream of RT-33089, Bridge and Flood Relief culvert at RT-24160 are situated within the area represented by reservoir unit and the area may need to be included in the 2D domain to capture structures, Footbridge upstream of RT-06439i1, Bridge at NSD_073. See Figure 4.	No justification for exclusion of structures, and as such they should be added in. New survey may be required to capture missed structures.	
Does a sample check of the structure dimensions match with the survey drawings?	N/A	No survey provided.		
Have bridge and culvert units been used appropriately; i.e. culvert schematised for bridges where the length:width ratio is greater than 2:1?	Pass			
Are spills over bridge and culvert parapets included?	Fail	Spill units not present at all bridge units/orifice units and no connections to the 2D domain to enable spill are provided.	Spills not included at all bridges/orifice units. If bridge surcharges during 0.1% AEP event then spill should be added. As no survey available, levels may have to be taken from LiDAR.	

Have inlet and exit losses been represented with appropriate units?	Pass			
Do head losses across structures appear reasonable for a high-magnitude event?	Pass			
Are appropriate losses for changes in culvert geometry and direction included?	Pass			
Do structure coefficients and modular limits appear reasonable?	Pass	Modular limits of all orifice units, sluice units and weir units appropriate. Modular limits of spill units vary: from 0.9 (default) to 0.5 (SENG3290) with no justification of variation provided. Weir coefficients at spill units vary from 1.7 to 0.5 with no justification of variation provided. Weir coefficients are appropriate.	Without survey/photographs of study area, there is limited to scope to update the structure coefficients as the model has been previously calibrated.	
If applicable, are any control rules appropriate?	Pass	Keadby sluice gravity outfalls closed throughout simulation.		

4. 1D Out-of-Bank Representation				
4.1 Extended cross-sections				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Is the discretisation of extended cross-sections too sparse or too detailed?	N/A	Extended cross-section have not been used to represent floodplains anywhere within the 1D model. 1D cross-sections have only been used to represent the channel in this model.		
Have extended cross-sections been used where depth of flooding is excessive?	N/A			
Do extended cross-sections intersect with one another?	N/A			
Are the extended cross-sections approximately perpendicular to flow?	N/A			
Is the cross-section spacing appropriate; i.e. is it erratic or reasonably consistent?	N/A			
Have the sections been sufficiently extended to avoid glass-walling?	N/A			
Have defences and any scheme options been appropriately represented?	N/A			
4.2 Floodplain reservoirs				
Do 1D reservoirs glass-wall?	Pass			
Are there a sufficient number of spills from the channel into the reservoirs?	Pass			
Have reservoirs been used where there is a steep channel gradient?	Pass	Channel gradient flat where 1D reservoir units connected.		

Do reservoir boundaries appear to be consistent with ground topography?	N/A	Shapefiles used to generate reservoir units not available.		
Does there appear to be any overlap between extended cross-sections and reservoirs (which would result in double-counting)?	Pass			

5. 2D Out-of-Bank Representation				
5.1 2D domain schematisation				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Is the number of domains appropriate?	Pass			
Is the 2D horizontal cell size suitable for the study objectives?	Pass	15m grid sized used, however in several locations there is no inactive cell between left and right bank HX cells.	Reduction in grid size would improve model accuracy; especially in relation to small watercourses/drains within the 2D domain. Reducing grid size would also adversely affect model run times.	
Is the grid orientation suitable?	Pass			
Is the domain extent sufficient so that glass-walling doesn't occur?	Fail	Glass-walling occurs upstream of DGND_23073, west of Arm Thorpe. Glass-walling first occurs during the 3.33% AEP event. See Figure 5.	Expand 2D code layer around this area to prevent glass-walling (g noting that a 20% AEP event is significantly larger than the flow threshold above which abstractions may occur (Q15).	
Is the connectivity to the 1D domain (e.g. HX or SX links) appropriate?	Pass			
Is the spacing between 1D-2D connection appropriate?	Pass	In several locations there is no inactive cell between HX cells. This could reduce model accuracy under flood conditions.	A reduction in grid size would improve the spacing between 2D connections, however this will impact runtimes and possibly effect model stability.	
Is the 1D-2D connectivity at structures suitable?	Pass			
Has the channel area been deactivated so that double-counting does not occur?	Fail	Channel deactivated throughout model, however there are discrepancies between the 1D and 2D cross-section widths throughout the model.	Whilst the code layer removing the 1D channel area from the 2D domain is snapped to HX link lines throughout, there is discrepancy between 1D and 2D cross-	

		See Figure 3.	section widths. The 1D cross-section widths or the 2D cross-section widths should be updated to ensure correlation between the 1D channel and the channel extent within the 2D domain.	
Has the floodplain been adequately represented between the 1D and 2D domains; i.e. extended cross-sections not extending into the 2D domain?	Fail	Discrepancies between the 1D and 2D cross-section widths throughout the model. See Figure 3.	The 1D cross-section widths or the 2D cross-section widths should be updated to ensure correlation between the 1D channel and the channel extent within the 2D domain.	
Is LiDAR used to represent the 2D topography; i.e. has a zpt layer been used of indeterminate age?	Pass	Model 2D domain covered by 1m and 2m LiDAR. However, 1m LiDAR was flown in 2011 and the 2m LiDAR was flown in 2008. Query in model log as to why available 2015 LiDAR data was not used.	Update model LiDAR data with more recent composite LiDAR DTM dataset.	
Have floodplain features and obstructions been represented appropriately?	Pass	Zshape and Zline features have been used to represent floodplain topography, including drainage channels and defences. Zshape features have also been used as LiDAR patches.		
Have buildings been represented in the 2D domain appropriately?	Pass	Building's represented through increased Manning's (0.5) which is higher than typical value of 0.3.		
5.2 Top-of-bank schematisation				
Have top-of-bank elevations been schematised in the model at the 1D-2D boundary?	Pass	Zpoints read in through 2d_bc input using ZP flag. 1D and 2D bank levels appear to match.		
Is there any evidence that the best available data (e.g. AIMS or topographic survey) has been used to	N/A	Levels taken from survey but as no survey provided this cannot be verified.		

define the bank top crests?				
Is there any evidence that checks have been undertaken between the bank top levels and LiDAR?	Fail	No evidence provided.	Comparison between surveyed bank levels and LiDAR should be undertaken to establish locations where bank levels are being over/underestimated.	
5.3 Out-of-bank roughness				
Are the 2D roughness values within a suitable range?	Pass			
Have any sensitivity tests been undertaken involving altering floodplain roughness?	Pass	Model was found to be insensitive to changes in roughness.		

6. Model Boundaries				
6.1 Inflow boundaries				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Have appropriate inflow boundary types been used?	Pass	FEH boundaries for all inflows. Inflows based upon pumping station catchment applied to the 2D domain directly at the Pump Station location. Inflows not based upon pumping station applied to the 1D domain as a Flood Modeller inflow.		
Does inflow boundary distribution seem reasonable; e.g. lateral inflows distributed logically?	Pass	Lateral inflows applied where drains meet watercourse. 2D inflows applied directly at pumping station location.		
Do initial conditions within the 1D domain seem appropriate?	Pass	All 1D initial conditions appear in bank.		
If applicable, are any sweetening flows appropriate, and been removed from the model?	Pass			
Do the upstream & downstream inflows correspond to the FEH/Hydrology report, if available?	N/A	Hydrology not included in reporting.		
Are any inflows located close to structure justified?	Pass	None located close to structures.		
If applicable, are any pump/abstraction units appropriate?	Pass	Drain pumps connected to the 2D domain via SX connection. Rules applied via Abstraction units match those in report appendix. Keadby pumps applied via 6 Abstraction units, rules appear to match those in the report.		

Has an appropriate storm duration been used, and any other storm durations assessed?	Fail	38 hours used for all inflows, no evidence that other durations were tested.	More critical durations could be tested. This is only necessary for assessing flood flows, and thus may not be required for this study.	
6.2 Downstream boundary				
Is the location and schematisation of the downstream boundary appropriate?	Pass	Downstream boundary taken from River Trent model.		
Is there any evidence that the sensitivity to downstream conditions has been assessed?	Pass	Model reports states that the model was not found to not be overly sensitive to downstream boundary levels.		

7. Calibration, Verification, and Sensitivity Analysis				
7.1 Calibration and verification				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Has the selection of events been appropriately justified?	Pass	Three events selected (November 2000, January 2008, December 2012) but no justification provided.		
Does the best available data appear to have been used?	Pass	Reporting states that datasets, both pump records and gauge records, were incomplete/unreliable for all events. However, this is still the best data available.		
Is there any evidence of the model replicating historical events satisfactorily?	Pass	Reporting states that a good fit was "achieved at key locations" in the model but not throughout.		
Has calibration knowledge been transferred to design events?	Pass	Reporting states that an "iterative process" was used to adjust pumping rates and hydrology to achieve calibration fit, however no evidence that these changes were carried forward to design runs.	Information detailing if steps taken in calibration were taken forward to design runs would be beneficial. Assumption is changes were carried forward.	
7.2 Sensitivity analysis				
Has sensitivity analysis been undertaken to test model sensitivity to e.g. roughness, the downstream boundary, flow changes.	Pass	Roughness, downstream boundary and inflows tested.		
Has model uncertainty been quantified?	Pass			
Have the major model assumptions been detailed?	Pass	Documented in reporting, notable include: FLC at HX lines of 0.3 or higher, boundary viscosity factor of 2.		

8. Model Run Parameters & Performance

8.1 Model run parameters

Check	Pass/ Fail?	Comment	Action (if required)	Issue addressed comment (if applicable)
What is the time step? Is it appropriate?	Fail	2D timestep for 15m grid size: 5s 1D timestep for 15m grid size: 5s.	2D timestep should be ½ or ¼ of the 2D grid size and 1D timestep should be half of the 2D grid size.	
Have any simulation parameters been edited? If so, are they within acceptable limits?	Pass	Htol set to 0.005 Minitr set to 3. Maxitr set to 013. Spill threshold has been increased from default to 0.0001 Tuflow Boundary Viscosity Factor has been increased to 2. TUFLOW FLC at HX lines set to 0.3 or higher. Despite the increased Boundary Viscosity factor and FLC values, there are still fluctuations in flow across the 2D domain, most notably between SSD_076 and SD_133. See Figures 6 and 7.	Check model schematisation where fluctuations in flow occur. Manning's patches can be used to slow the transition of flow between model domains.	
If applicable, have any changes in simulation parameters for different events been justified?	Pass	Stability used as justification for all model changes.		
Are run times reasonable?	Pass	Run time 28 hours for 0.1% AEP event.		
8.2 Performance				
Is model convergence good?	Fail	Poor convergence throughout simulation. RT-24052L: Poor convergence throughout, oscillations of flow but not stage is apparent.	RT-24052L spill coefficients could be looked at. Orifice unit 4010_00588ou modular limit could be lowered to aid	

		Poor convergence occurs at units 4010_00588 and 4019_01071 during multiple timesteps.	convergence. Orifice unit 4019_01071 modular limit could be lowered to aid convergence and spill added.	
Are there any negative depths?	Pass			
Is mass balance reasonable (target ± 1%)?	Pass			
Are there any warnings or errors within the 1D domain?	Fail	Notable messages include: No rules are currently valid for RULES unit associated with label Backflow at culvert inlets/outlets. Backflow occurs at: WHSD_c20991 WHSD_c20991d HFWDa_c5037 HFWDa_c5037d HFWDc_c5037 HFWDc_c5037d NSD_042Cus NSD_042C3	At various stages in the simulation, no operating rules are valid at all active Keadby Pumps and at TBridge_PU. Scenario where no rules are applicable should be checked and any possible impact on results noted.	
Are there any warnings or errors within the 2D domain?	Pass	Warnings present but none likely to impact results.		

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9. Audit Trail				
Check	**Pass/ Fail?**	**Comment**	**Action (if required)**	**Issue addressed comment (if applicable)**
Has a model report/interim handover report been provided?	Pass	Report provided.		
Has a model log been provided?	Pass	Log provided		
Is the file naming and structure clear and logical?	Pass	Yes		
Have check files been provided?	Pass	Yes		
Have sufficient comments been provided within the 1D model?	Pass	Yes		

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10. Concluding Remarks

10.1 Suitability of modelling approach

The reviewed linked Flood Modeller-TUFLOW model was suitable for use in the original flood risk study, however changes may be required in order to utilise the model for the proposed high flow study. The 2D domain grid size should be reduced along with other recommendations below.

10.2 Key findings and recommendations

For the purposes of the proposed High Flow study, the model will need to be run with flows below the 50% AEP event. As the 50% AEP event is the lowest order event provided with the reviewed copy of the model, the following comments reflect model performance under these conditions.

Some of the more fundamental issues with the model are to do with the linkages between the 1D and 2D domains. The maximum flood extent for the 50% AEP event is shown in Figure 8 and Figure 9 of the Appendix. There are large areas of out of bank flow, particularly on the Lower Torne, which consequently means that some improvements outlined below are required for the model to be acceptable for use during the 50% AEP event and below. Moreover, as shown in Figure 10, there are instances of poor convergence throughout the 50% AEP event simulation. The model may not include enough detail to accurately represent flows below the 50% AEP event. This will be especially true of channels within the 2D domain, where shallow flows are unlikely to be captured by the coarse grid resolution.

Furthermore, there are several issues with the model that need to be addressed before it is used for the High Flow Study.

The model was previously run with the same timestep for the 1D and 2D domains. The 1D model timestep should be ½ or ¼ of the 2D model timestep. Reducing the 1D timestep will aid both 1D model convergence and reduce flow oscillations across the 1D/2D boundaries. The 1D timestep would also have to be reduced further in line with any reduction in grid size.

Reducing the grid size will improve model representation of smaller channels within the 2D domain. However, stability issues within the 2D model may occur as result, as variations in topography will be represented in greater detail. The current pumping arrangement, where the pumps are linked to the 2D domain, will be improved with a reduced grid size, as the pumps could be represented with a single cell covering the drainage channel, rather than a 15m grid cell.

There is poor convergence throughout the model, which is exacerbated by long chainages between 1D model nodes and the relatively large timestep. Without the survey for the full model domain, schematisation of structures within the full 1D model cannot be verified, and neither can structure dimensions or bank levels.

Flow transfer between the 1D and 2D model domains operates poorly, as highlighted by the high Form Loss Coefficient values within the HX link files and the use of Boundary Viscosity values. Reduction in timestep and grid size is likely to improve flow transfer between domains, however the model may still struggle when out of bank flow occurs.

Glasswalling occurs upstream of model node DGND_23073, located to the west of Armthorpe. The 2D domain needs to be extended to prevent this. However, glasswalling only occurs during events greater than the 3.33% AEP event and therefore will not impact model performance during lower order events.

Discrepancies occur between the 1D and 2D cross-section widths throughout the model, which should be corrected for future model runs. Either the 2D sections should be updated to match the 1D sections, or the 1D cross-sections should be extended via LiDAR to tie in with the channel extent within the 2D domain.

Abstractions and logical rules have been used to represent pumps, rather than specific FMP pump units. If implemented correctly, the use of abstraction units will not impact model results. However, as a result of the current model setup, discrete representation of pump curves is not utilised. *There are a number of missing structures within the model with no explanation for their exclusion; these structures should be added to the model, however further survey would then be required to capture structure dimensions. Missing structures, that were not included in the supplied survey data, could impact results even at low flows.* *Spill units are not present at all structures within the 1D model. These should be added either in 1D or spills to the 2D with a smaller grid size.*

11. Model audit signoff	
Model audit signed off by	Sam Burrows
Model audit approved for issue by	Richard Karooni

12. Figures

Figure 1:

Appendix C - Survey Index

Survey	Date	Supplier	Other Comments
Interlock (upstream sections of North Soak Drain and South Soak Drain)	March 2015	Interlock	
North Soak Drain	2014	Maltby	
South Soak Drain	2014	Maltby	
South Staffs	2015	StafSurv Land Surveyors	Includes: Candy Farm Hawood Sewage Dyke River Torne South Engine Drain Tunnel Pits Quality of this survey is considered poor due as outlined in Memo3, November 2015, Capita.
Auckley Gauging Station	December 2012	Graham Walker of Tower Surveys	
River Torne	April 2006	Cartographical Surveys Limited	
River Torne and Three Rivers	2016	Central Surveys Limited	Undertaken as part of this commission

Figure 2: Sinuosity not captured/long chainages.

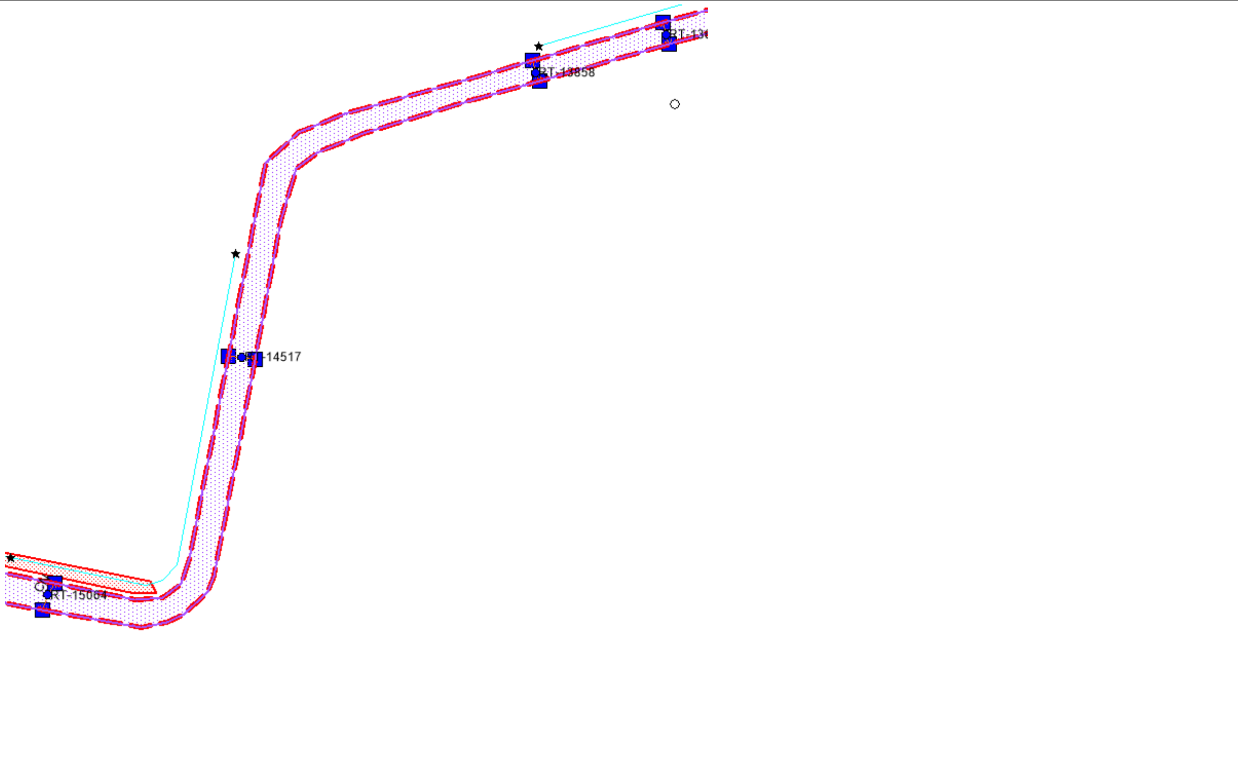

Figure 3: Discrepancy between 1D and 2D cross-section widths.

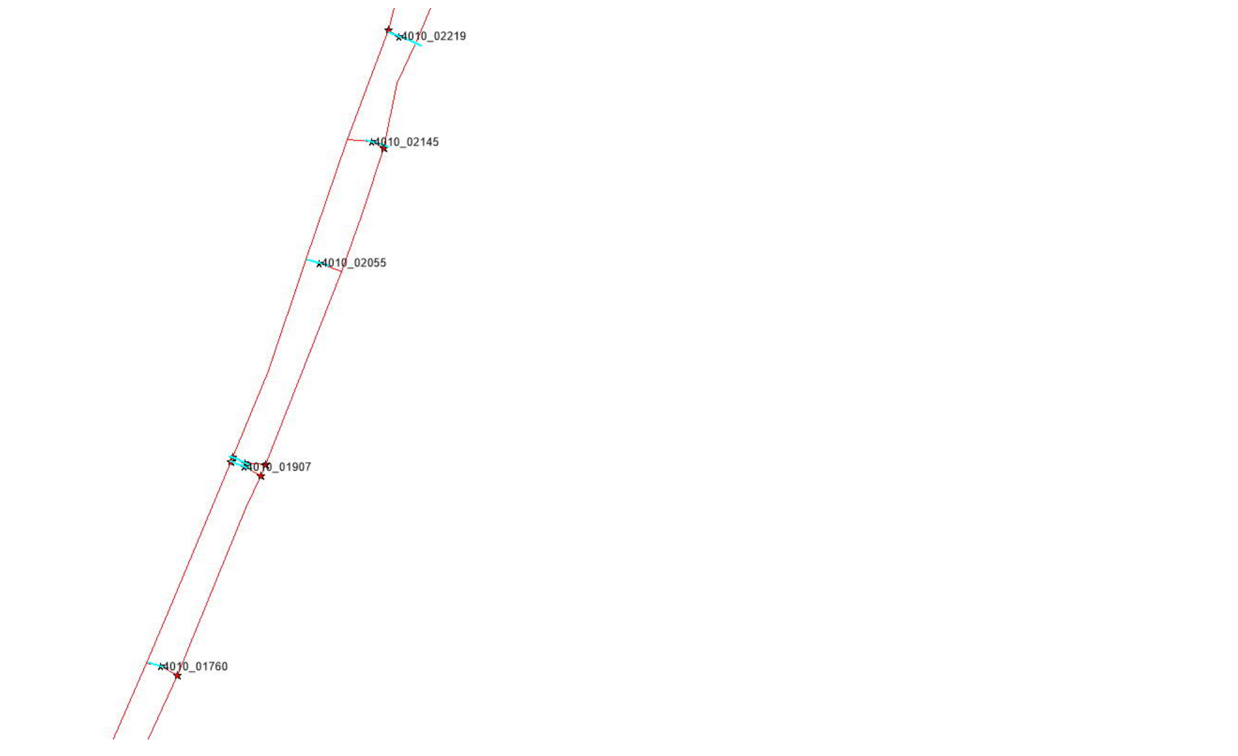

Figure 4: Structures not modelled within the area covered by the reservoir unit.

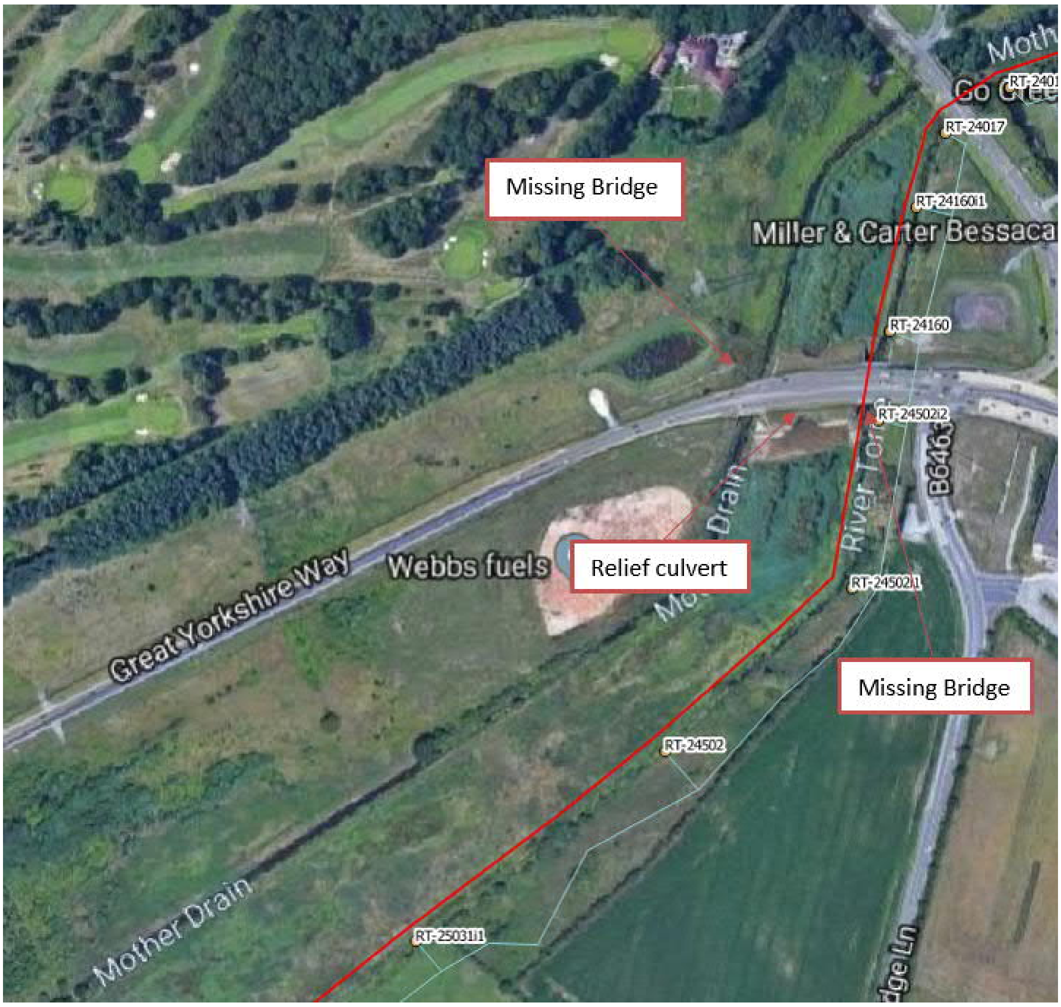

Figure 5: Glass-walling during the 0.1% AEP event. The first instance of Glass-walling in this location occurs during the 3.3% AEP Event.

Figure 6: Flow fluctuations at the 1D and 2D domain boundaries between nodes SSD_076 and SSD_133 During the 0.1% AEP event.

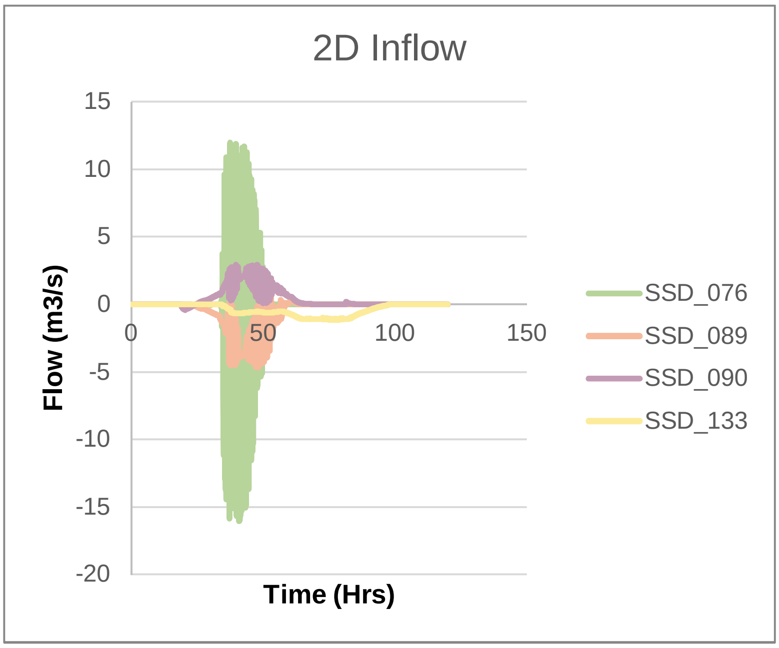

Figure 7: Flow fluctuations at the 1D and 2D domain boundaries at notable other locations within the model. During the 0.1% AEP event.

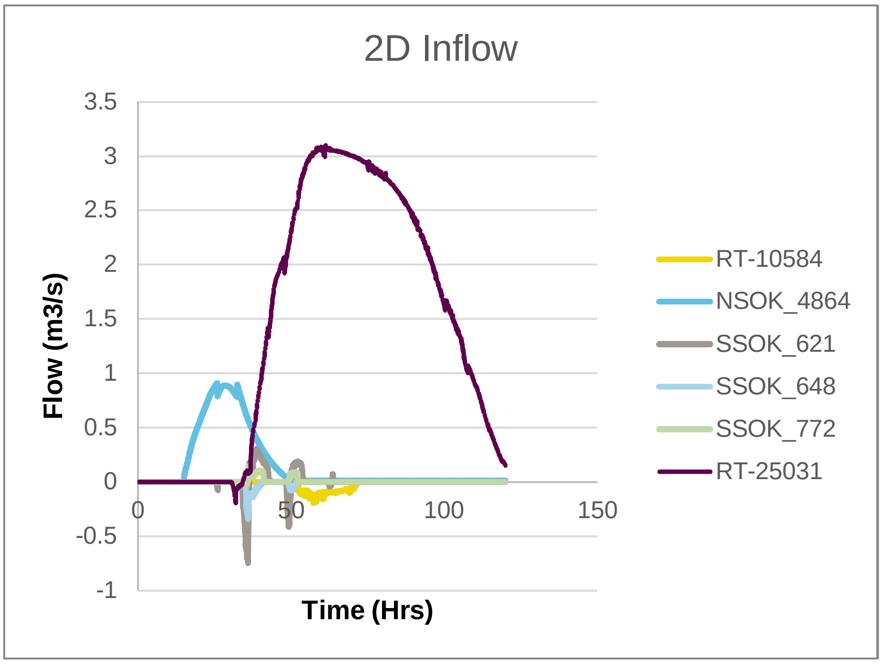

Figure 8: Lower Torne: 50% AEP flood extent and bank lines demonstrating areas where out of bank flooding occurs.

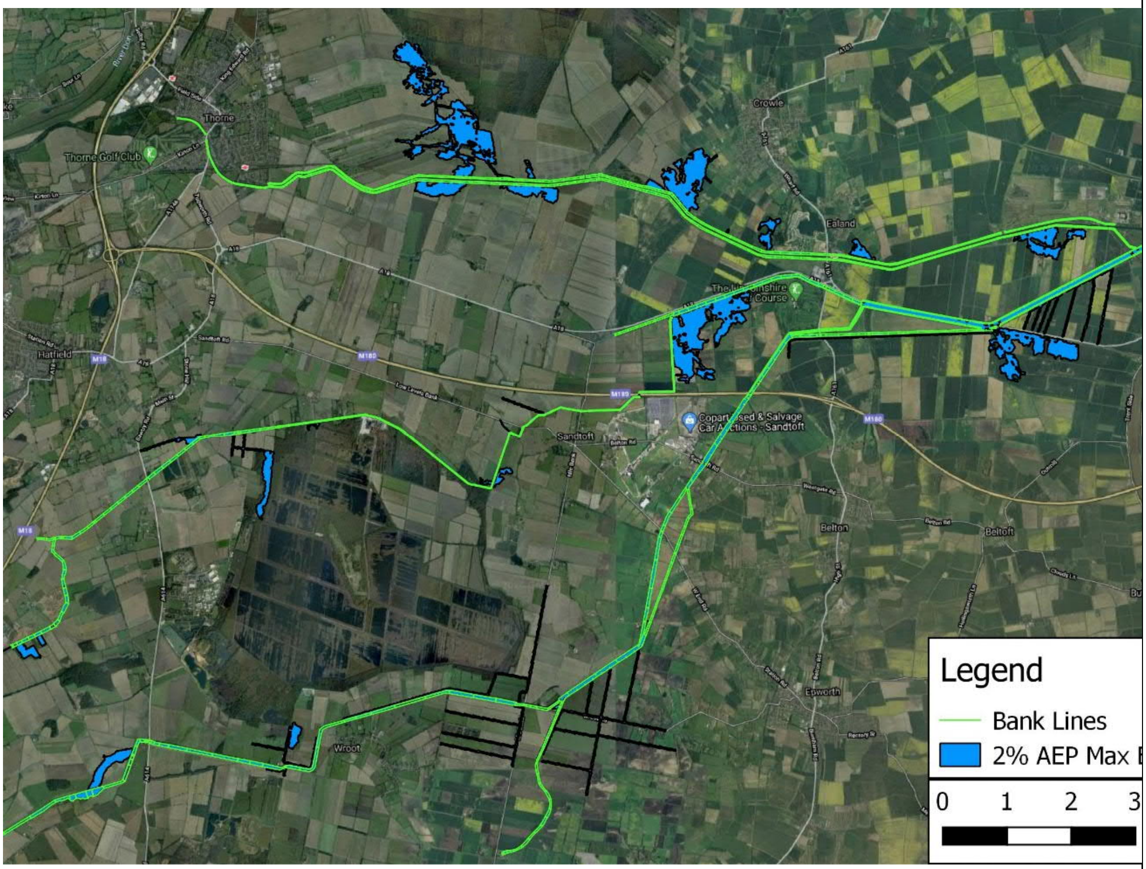

Figure 9: Upper Torne: 50% AEP flood extent and bank lines demonstrating areas where out of bank flooding occurs.

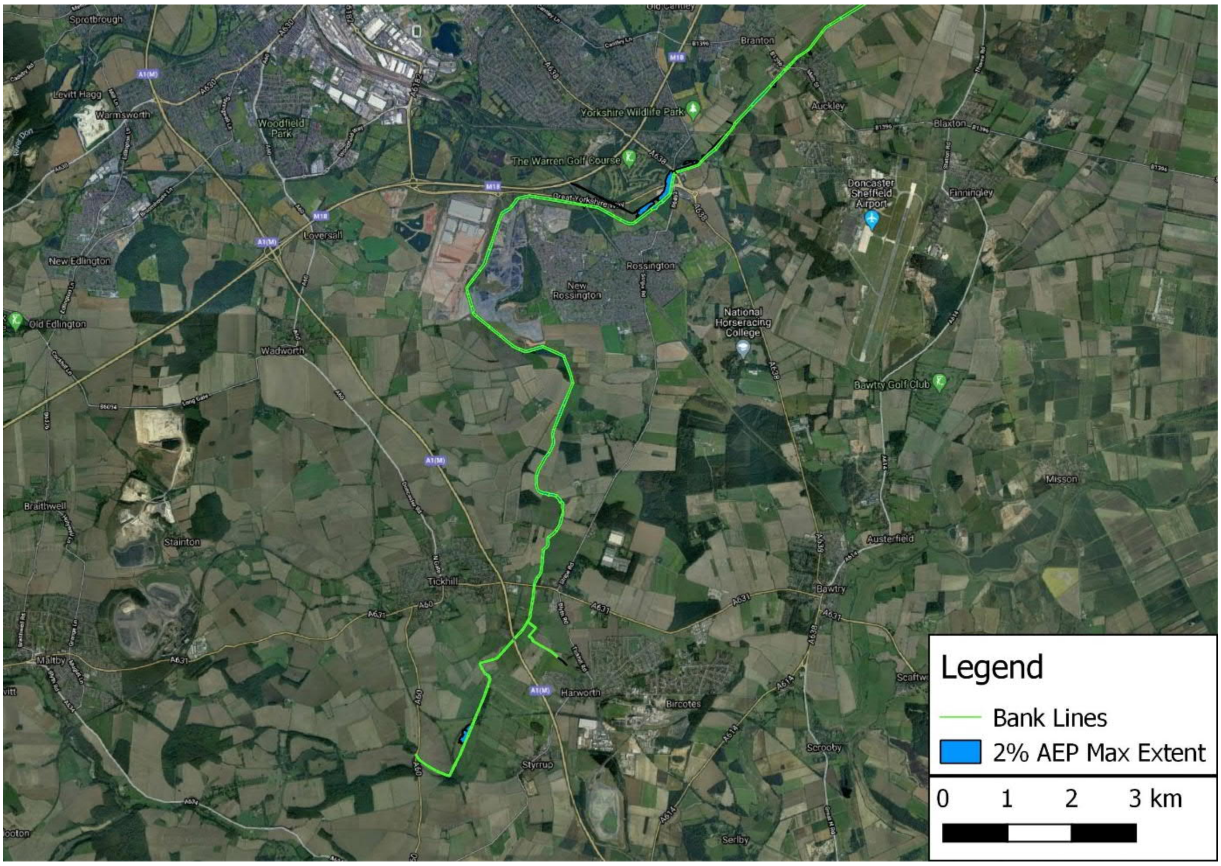

Figure 10: 50% AEP Flood Modeller convergence plot.